Heterosis and stability studies in *Cicer arietinum* [L.] against chilling and heat stress: a morphological, phenological and biochemical assessment

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in

Plant Breeding and Genetics

By

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Lovely Professional University

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LOVELY PROFESSIONAL UNIVERSITY, PUNJAB

2024

DECLARATION

I, hereby declared that the presented work in the thesis entitled **"Heterosis and stability studies in *Cicer arietinum* [L.] against chilling and heat stress: a morphological, phenological and biochemical assessment"** in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is the outcome of research work carried out by me under the supervision of Dr. Manoj Kumar Pandey, UID: 22848, working as Associate Professor, in the School of Agriculture (Plant Breeding and Genetics) of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of another investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled **"Heterosis and stability studies in *Cicer arietinum* [L.] against chilling and heat stress: a morphological, phenological and biochemical assessment"** submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Plant Breeding and Genetics / School of Agriculture, is a research work carried out by **Tamatam Dattesh**, **11814475**, is bonafide record of his original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

Manoj Kumar Pandey

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Name of supervisor: **Dr. Manoj Kumar Pandey, UID: 22848**

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ABSTRACT

The current examination, designated "Heterosis and stability studies in *Cicer arietinum* [L.] against chilling and heat stress: A morphological, Phenological and Biochemical assessment" on chickpea, at research farm, Department of Genetics & Plant Breeding, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India during the rabi 2020-21 (EN-1, EN-2, EN-3) and rabi 2022-2023 (Hybrid evaluation). The experimental design comprised 25 different genotypes of chickpea were cultivated in RCBD with two replicates in each environment in rabi 2020-21. Hybrid evaluation combined with parents was done in rabi 2022-23. Each plot is comprised with a couple of rows measuring 2.0 m each and 45 cm distant in between during rabi 2020-21 and 2022-23. From each replication, five vigorous plants were chosen for 22 quantitative traits *viz.*, first blossoming days, 50% blossoming days, harvest maturity days, plant height (cm), primary offshoots plant^{-1}, secondary offshoots plant^{-1}, capsules plant^{-1}, full capsules plant^{-1}, empty capsules plant^{-1}, seeds capsule^{-1}, test weight (gm), biological yield plant^{-1}, harvest index (%), total chlorophyll content (mg/ml), relative leaf water content (%), lipid peroxidation (nmol/ml), electrolyte leakage index (%), proline content (mg/gm), ascorbic acid content (mg), pollen viability, flower drop (%), seed yield plant^{-1}.

Analysis of the data was done to evaluate the following: heterosis, combining ability, path coefficient analysis, genetic advance, heritability, correlation coefficient, and stability analysis.

According to the ANOVA, the MSS owning to genotypes recorded significance for all the studied characters in all conditions of environment. Pooled environment recorded non-significant values for characters harvest index (%), total chlorophyll content (mg/ml), electrolyte leakage index (%), ascorbic acid content (mg) and flower drop (%). empty capsules plant^{-1} recorded significance for replication in EN-2.

For every characteristic in all environments, the PCV was greater than the GCV. Seed yield plant^{-1} and proline all environments, total chlorophyll content in EN-2 and EN-3, relative leaf water content, seeds capsule^{-1}, empty capsules plant^{-1} in

EN-1, Electrolyte leakage index (%) in EN-2, plant height in EN-3, and biological yield plant $^{-1}$ in pooled analysis all had high magnitudes for both coefficients.

There was a high heritability with a strong genetic advancement for plant height, full capsules plant^{-1}, lipid peroxidation (nmol/ml), proline content & seed yield plant^{-1} in EN-1, EN-2, EN-3 and pooled analysis, whereas, for test weight (gm), harvest index (%), total chlorophyll content, relative leaf water content, Electrolyte leakage index (%)and Flower drop (%) in EN-1, EN-2 and EN-3, empty capsules plant^{-1} in EN-1, EN-2 and pooled, seeds capsule^{-1} in EN-1 and EN-3, biological yield plant^{-1} in EN-1 and pooled, primary offshoots and secondary offshoots plant^{-1} in EN-1, Ascorbic acid content (mg) in EN-3 & capsules plant^{-1} in pooled. Higher heritability plus genetic advancement (moderate) was recorded for pollen viability in EN-1, EN-2, EN-3 and pooled, capsules plant^{-1} in EN-1, EN-2 and EN-3, primary offshoots plant^{-1} in EN-2, EN-3 and pooled, secondary offshoots plant^{-1} and seeds capsule^{-1} in EN-2 and pooled, ascorbic acid content (mg) in EN-1, empty capsules plant^{-1} & biological yield plant^{-1} in EN-2, harvest maturity days, test weight (gm), total chlorophyll content & relative leaf water content in pooled analysis. Their expression might have been a result of additive gene action, phenotypic selection might be useful for their improvement.

Current outcomes suggest that phenotypic significant positive association of seed yield plant^{-1} recorded for the traits harvest index (%), pollen viability, Biological yield, full capsules plant^{-1}, capsules plant^{-1} & relative leaf water content in all analysis, primary offshoots plant^{-1} and test weight (gm) in EN-1, EN-2 and pooled, secondary offshoots plant^{-1} and total chlorophyll content in EN-1, EN-3 and pooled, plant height in EN-2, EN-3 and pooled, seeds capsule^{-1} in EN-2 and pooled, proline in EN-2, first blossoming days, 50% blossoming days and harvest maturity days in pooled analysis respectively, whereas negative significant correlation was with empty capsules plant^{-1} in all analysis, harvest maturity days and first blossoming days in EN-2 and EN-3, Flower drop (%) in EN-2 and pooled, Lipid Peroxidation (nmol/ml) in EN-3 and pooled, 50% blossoming days in EN-2 and proline in pooled respectively.

The path coefficient analysis among these characters depicted that greatest direct positive effect on seed yield plant^{-1} was exerted by harvest index (%), biological yield, pollen viability, proline and Flower drop (%) in all analysis, empty capsules plant^{-1} and full capsules plant^{-1} in EN-1, EN-2 and EN-3, secondary offshoots plant^{-1} and total chlorophyll content in EN-2, EN-3 and pooled, 50% blossoming days in EN-1 and EN-2, seeds capsule^{-1} in EN-1 and EN-3, first blossoming days in EN-1 and pooled, harvest maturity days, lipid peroxidation (nmol/ml) and plant height in EN-3 and pooled, electrolyte leakage index (%) in EN-1, Ascorbic acid content (mg) in EN-2, relative leaf water content (%) in EN-3 and capsules plant^{-1} pooled analysis respectively while negative direct impacts were recorded by primary offshoots plant^{-1} in all analysis, capsules plant^{-1} in EN-1, EN-2 and EN-3, relative leaf water content EN-1, EN-2 and pooled, ascorbic acid content (mg) in EN-1, EN-3 and pooled, electrolyte leakage index (%) and test weight (gm) in EN-2, EN-3 and pooled, harvest maturity days, plant height and lipid peroxidation (nmol/ml) in EN-1 and EN-2, first blossoming days in EN-2 and EN-3, total chlorophyll content in EN-1 and pooled, seeds capsule^{-1} in EN-2 and pooled, test weight (gm) and 50% blossoming days in EN-3 and pooled, secondary offshoots plant^{-1} in EN-1, full capsules plant^{-1} and empty capsules plant^{-1} in pooled analysis respectively.

All attributes had mean differences that were statistically significant owing to genotypes, as shown by the phenotypic stability analysis of variance. For each trait, the interaction of G x E has been found to be significant, suggesting that genotypes react distinctively in different environmental circumstances.

The genotypes KWR-108, PBG-7, IPC-06-77, ICC-5434, IPC-07-56, SADABAHAR and JG-14 were noted for their fair and ideal stability, exhibiting adaptiveness and steady performance for yield and related characters over varied environments. Genotypes K-850, BPM and IPC 05-28 suggested stable but not ideal. Concerning genotypes ICC-5335 and BG-212, they displayed below average stability suggesting that thy were adapted to input rich or favourable environment.

The experimental setup using ANOVA exhibited significant variations amongst genotypes for each character, Further partitioning of parents & hybrids demonstrated that their MSS similarly recorded significant for every trait leaving secondary offshoots plant^{-1} amongst parents. Likewise, MSS for parent v/s hybrids was similarly significant for every character leaving seeds capsule^{-1}, harvest index

(%) and ascorbic acid content (mg) indicating significant difference between parents and hybrids and average heterosis.

Five promising hybrids basing per se performance regarding seed yield plant^{-1} were IPC 06-77 X PDG 4, ICC 5335 X PDG 4, IPC 06-77 X GNG 469, SADABAHAR X GNG 469, SADABAHAR X KPG 59. Based on overall mean values, IPC 06-77 X PDG 4 cross showed best performance for seed yield plant^{-1}.

GCA along with SCA was significant among all the traits studied. Parents IPC 06-77, ICC 5335 and PDG 4 for seed yield plant^{-1} were recorded as good general combiners.

SCA impacts for 8 crosses recorded positive significance *viz.,* BG 212 X KPG 59, IPC 07-56 X PDG 4, SADABAHAR X KPG 59, KWR 108 X KPG 59, ICC 5335 X GNG 469, ICC 5434 X PDG 4, IPC 06-77 X PDG 4, SADABAHAR X GNG 469. Each of these crosses had desired SCA impacts for other component traits as well. In addition, concerning seed yield & its component attributes, these crosses also showed heterobeltiosis.

Amongst 21 crosses, three crosses *viz.,* IPC 06-77 X PDG 4, ICC 5335 X PDG 4 & IPC 07-56 X PDG 4 were found to have higher mean performance, combining ability estimates better, and have a higher percentage of standard heterosis for yield related characters. As a result, these hybrids can be used for commercial purposes.

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Place : Jalandhar **(Dattesh Tamatam)**

Date :

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Sr.no.	Abbreviations	Stands for
1	%	Percentage
2	√	Square root
3	σ	sigma
4	‘t’ test	Student ‘t’ test
5	cm	Centimeter
6	d.f.	Degree of freedom
7	*et al.,*	And others
8	g	Gram
9	S.E	Standard error
10	S.S	Sums of squares
11	M.S.S	Mean sum of squares
12	Viz.	Namely
13	GM	Grand mean
14	Min.	Minimum
15	Max.	Maximum
16	No.	Number
17	RH	Relative heterosis
18	HB	Heterobeltiosis
19	G	Good
20	P	Poor
21	A	Average
22	F	Females
23	M	males
24	H	hybrids
25	SCA	Specific combining ability
26	GCA	General combining ability
27	EN-1	Sowing environment 1
28	EN-2	Sowing environment 2
29	EN-3	Sowing environment 3
30	R.C	Regression coefficient
31	D.F.R	Deviation from regression

Introduction

The third most widely cultivated pulse legume worldwide and a significant food legume for tropical and subtropical climates is the chickpea (*Cicer arientinum* L.), an annual legume of the family Fabaceae, subfamily Faboideae (The Plant List 2013, Feedipedia 2018, Kew Science 2018). Remains exceeding 7500 years old were previously found in the Middle East, which makes it the very first grain legume that humans were able to domesticate (Nagaroje *et al* 2016). Amongst those grown as pulses, it happens to be most crucial crop for general diet (Kerem *et al* 2007). With a chromosomal count of (2n=2x=16), a diploid species that self-pollinates. Its seed is 20–25% protein & frequently referred to as garbanzo bean, or bengal gram.

Out of the 43 species that make up the Cicer genus, *Cicer arietinum* is the only one that is grown commercially. Around 40,000 accessions have been reported and are accessible globally. Desi type and Kabuli type are the two main categories for grown chickpeas. Desi type seeds are often smaller in size, dark in color, and smooth or wrinkled in shape. Compared to desi type, kabuli type seeds are larger and cream-colored. Kabuli type seeds are more preferred for use in meals since they cook more quickly and have less fibrousness than Desi type seeds. Desi type are bushy with smaller flowers and leaflets. They are mostly grown in Southern Asia and Ethiopia and have purple anthocyanin colors in their stems and blue-violet blooms. Kabuli varieties, on the other hand, are primarily grown in the Mediterranean region and feature erect growth with white flowers (Bejiga *et al* 2006). It is a versatile grain legume that is widely consumed worldwide, specifically as plant-based protein source (Bejiga *et al* 2006).

Desi-type seeds are typically eaten in form of a dry pulse, either whole or split, or crushed into daal or flour, as well as in soups or sauces such as hummus (van der Maesen, 1989; Bejiga *et al* 2006). Kabuli varieties can be stored and are used in salads and vegetable mixtures. You can eat the fresh seeds and pods. Additionally, chickpeas can be roasted, salted, and eaten as a snack (Bejiga *et al* 2006). Like any other crop, chickpea quality and production are impacted by a variety of biotic, abiotic, and environmental factors. This study focuses on abiotic stress, one of the main restrictions. The main source of protein is the cool-season pulse crop known as chickpea. Domestic production of 13.75 million tonnes in 10.91 mha. Having productivity @ 12.6 q./ha (DES 2023, MOA&FW, GoI). All five of India's distinct agro-climatic zones the center, southern, northwestern plains, northeastern plains, and hill zones of north—are used for its cultivation. More than 80% of India's total chickpea cultivated area is in the central (including portions of, M.P, Maharashtra, Rajasthan, Gujarat, & Chhattisgarh) and southern (including Telangana, A.P, Tamil Nadu, & Karnataka) zones. Abiotic stress-related yield losses per annum in chickpea have been estimated to reach around 6.4 Mt worldwide (Ryan, 1997). According to J.S. Croser, the most frequent abiotic factors impacting its production are high temperatures, drought, and low temperatures. According to Krishnamurthy *et al* (2010), this is a result of the decrease in dry matter production and partitioning.

Chilling stress

The chickpea is sensitive to cold temperatures because of its warmer climate evolution in the Mediterranean region, Singh *et al* (1993). while blossoming and early capsule development stages, most winter cultivated pulses are also extremely sensitive to cold temperature stress (particularly among northern parts of India). The threshold for cold stress in cool-season pulses, including chickpea, is between 0 and 10 °C, based on a report by Kumar *et al* (2016). Since chickpeas are primarily a winter crop in the Indian subcontinent, they are subjected to freezing/chilling temperatures and decline in photoperiod during their germination, growth, and reproductive phases, particularly during their reproductive phase. This causes the floral and pod abortion, as well as poor pod set, which results in low yields (Clarke and Siddique, 2004; Srinivasan *et al* 1998.) primarily in India's north (Berger *et al* 2006; Srinivasan *et al* 1999). According to previous research, pollen fertility is decreased and fertilization is hampered by cold stress in chickpeas, which results in pod abortion (Nayyar *et al* 2005 a,b). In plant tissues, cold stress also affects membrane integrity, which causes ice to develop and solute leakage. According to Demidchik *et al* (2014), electrolyte leakage is frequently employed for testing plant tissues that have been damaged by stress. Under stress, electrolyte leakage increased, according to Nayyar *et al* (2005). It is possible for identification of cold-tolerating cultivars during seed germination and growth from the current available chickpea germplasm because research has shown that some survive at low temperatures (8 °C and 12 °C), at preliminary stages of growth (Croser *et al* 2003; Wery, 1990).

Heat stress

Abiotic stressors that represent a significant threat to agricultural productivity are becoming more prevalent due to climate change (Pradhan *et al* 2022). Abiotic stress caused by heat restricts plant growth and agricultural productivity (Wahid *et al* 2007) defined heat stress as a rise in temperature that exceeds a particular threshold over time and permanently inhibits plant growth. Heat stress causes physiological and biochemical problems in plants, which decreases their ability to grow and produce (Zhanassova *et al* 2021). Heat stress results in temperatures over 25°C (maximum 35 °C during the day and minimum 15 °C during nights), which lowers yields by 20% to 70% due to blossom droppage and abortion of pods (Kumar *et al* 2016). It has also been noted that HS during the stage of pod-filling might reduce seed size (Wang *et al* 2006). Proteins are denatured and aggregated by heat stress (Wahid *et al* 2007), membrane structures are disrupted (Xu *et al* 2006), photosynthesis is inhibited (Oukarroum *et al* 2016), photosynthetic pigments deteriorate (Zhang *et al* 2017), and antioxidant enzymes are altered (Kaushal *et al* 2011). The resulting imbalance between light energy absorption and consumption brought on by heat stress, thylakoid membranes are overexcited, which causes photoinhibition. According to (Ali *et al* 2020), the main cause of photoinhibition is the excessive synthesis and buildup of ROS like the Hydrogen Peroxide (H2O2), Superoxide radicals (O2), and Hydroxyl radicals (OH), and. As a result, presence of excessive ROS causes oxidative stress, which harms all cellular structures especially membranes by causing Lipid Peroxidation (nmol/ML) and the buildup of MDA (Wassie *et al* 2020). Damages brought on by heat stress also change the structure of the membrane, causing electrolyte leakage from plant cells (Rann, 2016), which lowers membrane stability and causes ion leakage.

In addition, proline, a molecule in stressed plants that has received extensive research, has been linked to the development of tolerance against a specific variety of stresses, inclusive of heat, salt, metals, and drought (Xu *et al* 2009; Poustini *et al* 2007; Knipp and Honermeier, 2006; Ruiz *et al* 2002; Sarkadi *et al* 2005). Proline, it is a highly water soluble suitable osmolyte which is uncharged at neutral pH. Furthermore, macromolecule-solvent interactions are not significantly perturbed at high concentrations (Yancey, 2001). Proline buildup improves cellular osmolarity, which triggers water influx or decreases outflow, thereby supplying the turgor required for cell expansion. As a result, the membrane integrity is preserved under dehydration or osmotic stress brought on indirectly by heat, salt, or chilling to prevent protein denaturation. Proline is essential for protecting photosynthetic activity and may maintain protein structures and their functions by interacting with enzymes (Hamilton and Heckathorn, 2001). When the body is undergoing stress recovery, proline also serves as a reservoir for energy, nitrogen, and carbon (Zhang *et al* 1997). During conditions of osmotic stress, it appears to have a variety of activities, including cellular function protection by scavenging ROS (Kaul *et al* 2008; Bohnert and Shen, 1999) and stabilizing membranes, proteins, & subcellular structures (Vanrensburg *et al* 1993). Therefore, studying and improving chickpea's heat and freezing tolerance is essential for growing it under temperature stress. This can be accomplished by examining numerous morphological, physiological, and biochemical parameters throughout assessment under different agroclimatic regions, time periods, and geographic locations.

Stability and G x E interactions

Yield stability is decreased by chickpea cultivars' varying responses to various environmental factors (Funga *et al* 2017). Several quantitative loci regulate the complex characteristic of yield, and G-E interactions significantly impact the direct selection of genotypes with high yield under stress circumstances (Kushwah *et al* 2021). As a result, assessment of GE is essential for locating superior and stable genotypes as well as for assessing how well they are adapted to various settings (Kanouni *et al* 2015). The performance and stability of cultivars in various contexts are correlated with genotype environment interaction (GEI) (Mwiinga *et al* 2020; Yan and Hunt, 2002). Ineffective G x E analysis of variance may lead to incorrect genotype selection for yield. To determine the best and most prolific cultivar, many environments must be tested (Ebdon and Gauch, 2002). Choosing an optimum genotype is challenging, though, because genotype and environment interact. Through multi-environment experiments, it is crucial to analyze the yield and stability of chickpea genotypes.

Heterosis and combining ability

Pal (1945) initially noted hybrid vigor and heterosis in six crossings of chickpea. According to him, the only feature that clearly demonstrated strong hybrid vigor was the quantity of pods per plant. Since that time, several publications were done describing hybrid vigor among chickpea (Gaur *et al* 2020; Gadekar and Dodiya, 2013; Bhatt and Singh, 1980). During breeding, the mating design employed and research material are critical. The existence of natural limits, such as how traits are inherited, pollination type, crossover manner employed, and the way that pollen is distributed, are all aspects that must be taken into consideration when choosing the breeding design (Nduwumuremyi *et al* 2013). Other considerations include space, time, expenses, and the selection of crossing design. A variation of the top cross that incorporates hybridization between lines (females) and broad-based testers (males) is line x tester breeding design. According to the plan (Muthoni and Shimelis, 2020; Nduwumuremyi *et al* 2013). Line x tester mating designs have been used by numerous researchers in the chickpea plant to select parents with strong combing ability, crossings with noticeable hybrid vigor, and different types of gene actions (Sasane *et al* 2022; Kumar *et al* 2018).

Considering the aforementioned factors, the current study is set up to create a screening method and test the available germplasm collection of chickpeas for its ability to withstand temperature stress in order to use it in breeding initiatives to create chickpea varieties that are resistant to both low and high temperatures as well as climate change. It also aims to pinpoint characteristics that were most closely linked to seed yield during heat and chilling stress. In order to determine the stable genotypes that are best adapted to the varied environments of Punjab, efforts were made to evaluate the genotype x environment interactions for seed yield in the elite chickpea genotypes.

Objectives:

1. Screening of chickpea germplasm against low and high temperature for tolerance using morphological, phenological and biochemical traits.
2. To investigate the performance of different genotypes under different environments through G x E interactions.
3. To estimate the heterosis for seed yield and its component traits.
4. To estimate the general and specific combining ability for various traits.

5. To study the nature and magnitude of gene action governing seed yield and its component traits.

II. REVIEW OF LITERATURE

The initial step for any breeding program requires a well-defined understanding of the extend of diversity present among the materials considered. Maximum diversity present among the materials will determine the success of any breeding program. Therefore, this study attempted to assess the variability present among the genotypes by using different aspects such as variability, heritability, character association, genetic variability. The review of literature for the different aspects of diversity is briefly listed under the given subheads:

2.1 Genetic parameters
2.2 Correlation coefficient
2.3 Path coefficient analysis
2.4 Stability analysis
2.5 Heterosis
2.6 Combining ability

2.1 Genetic parameters

It is essential to comprehend the extent and kind of genotypic and phenotypic variation across crop species in order to design an effective breeding program that will produce improved cultivars. Studying the diversity that already exists becomes crucial as an outcome. Johannsen (1903) introduced the notion of variety while expanding on the idea of pure lines. Vavilov (1951) asserted that increased variety increased the likelihood of obtaining favorable genotypes, which ultimately turned out to be the primary factor in agricultural plant development via selection. Any crop's potential for improvement is primarily based on the type and intensity of its variability. There are two categories for phenotypic diversity in germplasm: environmental and genotypic.

Table 2.1 provides a complete character-wise evaluation of GCV, PCV, GA as % & h^2 (bs).

Table 2.1: Variability, genetic advance & heritability literature review

1. **First blossoming days**

S.No	Reference	No. of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Sanjeev *et al* (2023)	80	68.93	9.46	6.67	5.53	High heritability and low GA found, PCV is greater than GCV
2.	Shivangi *et al* (2023)	28	98.65	38.80	18.83	18.70	Very high heritability and low GA found, PCV is greater than GCV
3.	Shivangi *et al* (2023)	28	96.51	34.27	16.64	16.34	Very high heritability and high GA found, PCV is greater than GCV
4.	Shivangi *et al* (2023)	28	95.15	39.92	19.38	18.90	Very high heritability and high GA found, PCV is greater than GCV
5.	Vikram *et al* (2022)	64	77.66	14.82	9.27	8.17	High heritability and moderate GA found, PCV is greater than GCV
6.	Nikhitha *et al* (2022)	27	97.1	4.29	2.15	2.11	Very high heritability and low GA found, PCV is greater than GCV
7.	Vijayakumar *et al* (2019)	25	76.00	4.83	3.07	2.68	High heritability and low GA found, PCV is greater than GCV
8.	Vijayakumar *et al* (2019)	25	74.00	6.37	4.16	3.59	High heritability and low GA found, PCV is greater than GCV

9.	Singh *et al* (2018)	15	5.47	-	1.48	0.35	Low heritability, PCV is greater than GCV
10.	Nadia *et al* (2008)	14	99.70	24.88	12.09	12.07	Very high heritability and high GA found, PCV is greater than GCV

2. 50 % blooming days

S.No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Rajesh *et al* (2023)	57	61.17	4.52	3.59	2.81	High heritability and low GA were found, PCV greater than GCV
2.	Kishore *et al* (2023)	240	79.59	9.05	5.52	4.92	High heritability and low GA were found, PCV greater than GCV
3.	Pravallika *et al* (2022)	24	66.40	11.68	8.54	6.96	High heritability and medium GA were found, PCV greater than GCV
4.	Harish *et al* (2022)	64	76.04	12.20	7.79	6.79	High heritability and medium GA were found, PCV greater than GCV
5.	Karthikeyan *et al* (2022)	20	98.05	17.45	9.32	8.89	Very high heritability and medium GA were found, PCV greater than GCV
6.	Khade *et al* (2022)	18	95.98	11.76	5.95	5.82	Very high heritability and medium GA were found, PCV greater than GCV
7.	Shikha *et al* (2022)	30	79.8	11.9	7.24	6.64	high heritability and medium GA were found, PCV greater than GCV

8.	Gautam *et al* (2021)	225	53.71	4.13	4.57	1.15	Medium heritability and low GA were found, PCV greater than GCV
9.	Meena *et al* (2021)	40	92.8	8.90	6.40	6.17	Very high heritability and low GA were found, PCV greater than GCV
10.	Manasa *et al* (2020)	30	94.87	12.65	13.17	12.82	Very high heritability and medium GA were found , PCV greater than GCV
11.	Kumar *et al* (2019)	50	85.52	10.25	8.39	7.76	Very high heritability and medium GA were found, PCV greater than GCV
12.	Kishor *et al* (2018)	40	92.1	7.06	5.48	5.26	Very high heritability low GA were found, PCV greater than GCV

3. Harvest maturity days

Sl. No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Nimita *et al* (2022)	110	96.42	17.36	8.73	8.57	Very high heritability and medium GA found, PCV greater than GCV
2.	Rajesh *et al* (2023)	57	96.35	10.68	5.38	5.28	Very high heritability and medium GA found, PCV greater than GCV
3.	Suman *et al* (2023)	23	29.701	2.67	4.36	2.38	Low heritability and low GA found, PCV greater than GCV

4.	Sanjeev *et al* (2023)	80	48.96	3.68	3.65	2.55	Medium heritability low GA found, PCV greater than GCV
5.	Nikhitha *et al* (2022)	27	71.0	4.25	2.90	2.44	high heritability and low GA found, PCV greater than GCV
6.	Nikita *et al* (2021)	31	25.3	2.33	3.49	1.75	Low heritability and high GA found, PCV greater than GCV
7.	Sanjay *et al* (2019)	50	65.34	3.95	2.94	2.37	High heritability and low GA found, PCV greater than GCV
8.	Mukesh *et al* (2016)	40	52.03	2.08	2.65	1.91	Medium heritability and low GA found, PCV greater than GCV

4. Plant height (cm)

Sl. No	**Reference**	**No of genotypes**	**h^2 %**	**GA % mean**	**PCV %**	**GCV %**	**Finding**
1.	Rajesh *et al* (2023)	57	98.44	28.09	13.85	13.74	Very high heritability high GA were found, PCV greater than GCV
2.	Viswanatha *et al* (2022)	26	88.90	20.03	10.94	10.31	Very high heritability high GA were found, PCV greater than GCV
3.	Shikha *et al* (2022)	30	86.0	24.7	13.98	12.96	Very high heritability low GA were found, PCV greater than GCV

4.	Kumar *et al* (2021)	52	74.14	23.22	14.22	12.56	High heritability and high GA found, PCV greater than GCV
5.	Gautam *et al* (2021)	225	16.33	1.16	2.40	1.82	Low heritability medium GA were found, PCV greater than GCV
6.	Meena *et al* (2021)	40	86.79	5.94	2.79	2.59	Very high heritability low GA were found, PCV greater than GCV
7.	Kumar *et al* (2020)	13	90.42	8.35	3.09	2.94	Very high heritability low GA were found, PCV greater than GCV
8.	Manasa *et al* (2020)	30	94.70	11.07	6.70	6.52	Very high heritability medium GA were found, PCV greater than GCV
9.	Kumar *et al* (2019)	50	73.47	6.69	4.44	3.81	Very high heritability low GA were found, PCV greater than GCV
10.	Kishor *et al* (2018)	40	89.0	7.45	3.96	3.74	Very high heritability low GA were found, PCV greater than GCV
11.	Mohan *et al* (2019)	50	66.92	17.42	20.97	16.67	high heritability medium GA were found, PCV greater than GCV

5. **Primary offshoots plant^{-1}**

Sl. No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Rajesh *et al* (2023)	57	95.27	32.62	16.62	16.23	Very high heritability high GA were found, PCV greater than GCV
2.	Khade *et al* (2022)	18	44.97	12.40	13.39	8.98	Medium heritability medium GA were found, PCV greater than GCV
3.	Shikha *et al* (2022)	30	60.0	15.9	12.87	9.97	high heritability medium GA were found, PCV greater than GCV
4.	Kishore *et al* (2023)	240	75.34	22.36	14.41	12.50	High heritability high GA were found, PCV greater than GCV
5.	Gautam *et al* (2021)	225	84.58	0.83	20.27	18.64	Very high heritability low GA were found, PCV greater than GCV
6.	Meena *et al* (2021)	40	66.63	2.35	16.49	13.46	High heritability low GA were found, PCV greater than GCV
7.	Kumar *et al* (2020)	13	90.13	1.38	17.99	17.08	Very high heritability low GA were found, PCV greater than GCV
8.	Manasa *et al* (2020)	30	32.00	0.20	8.56	4.84	Low heritability low GA were found, PCV greater than GCV
9.	Kumar *et al* (2019)	50	90.72	0.76	22.26	21.19	Very high heritability low GA were found, PCV greater than GCV

6. **Secondary offshoots plant^{-1}**

S.No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Rajesh *et al* (2023)	57	89.42	29.67	16.11	15.23	Very high heritability high GA were found, PCV greater than GCV
2.	Khade *et al* (2022)	18	92.54	32.80	17.20	16.55	Very high heritability high GA were found, PCV greater than GCV
3.	Shikha *et al* (2022)	30	63.0	31.3	23.94	19.06	high heritability high GA were found, PCV greater than GCV
4.	Gautam *et al* (2021)	225	96.64	4.54	23.68	23.28	Very high heritability low GA were found, PCV greater than GCV
5.	Tsehaye *et al* (2020)	100	96.2	4.75	37.62	36.89	Very high heritability low GA were found, PCV greater than GCV
6.	Manasa *et al* (2020)	30	49.10	2.02	19.40	13.60	Medium heritability high GA were found, PCV greater than GCV
7.	Kumar *et al* (2019)	50	84.89	1.61	19.06	17.55	Very high heritability low GA were found, PCV greater than GCV
8.	Mohan *et al* (2019)	50	63.17	27.29	20.97	16.67	high heritability high GA were found, PCV greater than GCV
9.	Singh *et al* (2018)	105	7.70	0.13	16.83	14.67	Low heritability low GA were found, PCV greater than GCV

7. Capsules plant^{-1}

Sl. No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Rajesh *et al* (2023)	57	97.40	42.01	20.94	20.67	Very high heritability low GA were found, PCV greater than GCV
2.	Kishore *et al* (2023)	240	84.74	28.48	16.31	15.02	Very high heritability high GA were found, PCV greater than GCV
3.	Shikha *et al* (2022)	30	92.7	46.3	24.24	23.34	Very high heritability high GA were found, PCV greater than GCV
4.	Khade *et al* (2022)	18	94.18	40.03	20.63	20.02	Very high heritability high GA were found, PCV greater than GCV
5.	Pravallika *et al* (2022)	23	86.60	46.34	25.99	24.18	Very high heritability high GA were found, PCV greater than GCV
6.	Gautam *et al* (2021)	225	92.83	12.71	38.63	37.22	high heritability medium GA were found, PCV greater than GCV
7.	Meena *et al* (2021)	40	97.12	20.09	18.33	18.07	high heritability medium GA were found, PCV greater than GCV
8.	Tsehaye *et al* (2020)	100	99.6	40.45	39.00	38.92	Very high heritability high GA were found, PCV greater than GCV
9.	Kumar *et al* (2020)	13	95.72	18.10	22.75	22.25	Very high heritability medium GA were found, PCV greater than GCV

8. **Full capsules plant^{-1}**

Sl. No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Shivangi *et al* (2023)	28	97.40	27.81	13.50	13.32	Very High heritability and high GA were found, PCV is greater than GCV
2.	Shivangi *et al* (2023)	28	91.80	26.49	12.86	12.32	Very high heritability and high GA was found, PCV is greater than GCV
3.	Shivangi *et al* (2023)	28	90.44	20.63	10.01	9.52	Very High heritability and high GA were found, PCV is greater than GCV
4.	Kathikeyan *et al* (2022)	20	98.62	51.00	25.10	24.93	Very high heritability and high GA was found, PCV is greater than GCV
5.	Swathi and Lal, (2021)	26	93.2	56.77	29.565	28.544	Very High heritability and high GA were found, PCV is greater than GCV
6.	Sanjay *et al* (2019)	50	89.14	66.86	36.41	34.38	High heritability and high GA were found, PCV is greater than GCV
7.	Singh *et al* (2018)	15	33.30	-	15.82	9.12	Low heritability, PCV is greater than GCV

9. Empty capsules plant^{-1}

Sl. No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Shivangi *et al* (2023)	28	95.13	178.91	86.85	84.71	High heritability and high GA were found, PCV is greater than GCV
2.	Shivangi *et al* (2023)	28	88.75	180.94	87.83	82.75	High heritability and high GA were found PCV is greater than GCV
3.	Shivangi *et al* (2023)	28	88.42	192.56	93.47	87.90	High heritability and high GA were found PCV is greater than GCV
4.	Dhopre *et al* (2022)	25	62.11	69.17	54.6	42.6	High heritability and high GA were found PCV is greater than GCV
5.	Dhopre *et al* (2022)	25	67.41	69.13	50.22	41.23	High heritability and high GA were found PCV is greater than GCV
6.	Dhopre *et al* (2022)	25	74.21	73.25	47.91	41.28	High heritability and high GA were found PCV is greater than GCV
7.	Tahir and Mirghani (2016)	8	61.5	10	75.4	59.1	High heritability and low GA were found PCV is greater than GCV

10. Seeds capsule^{-1}

S.No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Rajesh *et al* (2023)	57	63.54	24.43	18.67	14.88	Medium heritability medium GA were found , PCV greater than GCV
2.	Kishore *et al* (2023)	240	95.57	30.09	15.29	14.94	Very high heritability high GA were found , PCV greater than GCV
3.	Shikha *et al* (2022)	30	52.7	18.6	17.14	12.45	Medium heritability medium GA were found , PCV greater than GCV
4.	Khade *et al* (2022)	18	41.14	12.77	15.06	9.66	Low heritability high GA were found , PCV greater than GCV
5.	Pravallika *et al* (2022)	23	76.50	37.46	23.79	20.82	High heritability high GA were found , PCV greater than GCV
6.	Gautam *et al* (2021)	225	88.69	2.55	24.21	22.80	Very high heritability low GA were found , PCV greater than GCV
7.	Meena *et al* (2021)	40	41.25	0.15	14.33	10.98	Low heritability low GA were found , PCV greater than GCV
8.	Tsehaye *et al* (2020)	100	5.26	0.04	30.95	7.10	Low heritability low GA were found , PCV greater than GCV
9.	Kumar *et al* (2020)	13	86.30	12.34	30.23	28.09	Very high heritability medium GA were found , PCV greater than GCV

10.	Manasa *et al* (2020)	30	78.23	0.36	11.93	10.55	High heritability and low GA found, PCV is greater than GCV

11. Test weight (gm)

Sl. No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Gulwane *et al* (2022)	44	98.50	47.87	23.57	23.40	Very high heritability and high GA found, PCV is greater than GCV
2.	Karthikeyan *et al* (2022)	20	99.80	32.83	83.25	81.14	Very high heritability and medium GA found, PCV is greater than GCV
3.	Viswanath *et al* (2022)	26	68.60	24.10	17.06	14.12	high heritability and high GA found, PCV greater than GCV
4.	Xalxo *et al* (2021)	22	99.50	81.49	39.77	39.66	Very high heritability and high GA found, PCV greater than GCV
5.	Tak & Meena, (2021)	40	86.35	19.92	11.20	10.40	Very high heritability and high GA found, PCV is greater than GCV
6.	Hailu *et al* (2020)	49	91.88	23.81	12.56	12.04	Very high heritability and medium GA found, PCV is greater than GCV
7.	Singh *et al* (2021)	20	96.0	90.36	45.87	44.85	Very high heritability and high GA found, PCV is greater than GCV

8.	Anusha *et al* (2020)	25	91.6	27.0	14.3	13.7	Very high heritability and medium GA found, PCV greater than GCV
9.	Sanjay *et al* (2019)	50	60.78	13.11	30.08	29.79	Low heritability and low GA found, PCV greater than GCV
10.	Mohibullah *et al* (2020)	18	58	14.00	11.02	8.38	high heritability and low GA found, PCV greater than GCV

12. Biological yield plant^{-1}

Sl. No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Pravalik *et al* (2022)	23	50.60	13.36	12.82	9.12	Medium heritability and low GA werefound, PCV is greater than GCV
2.	Viswanath *et al* (2022)	26	69.80	46.17	32.11	26.83	High heritability and high GA was found, PCV is greater than GCV
3.	Bharathi *et al* (2022)	26	65.16	26.40	19.69	15.88	High heritability and high GA was found, PCA is greater than GCV
4.	Meena *et al* (2021)	40	74.51	15.79	9.77	8.37	high heritability and medium GA was found, PCV is greater than GCV
5.	Singh *et al* (2021)	20	85.0	48.38	26.38	25.1	Very high heritability and high GA was found, PCV is greater than GCV
6.	Kumar *et al* (2021)	50	92.74	46.22	22.93	21.91	High heritability and high GA were found, PCV is greater than GCV

7.	Gautam *et al* (2021)	225	96.75	15.44	37.69	37.07	Very high heritability and low GA was found, PCV is greater than GCV
8.	Mukesh *et al* (2016)	40	73.94	24.80	16.28	14.00	high heritability and high GA was found, PCV is greater than GCV

13. Harvest index (%)

Sl. No	Reference	No of genotypes	h^2 %	GA % mean	PCV %	GCV %	Finding
1.	Rajesh *et al* (2023)	57	86.20	28.53	16.07	14.92	Very high heritability and high GA found, GCV greater than PCV
2.	Shikha *et al* (2022)	30	64.0	22.7	17.23	13.78	High heritability and high GA found, PCV greater than GCV
3.	Pravallika *et al* (2022)	23	63.80	26.77	20.38	16.28	High heritability and high GA found, PCV greater than GCV
4.	Viswanath *et al* (2022)	26	72.80	23.17	15.45	13.18	High heritability and high GA found, PCV greater than GCV
5.	Bharathi *et al* (2022)	26	65.67	20.42	15.12	12.24	High heritability and high GA found, PCV greater than GCV
6.	Gautam *et al* (2021)	225	70.51	6.31	10.48	8.80	High heritability and low GA found, PCV greater than GCV
7.	Meena *et al* (2021)	40	71.30	3.21	10.12	8.55	High heritability and low GA found, PCV greater than GCV

8.	Tsehaye *et al* (2020)	100	6.01	0.01	20.50	5.02	Low heritability and low GA found, PCV greater than GCV
9.	Tsehaye *et al* (2020)	13	86.60	12.05	15.23	14.17	Very high heritability and high GA found, PCV greater than GCV
10.	Sanjay *et al* (2019)	50	67.45	14.23	10.25	8.41	High heritability and low GA found, PCV greater than GCV

14. Total chlorophyll content

1.	Lamara *et al* (2022)	34	35.45	5.07	6.94	4.14	Low heritability and low GA found, PCV greater than GCV
2.	Kumar *et al* (2021)	25	95.1	22.1	11.29	11.01	Very high heritability and high GA found, PCV greater than GCV
3.	Kumar *et al* (2021)	25	87.00	36.84	19.96	18.92	High heritability and high GA found, PCV greater than GCV
4.	Kumar *et al* (2021)	25	76.00	26.98	17.21	15.01	High heritability and high GA found, PCV greater than GCV
5.	Semba and Rao, (2022)	15	96.3	48.19	24.29	23.83	Very high heritability and high GA found, PCV greater than GCV
6.	Chandrakala *et al* (2023)	50	94	61.77	31.68	30.82	Very high heritability and high GA found, PCV greater than GCV
7.	Chetariya *et al* (2019)	71	73.82	6.92	4.55	3.91	High heritability and low GA found, PCV greater than GCV

8.	Usman *et al* (2014)	36	2.56	1.94	36.56	5.89	Very low heritability and low GA found, PCV greater than GCV

15. Relative leaf water content

1.	Lamara *et al* (2022)	34	21.54	2.19	4.94	2.29	Low heritability and low GA found, PCV greater than GCV
2.	Kumar *et al* (2021)	25	77.5	8.5	5.31	4.67	High heritability and low GA found, PCV greater than GCV
3.	Kumar *et al* (2021)	25	80.5	7.3	4.42	3.97	High heritability and low GA found, PCV greater than GCV
4.	Kushwah *et al* (2021)	204 RIL's	86.60	17.51	9.82	9.13	High heritability and moderate GA was found, PCV greater than GCV
5.	Kushwah *et al* (2021)	204 RIL's	92.40	29.97	15.74	15.13	High heritability and high GA was found, PCV greater than GCV
6.	Heidari *et al* (2020)	16	92.84	16.98	8.88	8.56	Very high heritability and moderate GA was found, PCV greater than GCV
7.	Meena *et al* (2014)	22	92.4	15.7	8.3	7.9	Very high heritability and moderate GA was found, PCV greater than GCV

8.	Jitender *et al* (2014)	25	67	4.83	3.92	3.2	High heritability and low GA was found, PCV greater than GCV
9.	Ilakiya *et al* (2022)	3	89.88	23.86	13.46	12.76	High heritability and high GA was found, PCV greater than GCV
10.	Ilakiya *et al* (2022)	3	92.52	25.36	12.80	12.80	Very high heritability and high GA was found, PCV greater than GCV
11.	Ilakiya *et al* (2022)	3	86.90	22.97	12.83	11.96	High heritability and high GA was found, PCV greater than GCV

16. Lipid Peroxidation (nmol/ml)

1.	Zahedi *et al* (2016)	25	83.23	-	47.98	42.34	High heritability was found, PCV greater than GCV
2.	Ilakiya *et al* (2022)	3	62.41	45.65	38.35	30.29	High heritability and high GA was found, PCV greater than GCV
3.	Ilakiya *et al* (2022)	3	80.05	69.93	37.94	37.94	High heritability and high GA was found, PCV greater than GCV
4.	Ilakiya *et al* (2022)	3	75.03	59.22	38.31	33.42	High heritability and high GA was found, PCV greater than GCV

17. Proline content (mg/gm)

1.	Zahedi *et al* (2016)	25	62.52	-	46.03	36.76	High heritability was found, PCV greater than GCV
2.	Lamara *et al* (2022)	34	49.94	78.30	76.74	54.01	Moderate heritability and high GA was found, PCV greater than GCV
3.	Singh *et al* (2014)	18	99.90	47.85	23.26	23.25	Very high heritability with high GA was found, PCV greater than GCV
4.	Singh *et al* (2014)	18	98.90	18.44	9.30	9.25	Very high heritability with high GA was found, PCV greater than GCV
5.	Jitender *et al* (2014)	25	98	51.27	34.09	33.8	Very high heritability with high GA was found, PCV greater than GCV
6.	Ilakiya *et al* (2022)	3	84.02	23.69	14.22	13.03	High heritability with high GA was found, PCV greater than GCV
7.	Ilakiya *et al* (2022)	3	76.89	21.78	12.06	12.06	High heritability with high GA was found
8.	Ilakiya *et al* (2022)	3	90.64	28.06	15.03	14.31	High heritability with high GA was found, PCV greater than GCV
9.	Mouhamady *et al* (2020)	1	86.79	5.08	2.83	2.64	High heritability with low GA was found, PCV greater than GCV

18. Ascorbic acid content (mg)

1.	Semba and Rao (2022)	15	88.2	24.37	13.41	12.59	High heritability and high GA was found, PCV was greater than GCV
2.	Chandrakala *et al* (2023)	50	93	33.54	17.36	16.81	Very high heritability and high GA found, PCV greater than GCV
3.	Chacko *et al* (2023)	12	96.4	36.195	18.224	17.894	Very high heritability and high GA found, PCV greater than GCV
4.	Annapoorna *et al* (2021)	20	99.90	95.67	46.51	46.47	Very high heritability and high GA found, PCV greater than GCV
5.	Ilakiya *et al* (2022)	3	88.59	29.40	16.54	15.57	High heritability and high GA found, PCV greater than GCV
6.	Ilakiya *et al* (2022)	3	89.43	27.26	13.99	13.99	High heritability and high GA found, PCV greater than GCV
7.	Ilakiya *et al* (2022)	3	77.96	25.17	15.67	13.84	High heritability and high GA found, PCV greater than GCV

19. Pollen viability (%)

1.	Vijayakumar *et al* (2019)	25	72.00	13.35	9.05	7.66	High heritability with moderate GA was found, PCV was greater than GCV
2.	Vijayakumar *et al* (2019)	25	78.00	19.12	11.85	10.48	High heritability with moderate GA was found, PCV was greater than GCV

3.	Kushwah *et al* (2021)	204 RIL's	88.20	12.76	7.02	6.59	High heritability with moderate GA was found, PCV was greater than GCV
4.	Kushwah *et al* (2021)	204 RIL's	92.10	24.46	12.89	12.37	Very high heritability with high GA was found, PCV was greater than GCV

22. Seed yield plant^{-1}

Sl. No	**Reference**	**No of genotypes**	**h^2 %**	**GA % mean**	**PCV %**	**GCV %**	**Finding**
1.	Rajesh *et al* (2023)	57	95.64	40.00	34.70	20.30	Very high heritability and high GA found, PCV is greater than GCV
2.	Khade *et al* (2022)	18	98.08	46.91	23.0	23.22	Very high heritability and high GA found, PCV is greater than GCV
3.	Shikha *et al* (2022)	30	90.1	41.4	22.30	21.16	Very high heritability and high GA found, PCV is greater than GCV
4.	Viswanath *et al* (2022)	26	62.40	20.19	15.73	12.42	high heritability and high GA found, PCV is greater than GCV
5	Bharathi *et al* (2022)	26	89.72	48.17	26.06	24.68	high heritability and high GA found, PCV is greater than GCV
6	Gulwane *et al* (2022)	44	87.70	44.13	24.44	22.88	High heritability and high GA found, PCV is greater than GCV

7	Mohibullah *et al* (2020)	18	91.0	60.0	32.00	30.48	High heritability and high GA found, PCV is greater than GCV
8	Sanjay *et al* (2019)	50	74.70	35.85	23.30	20.14	High heritability and high GA found, PCV is greater than GCV
9	Anusha *et al* (2020)	25	73.0	32.4	21.5	18.4	Very high heritability and high GA found, PCV is greater than GCV

2.2 CORRELATION STUDIES

The nature and degree of connection between two or more quantifiable features can be ascertained with the use of the correlation coefficient analysis. It simplifies intricate connections between occurrences into basic types of correlation. The correlation coefficient (r) calculated by Karl Pearson in 1902 has proved highly effective as a basis for selection. Character association can be quantified using the coefficient of correlation (Galton, 1889).

Correlation fundamental concept in plant breeding was discussed and developed by Fisher in 1918 & Wright in 1921.

Phenotypic and genotypic correlations are the two main forms of correlation that plant breeders are interested in. A direct relationship between two traits that is impacted by environmental and genetic variables is known as a phenotypic correlation. The association amongst two breeding values is termed genotypic correlation. Table 2.2 summarises the analysis of the relationship between yield, contributing traits, & among one another in chickpea.

Table 2.2: Literature on correlation on combined character components with Seed yield plant^{-1}

Sl. No.	Material used for the study	Correlation with grain yield		References
		Genotypic	Phenotypic	
1)	**First blossoming days**			
1.	20 chickpea genotypes	-ve	-ve	Tutlani *et al* (2023)
2.	27 Chickpea genotypes and 3 checks	-ve	-ve	Nikhitha & Walia (2022)
3.	64 chickpeas genotypes including both Desi and Kabuli types	+ve*	+ve*	Vikram *et al* (2022)
4.	204 RILs	-ve	-	Kushwah *et al* (2021)
5.	15 lines of kabuli chickpea	-ve*	-	Singh *et al* (2018)
6.	80 progenies	-ve	-ve	Paneliya *et al* (2017)
7.	21 kabuli chickpea genotypes	+ve*	+ve	Jagadish and vijayalakshmi (2015)

8.	1956 accessions of chickpea	-ve*	-ve*	Upadhyaya *et al* (2002)
2)	**50% blossoming days**			
1.	540 germplasm 5 checks	-ve*	-ve*	Reddy *et al* (2023)
2.	20 chickpea genotypes	-ve	-ve	Tutlani *et al* (2023)
3.	57 chickpea genotypes	+ve	+ve	Ningwal *et al* (2023)
4.	27 Chickpea genotypes and 3 checks	-ve	-ve	Nikhitha & Walia (2022)
5.	64 chickpeas genotypes including both Desi and Kabuli types	+ve*	+ve*	Vikram *et al* (2022)
6.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	-ve	-ve	Xalxo *et al* (2021)
7.	25 chickpea genotypes	-ve*	-ve*	Tak & Meena (2021)
8.	56 chickpea genotypes	-ve	-	Hailu (2020)

9.	10 chickpea varieties	-ve*	-ve	Nawaz (2018)
10.	160 advanced homozygous lines	-ve	-ve	Sohail (2018)
11.	108 diverse genotypes	-ve*	-ve	Nawaz (2018)
12.	21 kabuli chickpea genotypes	+ve*	+ve	Jagadish and vijayalakshmi, (2015)
3)	**Harvest maturity days**			
1.	540 germplasm 5 checks	-ve*	-ve*	Reddy *et al* (2023)
2.	20 chickpea genotypes	+ve	+ve	Tutlani *et al* (2023)
3.	57 chickpea genotypes	-ve	-ve	Ningwal *et al* (2023)
4.	27 Chickpea genotypes and 3 checks	+ve	+ve	Nikhitha & Walia (2022)
5.	64 chickpeas genotypes including both Desi and Kabuli types	+ve*	+ve*	Vikram *et al* (2022)

6.	10 chickpea varieties	-ve*	-ve*	Nawaz (2018)
7.	160 advanced homozygous lines	-ve*	-ve	Sohail (2018)
8.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	-ve*	-ve*	Xalxo *et al* (2021)
9.	25 chickpea genotypes	-ve	-	Tak & Meena (2021)
10.	56 chickpea genotypes	-ve*	-ve*	Hailu (2020)
11.	108 diverse genotypes	+ve	+ve	Nawaz (2018)
12.	21 kabuli chickpea genotypes	+ve	+ve	Jagadish and vijayalakshmi (2015)
4)	**Plant Height**			
1.	540 germplasm 5 checks	-ve*	-ve	Reddy *et al* (2023)
2.	20 chickpea genotypes	+ve	+ve	Tutlani *et al* (2023)
3.	57 chickpea genotypes	+ve	+ve	Ningwal *et al* (2023)
4.	27 Chickpea genotypes and 3 checks	+ve	+ve	Nikhitha & Walia (2022)
5.	64 chickpeas genotypes including both Desi and Kabuli types	+ve*	+ve*	Vikram *et al* (2022)

6.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	-ve	-ve	Xalxo *et al* (2021)
7.	25 chickpea genotypes	+ve	+ve	Tak & Meena (2021)
8.	56 chickpea genotypes	-ve	-ve	Hailu (2020)
9.	160 advanced homozygous lines	-ve	-ve	Sohail (2018)
10.	10 chickpea varieties	+ve*	+ve*	Nawaz (2018)
11.	108 diverse genotypes	+ve	+ve*	Nawaz (2018)
12.	15 lines of kabuli chickpea	+ve*		Singh *et al* (2018)
13.	21 kabuli chickpea genotypes	-ve	-ve	Jagadish and vijayalakshmi (2015)
5)	**Primary offshoots plant^{-1}**			
1.	540 germplasm 5 checks	+ve*	+ve*	Reddy *et al* (2023)
2.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	+ve	Vikram *et al* (2022)
3.	27 Chickpea genotypes and 3 checks	+ve	+ve	Nikhitha & Walia (2022)
4.	57 chickpea genotypes	+ve	+ve	Ningwal *et al* (2023)

5.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	+ve	Xalxo *et al* (2021)
6.	25 chickpea genotypes	+ve	+ve	Tak & Meena (2021)
7.	56 chickpea genotypes	+ve	+ve	Hailu (2020)
8.	160 advanced homozygous lines	+ve	+ve	Sohail (2018)
9.	10 chickpea varieties	-ve	-ve	Nawaz (2018)
10.	108 diverse genotypes	-ve*	-ve	Nawaz (2018)
6)	**Secondary offshoots plant^{-1}**			
1.	540 germplasm 5 checks	+ve*	+ve*	Reddy *et al* (2023)
2.	57 chickpea genotypes	+ve*	+ve*	Ningwal *et al* (2023)
3.	64 chickpeas genotypes including both Desi and Kabuli types	+ve*	+ve*	Vikram *et al* (2022)

4.	27 Chickpea genotypes and 3 checks	+ve	+ve	Nikhitha & Walia (2022)
5.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	-	Xalxo *et al* (2021)
6.	25 chickpea genotypes	+ve*	+ve*	Tak & Meena (2021)
7.	56 chickpea genotypes	+ve	-ve	Hailu (2020)
8.	160 advanced homozygous lines	+ve*	+ve*	Sohail (2018)
9.	10 chickpea varieties	+ve	-ve	Nawaz (2018)
10.	108 diverse genotypes	+ve	-	Nawaz (2018)
7)	**Capsules plant^{-1}**			
1.	540 germplasm 5 checks	+ve*	+ve*	Reddy *et al* (2023)
2.	20 chickpea genotypes	+ve*	+ve*	Tutlani *et al* (2023)
3.	57 chickpea genotypes	+ve*	+ve	Ningwal *et al* (2023)

4.	27 Chickpea genotypes and 3 checks	+ve	+ve	Nikhitha & Walia (2022)
5.	64 chickpeas genotypes including both Desi and Kabuli types	+ve*	+ve*	Vikram *et al* (2022)
6.	39 chickpea genotypes	+ve*	-	Devi *et al* (2022)
7.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	*-ve	*-ve	Xalxo *et al* (2021)
8.	25 chickpea genotypes	-ve	-ve	Tak & Meena (2021)
9.	56 chickpea genotypes	*+ve	+ve	Hailu (2020)
10.	160 advanced homozygous lines	*+ve	*+ve	Sohail (2018)
11.	10 chickpea varieties	*-ve	*-ve	Nawaz (2018)
12.	108 diverse genotypes	+ve*	+ve*	Nawaz (2018)

8)	**Full capsules plant^{-1}**			
1.	Population of 296 RILs	+ve	-	Paul *et al* (2018)
2.	Fifteen lines of kabuli chickpea	+ve*	-	Singh *et al* (2018)
3.	267 landraces, 13 advanced lines, 7 wild accessions and 13 unknown accessions	+ve*	-	Atieno *et al* (2017)
4.	Twenty-two genotypes of chickpea	+ve	-	Yucel and Anlarsal (2010)
9)	**Empty capsules plant^{-1}**			
1.	Twenty-five chickpea genotypes	+ve	-	Dhopre *et al* (2022)
2.	Multiple doses of fertilizer on chickpea	-ve	-	Sabaghnia & Janmohammadi (2019)
3.	64 chickpea genotypes	+ve	-	Chegini *et al* (2017)
4.	267 landraces, 13 advanced lines, 7 wild accessions and 13 unknown accessions	+ve	-	Atieno *et al* (2017)
5.	Twenty-two genotypes of chickpea	+ve	-	Yucel and Anlarsal 2010

10)	**Seeds capsule^{-1}**			
1.	540 germplasm 5 checks	-ve*	+ve	Reddy *et al* (2023)
2.	57 chickpea genotypes	+ve	+ve	Ningwal *et al* (2023)
3.	64 chickpeas genotypes including both Desi and Kabuli types	+ve*	+ve*	Vikram *et al* (2022)
4.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve*	+ve	Xalxo *et al* (2021)
5.	25 chickpea genotypes	-ve	+ve *	Tak & Meena (2021)
6.	56 chickpea genotypes	+ve	+ve	Hailu (2020)
7.	160 advanced homozygous lines	-ve	-	Sohail (2018)
8.	10 chickpea varieties	-ve	-ve	Nawaz (2018)
9.	108 diverse genotypes	-ve	-	Nawaz (2018)

11)	**100 seed weight**			
1.	540 germplasm 5 checks	+ve	+ve	Reddy *et al* (2023)
2.	57 chickpea genotypes	+ve	+ve	Ningwal *et al* (2023)
3.	27 Chickpea genotypes and 3 checks	+ve	+ve	Nikhitha & Walia (2022)
4.	64 chickpeas genotypes including both Desi and Kabuli types	+ve*	+ve*	Vikram *et al* (2022)
5.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve*	+ve*	Xalxo *et al* (2021)
6.	25 chickpea genotypes	-ve	+ve *	Tak & Meena (2021)
7.	56 chickpea genotypes	+ve*	+ve*	Hailu (2020)
8.	10 chickpea varieties	+ve*	+ve	Nawaz (2018)
9.	160 advanced homozygous lines	+ve*	+ve*	Sohail (2018)
10.	108 diverse genotypes	-ve	-ve	Nawaz (2018)

12)	Biological yield plant^{-1}			
1.	57 chickpea genotypes	+ve*	+ve*	Ningwal *et al* (2023)
2.	64 chickpeas genotypes including both Desi and Kabuli types	+ve*	+ve*	Vikram *et al* (2022)
3.	27 Chickpea genotypes and 3 checks	+ve	+ve	Nikhitha & Walia (2022)
4.	39 chickpea genotypes	+ve*	-	Devi *et al* (2022)
5.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	-ve	-ve	Xalxo *et al* (2021)
6.	25 chickpea genotypes	+ve*	+ve*	Tak & Meena (2021)
7.	56 chickpea genotypes	+ve*	-	Hailu (2020)
8.	10 chickpea varieties	+ve*	+ve*	Nawaz (2018)
9.	160 advanced homozygous lines	+ve*	+ve*	Sohail (2018)

10.	108 diverse genotypes	+ve*	+ve*	Nawaz (2018)
13)	**Harvest index (%)**			
1.	57 chickpea genotypes	-ve*	-ve	Ningwal *et al* (2023)
2.	64 chickpeas genotypes including both Desi and Kabuli types	-ve	-ve	Vikram *et al* (2022)
3.	27 Chickpea genotypes and 3 checks	+ve	+ve	Nikhitha & Walia (2022)
4.	39 chickpea genotypes	+ve*	-	Devi *et al* (2022)
5.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	+ve	Xalxo *et al* (2021)
6.	25 chickpea genotypes	+ve	+ve	Tak & Meena (2021)
7.	56 chickpea genotypes	+ve	+ve	Hailu (2020)
8.	10 chickpea varieties	-ve	-ve	Nawaz (2018)
9.	160 advanced homozygous lines	+ve	+ve	Sohail (2018)

10.	108 diverse genotypes	-ve*	-ve	Nawaz (2018)
14)	**Total chlorophyll content (mg/ml)**			
1.	540 germplasm 5 checks	+ve*	+ve	Reddy *et al* (2023)
2.	20 chickpea genotypes	+ve	+ve	Tutlani *et al* (2023)
3.	39 chickpea genotypes	+ve*	-	Devi *et al* (2022)
4.	25 strains of chickpea	+ve*	+ve*	Kumar *et al* (2021)
5.	30 chickpea genotypes	-ve	+ve	Madhuri *et al* (2020)
6.	Six chickpea genotypes	+ve	-	Awasthi *et al* (2017)
7.	21 kabuli chickpea genotypes	-ve*	-ve	Jagadish and vijayalakshmi (2015)
8.	Eight genotypes of chickpea	+ve*	-	Rasool *et al* (2011)
15)	**Relative leaf water content (%)**			
1.	20 chickpea genotypes	-ve*	-ve	Tutlani *et al* (2023)

2.	204 RILs	+ve	-	Kushwah *et al* (2021)
3.	25 strains of chickpea	+ve	+ve	Kumar *et al* (2021)
4.	30 chickpea genotypes	+ve	+ve	Madhuri *et al* (2020)
5.	21 kabuli chickpea genotypes	+ve	+ve	Jagadish and vijayalakshmi (2015)
16)	**Lipid Peroxidation (nmol/ml)**			
1.	20 chickpea genotypes	-ve	-ve	Tutlani *et al* (2023)
17)	**Electrolyte leakage index (%)**			
1.	Two chickpea genotypes	-ve*	-	Moghimi *et al* (2023)
2.	39 chickpea genotypes	-ve*	-	Devi *et al* (2022)
3.	Two genotypes of chickpea	+ve*	-	Moalem *et al* (2018)
4.	Six chickpea genotypes	-ve	-	Awasthi *et al* (2017)

18)	**Proline content (mg/gm)**			
1.	20 chickpea genotypes	+ve	+ve	Tutlani *et al* (2023)
2.	Two chickpea genotypes	-ve*	-	Moghimi *et al* (2023)
3.	40 chickpea genotypes	-ve	-	Rajput *et al* (2023)
4.	120 Kabuli chickpea	+ve*	-	Hussain *et al* (2022)
5.	30 chickpea genotypes	-ve	+ve	Madhuri *et al* (2020)
6.	Two genotypes of chickpea	-ve	-	Moalem *et al* (2018)
19)	**Ascorbic acid content (mg)**			
1.	Six chickpea genotypes	+ve	-	Awasthi *et al* (2017)
2.	50 coriander genotypes	+ve*	+ve*	Chandrakala *et al* (2023)

20)	**Pollen viability (%)**			
1.	204 RILs	+ve	-	Kushwah *et al* (2021)
2.	39 chickpea genotypes	+ve*	-	Devi *et al* (2022)
22)	**Seed yield plant^{-1}**			
1.	10 chickpea varieties	+ve	+ve	Nawaz, (2018)
2.	160 advanced homozygous lines	+ve*	+ve*	Sohail, (2018)
3.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve*	+ve*	Xalxo *et al* (2021)
4.	56 chickpea genotypes	+ve*	+ve*	Hailu, (2020)
5.	25 chickpea genotypes	+ve*	-	Tak & Meena (2021)
6.	108 diverse genotypes	+ve	+ve	Nawaz (2018)

2.3 PATH COEFFICIENT ANALYSIS

Dewey and Lu (1959) were the pioneers in plant breeding for path analysis, who defined it as a technique for classifying observable correlations as effects that are both direct and indirect. Wright (1921) first described the technique. It is a standard regression coefficient that helps describe and illustrate the relative importance of the forces really operating in the cause-and-effect system, as opposed to only quantifying the natural relationship. Additional information on the characters' indirect & direct impacts on yield may be found in the path analysis. It is therefore feasible to compute the relative contributions of each component to produce.

This technique was first applied in plant breeding in 1959 by Dewey & Lu, who noted that the techniques provide vital information about the specific forces operating to generate a particular relationship. By assigning values to the path coefficients relating to yield and dividing the overall correlation coefficient into direct and indirect impacts, they were able to figure out the complicated relationship in the selection program with much more clarity and precision. Table 2.3 documents the review of literature on the indirect & direct impacts of yield components using path analysis.

Table 2.3: Path analysis literature

Sl. No.	**Material used for the study**	**Direct effect on grain yield**	**References**
1)	**First blossoming days**		
1.	27 Chickpea genotypes and 3 checks	-ve	Nikhitha & Walia (2022)
2.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	Vikram *et al* (2022)
3.	20 genotypes of chickpea	+ve	Tutlani *et al* (2023)
4.	204 RILs	-ve	Kushwah *et al* (2021)
5.	15 lines of kabuli chickpea	-ve	Singh *et al* (2018)
6.	Single seed descent (SSD) and random bulk population (RBP) of GJG 0315 X ICCV 96029	+ve	Paneliya *et al* (2017)
7.	21 kabuli chickpea genotypes	-ve	Jagadish and vijayalakshmi (2015)
2)	**50% blossoming days**		
1.	540 chickpea germplasm, including 5 checks	+ve	Reddy *et al* (2023)
2.	27 Chickpea genotypes and 3 checks	+ve	Nikhitha & Walia (2022)
3.	64 chickpeas	-ve	Vikram *et al* (2022)

	genotypes including both Desi and Kabuli types		
4.	20 genotypes of chickpea	-ve	Tutlani *et al* (2023)
5.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	Xalxo *et al* (2021)
6.	25 chickpea genotypes		Tak & Meena (2021)
7.	56 chickpea genotypes	+ve	Hailu, (2020)
8.	10 chickpea varieties	-ve	Nawaz (2018)
9.	108 diverse genotypes	+ve	Nawaz (2018)
10.	160 advanced homozygous lines	+ve	Sohail (2018)
3)	**Harvest maturity days**		
1.	540 chickpea germplasm, including 5 checks	-ve	Reddy *et al* (2023)
2.	64 chickpeas genotypes including both Desi and Kabuli types	-ve	Vikram *et al* (2022)
3.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	Xalxo *et al* (2021)
4.	25 chickpea genotypes	-ve	Tak & Meena (2021)

5.	56 chickpea genotypes	-ve	Hailu (2020)
6.	160 advanced homozygous lines	-ve	Sohail (2018)
7.	10 chickpea varieties	+ve	Nawaz (2018)
8.	108 diverse genotypes	-ve	Nawaz (2018)
4)	**Plant Height**		
1.	540 chickpea germplasm, including 5 checks	-ve	Reddy *et al* (2023)
2.	27 Chickpea genotypes and 3 checks	+ve	Nikhitha & Walia (2022)
3.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	Vikram *et al* (2022)
4.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	-ve	Xalxo *et al* (2021)
5.	25 chickpea genotypes	+ve	Tak & Meena (2021)
6.	56 chickpea genotypes	+ve	Hailu (2020)
7.	160 advanced homozygous lines	-ve	Sohail (2018)
8.	10 chickpea varieties	+ve	Nawaz (2018)
9.	108 diverse genotypes	-ve	Nawaz (2018)
5)	**Primary offshoots plant^{-1}**		
1.	540 chickpea germplasm, including 5 checks	+ve	Reddy *et al* (2023)

2.	27 Chickpea genotypes and 3 checks	+ve	Nikhitha & Walia (2022)
3.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	Vikram *et al* (2022)
4.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	Xalxo *et al* (2021)
5.	25 chickpea genotypes	-ve	Tak & Meena (2021)
6.	56 chickpea genotypes	+ve	Hailu (2020)
7.	10 chickpea varieties	+ve	Nawaz (2018)
8.	160 advanced homozygous lines	+ve	Sohail (2018)
9.	108 diverse genotypes	+ve	Nawaz (2018)
6)	**Secondary offshoots plant^{-1}**		
1.	540 chickpea germplasm, including 5 checks	-ve	Reddy *et al* (2023)
2.	27 Chickpea genotypes and 3 checks	-ve	Nikhitha & Walia (2022)
3.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	Vikram *et al* (2022)
4.	56 genotypes (10 lines, 6 testers &	+ve	Xalxo *et al* (2021)

	their 40 F_1 population)		
5.	25 chickpea genotypes	-ve	Tak & Meena (2021)
6.	56 chickpea genotypes	+ve	Hailu (2020)
7.	10 chickpea varieties	-ve	Nawaz (2018)
8.	160 advanced homozygous lines	-ve	Sohail (2018)
9.	108 diverse genotypes	-ve	Nawaz (2018)
7)	**Capsules plant^{-1}**		
1.	540 chickpea germplasm, including 5 checks	+ve	Reddy *et al* (2023)
2.	27 Chickpea genotypes and 3 checks	+ve	Nikhitha & Walia (2022)
3.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	Vikram *et al* (2022)
4.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	-ve	Xalxo *et al* (2021)
5.	25 chickpea genotypes	+ve	Tak & Meena (2021)
6.	56 chickpea genotypes	+ve	Hailu (2020)

7.	10 chickpea varieties	-ve	Nawaz (2018)
8.	160 advanced homozygous lines	-ve	Sohail (2018)
9.	108 diverse genotypes	-ve	Nawaz (2018)
8)	**Full capsules plant^{-1}**		
	26 genotypes of Chickpea including one check	-ve	Swathi and Lal (2021)
	15 chickpea genotypes	-ve	Singh *et al* (2018)
	267 landraces, 13 advanced lines, 7 wild accessions and 13 unknown accessions	-ve	Atieno *et al* (2017)
	Twenty-two genotypes of chickpea	-ve	Yucel and Anlarsal 2010
9)	**Empty capsules plant^{-1}**		
1.	Twenty-two genotypes of chickpea	+ve	Yucel and Anlarsal 2010
2.	64 chickpea genotypes	-ve	Chegini *et al* (2017)
3.	267 landraces, 13 advanced lines, 7 wild accessions and 13 unknown accessions	+ve	Atieno *et al* (2017)
10)	**Seeds capsule^{-1}**		
1.	540 chickpea germplasm, including 5 checks	+ve	Reddy *et al* (2023)

2.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	Vikram *et al* (2022)
3.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	Xalxo *et al* (2021)
4.	25 chickpea genotypes	+ve	Tak & Meena (2021)
5.	56 chickpea genotypes	+ve	Hailu (2020)
6.	10 chickpea varieties	+ve	Nawaz (2018)
7.	160 advanced homozygous lines	-ve	Sohail (2018)
8.	108 diverse genotypes	-ve	Nawaz (2018)
11)	**100 seed weight**		
1.	540 chickpea germplasm, including 5 checks	+ve	Reddy *et al* (2023)
2.	27 Chickpea genotypes and 3 checks	+ve	Nikhitha & Walia (2022)
3.	64 chickpeas genotypes including both Desi and Kabuli types	-ve	Vikram *et al* (2022)
4.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	Xalxo *et al* (2021)

5.	25 chickpea genotypes	-ve	Tak & Meena (2021)
6.	56 chickpea genotypes	+ve	Hailu (2020)
7.	160 advanced homozygous lines	+ve	Sohail (2018)
8.	10 chickpea varieties	+ve	Nawaz (2018)
9.	108 diverse genotypes	+ve	Nawaz (2018)
12)	**Biological yield plant^{-1}**		
1.	27 Chickpea genotypes and 3 checks	+ve	Nikhitha & Walia (2022)
2.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	Vikram *et al* (2022)
3.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	Xalxo *et al* (2021)
4.	25 chickpea genotypes	-ve	Tak & Meena (2021)
5.	56 chickpea genotypes	+ve	Hailu (2020)
6.	160 advanced homozygous lines	-ve	Sohail (2018)
7.	10 chickpea varieties	-ve	Nawaz (2018)

8.	108 diverse genotypes	-ve	Nawaz (2018)
13)	**Harvest index (%)**		
1.	27 Chickpea genotypes and 3 checks	+ve	Nikhitha & Walia (2022)
2.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	Vikram *et al* (2022)
3.	56 genotypes (10 lines, 6 testers & their 40 F1 population)	-ve	Tak & Meena (2021)
4.	6 chickpea varieties	-ve	Xalxo *et al* (2021)
5.	56 chickpea genotypes	-ve	Hailu (2020)
6.	10 chickpea genotypes	-ve	Nawaz (2018)
7.	83 diverse genotypes with 3 check Varieties	+ve	Sohail (2018)
8.	108 diverse genotypes	+ve	Nawaz (2018)
14)	**Total chlorophyll content (mg/ml)**		
1.	20 genotypes of chickpea	-ve	Tutlani *et al* (2023)
2.	540 chickpea germplasm, including 5 checks	+ve	Reddy *et al* (2023)
3.	25 chickpea genotypes comprising indigenous and exotic	+ve	Kumar *et al* (2021)
4.	21 kabuli chickpea genotypes	-ve	Jagadish and vijayalakshmi (2015)
5.	30 chickpea genotypes (irrigated)	-ve	Madhuri *et al* (2020)

6.	30 chickpea genotypes (rainfed)	+ve	Madhuri *et al* (2020)
7.	27 lines of soybean	+ve	Malik *et al* 2007
15)	**Relative leaf water content (%)**		
1.	20 genotypes of chickpea	+ve	Tutlani *et al* (2023)
2.	25 chickpea genotypes comprising indigenous and exotic	-ve	Kumar *et al* (2021)
3.	204 RILs	+ve	Kushwah *et al* (2021)
4.	21 kabuli chickpea genotypes	+ve	Jagadish and vijayalakshmi (2015)
5.	30 chickpea genotypes (irrigated)	+ve	Madhuri *et al* (2020)
6.	30 chickpea genotypes (rainfed)	-ve	Madhuri *et al* (2020)
16)	**Lipid Peroxidation (nmol/ml)**		
1.	20 genotypes of chickpea (60 DAS)	+ve	Tutlani *et al* (2023)
2.	20 genotypes of chickpea (100 DAS)	-ve	Tutlani *et al* (2023)
18)	**Proline content (mg/gm)**		
1.	30 chickpea genotypes	+ve	Madhuri *et al* (2020)
2.	20 genotypes of chickpea (60 DAS)	-ve	Tutlani *et al* (2023)
3.	20 genotypes of chickpea (100 DAS)	+ve	Tutlani *et al* (2023)
19)	**Ascorbic acid content (mg)**		
1.	50 coriander genotypes	+ve	Chandrakala *et al* (2023)
20)	**Pollen viability (%)**		
1.	204 RIL's	+ve	(Kushwah *et al* (2021)

22)	Seed yield plant^{-1} (gm)		
1.	64 chickpeas genotypes including both Desi and Kabuli types	+ve	Vikram *et al* (2022)
2.	56 genotypes (10 lines, 6 testers & their 40 F_1 population)	+ve	Xalxo *et al* (2021)
3.	25 chickpea genotypes	+ve	Tak & Meena (2021)
4.	56 chickpea genotypes	+ve	Hailu (2020)
5.	160 advanced homozygous lines	+ve	Sohail (2018)
6.	10 chickpea varieties	+ve	Nawaz (2018)
7.	108 diverse genotypes	+ve	Nawaz (2018)

1.4 Stability analysis

The interaction between genetic and environmental impacts on development is referred to as genotype x environment interaction, and it diminishes the phenotype-genotype association. The scale of it can be determined by gradually increasing the amount of experimental material over the course of time and space, and under controlled conditions. Because genotypes' phenotypic responses to environmental changes may differ, genotype-environment interaction is extremely essential in plant breeding. Phenotypic stability refers to a genotype's ability to produce a limited range of phenotypes in a variety environment. For the commercial cultivation of crop plants, phenotypically stable types are preferred. Screening and identifying genotypes that might function more or less evenly under various environmental situations is crucial in breeding programs.

Finlay and Wilkinson (1963) provided a more effective method of determining phenotypic stability. The slope of the linear regression was utilized as a measure for stability. Eberhart and Russell (1966) explained the necessity of taking into consideration both linear (bi) & non-linear (S2di) components of genotype environment interaction when measuring genotype stability. Linear regression can be considered as a measure of responsiveness for a certain genotype, according to Breese (1969) and Paroda and Hayes (1971), but the deviation around the regression line is thought to be a measure of stability, with the genotype with the lowest deviations being the most stable. Here is an overview of the stability in chickpea data from several researchers.

Mahmood *et al* (2021) during the 2019–20 growing season, eleven different sites across the Punjab region of Pakistan were used to study yield stability in sixteen advanced chickpea lines. GGE-biplot between PC1 and 2, indicated that genotype K-15019 did the best in all settings. Mega environment analysis revealed that the environments EN-2 and E8 were the settings that are most useful for genotype screening and most discriminating for grain yield, and that genotypes K-15019, CH47/12, K-15001, CH66/10, and CH53/12 were higher yielding and more stable across environments.

Shimray *et al* (2022) investigated on an association mapping panel of 380 chickpea genotypes for three separate years, covering 2014–2015, 2015–2016, and 2016–2017, for factors that affect yield. The two most significant factors that influence yield, according to AMMI study, are seed weight and seed number. The genotypes were responsible for 93.08% of total variance overall, whereas, interaction effect for the two traits was only

4.1%. For the seed weight, IG5986, ILC6025, ICCV14307, IG5982 and, as well as the seed number, IG5893, ILC6891, & IG5856, were shown to be desirable genotypes by AMMI biplot analysis.

Qaisi and Bayati (2023) carried out a field experiment during crop season 2021-22, at a single location in three different planting dates. The findings showed that for all the examined variables and in all three contexts, genetic variance was greater than environmental variance. According to the stability study, there was a strong relationship between environments, genotypes, and their interactions. Total seed production in the three habitats under study had significant levels of phenotypic variance and coefficient of genetic variation, and all of the environments and examined attributes had high levels of broad sense heritability. Relevance for every characteristic examined. In the two genotypes FLIP12-10C and FLIP12-182C for the proportion of protein in the examined settings, the genotype FLIP12-73C was consistent in the attributes of seed yield. Significant phenotypic stability was observed for the genotypes FLIP12-185C, FLIP12-73C, and FLIP12-264C.

Babbar and Tiwari (2018) examined the effects of G x E interactions among 40 different genotypes of chickpeas to find genotypes that are largely constant across environments. Results showed that for all of the features examined in the three contexts, the PCV was larger in size than its equivalent GCV. In all three settings and pooled analysis, the traits biological yield plant^{-1} (97.8% and 108.2%), seed yield (97.3% and 104%), and capsules plant^{-1} (95.5% and 83%) revealed strong heritability along with great genetic advance % mean. The genotypes ICC 4958, GG 2, ICCL 81248 ICC 8474, ICCV 07109, ICCV 07102, ICCV 07110, MP JG 2003-115, JAKI 9218, ICC 1882, JG 130, and MP JG 99-115 These genotypes were all specifically designed for exploiting the yield of seeds per plant because they all had regression coefficients larger than one coupled with high mean values.

Hasan and Deb (2017) conducted an experiment over the course of four successive rabi seasons, from 2009-2010 to 2012-2013, to determine the stability and GxE interaction. According to an ANOVA, the majority of the characters' genotypes and years differed considerably. The outcomes of combined regression analysis demonstrated that the genotype-dependent mean squares were significant for all examined features. All examined traits, except for DMF, showed significant variation brought on by environmental change. The genotypes 1 for DFF, DMF, and NPBFF, 2 for NPBMF and

NSBFF, 4 for NSBMF, 5 for NPBMF and NPBFF, 6 for SW/P & NSBMF, & 7 for NPBFF & NPBMF were regarded stable in this investigation.

Desai *et al* (2016) 10 distinct genotypes were examined for G x E interaction and stability in four contexts, including two sowing dates and two locations. With respect to the NPP, SY/P, TW, HI, and protein (%). The G x E interaction variance was significant, according to an ANOVA study. Three cultivars—GG-1, GJG-3, and Dahod Yellow—as well as the genotypes IC-269273 and IC-269295 recorded stable performance across the environments. Dahod Yellow exhibited the largest average seed yield plant^{-1} among among these five genotypes and was the most resilient to environmental changes.

Pathy *et al* (2022) examined 23 genotypes of chickpea between 2015 and 2017. Significant differences caused by environment, genotypes, and their interaction were found by pooled analysis of variance. Two significant principal components were recovered by AMMI analysis, and they accounted for all the variation. For genotypes, the majority of these measures had comparable rankings.

Dhopre *et al* (2022) conducted a study on 25 genotypes of chickpea in CRBD on November 28, December 28, and January 28 of 2019–20. There were two replications in each environment. 15 Desi and 10 Kabuli type genotypes were present. For all of the qualities under study, the analysis of variance showed a considerable variation between genotypes. For all of the examined qualities, it was determined that the environmental variation (linear) was substantial. All of the qualities were shown to have a significant GE (Linear) component. The genotypes JG-11 (Desi), RVG-202 (Desi), RVG-204 (Desi), ICC-4958 (Desi), RVSSG-62 (Kabul), and RVSSG-61 (Kabul) all showed regression coefficients greater than one and mean values higher than the grand mean, demonstrating that these genotypes are suggested for very-late planted conditions with high seed production.

Shivani and Sreelakshmi (2015) During 2009–10, 2010–11, and 2011–12, stability was examined on 25 genotypes. The genotypes varied considerably for every character except 50% blossoming days, the primary offshoots plant^{-1}, and seed yield, according to an ANOVA for seed yield and its constituent variables. Days to 50% blooming, primary branches plant^{-1}, test weight (gm) all showed considerable variation caused by non-linear environmental factors (pooled deviations), showing unexpected environmental factors infuence on them. Regarding stability, the genotypes ICC 11574, ICC 5034, and ICCV 09104 were the least stable and best suited to favourable circumstances. While the genotypes ICCV 09314, ICCV 86111, ICCV 09308 and ICC 5583 were adapted to unfavourable settings, the genotypes ICCV 86105, ICCV 09118, ICC 5360 and ICCV 08311 were adapted to favourable environments (bi>1), higher mean and substantial variances.

Danyali *et al* (2012) examined several univariate and multivariate stability approaches to assess the G x E interaction in 17 chickpea genotypes under 16 environmental conditions in Iran's chickpea growing regions. The results of a combined analysis of variance across environments showed that the yield performance of a genotype was highly influenced by both GE interactions and environmental factors. In order to determine stable genotypes in connection to the yield taken into account in this study and to explain the GE interaction, twenty univariate and multivariate stability approaches and methodologies were applied. These techniques revealed that S 96003 and S 95293 were the genotypes that were the most reliable. These genotypes might not be as effective as those that are sensitive in a favourable environment, though. We can use each of these groups to introduce some genotypes to farmers in accordance with the sort of stability that was sought for each group.

Das *et al* (2022) examined the stability of eight chickpea genotypes under six environmental conditions for grain yield and other yield related variables. According to the data, the mean grain yields of genotypes ICCV14102 (1220.57 kg/ha), ICCV 15115 (1125.40 kg/ha), and ICCV14108 (1110.01 kg/ha) are higher than the grand mean yield (1054.48 kg/ha), however the yields of five other genotypes are lower. The most stable genotypes were ICCV 14102 (YSI = 4) and ICCV 15115 (YSI = 8) across the environment, according to the yield stability index and WAAS rating, and it is recommended that these genotypes be released after thorough review.

Pouresmael *et al* (2018) during three consecutive cropping seasons (2010–2013), stability of 12 native landrace chickpeas and three check cultivars were examined in four locations. To confirm the existence of variations between genotypes, ANOVA was used. Grain yield was significantly influenced by the main effects of year, location, and genotype as well as by their two- and three-way interactions. The three major factors accounted for 62% of the total genotype by environment interaction, according to AMMI research. The regions of Kermanshah and Urmia were determined to be favourable settings for chickpea growing based on high crop output. According to the findings, the landraces G1, G2, G3, G8, and G12 might be employed in breeding programs to create new chickpea varieties because they had the highest average performance and stability in comparison to check cultivars.

Rao *et al* (2023) conducted a multi-environment study in chickpea under five settings with 50 genotypes w during Rabi, 2021–2022, with the goal of identifying superior and locally adaptive genotypes under rainfed circumstances. Significant genotype, environment, and GE interaction were found in the AMMI ANOVA for grain yield (kg ha-1) of 50 chickpea genotypes, demonstrating the presence of genetic and environmental heterogeneity. 50 genotypes' average grain yields varied from 1296 kg/ha (G39) to 2222 kg/ha (G8) across different conditions. When grown in the environment EN-2 (Palem), the genotype G24 produced higher grain yields than the mean yield. The findings showed that Warangal's environment E5 was the ideal place for grain yield to potentially manifest itself. G17 genotype demonstrated good grain yield and high stability across the regions with desirable mean performance, according to stability analyses.

1.5 HETEROBELTIOSIS, RELATIVE HETEROSIS & STANDARD HETEROSIS

Essential genetic technique for increasing end produce output in self and cross-pollinated crops is heterosis. It is regarded as most significant breeding breakthrough in enhancement programs. F1's heterosis is the character specific divergence from the reference. Shull (1952) invented heterosis word. According to Falconer and Mackay (1996), it is the disparity between certain characteristic hybrid estimate to average for the same trait in both parents. Hybrid's superiority genetic expression over its parents is heterosis, Miranda (1999).

In the literature, there are three major types of estimation of heterosis: mid-parent/ average heterosis, *i.e.,* elevated F_1 vigor over the parental mean; better parent heterosis, *i.e.,* elevated F_1 vigor over better parent by Sinha & Khanna, 1975; and economic heterosis, which is the elevated vigor of the Fi over check variety. Although heterosis benefits various economically significant crops, the genetic and physiological processes behind this occurrence remain unknown (Hallauer and Miranda, 1988). To explain the mechanisms underlying the phenomenon of heterosis, three key theories have been proposed: dominance, over-dominance, and epistasis. However, it is widely assumed that heterosis is mostly caused by dominance gene action (Singh, 2005).

Table 2.5 summarizes the findings of many researchers on the degree of heterosis in chickpea.

Table 2.5: Review of literature on Relative heterosis, Heterobeltosis and Economic heterosis

References	Mating Designs	Relative heterosis	Heterobeltosis	Economic heterosis	Significant Finding
First blossoming days					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-10.48 to 0.33	-8.64 to 4.14		RSG-963 × Avrodhi(-10.48) & Avrodhi × HC-5 (-8.64) showed highly significant and desirable relative heterosis and heterobeltosis respectively
Malge *et al* (2021)	4 x 6 (L x T)	-30 to -8.33	-31.67 to 8.33	-31.67 to 8.33	negative significant average heterosis and heterobeltiosis for cross PDKVKanchan x WR-315 (-30.00)
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-	-	
Rana *et al* (2019)	9 x 4 (L x T)	-	-	-	
Sasane *et al* (2018)	4 x 6 (L x T)			-	
Yamini *et al* (2015)	7 x 7 (Diallel)	-23.5 to 26.2	-28.45 to 18	-	ICCV 05106 x ICCV 95333 (-28.45) showed highly significant and desirable heterobeltosis respectively
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**
50% blossoming days					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-10.79 to 2.21	-8.47 to 3.18	-	RSG-963 × HC-5(-10.79) & Avrodhi × HC-5(-8.47) for 50% blossoming days exhibited negative heterosis.
Malge *et al* (2021)	4 x 6 (L x T)	-16.59 to 11.76	-18.52 to 11.76	-9.38 to 26.04	Highest significant negative average heterosis and heterobeltiosis was observed in the cross PDKV Kanchan × GAU-1107 (-16.59%) & PDKV Kanchan × GAU1107 (-18.52%)

Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-9.52 to 1.81	-7.88 to 10.91	GNG-2207 x JAKI-9218 (-9.52%), JG-62 x C-565 (-7.88%) showed significantly higher negative heterosis over better parent & over standard check.
Rana *et al* (2019)	9 x 4 (L x T)	-3.14 to 0.66	-5.18 to 0.00	-	ICC-4958×WCG3(-5.18), C-235× Sadbhavana (-3.14) was observed negative heterosis.
Johnson *et al* (2019)	7 x 3 (L x T)	-	-4.602 to 24.110	-	JG130 X JG97 (-4.602) significantly negative heterosis was recorded.
Sasane *et al* (2018)	4 x 6 (L x T)	-10.60 to 12.87	-17.09 to 12.75	-17.09 to 12.75	Highest significant negative average heterosis and heterobeltiosis was observed in the cross Chanoli x Phule G-12310 (-10.60% and -17.09%).
Yamini *et al* (2015)	7 x 7 (Diallel)	-21.26 to 14.29	-27.66 to 1.72	-	ICCV05106 X ICCV 95333 (-21.26) & JG-11 x Vihar (-27.66) showed significantly higher negative heterosis and heterobeltosis.
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**
Harvest maturity days					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-5.2 to 0.76	-5.06 to 0.62	-	RSG-888 × CSJ-515 (-5.2) 7 (-5.06) was observed has highly negative significant in heterosis & heterobeltosis.
Malge *et al* (2021)	4 x 6 (L x T)	-3.09 to 5.94	-4.67 to 4.48	0.99 to 6.44	Highly negative significant in heterosis & heterobeltosis observed PhuleVikram x GAU-1107 (-3.09) & (-4.67)
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-4.40 to 2.83	-4.69 to 6.45	Phule Vikram×Digvijay (-4.40),C-565×Digvijay(-4.69) was observed as higher negative heterobeltosis and economic heterosis.
Rana *et al* (2019)	9 x 4 (L x T)	-4.92 to 0.52	-7.06 to 0.42	-	C-235×WCG-3 (-4.92) & C-235×Sadbhavana (-7.06) was observed has highly negative significant in heterosis & heterobeltosis.

Johnson *et al* (2019)	7 x 3 (L x T)	-	1.485 to 40.224	-	JG130 X ICCV96030 (40.224) significantly positive heterobeltosis was recorded.
Sasane *et al* (2018)	4 x 6 (L x T)	-8.01 to 1.24	-13.15 to 0.49	-13.15 to 0.49	Highly significant negative heterosis, heterobeltosis & ecnomic heterosis was observed in PKV Kabuli-2 x Phule G-12310 (-8.01) &Chanoli x Phule G-12310 (-13.15).
Yamini *et al* (2015)	7 x 7 (Diallel)	-12.92 to 10.34	-17.25 to 15.02		JG-11 x MNK-1 (-12.92) & NBeG -3 x JG-11(-17.25) was showed significantly negative heterosis & heterobeltosis.
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**
Plant height					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-10.51 to 16.87	-12.9 to 16.83	-	CSJD-884 × RSG-973 (-10.51) & (-12.9) exhibited negative and significant relative heterosis and heterobeltiosis.
Malge *et al* (2021)	4 x 6 (L x T)	-4.8 to 21.81	-9.63 to 14.21	-13 to 13.20	Highest significant negative average heterosis and heterobeltiosis was observed in the PhuleVikram x GJG-0814(-4.8)&Chanoli x C-1821(-9.63)
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-20.81 to 4.74	-23.49 to -9.11	C-565×Phule Vikram (-20.81) was observed as higher negative heterobeltosis.
Rana *et al* (2019)	9 x 4 (L x T)	-11.74 to 12.73	-2.91 to 12.73	-	C-235×Pusa-1103(-11.74) & WCG-9550×Pusa-1103(-2.91) showed negative heterosis and heterobeltosis.
Johnson *et al* (2019)	7 x 3 (L x T)	-	-5.814 to 21.985	-	JG130 XICCV96029 (-5.814) showed higher negative heterobeltosis.
Sasane *et al* (2018)	4 x 6 (L x T)	-19.50 to 18.61	-22.96 to 11.11	-	Chanoli x MNK-1 (-19.50) & Chanoli x Virat (-22.96) was significantly negative.
Yamini *et al* (2015)	7 x 7 (Diallel)	-11.49 to 15.07	-24.29 to 7.09	-	JG-11 x KAK-2 (-11.49) & (-24.29) showed significantly higher negative heterosis and heterobeltosis.

References	Mating Designs	Relative heterosis	Heterobeltosis	Economic heterosis	Significant Finding
Primary offshoots plant^{-1}					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-7.47 to 38.31	-8.06 to 31.48	-	RSG-888 × RSG-973(-7.47) was highly negative significant in both heterosis and heterobeltosis.
Malge *et al* (2021)	4 x 6 (L x T)	-43.29 to 13.36	-43.29 to 13.36	-59.76 to 20	Chanoli x C-1821(-43.29) & (-59.16) showed higher negative heterosis.
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-33.33 to 3.51	-33.33 to 3.51	Phule Vikram×Digvijay (-33.33) was observed as higher negative heterobeltosis.
Rana *et al* (2019)	9 x 4 (L x T)	-	-15.8 to 16.21	5.53 to 32.54	KGD-1161× Pusa-256 (-15.8) showed significantly negative heterobeltosis.
Johnson *et al* (2019)	7 x 3 (L x T)	-	97.213 to 10.477	-	indira chana-1 (97.213) is a low diversity & significantly positive heterobeltosis.
Sasane *et al* (2018)	4 x 6 (L x T)	-32.50 to 27.08	-35.71 to 12.5	-36.21 to 5.17	Highest significant of negative heterosis, heterobeltosis& economic heterosis was observed in Chanoli x Virat (-32.50)
Yamini *et al* (2015)	7 x 7 (Diallel)	-32.56 to 50.44	-45.31 to 40.63	-	MNK-1 x Vihar(-32.56) showed negative heterosis & heterobeltosis.
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**
Secondary offshoots plant^{-1}					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-12.84 to 40.04	-14.49 to -14.49	-	CSJD-884 × Avrodhi (-12.84) & RSG-973 × Avrodhi (-14.49) showed significantly negative heterosis & heterobeltosis
Malge *et al* (2021)	4 x 6 (L x T)	-45.74to 25.68	-61.85 to 20.22	-66.47 to 15.45	Chanoli x C-1821(-45.74) & (-61.85) was observed negative heterosis & heterobeltosis
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-38.10 to 8.10	-38.10 to 8.10	C-565×Phule Vikram (-38.10) was observed as higher negative heterobeltosis.
Rana *et al* (2019)	9 x 4 (L x T)	-	-	-	-
Johnson *et al* (2019)	7 x 3 (L x T)	-	-24.26 to 55.37	-	JG 16 x ICCV96030 showed significantly negative heterobeltosis.

Sasane *et al* (2018)	4 x 6 (L x T)	-24.48 to 50.08	-32.14 to 49.34	-42.52 to 19.63	Highly significant heterosis, heterobeltosis & ecnomic heterosis was observed in Kripa x Phule G-0739 (-24.48) & Kripa x Phule G-0739 (-32.14), (-20.09)
Yamini *et al* (2015)	7 x 7 (Diallel)	-	-	-	-
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**
Capsules plant^{-1}					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-8.04 to 24.97	-12.32 to 13.02	-	RSG-973× RSG-974 (-8.04) & RSG-888 × CSJ-515 (-12.32) was highly negative significant in heterosis and heterobeltosis.
Malge *et al* (2021)	4 x 6 (L x T)	-4.8 to 21.81	-9.63 to 14.21	-13 to 13.20	highly negative significant observed PhuleVikram x GJG-0814(-4.8), Chanoli x C-1821(-9.63)
Lakhote *et al* (2020)	7 x 7 (Diallel)		-52.54 to 9.39	-52.54 to 4.80	C-565×Phule Vikram (-52.54) was observed as higher negative heterobeltosis and economic heterosis.
Rana *et al* (2019)	9 x 4 (L x T)	-8.90 to 12.77	9.69 to 26.78	-	GNG-1581×WCG-3 (-8.90) highly negative & Vallabh Hara×WCG-3(9.69) showed significantly positive heterosis & heterobeltosis.
Yamini *et al* (2015)	7 x 7 (Diallel)	10.38 to 187.59	-13.23 to 145.99	-	NBeG-3 x MNK-1 (10.38) showed significantly positive heterosis and NBeG-3 x MNK-1(-13.23) showed negative heterobeltosis.

References	Mating Designs	Relative heterosis	Heterobeltosis	Economic heterosis	Significant Finding
Full capsules plant^{-1}					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-	-	-	-
Malge *et al* (2021)	4 x 6 (L x T)	-	-	-	-
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-	-	-
Rana *et al* (2019)	9 x 4 (L x T)	-	-	-	-
Johnson *et al* (2019)	7 x 3 (L x T)	-	1.628 to 80.493	-	Indira chana-1 X JG97(80.493) showed positive significant in Heterobeltosis
Sasane *et al* (2018)	4 x 6 (L x T)	-33.73 to 60.89	-41.46 to 53.41	-63.31 to 21.42	Highly significant negative heterosis, heterobeltosis & ecnomic heterosis was observed in Kripa x MNK-1 (-33.73), (-41.46) & (-63.31).
Yamini *et al* (2015)	7 x 7 (Diallel)				
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**

Empty capsules plant^{-1}					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-	-	-	-
Malge *et al* (2021)	4 x 6 (L x T)	-44.3 to 670	-63.93 to 285	-42.1 to102.63	Chanoli x WR-315(-44.3), (-63.93) & (-42.1) was observed negative heterosis, heterobeltosis& Economic heterosis.
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-	-	-
Rana *et al* (2019)	9 x 4 (L x T)	-	-	-	-
Johnson *et al* (2019)	7 x 3 (L x T)	-	-	-	-
Sasane *et al* (2018)	4 x 6 (L x T)	-44.74 to 47.45	-44.74 to 47.45	-44.74 to 47.45	Highly significant negative heterosis, heterobeltosis & ecnomic heterosis was observed in Chanoli x Phule G-12310 (-44.74) & (-44.74).
Yamini *et al* (2015)	7 x 7 (Diallel)				
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**
Seeds capsule^{-1}					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-16.83 to 26.21	-18.52 to 14.81	-	RSG-888 × RSG-973 (-16.83) & RSG-963 × RSG-974 (-18.52) was highly negative significant in heterosis and heterobeltosis.

Malge *et al* (2021)	4 x 6 (L x T)	-14.89 to 20	-20.00 to 20.00	-13.04 to 4.35	AKG-1303 x C-1821 (-14.89), PhuleVikram x WR-315 & PhuleVikram x WR-315(-20.00) showed highly negative heterosis and heterobeltosis.
Lakhote *et al* (2020)	7 x 7 (Diallel)		-49.92 to 12.55	-49.92 to 10.27	C-565×Phule Vikram (-49.92) was observed as higher negative heterobeltosis and economic heterosis.
Rana *et al* (2019)	9 x 4 (L x T)	-11.01 to 33.91	-20.34 to 30.19	-	GNG-1581×Pusa-256 (-11.01) & (-20.34) showed highly negative significant in heterobeltosis & heterosis.
Johnson *et al* (2019)	7 x 3 (L x T)	-	-	-	-
Sasane *et al* (2018)	4 x 6 (L x T)	-28.19 to 11.11	-30.31 to 4.48	-30.31 to 4.48	Highly significant negative heterosis, heterobeltosis & ecnomic heterosis was observed in Kripa x Phule G-12310 (-28.19),(-30.31)&(-30.31).
Yamini *et al* (2015)	7 x 7 (Diallel)				
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**
Test weight (gm)					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-5.99 to 19.56	-8.60 to 14.91	-	RSG-888 × CSJD-884 (-5.99) & (-8.60) was observed highly negative heterosis and heterobeltosis.
Malge *et al* (2021)	4 x 6 (L x T)	-43.29 to 13.36	-60.51 to 12.84	-59.76 to 20	Chanoli x GJG-0814 (-43.29), (-60.51) & (-59.76) was observed negative heterosis, heterobeltosis& Economic heterosis.
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-39.37 to 10.34	-19.87 to 39.72	C-565×Digvijay (-39.37), GNG-2207× WR-315(-19.87) was observed as higher negative heterobeltosis and economic heterosis.
Rana *et al* (2019)	9 x 4 (L x T)	-11.75 to 54.64	-28.47 to 49.84	-	Highly negative significant in heterosis & heterobeltosis observed Vallabh Hara×Pusa-256 (-11.75) & (-28.47)
Johnson *et al* (2019)	7 x 3 (L x T)	-	-8.327 to -47.237	-	Indira chana-1 X ICCV96030 (-8.327) showed highly negative significant in Heterobeltosis.

Sasane *et al* (2018)	4 x 6 (L x T)	-68.0 to 21.08	-79.75 to 11.19	-72.41 to 65.52	Highly significant negative heterosis, heterobeltosis & ecnomic heterosis was observed in Chanoli x Phule G-0739 (-68.0),(-79.75)&(-72.41).
Yamini *et al* (2015)	7 x 7 (Diallel)				
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**
			Biological yield		
Choudhary *et al* (2023)	7 x 4 (Diallel)	-33.91 to 53.74	-44.21 to 34.52	-	CSJ-515 × Avrodhi (-33.91) & (-44.21) was showed highly negative heterosis and heterobeltosis.
Malge *et al* (2021)	4 x 6 (L x T)	-3.09 to 5.94	-4.67 to 4.48	0.99 to 6.44	PhuleVikram x GAU-1107 (-3.09), (-4.67) showed heterosis and heterobeltosis.
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-	-	-
Rana *et al* (2019)	9 x 4 (L x T)	3.42 to 31.98	-5.67 to 26.48		WCG-9550× Sadbhavana (3.42) & (-5.67) has showed positive heterosis and negative heterobeltosis.
Johnson *et al* (2019)	7 x 3 (L x T)	-	23.11 to 66.73	-	JG14 X JG97 (66.73) significantly positive heterobeltosis was recorded.
Sasane *et al* (2018)	4 x 6 (L x T)	-	-	-	-
Yamini *et al* (2015)	7 x 7 (Diallel)				
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**
			Harvest index (%)		
Choudhary *et al* (2023)	7 x 4 (Diallel)	-20.01 to 29.04	-26.97 to 23.07	-	CSJD-884 × RSG-974 (-20.01) & (-26.97) observed highly negative heterosis and heterobeltosis.
Malge *et al* (2021)	4 x 6 (L x T)	-	-	-	-
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-	-	-
Rana *et al* (2019)	9 x 4 (L x T)	-25.14 to 28.20	-35.64 to 26.57	-	RSG-963×Pusa-256(-25.14) & (-35.64) was observed significantly high in negative heterosis and heterobeltosis.

Johnson *et al* (2019)	7 x 3 (L x T)	-	-7.421 to 27.653	-	JG315 X ICCV96030 (-7.42) recorded has significantly negative heterobeltosis.
Sasane *et al* (2018)	4 x 6 (L x T)	-	-	-	-
Yamini *et al* (2015)	7 x 7 (Diallel)	-13.8 to 27.35	-22.02 to 20.86	-	MNK-1 x Vihar (-13.8) & (-22.02) was showed significantly negative heterosis & heterobeltosis.
References	**Mating Designs**	**Relative Heterosis**	**Heterobeltoisis**	**Economic heterosis**	**Significant finding**
Total chlorophyll content (mg/ml)					
Choudhary *et al* (2023)	8x8 (Half Diallel)	-	-25.78* to 14.22*	-	Highly significant and desirable heterobeltiosis were showed by P3 × P6 (14.22*), P2 x P7 (13.57*), P2 x P8 (13.18*) respectively.
References	**Mating Designs**	**Relative Heterosis**	**Heterobeltoisis**	**Economic heterosis**	**Significant finding**
Relative leaf water content (%)					
Choudhary *et al* (2023)	8x8 (Half Diallel)	-	-2.99 to 11.67*	-	Highly significant and desirable heterobeltiosis were showed by P6 × P8 (11.67*), P2 × P8 (7.79*), P3 × P6 (7.51*) respectively.
References	**Mating Designs**	**Relative Heterosis**	**Heterobeltoisis**	**Economic heterosis**	**Significant finding**
Proline content (mg/gm)					
Choudhary *et al* (2023)	8x8 (Half Diallel)	-	-10.79* to 15.86*	-	Highly significant and desirable heterobeltiosis were showed by P3 × P6 (15.86*), P2 × P4 (14.95*), P2 × P7 (14.52*) respectively.
References	**Mating Designs**	**Relative Heterosis**	**Heterobeltoisis**	**Economic heterosis**	**Significant finding**
Pollen viability					
Choudhary *et al* (2023)	8x8 (Half Diallel)	-	-3.82* to 4.68*	-	Highly significant and desirable heterobeltiosis were showed by P5 × P8 (4.68*), P6 × P8 (4.61*), P3 × P6 (4.38*) respectively.
References	**Mating Designs**	**Relative heterosis**	**Heterobeltosis**	**Economic heterosis**	**Significant Finding**

Seed yield plant^{-1}					
Choudhary *et al* (2023)	7 x 4 (Diallel)	-25.35 to 49.99	-36.62 to 35.46	-	CSJ-515 × Avrodhi (-25.35) & (-36.62) was showed negative heterosis in both heterosis & heterobeltosis.
Malge *et al* (2021)	4 x 6 (L x T)	-45.74 to 25.68	-61.85 to 20.22	-66.47 to 15.45	Chanoli x C-1821(-45.74) & (-61.85) was observed negative heterosis, heterobeltosis& Economic heterosis.
Lakhote *et al* (2020)	7 x 7 (Diallel)	-	-62.28 to 140.56	-64.47 to -0.19	GNG-2207× WR-315 (-62.28), (-64.47) was observed as higher negative heterobeltosis and economic heterosis.
Rana *et al* (2019)	9 x 4 (L x T)	-6.89 to 82.80	-18.88 to 76.72	-	Vallabh Hara×WCG-3 (-6.89) & (-18.88) showed has significantly negative heterosis & heterobeltosis.
Johnson *et al* (2019)	7 x 3 (L x T)	-	37.86 to 168.91	-	JG130 X JG97 (168.91) significantly positive heterobeltosis was recorded.
Sasane *et al* (2018)	4 x 6 (L x T)	-64.57 to 63.70	-73.04 to 48.48	-73.04 to 48.48	Highly significant negative heterosis, heterobeltosis & ecnomic heterosis was observed in Chanoli x Phule G-0739 (-64.57) & (-73.04).
Yamini *et al* (2015)	7 x 7 (Diallel)	16.09 to 145.05	-12.95 to 129.51	-	JG-11 x ICCV95333 (16.09) showed significantly positive heterosis andNBeG-3 x ICCV05106(-12.95) showed negative heterobeltosis.

1.6 COMBINING ABILITY ANALYSIS

Concepts of GCA and SCA was introduced by Sprague and Tatum in 1942. GCA tells about average performance of a parent in a cross combination and SCA about deaviations of single crosses froom average of parents, Hallauer & Miranda in 1988.

One method to estimate them is LxT by Griffing, 1956

The capacity of chickpea germplasm to combine is extremely valuable to pulse breeders. According to Sprague & Tatum, 1942, GCA & SCA are strong predictors of inbred potential for hybrid combinations. The capacity of inbreds to combine is the final determinant defining their future value for hybrid creation (Hallauer and Miranda, 1988). Using this concept, partitioning of genetic variance into var GCA and SCA can be done, Sughroue & Hallauer, 1997. In which GCA is used for additive gene action estimation and SCA for non-additive, Kambal & Webster in 1965.

Multiple methods like poly cross test by Tsydal et al., 1942; top cross by Jenkin & Bruson, 1932; LxT by Kempthrone in 1957 were devised to estimate combining ability.

Table 2.6 examines the outcomes of different workers on chickpea combining abilities.

2.6 Review of literature on Combining ability					
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
First blossoming days					
Malge *et al* (2021)	4 x 6 (Line x tester)	-1.521 to 1.396	-2.229 to 3.354	-	JCP-101 recorded significant GCA effect for plant stand
Jha *et al* (2019)	6 × 6 (Half Diallel)	-2.889 * to -2.889 *	-3.565* to 12.35*	δ2GCA-53.043 * δ2SCA-57.918 * δ2GCA/ δ2SCA-0.92	P2 (-2.889 *), P1 (-1.764 *), P5 (-1.472 *) significant negative GCA, P1 × P3 (-3.565*), P3 × P4 (-2.399*) significant negative SCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
50% blossoming days					
Halladakeri *et al* (2022)	7 x 7 (Diallel)	-	-2.93 to 1.35	-	Based on per se performance and SCA, the superior crosses were ICC14815×ICC16348 and ICC14815×ICC16349 for 50% blossoming days
Sasane *et al* (2022)	4 x 6 (Line x tester)	-3.583 to 4.29	-5.917 to 5.417	-	Chanoli x Phule G-12310 showed significant negative SCA effects for 50% blossoming days.
Malge *et al* (2021)	4 x 6 (Line x tester)	-2.146 to 4.521	-8.104 to 5.896	-	PDKV Kanchan recorded negative (desirable) significant GCA effect for 50% blossoming days.
Gaur *et al* (2020)	6 x 6 (haif-Diallel)	44.74	31.46	σ2gca=1.66 σ2Sca=30.05	JGK1, GNG1969 lines are appeared as good general combiner for 50% blossoming days
Kumar *et al* (2019)	5 x 5 (haif-Diallel)	-1.55* to 0.83*	-2.19* to 1.59*	σ2gca=0.72 σ2Sca= 0.74	Sadbhavana (-1.55*), RSG-963 (-1.33*), Vallabh Hara (-0.83*) recorded negative (desirable) significant GCA, KGD-1161×Pusa -256 (-2.19*), ICC-4958× WCG-3 (1.57*), GNG-1581×Pusa -1103 (1.54*) showed significant negative SCA.

References	Mating Designs	GCA	SCA	Gene action	Significant Finding
Harvest maturity days					
Halladakeri *et al* (2022)	7 x 7 (Diallel)	-	-2.83* to 3.50*	-	P1 x P6 (-2.83*) recorded significant negative SCA
Sasane *et al* (2021)	4 x 6 (Line x tester)	-2.979* to 2.146*	-4.354* to 3.646*	-	Phule G-12310 (-2.97*), BDNGK-807 (-2.02*), PKV Kabuli-2 (PKV Kabuli-2) recorded significant negative GCA, Chanoli x Phule G-12310 (-4.354*) recorded significant negative SCA
Malge *et al* (2021)	4 x 6 (Line x tester)	-0.458* to 0.958*	-2.542* to 2.333*	-	PDKV Kanchan (-0.458*), WR-315 (-0.417*), JCP-101 (-0.417*) recorded significant negative GCA, PhuleVikramxGAU-1107 (-2.542*) recorded significant negative SCA
Kumar *et al* (2019)	5 x 5 (half-Diallel)	-3.70* to 1.83*	-2.36* to 3.97*	σ2gca= 0.72 σ2Sca= 0.74	RSG-963 (-3.70*), Sadbhavana (-1.91*), WCG-9550 (-3.70*) recorded significant negative GCA, GNG-1581×WCG-3 (-2.36*), HK-4×WCG-3 (-2.19*), Vallabh Hara×WCG-3 (-2.11*) recorded significant negative SCA
Dudhe and Kumar (2018)	5 x 5 (Half diallel)	-4.19* to 1.95	-1.61 to 4.35*	-	SAKI 9516 (-4.19*) recorded significant negative GCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Plant height					
Halladakeri *et al* (2022)	7 x 7 (Diallel)		-8.26* to 4.40*	-	P6 x P7 (4.40*) recorded significant positive SCA
Sasane *et al* (2022)	4 x 6 (Line x tester)	-4.071* to 5.263*	-3.879 to 3.571	-	Shubhra (5.26*), PKV Kabuli-2 (3.24*) recorded significant positive GCA
Malge *et al* (2021)	4 x 6 (Line x tester)	-8.663* to 3.740*	-4.431 to 2.083	-	PDKV Kanchan (3.740*) recorded significant positive GCA
Kumar *et al* (2019)	5 x 5 (half-Diallel)	-2.49* to 2.06*	-1.36* to 3.09*	σ2gca= 2.91 σ2Sca= 1.02	HK-4 (2.06*), KGD-1161 (2.03*), Pusa-1103 (2.02*) recorded significant positive GCA, C-235×WCG-3 (3.09*), HK-4×Pusa -1103 (1.36*), DCP-92-3×Sadbhavana (0.98*) recorded significant positive SCA

References	Mating Designs	GCA	SCA	Gene action	Significant Finding
Primary offshoots plant^{-1}					
Halladakeri *et al* (2022)	7 x 7 (Diallel)		-23.64 to 13.69		-
Sasane *et al* (2021)	4 x 6 (Line x tester)	-0.448* to 0.627*	-1.019* to 0.877*		BDNGK-798 (0.62*) recorded significant positive GCA, Chanoli x Phule G-12310 (0.877*) recorded significant positive SCA
Malge *et al* (2021)	4 x 6 (Line x tester)	-0.329* to 0.225*	-0.858* to 0.817*		PDKV Kanchan (0.225*), Chanoli (0.208*), WR-315 (0.146*) recorded significant positive GCA, ChanolixJCP-101 (0.817*) recorded significant positive SCA
Kumar *et al* (2019)	5 x 5 (half-Diallel)	-0.68* to 0.68*	-0.44* to 0.63*	σ2gca= 0.16 σ2Sca= 0.08	Vallabh Hara (0.68*), WCG-3 (0.44*), KGD-1161 (0.28*) recorded significant positive GCA, GNG-1581×Pusa -1103 (0.63*), KGD-1161×Sadbhavana (0.58*), HK-4×WCG-3 (0.41*) recorded significant positive SCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Secondary offshoots plant^{-1}					
Halladakeri *et al* (2022)	7 x 7 (Diallel)		-9.19* to 3.93*		P6 x P7 (3.93*), P1 x P4 (3.89*), P1 X P7 (2.50*) recorded significant positive SCA
Malge *et al* (2021)	4 x 6 (Line x tester)	-3.560* to 3.640*	-4.581* to 4.356		JCP-101 (3.640*) recorded significant positive GCA
Sasane *et al* (2021)	4 x 6 (Line x tester)	-2.442* to 3.379*	-3.550* to 3.796*		Chanoli (3.37*), Shubhra (1.84*), BDNGK-798 (1.08*) recorded significant positive GCA, Chanoli x Phule G-12310 (3.79*), Kripa x MNK-1 (2.69*), PKV Kabuli-2 x Shubhra (2.56*) recorded significant positive SCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Capsules plant-1					
Halladakeri *et al* (2022)	7 x 7 (Diallel)		-4.48* to 4.96*		P1 X P2 (4.96*), P2 x P6 (1.81*) recorded significant positive SCA

Malge *et al* (2021)	4 x 6 (Line x tester)	-2.604* to 2.542	-9.942* to 9.708*		PDKVKanchanxGJG-0814 (9.708*), AKG-1303xJCP-101 (8.242*) recorded significant positive SCA
Sasane *et al* (2021)	4 x 6 (Line x tester)	-12.29* to 9.30*	-7.51* to 10.13*		Shubhra (9.30*), Chanoli (7.57*), BDNGK-798 (3.19*) recorded significant positive GCA, PKV Kabuli-2 x Shubhra (10.13*), PKV Kabuli-2 x BDNGK-798 (5.54*) recorded significant positive SCA
Kumar *et al* (2019)	5 x 5 (half-Diallel)	-5.13* to 5.48*	-1.35* to 2.23*	σ2gca= 8.67 σ2sca= 0.77	Vallabh Hara (5.48*), WCG-9550 (3.85*), KGD-1161 (2.81*) recorded significant positive GCA, WCG-9550×Pusa -1103 (2.23*), C-235×WCG-3 (1.08*), VallabhHara×Pusa -256 (1.06*) recorded significant positive SCA
Dudhe and Kumar (2018)	5 x 5 (Half diallel)	-2.51 to 3.19*	-0.55 to 3.87*		Pusa 1103 (3.19*) recorded significant positive GCA, Pusa 1103 x DG 54 (3.87*), Pusa 1103 x DG 72 (3.11*) recorded significant positive SCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Empty capsules plant^{-1}					
Malge *et al* (2021)	4 x 6 (Line x tester)	-0.577* to 0.685*	-0.798 to 0.698		JCP-101 (-0.577*), Chanoli (-0.373*),PDKV Kanchan (-0.273*) recorded significant negative GCA
Sasane *et al* (2021)	4 x 6 (Line x tester)	-0.704* to 0.633*	-1.138* to 1.138*		MNK-1 (-0.70*), Chanoli (-0.42*), Shubhra (-0.37*) recorded significant negative GCA, Chanoli x Phule G-12310 (-0.72*) recorded significant negative SCA
Jha *et al* (2019)	6 × 6 (Half Diallel)	-0.528 * to 0.389 *	-0.339 to 0.702	δ2GCA-1.109 * δ2SCA- 0.188 δ2GCA/ δ2SCA- 5.90	P2 (-0.528 *), P1 (-0.278 *) significant negative GCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
seeds capsule^{-1}					
Halladakeri *et al* (2022)	7 x 7 (Diallel)		-0.69* to 0.60*		P3 x P6 (0.60*), P4 x P6 (0.55*), P2 x P5 (0.26*) recorded significant positive SCA

Malge *et al* (2021)	4 x 6 (Line x tester)	-0.027* to 0.048*	-0.177* to 0.127*		Phule Vikram (0.048*), JCP-101 (0.027*), GJC-3 (0.015*) recorded significant positive GCA, PhuleVikramxGJC-3 (0.127*), AKG-1303xJCP-101 (0.115*) recorded significant positive SCA
Sasane *et al* (2021)	4 x 6 (Line x tester)	-0.058* to 0.110*	-0.082 to 0.162*		Chanoli (0.11*), BDNGK-798 (0.057*) MNK-1(0.05*) recorded significant positive GCA, Kripa x MNK-1(0.162*) recorded significant positive SCA
Kumar *et al* (2019)	5 x 5 (half-Diallel)	-0.16* to 0.17*	-0.27* to 0.17*	σ2gca= 0.01 σ2sca= 0.02	WCG-3 (0.17*), RSG-963 (0.10*), C-235 (0.08*) recorded significant positive GCA, VallabhHara×Sadbhavana (0.17*), GNG-1581×Pusa -1103 (0.17*), C-235×Pusa -256 (0.16*) recorded significant positive SCA
Dudhe and Kumar (2018)	5 x 5 (Half diallel)	-0.19 to 0.52	-0.67 to 0.86	-	-
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Test weight (gm)					
Halladakeri *et al* (2022)	7 x 7 (Diallel)		-1.25* to 5.85*		P2 x P7 (5.85*), P3 x P5 (1.32*) recorded significant positive SCA
Malge *et al* (2021)	4 x 6 (Line x tester)	-9.160* to 4.081*	-3.906* to 3.631*		Phule Vikram (4.081*), AKG1303 (3.223*), PDKV Kanchan (1.856*) recorded significant positive GCA, PDKVKanchanxGJG-0814 (3.631*), AKG-1303xGAU-1107 (2.377*) recorded significant positive SCA
Sasane *et al* (2021)	4 x 6 (Line x tester)	-19.002* to 7.56*	-4.948* to 4.002*		Kripa (7.56*), PKV Kabuli-2 (7.04*), BDNGK-807 (4.39*) recorded significant positive GCA, Chanoli x Shubhra (4.00*), Kripa x MNK-1 (3.44*), Chanoli x Virat (3.44*) recorded significant positive SCA
Kumar *et al* (2019)	5 x 5 (half-Diallel)	-6.67* to 10.08*	-6.05* to 5.59*	σ2gca= 19.18 σ2sca= 8.82	HK-4 (10.08*), RSG-963 (7.34*), Pusa-256 (4.64*), recorded significant positive GCA, GNG-1581×WCG-3 (5.59*), RSG-963×Pusa -256 (4.46*), HK-4×Pusa -256 (3.99*) recorded significant positive SCA

Dudhe and Kumar (2018)	5 x 5 (Half diallel)	- 3.30* to 2.43	0.17 to 3.22*		KWR 108 x DG 54 (3.22*), Pusa 1103 x DG 54 (2.56*), DG 72 x SAKI 9516 (2.26*) recorded significant positive SCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Biological yield plant^{-1}					
Halladakeri *et al* (2022)	7 x 7 (Diallel)		-6.69* to 6.49*		P2 x P7 (6.49*), P4 x P5 (5.39*), P1 x P5 (5.09*) recorded significant positive SCA
Kumar *et al* (2019)	5 x 5 (half-Diallel)	-3.11* to 3.64*	-3.57* to 4.35*	σ2gca= 1.66 σ2sca= 3.74	C-235 (3.64*), KGD-1161 (2.81*), ICC-4958 (1.39*) recorded significant positive GCA, ICC-4958× WCG-3 (4.35*), GNG-1581×Pusa -1103 (3.73*), HK-4×Pusa -1103 (2.57*) recorded significant positive SCA
Dudhe and Kumar (2018)	5 x 5 (Half diallel)	-0.08 to 0.11	-0.24 to 0.18	-	-
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Harvest index (%)					
Halladakeri *et al* (2022)	7 x 7 (Diallel)		-13.72* to 14.58*		P3 x P4 (14.58*), P2 x P7 (12.83*), P2 x P6 (7.02*) recorded significant positive SCA
Kumar *et al* (2019)	5 x 5 (half-Diallel)	-3.92* to 6.52*	-6.30* to 7.83*	σ2gca= 5.01 σ2sca= 13.54	WCG-9550 (6.52*), GNG-1581 (5.06*), HK-4 (2.37*) recorded significant positive GCA, VallabhHara×Pusa -256 (7.83*), WCG-9550×Sadbhavana (6.72*), KGD-1161×WCG-3 (5.70*) recorded significant positive SCA
Dudhe and Kumar (2018)	5 x 5 (Half diallel)	-3.09 to 4.74*	-0.31 to 4.99*		Pusa 1103 (4.74*) recorded significant positive GCA, Pusa 1103 x SAKI 9516 (4.99*), Pusa 1103 x DG 54 (4.64*), Pusa 1103 x KWR 108 (3.46*) recorded significant positive SCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Total chlorophyll content					
Choudhary *et al* (2023)	8x8 (Half Diallel)	-1.78* to 1.06*	-2.89* to 4.01*	-	P5 × P8 (4.01*), P2 x P7 (3.40*), P2 × P3 (3.07*) significant positive SCA
Bhattarai *et al* (2016)	5x5 (Half Diallel)	-0.31* to 0.23*	-0.22 to 0.55*	-	Nagcarlan (0.23*), H 7997 (0.16*) significant positive GCA, H7997×Nagcarlan (0.55*),

					BL1176×Nagcarlan (0.55*), H7997×BL1176 (0.53*) significant positive SCA
Jagadish and Jayalakshmi (2014)	6x6 (Half Diallel)	-1.65* to 1.35*	-2.04* to 2.617*	σ^2 gca- 0.99 σ^2 sca- 1.79	Phule G 05107 (1.35*) and MNK 1 (0.53*) significant positive GCA, KAK 2 x NBeG 72 (2.617*), KAK 2 x Phule G 05107 (1.594*) significant positive SCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Relative leaf water content					
Choudhary *et al* 2023	8x8 (Half Diallel)	-1.81* to 1.07*	-6.12* to 7.24*	-	P5 × P8 (7.24*), P6 × P8 (5.57*), P1 × P4 (4.40*) significant positive SCA
Dudhe and Kumar (2018)	5 x 5 (Half diallel)	-1.87 to 1.98	-1.84 to 4.52*	-	Pusa 1103 x DG 72 (4.52*) significant positive SCA
Bhattarai *et al* (2016)	5x5 (Half Diallel)	-3.13* to 2.45*	-8.13* to 5.51*	-	Nagcarlan (2.45*) significant positive GCA, BL1176×Nagcarlan (5.51*), BL1173×BL1176 (4.10*), BL1173×Nagcarlan (4.02*) significant positive SCA
Jagadish and Jayalakshmi (2014)	6x6 (Half Diallel)	-2.18* to 3.34*	-5.195* to 2.755	σ^2 gca- 0.99 σ^2 sca- 1.79	Vihar (3.34*) significant positive GCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Proline content (mg/gm)					
Choudhary *et al* (2023)	8x8 (Half Diallel)	0.44* to 0.84*	-1.05* to 1.01*	-	P5 × P8 (1.01*), P2 × P4 (0.81*), P2 × P7 (0.81*) significant positive SCA
Bhattarai *et al* (2016)	5x5 (Half Diallel)	-0.50* to 0.51*	-1.14* to 2.18*	-	CLN 1621E (0.51*) significant positive GCA, BL1173×H7997 (2.18*), BL1176×Nagcarlan (1.34*), CLN1621E×BL1176 (1.07*) significant positive SCA
References	**Mating Designs**	**GCA**	**SCA**	**Gene action**	**Significant Finding**
Pollen viability					
Choudhary *et al* (2023)	8x8 (Half Diallel)	-1.56* to 1.17*	-3.78* to 4.42*	-	P2 × P4 (3.29*), P3 × P6 (2.36*), P1 × P5 (1.99*) significant positive SCA
Bhattarai *et al* (2016)	5x5 (Half Diallel)	-4.98* to 5.28*	-9.62* to 11.71*	-	H 7997 (5.28*) significant positive GCA, BL1173×Nagcarlan (11.71*), H7997×CLN1621E (7.41*) significant positive SCA

References	Mating Designs	GCA	SCA	Gene action	Significant Finding
Seed yield plant^{-1}					
Halladakeri *et al* (2022)	7 x 7 (Diallel)		-5.21* to 3.22*		P3 x P5 (3.22*), P3 x P4 (3.00*), P3 x P6 (2.42*) recorded significant positive SCA
Malge *et al* (2021)	4 x 6 (Line x tester)	-9.750* to 3.900*	-4.213* to 5.007*		Phule Vikram (3.900*), PDKV Kanchan (3.562*), AKG1303 (2.288*) recorded significant positive GCA, PDKVKanchanxGJG-0814 (5.007*), AKG-1303xJCP-101 (4.800*) recorded significant positive SCA
Sasane *et al* (2021)	4 x 6 (Line x tester)	-5.415* to 3.967*	-2.766* to 3.333*		PKV Kabuli-2 (3.96*), Shubhra (3.17*), BDNGK-807 (1.38*) recorded significant positive GCA, PKV Kabuli-2 x Shubhra (3.33*), Kripa x Phule G-0739 (2.08*) recorded significant positive SCA
Kumar *et al* (2019)	5 x 5 (half-Diallel)	-2.35* to 2.35*	-3.45* to 2.97*	σ2gca= 0.36 σ2sca= 3.27	GNG-1581 (2.35*), WCG-9550 (1.10*), ICC-4958 (0.96*) recorded significant positive GCA, ICC-4958×Pusa -1103 (2.97*), HK-4×Pusa -256 (2.96*), KGD-1161×WCG-3 (2.88*) recorded significant positive SCA
Dudhe and Kumar (2018)	5 x 5 (Half diallel)	-2.59 to 3.12*	-0.59 to 5.18*	-	Pusa 1103 (3.12*) recorded significant positive GCA, Pusa 1103 x SAKI 9516 (5.18*), Pusa 1103 x KWR 108 (4.34*), Pusa 1103 x DG 54 (3.84*) recorded significant positive SCA

III. Materials and methods

A brief account of experiments conducted, details of parents selected for the study, hybridization programme, The experimental design utilized and the statistical methodologies employed in the current study are laid out below.

3.1. Experimental site

3.2. Weather and Climate

3.3. Materials involved in experiment

3.4. Experimental details

3.5. Observations recorded

3.6. Statistical analysis

3.1. EXPERIMENTAL SITE

This experimental research entitled as **"Heterosis and stability studies in chickpea (*Cicer arietinum* L.) against chilling and heat stress: a morphological, phenological and biochemical assessment"** was done during *rabi* 2020-23, at experimental farm, Dept. of Genetics and Plant Breeding, Lovely Professional University, Phagwara, Kapurthala (district), Punjab.

3.1.1 Soil of experimental field:

The soil of the Kapurthala district is semi-arid, having a sandy-loam to clayey texture with a pH range of 7.8-8.5. The soil is nitrogen deficient yet high in phosphorus and potassium. To ensure a successful crop, recommended agronomic procedures were implemented.

3.2 WEATHER AND CLIMATE

Jalandhar is located at latitude 310 19' 32'' N and longitude 750 34'45'' E, elevated to 243 m above MSL. The climate is classified as agro-ecological (Northern plain, hot sub-humid eco area of Punjab). Agro-climatic zone (Trans- Gangetic plain region). The area falls under the semi-arid zone, receiving a yearly precipitation of 527.1 mm. Except for a brief period during the South-West monsoon season, the district's climate is characterized by general dryness. The year is divided into four seasons: the cold season (winter) from November to March, the hot season (summer) from April to June, the monsoon season from the final week of June to the middle of September, and the post-monsoon season till the beginning of November. The temperature scale for the rabi seasons 2020-21 and 2022-23 is displayed in the APPENDICES III.

3.3 MATERIALS INVOLVED IN EXPERIMENT

This assay incorporates a total of fifty-one distinct genotypes of chickpea as the experimental material used for Screening and stability studies, material collected from various geographical locations and are present in the table 1. Based on Screening for temperature stress (Yield, Lipid Peroxidation (nmol/ML), Electrolyte leakage index (%)and Proline) selected 10 parents for crosses.

Table 3.3.1: List of genotypes and source

Sl.no.	Name	Source	Sl.no.	Name	Source
1	PDE 9802 E	IIPR, Kanpur	27	KWR 108	IIPR, Kanpur
2	SUBHRA	IIPR, Kanpur	28	JG 14	JNKVV, Jabalpur
3	BG 3043	IARI, New Delhi	29	ICC 3020	ICRISAT
4	PUSA 547	IARI, New Delhi	30	IPC-06-77	IIPR, Kanpur
5	IPCK 04-29	IIPR, Kanpur	31	KPG-59	IIPR, Kanpur
6	PUSA 72	IARI, New Delhi	32	K-850	IIPR, Kanpur
7	RSG 931	RARI, Durgapur	33	ICC 5335	ICRISAT
8	RSGK 6	IIPR, Kanpur	34	IPC 9767	IIPR, Kanpur
9	CSJK 54	RARI, Durgapur	35	ICC 244-263	IIPR, Kanpur
10	CSJK 6	RARI, Durgapur	36	BG 212	IARI
11	KAK-2	IIPR, Kanpur	37	ICC 3525	ICRISAT
12	JG 16	JNKVV, Jabalpur	38	ICC 5434	ICRISAT
13	RGC 888	IIPR, Kanpur	39	ICC 5439	ICRISAT
14	JG 130	ICRISAT	40	BPM	IIPR, Kanpur
15	BGD 9971	IIPR, Kanpur	41	IPC 07-56	IIPR, Kanpur
16	DCP 92-3	IIPR, Kanpur	42	IPC 05-28	IIPR, Kanpur
17	GG-2	GAU, Junagadh	43	PUSA 3043	IARI
18	PUSA 372	IARI, New Delhi	44	RSG 945	IIPR, Kanpur
19	NBEG 47	ARS, Nandhyal	45	SADABAHAR	IIPR, Kanpur
20	RGG 6	IIPR, Kanpur	46	RSG 931	RARI, Durgapur
21	PUSA 3022	IARI, New Delhi	47	RSG 888	IIPR, Kanpur
22	RSG 963	RARI, Durgapur	48	GNG 469	IIPR, Kanpur
23	RSG 974	RARI, Durgapur	49	PDG-4	PAU, Ludhiana
24	CSJ 515	RARI, Durgapur	50	PBG 5	PAU, Ludhiana
25	RSG 973	RARI, Durgapur	51	PBG-7	PAU, Ludhiana
26	RSG 807	RARI, Durgapur			

3.4 EXPERIMENTAL DETAILS

The materials used and the statistical procedures employed during the research process are listed below. The chapter is divided into the following sections:

1	Name of the experiment	:	Heterosis and Stability studies in Chickpea (*Cicer arietinum* L.) against chilling and heat stress: A Morphological, Phenological and biochemical assessment
2	Season	:	*Rabi*-2020-21, 2021-22 and 2022-23
3	Environment	:	2020-21 summer (25 Nov, 10 December, and 25 December)
4	Screening and variability	:	51 genotypes
5	Parents	:	10 (7 Lines, 3 Testers)
6	Hybrid evaluation	:	32 (21 hybrids+10 parents+1 check)
7	Experimental design	:	RBD
8	Number of replications	:	2
9	Spacing	:	45x10 cm (Stability, screening, and Evaluation), 45x10 cm (Crossing)
10	Plant protection	:	Need based

The experiments I, II and III were conducted at Lovely Professional University, Phagwara village. The whole experiments were carried out during 2021 to 2023.

Table 3.4: Chronology of the experiments

Experiment	Purpose	Month & Year
Experiment-I+II	**Screening of chickpea germplasm against Chilling and Heat tolerance and stability studies.** • Three dates of sowing were employed for this to be achieved with 15 days gap between each sowing (25 November, 10 December, and 25 December). • Screening was done using morphological, phenological biochemical traits. • The preliminary screening was started with 51 genotypes out of which 25 were selected basing their performance. • The data was subjected to analysis (ANOVA, PCV & GCV, h^2 (bs), GA, Correlation and Path analysis).	Nov 20-May 21
Experiment-III	**Parental selection and crossing block for L x T mating** • Based on the analysis of the last seasonal data, ten genotypes were selected for the mating design. • For lines (females), basing the traits seed yield and No. of filled pods per pod, the genotypes exhibiting stable and high yield amongst others over the environments were selected. • For testers (males), the selection was done based on the biochemical marker traits for temperature stress i.e., Proline and Lipid peroxidation content.	Nov 21-May 22
Experiment-IV	**Studied Heterosis and combining ability of the crosses along with parents** • The hybrids + their parents + a standard was examined for their performance using same morphological, phenological and biochemical traits. • Their data was subject to analysis and further identification of promising hybrids was done.	Nov 22-May 23

3.5 OBSERVATIONS RECORDED

Yield characteristics were analyzed and documented. Except for the first flowering days, 50% blossoming days, and harvest maturity days, which were documented plot by plot, every plot contained five plants chosen at random, marked for recording data. The mean value for the treatment was calculated by taking the average. The following observations were made:

3.5.1 Morphological parameters:

1. First blossoming days: (days)

From sowing in the field to the emerging of the first blossom in the plants in a plot, days were counted.

2. 50% blossoming days: (days)

From sowing in the field to the emergence of the flowers in 50% of the plants in a plot, days were counted.

3. Harvest maturity days:

From the date of sowing in field to maturity and harvest among each plot, days number was determined.

4. Plant height (cm):

It was measured with a meter measure at the final stage of crop nearing harvest, from soil surface level to the tip.

5. Primary offshoots plant^{-1}:

when crop was nearing harvest, primary branches were counted in each plant and the average was computed.

6. Secondary offshoots plant^{-1}:

When crop was nearing harvest, secondary branches were counted in each plant and the average was computed.

7. Capsules per branches:

Total capsules were calculated by counting the capsules borne on each plant individually.

8. Full capsules plant^{-1}:

It was calculated by counting the full capsules (pods filled with seeds) borne on each plant individually.

9. Empty capsules plant^{-1}:

It was calculated by counting the full capsules (pods not filled with seeds) borne on each plant individually.

10. Seeds capsule^{-1}:

The total seeds present in each pod was counted in selected five randomly pods.

11. Seed yield plant^{-1}:

At the time of harvest, total seed yield plant^{-1} was measured and recorded.

12. Biological yield plant^{-1}:

At the moment of harvest, the entire weight of the uprooted plant, including pods, was measured and recorded.

13. Harvest index (%):

It is calculated by dividing seed yield plant^{-1} by biological yield plant^{-1} and multiplying by 100.

14. Test weight (gm):

100 seed weight was measured of randomly selected hundred seeds of each genotype.

3.5.2 Physiological parameters:

1. Total chlorophyll content (mg/ml): Low and high temperature conditions have a negative impact on chlorophyll content during stress as the leaves turn yellow which damage the chlorophyll pigment. The reduction in chlorophyll is due to suppression of certain specific enzymes which are responsible for green pigment synthesis in plants. The method of estimation followed was outlined by Hiscox and Israeltam, 1979. Total chlorophyll content from the leaves was estimated at developmental stage under stress conditions.

Extraction procedure:

Clean & chop fresh leaf tissue (100mg)

↓

10ml of DMSO (Dimethyl sulfoxide) solution

↓

Incubate at 60-650C

↓

Leaves become colourless

Estimation:

1. Spectrophotometric measurements of absorbance at 645 and 665 nm.
2. As a blank, use DMSO solution.

Calculation:

Calculation of the total content of chlorophyll was carried out by substituting the obtained reading values in the formula given below. Total chlorophyll content was expressed as mg g' fresh weight.

$$\text{Total chl. g' tissue} = (20.2\ OD\ 665 + 8.02\ OD645) \times \frac{V}{1000} \times W$$

Where,

OD665	=	Optical density at 665nm
OD645	=	Optical density at 645nm
W	=	Weight of the sample
V	=	Total volume of the solution made

2. Relative leaf water content (%): Uptake of water by plants is reduced during conditions of low and high temperature due to poor osmotic potential which ultimately leads to the reduction in relative leaf water content in the sensitive genotype. Method for estimation followed was outlined by Barr and Weatherley, 1962. The relative leaf water content of leaves at various stages of growth and development under stress was determined.

Procedure:

Fresh weight (FW) at excision

↓

Soak in distilled water for 24hrs at 25°C in dark

↓

Record Turgor weight (TW) after 24 hrs

↓

Dried for 48h at 80°C in hot air oven

↓

Record Dry weight (DW).

Calculation:

The relative leaf water content was estimated by substituting in the following formula.

$$RLWC\ \% = \frac{FW\text{-}DW}{TW\text{-}DW} \times 100$$

3.5.3 Biochemical parameters: (Jaworski, 1971)

1. Lipid Peroxidation (nmol/ML):

Thiobarbituric acid (TBA) color reaction was used to study lipid peroxidase production in leaf samples collected from stressed plants.

Reagents:

Thiobarbituric acid (TBA) reagent: a 1:2 mixture of 18% Trichloroacetic acid (TCA) and 0.45% TBA.

Procedure:

Stressed plant leaf samples

↓

100 mg dry leaf powder in a glass tube

↓

Add TBA reagent (10ml)

↓

Heat for 15 min over a water bath @ 100°C

↓

Filter through Whatman (No.42) filter paper

Estimation:

1. The absorbance of the filtrate was measured using a spectrophotometer at 532nm and 600nm.
2. As a blank, use boiling TBA reagent.

Calculation: The percentage of Lipid Peroxidation (nmol/ML) calculated by substituting the readings in the below given formula.

$$LP = \frac{A_{532} - A_{600}}{155} \times 1000$$

2. Electrolyte leakage index (%): (Whitlow *et al* 1992)

Electrolyte leakage index (%) (ELI) was measured from the leaves collected from the plants under stress condition.

Procedure:

80 mg fresh leaves obtained from stressed plants

↓

Washed in distilled water @ 5 min to remove electrolytes from the surface

↓

Place in glass tubes, add 10 ml of distilled water

↓

Subjected to vacuum-infiltration

↓

Capped tubes were stirred @ 150 rpm for 30 min on a shaker

↓

Water extract containing ions released from tissues

↓

Place in a cell with electrodes

↓

Measure electrical conductivity (µS/cm) at 25ºC

↓

Samples are kept in boiling water bath @ 10 min

↓

Capped tubes were stirred @ 150 rpm for 30 min on a shaker

↓

Measure electrical conductivity (µS/cm) at 25ºC

The ELI was calculated by substituting the readings in the below mentioned formula

$$\text{ELI (\%)} = \frac{L_t - L_o}{L_b - L_o} \times 100$$

Where,

L_t = electrical conductivity of the sample under stress

Lo = electrical conductivity at temperature of plant growth

L_b = electrical conductivity of the same sample after boiling

The ELI represents the leakage of electrolytes from damaged tissues as the percent of the leakage from tissues destroyed by boiling (100%).

3. Proline content (mg/gm): (Bates *et al* 1973)

Proline content (mg/gm) was measured from the leaves collected from the plants under stress condition.

Reagents:

1. Methanol: Chloroform: Water (12:5:1 v/v)
2. Glacial acetic acid
3. Acid ninhydrin
4. Benzene

Extraction:

Step-1

Sample was weighed

↓

Extract in 6ml of Methanol: Chloroform: Water (12:5:1) @ room temperature

↓

Centrifuge @ 10 minutes

↓

Collect supernatant

↓

Add 4ml of Methanol: Chloroform: Water

↓

Centrifuge @ 10 min

↓

Collect supernatant and pooled

↓

Make final volume to 10ml with same solvent

Step-2

Add 6 ml of chloroform and 4ml of distilled water

↓

Stand for 15 minutes in separating funnel

↓

The two layers get separated

↓

Discard lower layer and collect upper layer

↓

Make final volume to 10 ml by adding distilled water.

Estimation:

Take 5ml of this solution and add 2.5ml of acid Ninhydrin

↓

Boil this @ 45 minutes in boiling water

↓

Pink colour is formed and let it cool

↓

Add 5ml of Benzene and shake

↓

Stand it in a separating funnel @ 30 min

↓

Discard lower layer and collect upper pink layer

↓

Record OD at 515nm, use benzene as blank

↓

Proline is used as standard to make standard curve

4. Ascorbic acid content (mg): (Harris and Ray, 1935)

Reagents:

1. Oxalic acid (4%)
2. Dye- 2,6-dichlorophenol endophenol
3. Ascorbic acid working standard solution

Extraction:

Take 5g of sample

↓

Add of 10 ml of 4%(w/v) oxalic acid

↓

Ground and strained through a muslin cloth

↓

Make final volume to 25 ml with 4% oxalic acid

Estimation:

Take 5ml of the ascorbic acid working standard solution in a 100ml conical flask

↓

Add 10ml of 4% oxalic acid

↓

Titrate against the dye (V1 ml)

↓

End point is the appearance of pink colour

↓

Take 5ml of previous sample extract

↓

Add 10ml of 4% oxalic acid

↓

Titrate against the dye (V2 ml)

Calculation:

$$\text{Ascorbic acid mg} = \frac{0.5\text{ mg}}{\text{V1 ml}} \times \frac{\text{V2 ml}}{5\text{ ml}} \times \frac{100\text{ ml}}{\text{Sample wt.}} \times 100$$

3.5.4. Phenological traits:

1. Pollen viability (%): (Singh, 2003)

Pollen viability was done using acetocarmine dye staining method.

Procedure:

Collect open flowers under stress temperature

↓

Place pollen on a slide

↓

Add a drop of 1% acetocarmine solution

↓

Cover with cover slip

↓

Keep in dark for 5 min

↓

Observed and counted under a microscope

↓

Stained- viable, Un stained- Non viable

2. Flower drop (%):

Flower drop (%) was recorded by counting the dropped flowers during the flowering time at peak stress conditions *i.e.*, early mornings during winters for chilling stress and peak sun hours during early summers for heat stress.

3.6 STATISTICAL ANALYSIS

The data obtained in respect of all the characters has been subjected to the following statistical analyses.

1. Analysis of variance **(Panse and Sukhatme, 1952)**
2. Heritability **(Hanson *et al* 1956)**
3. Genetic advance **(Johnson *et al* 1955)**
4. Correlation coefficient analysis **(Miller *et al* 1958)**
5. Path coefficient analysis **(Dewey and Lu, 1959)**
6. Stability analysis **(Eberhart and Russell, 1966)**
7. Estimation of heterosis **(Fonseca and Patterson 1968)**
8. Combining ability analysis **(Line × Tester analysis; Kempthorne, 1957).**

Data on individual characters were statistically analyzed using mean values from two replications. The following statistical approaches were used:

Mean: The mean was calculated by following method:

Where,

$$\text{Grand mean } (\overline{X}) = \frac{\sum xi}{N}$$

$\overline{X}$ = Grand mean or over all mean of the observation

$\sum xi$ = Sum of all observations; [i= 1,2,3………n.]

N = Number of observations

Range:

The start and the end estimates for every trait within the experimental population were used to calculate the range for each character.

Coefficient of variation (CV %)

Burton's (1952) formula was employed to compute the phenotypic & genotypic coefficients of variation.

$$\text{Genotypic coefficient of variation (GCV \%)} = \frac{\sqrt{\sigma^2 g}}{\overline{X}} x100$$

Phenotypic coefficient of variation (PCV%)= $\frac{\sqrt{\sigma^2 p}}{\bar{X}}$ x100

Where,

$\sqrt{\sigma^2 g}$ = Genotypic standard deviation

$\sqrt{\sigma^2 p}$ = Phenotypic standard deviation

$\bar{X}$ = General mean of the character

3.6.1 ANOVA

Data was statistically examined basing the average value of each of the plants chosen to observe to determine the total amount of variability contained in the material under research for every characteristic as well as each population. The initial and primary step is doing an analysis of variance to determine significance of variations between populations. ANOVA was done using the procedures recommended by Panse and Sukhatme (1952). The following was the outline:

Table 3.6.1.1 ANOVA for completely randomized block design

Source of variation	d.f.	Sum of square	Mean sum of square	Fcal. value	Expected mean squares
Replication	r-1	RSS	RMS	RMS/EMS	-
Genotype	g-1	GSS	GMS	GMS/EMS	$\sigma^2 e + r\sigma^2 g$
Error	(r-1) (g-1)	ESS	EMS	-	$\sigma^2 e$
Total	**rg-1**	**TSS**	**-**	**-**	**-**

Where,

r = Number of replications

g = Number of genotypes

d.f. = Degree of freedom

RSS = Replication sum of square

GSS = Genotype sum of square

ESS = Error sum of square

TSS = Total sum of square

RMS = Replication mean sum of square

GMS = Genotypic mean sum of square

EMS = Error mean sum of square = σ^2e

Table 3.6.1.2 Details of ANOVA (Parents + Crosses)

Source of variation	**d.f.**	**SS**	**MS**	**F ratio**
Replications	(r-1)	SSr	MSr	MSr/MSe
Treatments	(t-1)	SSt	MSt	MSt/MSe
Parents	(p-1)	SSp	MSp	MSp/MSe
Crosses	(c-1)	SSc	MSc	MSc/ MSe
Parents *vs* crosses	1	SSp *vs* SSc	MSp *vs* MSc	MSp *vs* MSc/ MSe
Error	(r-1) (t-1)	SSe	MSe	-

Where,

r = Number of replications

t = Number of treatments

p = Number of parents

c = Number of crosses

σ^2e = Genotypic variance

A significant F value implicates test's entries significantly vary from one another, necessitating the computation of C.D.

$$C.V. = \frac{\sqrt{EMS}}{GM} x100$$

$$SE_{diff} = \sqrt{\frac{2EMS}{r}}$$

$$SEm\pm = \sqrt{\frac{EMS}{r}}$$

CD at 5% prob. Level = SE $_{diff}$ x $t_{5\%}$ table value

where,

C.V. %	=	Coefficient of variation
SEm±	=	Standard error of means
S E diff	=	Standard error of difference
GM	=	Grand mean
C.D.	=	Critical difference
t 5%	=	t, table value 5% probability level at error d.f.

3.6.2. HERITABILITY (h^2 BS)

Hanson *et al* (1956) provided a method for calculating heritability (bs).

$$h^2 (Bs) = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

h^2 (bs)	=	Heritability in broad sense
$\sigma^2 g$	=	Genotypic variance
$\sigma^2 p$	=	Phenotypic variance

3.6.3. GENETIC ADVANCE

Estimated phenotypic and genotypic variances, as well as heritability, were employed to calculate the predicted genetic advancement, as Johnson *et al* (1955) proposed and stated as-

$$GA = K \times \sigma^2 p \times h^2$$

Where,

K	=	selection intensity (2.06 at 5% level)
$\sigma^2 p$	=	Phenotypic standard deviation
h^2	=	Heritability (Bs) in fraction

3.6.3.1. GENETIC ADVANCE AS A PERCENT OF MEAN

This was expressed by following formula:

$$\text{Genetic advance (as \% of mean)} = \frac{GA}{\bar{X}} x100$$

Where,

GA	=	Genetic advance
$\bar{X}$	=	Mean

3.6.4 ESTIMATION OF CORRELATIONS

The genotypic and phenotypic coefficient of correlation among traits have been determined using the following formula, using the relevant components of variance and co-variance.

Phenotypic correlation (rp) = PCOVxy / √PVx . PVy

Genotypic correlation (rg) = GCOVxy / √GVx . GVy

$$r_{xy} = \frac{\mathrm{Cov}\,(x, y)}{\sqrt{V(x) \times V\,(y)}}$$

Where,

r_{xy}	=	Correlation coefficient between character x and y,
Cov (x,y)	=	Co-variance of character x and y,
V(x)	=	Variance of character x, and
V(y)	=	Variance of character y.
rp	=	Phenotypic correlation.
rg	=	Genotypic correlation

The estimated values were compared with Fisher and Yates (1938) tabulated v alues at t-2 d.f. to determine the significance of correlation coefficients, at 2 probability levels of, 5% and 1%.

3.6.5. PATH COEFFICIENT ANALYSIS

Path coefficient is a standardized partial regression, which measures the direct influence of one variable upon another and allows partition of correlation coefficient into components of direct and indirect effects.

To estimate various direct and indirect effects, the following set of simultaneous equations were formed and solved.

$$r_{1y} = P_{1y} + r_{12}P_{2y} + r_{13}P_{3y} + \ldots + r_{1I}P_{Iy}$$

$$r_{2y} = r_{2y}P_{1y} + P_{2y} + r_{23}P_{3y} + \ldots + r_{2I}P_{Iy}$$

$$r_{Iy} = r_{I1}P_{1y} + r_{I2}P_{2y} + r_{I3}P_{3y} + \ldots + r_{3I}P_{Iy}$$

Where,

r_{1y} to r_{Iy}	=	Coefficient of correlation between causal factor 1 to I and dependent character y
r_{12} to $r_{I-1,I}$	=	Coefficient of correlation among causal factors themselves
P_{1y} to P_{Iy}	=	Direct effects of characters 1 to I on character y

Residual effect, which measures the contribution of the characters not considered in the causal scheme, was obtained as:

Residual effect :

$$(P_{RY}) = \sqrt{1\text{-}\mathrm{R}^2}$$

Where,

$$R^2 = \sum_{\mathrm{iy}} \mathrm{P}_{\mathrm{i}}^2\mathrm{Y} + 2\sum_{\substack{\mathrm{i}\neq\mathrm{j} \\ \mathrm{i}>\mathrm{j}}} \mathrm{P}_{\mathrm{iy}}\ \mathrm{P}_{\mathrm{jy}}\ \mathrm{R}_{\mathrm{ij}}$$

3.6.7 Estimation of Stability parameters

The variances of error pertaining to each environment (years) were subjected to the Bartlett's test of homogeneity prior to pooled analysis variance.

The Eberhart and Russell (1966) model was used for stability analysis. The model is described as –

Yij = m + bij lj + ij (i=1,2,3……...t)

(j=1,2……..…s)

Where,

Yij = Mean of the ith variety in jth environment

m = Mean of all the varieties over all the environments

bij = The regression coefficient of the ith variety on the

Environmental index, which measures how this variety responds to different settings.

lj = the environment index which is defined as the deviation of the mean of all the varieties at a given location from the overall mean

Ij = the deviation from regression of the ith variety at ith environment.

Eberhart & Russell (1966) following three parameters:

1. **Mean performance:** The value of this parameter is employed to recognize genotype performance over location/time, etc.
2. **Regression coefficient:** Calculated as regression for each variety's output in different environments or locations on the environmental or location means. A stable genotype was defined as one with a regression coefficient of unity (b=1) and should not change significantly from the variety.
3. **Deviation from regression:** The deviation from regression line must be as small as possible ($s^2di= 0$).

3.6.8 Heterosis estimation

The estimation of heterosis was conducted using the mean of parents and F1 hybrids, using the methodology proposed by Fonseca and Patterson (1968).

Standard heterosis = *F1-SV/SV X 100*

Heterobeltiosis = *F1-BP/BP X 100*

Relative heterosis = *F1- MP/MP X 100*

Where,

$F1$ = F1 hybrid mean

MP = Mid parental mean

BP = Better parent mean

SV = Standard varietal mean

Test of Significance

The following method was used to figure out the standard error for heterosis:

S.E. for MP = √3EMS2r

S.E. for MP and SV = √2EMSr

C.D. = S.E. for H x t

Where,

EMS stands for Error Mean Square

R stands total Number of replications

't' value required depends on the significance level (usually 5% or 1%)

Least significance differences (critical differences)

The CD represents the smallest difference between two values that needs to be exceeded for the disparity to be statistically significant. This approach enables researchers to establish whether the variation between the estimations of heterosis is statistically meaningful, considering the variability inherent in the data and the specific associated degrees of freedom with the statistical analysis.

The formula for calculating the Critical Difference (CD) is as follows:

CD = Sem x ‘t’ table value at the degrees of freedom

3.6.9 COMBINING ABILITY ANALYSIS

Originally introduced by Kempthorne in 1957, the L x T technique, is a well-established method frequently applied in plant breeding and genetics. Its primary purpose is to evaluate the contributions of parental lines and specific crosses by assessing the combining ability effects. This technique proves invaluable in discerning the relative significance of two key factors: general (GCA) & specific combining ability (SCA) in the inheritance patterns of various traits.

Statistical model:

The analysis was conducted with the statistical methodology outlined below:

Yijk = μ + mi fj+ Sij + ejik

Where,

μ = overall population mean

mi = general combining ability (GCA) effect of the i^{th} male parent

fj = gca effect of the j^{th} (female) parent

Sij = GCA of the $(i \times j)^{th}$ cross between the i^{th} male parent and the j^{th} female parent

ejik = random error effect correlated with $(ijk)^{th}$ observation in k^{th} replication

Table 3.6.9 ANOVA table for LxT combining ability

S.o.V	**D.f.**	**Mean Squares**	**Expectations of mean squares**
Replications	(r-1)		
Hybrids	(lt - 1)		
Lines	(l-1)	M1	σ2e + r [Covrr.(F.S) - 2 Covrr.(H.S) + rl [Covrr.(H.s.)]
Testers	(t-1)	M2	σ2e + r [Covrr.(F.S) - 2 Covrr.(H.S) + rl [Covrr.(H.s.)]
Lines x testers	(l-1) (t-1)	M3	σ2e + r [Covrr.(F.S) - 2 Covrr.(H.S) + rl [Covrr.(H.s.)]
Error	(r-1) (lt-1)	M4	σ2e

Where,

r = number of replications
l = number of lines
t = number of testers
Covrr. (F.S) = covariance of full sibs
Covrr. (H.S) = covariance of half sibs

3.6.9.1 Estimation of variance components

Covariance estimation between full siblings and half-siblings was carried out using genetic probability-based mean squares analysis.

Cov.(F.S) = M1+ M2 + M3 – 3M+ σr Covr. (H.S.)- r(1+t) Covr. (H.S.)/3r

Cov. (H.S.) = M1 + M2 – 2M3/r (1+t)

The variances related to gca (σ^2sca) and specialized combining ability (σ^2sca) were estimated using the covariance of full and half siblings.

σ^2gca = Cov. (H.S.)

σ^2gca = Cov. (F.S.) – 2Cov. (H.S.)

3.6.9.2 GCA variations for lines and testers and SCA variances for hybrids were calculated as follows:

Variance of GCA for lines (σ^2GCA lines) = (M1 - M3) / (rt)

Variance of GCA for testers (σ^2GCA testers) = (M2 - M3) / (rl)

Variance of SCA for hybrids (σ^2SCA hybrids) = (M3 - M4) / (r)

Combining ability effects estimation

The gca and sca effects were determined utilizing the prescribed methodology

Xijk = μ + gi+ gj + Sij + eijk

3.6.9.3 Test of significant of combining ability

Determined the variances of the estimations using the given formula. Subsequently, we calculated the standard errors of these estimations by their respective variances square roots

S.E. (gca for the line) = (M4/rt)1/2

S.E. (gca for the tester) = (M4/rl)1/2

S.E. (sca the effect) = (M4/r)1/2

Where,

M4 represents the error variance.

r stands for the number of replications.

l refers to the lines.

t represents the testers.

3.6.9.4 Least significant differences between estimates:

Calculating the Least Significant Difference (LSD) is a statistical procedure used in the context of analysis of variance (ANOVA) to determine whether the differences between means in multiple groups are statistically significant.

S.E. (gi – gj) lines = $(2M4/rt)^{1/2}$

S.E. (gi – gj) testers = $(2M4/rl)^{1/2}$

S.E. (Sij – Skl) crosses = $(2M4/r)^{1/2}$

3.6.9.5 Estimation of additive and dominance variance

The formula was used to estimate additive and dominance variances under heterozygous (F=0) and homozygous conditions (F=1).

$$\sigma 2 \text{ GCA} = [1+F/4]\ \sigma 2 \text{ A}$$

$$\sigma^2 A = [4/1+F]\ \sigma^2 GCA$$

$$\sigma^2 SCA = [1+F/4]\ \sigma^2 D$$

$$\sigma^2 D = \sigma^2 GCA\ [2/1+F]^2$$

Where,

F	=	co-efficient of inbreeding
σ^2 A	=	variance additive
σ^2 D	=	variance dominance

IV- RESULTS

The current investigation's experimental findings entitled "**Heterosis and stability studies in chickpea (*Cicer arietinum* L.) against chilling and heat stress: a morphological, phenological and biochemical assessment"** are outlined under in the given headings

4.1 Parameters of genetic variability

- 4.1.1 Analysis of variance
- 4.1.2 Mean and range
- 4.1.3 Phenotypic and genotypic coefficient of variation
- 4.1.4 Heritability
- 4.1.5 Genetic advance

4.2 Correlation coefficient analysis

4.3 Path coefficient analysis

4.4 Stability analysis

4.5 Parameters of genetic variability

- 4.5.1 Analysis of variance
- 4.5.2 Per se performance of parents and their crosses

4.6 Estimation of heterosis, heterobeltiosis and standard heterosis

4.7 Combining ability analysis

4.1 PARAMETERS OF GENETIC VARIABILITY

4.1.1 ANALYSIS OF VARIANCE (ANOVA)

Table 4.1 shows results of the analysis of variance on traits considered in the experiment. The estimated genetic variability was detected for twenty-two characteristics across 25 entries. The ANOVA revealed that MSS owing to genotypes was significant for all the examined characteristics in all the conditions of the environment. Pooled environment recorded non-significant values for characters harvest index (%), total chlorophyll content, electrolyte leakage index, Ascorbic acid content and Flower drop. Empty capsules plant^{-1} revealed significance for replication in EN-2.

Table 4.1: ANOVA for chickpea seed yield and associated constituents

Source	d.f.		MSS										
			First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
Replication	1	EN-1	0.5	0.02	1.28	0.59	0.039	0.039	0.02	0.11	0.23	0.06	0.009
		EN-2	1.28	5.12	3.38	0.4	0.02	0.003	4.86	1.09	1.34*	0.0008	0.005
		EN-3	0.08	0.32	0.98	0.033	0.0008	0.003	0.05	0.064	0.0008	0.02	0.18
		Pooled	0.16	2.94	5.22	0.84	0.045	0.013	1.74	0.89	0.14	0.002	0.021
Genotype	24	EN-1	11.90*	8.13*	28.98*	45.79*	0.44*	0.89*	61.95*	86.75*	8.47*	0.38*	5.55*
		EN-2	6.32*	6.70*	19.16*	50.52*	0.28*	0.63*	66.79*	76.48*	2.14*	0.093*	4.85*
		EN-3	8.78*	9.82*	13.27*	64.79*	0.109*	0.10*	28.22*	37.02*	5.25*	0.02*	7.38*
		Pooled	64.02*	81.22*	780.74*	224.52*	0.61*	2.02*	592.77*	714.78*	13.31*	0.25*	6.29*
Error	24	EN-1	0.87	0.97	1.11	1.72	0.015	0.02	1.12	1.38	0.37	0.028	0.054
		EN-2	0.86	1.2	1.38	0.74	0.031	0.08	3.44	4.32	0.25	0.024	0.067
		EN-3	0.66	0.61	0.52	0.46	0.02	0.02	1.56	1.4	0.26	0.02	0.075
		Pooled	5.33	5.05	19	22.35	0.12	0.25	27.63	36.81	2.54	0.088	2.49
CV		EN-1	1.0551	1.031	0.6321	3.4107	3.2498	2.2224	1.7976	2.3549	6.737	9.1356	2.1561
		EN-2	1.0568	1.1586	0.6882	2.2933	4.7378	4.7569	3.1186	4.2797	4.6393	8.9281	2.4825
		EN-3	0.9971	0.8904	0.4986	2.5504	4.3493	3.1613	3.1999	4.3852	4.2778	9.8849	2.766
		Pooled	2.6832	2.4229	2.7108	13.7735	9.6749	8.4086	10.003	14.4918	14.933	17.057	15.1353

Table 4.1: ANOVA for chickpea seed yield and associated constituents

Source	d.f.		MSS										
			Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
Replication	1	EN-1	0.021	0.45	0.02	0.59	0.2	0.025	0.022	1.46	3.38	1.14	0.036
		EN-2	0.18	1.4	0.0002	0.107	0.002	0.046	0.018	3.61	1.28	10.69	0.101
		EN-3	0.065	1.33	0.0008	0.208	0.000008	0.3	0.042	0.14	2.69	2.13	0.002
		Pooled	0.0001	0.92	0.005	0.00008	0.084	0.083	0.08	0.033	1.83	4.47	0.002
Genotype	24	EN-1	8.36*	95.3*	0.208*	163.46*	21.61*	170.02*	0.45*	14.36*	42.84*	40.68*	6.49*
		EN-2	7.74*	83.57*	0.43*	148.6*	26.6*	181.28*	0.42*	11.62*	40.6*	45.45*	8.03*
		EN-3	4.43*	108.1*	0.28*	75.24*	31.68*	146.95*	0.47*	46.42*	46.42*	47.45*	3.18*
		Pooled	132.12*	57.1	0.25	140.04*	51.49*	98.24	0.68*	17.17	157.6*	28.53	28.34*
Error	24	EN-1	0.47	2.28	0.009	0.29	0.16	0.36	0.009	4.02	2.92	1.33	0.091
		EN-2	0.88	1.84	0.004	0.5	0.4	0.37	0.018	4.74	2.88	2.79	0.27
		EN-3	0.13	1.71	0.02	0.38	0.24	0.15	0.018	2.22	2.38	2.39	0.02
		Pooled	3.26	47.24	0.25	54.25	10.75	82.53	0.22	12.83	21.35	24.1	2.51
CV		EN-1	3.5041	3.4943	5.5468	1.2297	2.0021	1.2812	7.7349	6.376	2.2622	4.0294	3.5481
		EN-2	4.8838	3.1918	3.9938	1.6226	2.9271	1.2893	9.3476	7.0387	2.2273	5.9003	6.3434
		EN-3	3.6728	3.027	9.285	1.5745	1.9772	0.7859	7.1808	4.7544	2.3284	4.9649	3.4839
		Pooled	11.1146	15.971	22.6023	17.3344	14.5986	18.8152	30.9088	11.4602	6.3561	16.7033	22.5179

4.1.2 MEAN, RANGE, COEFFICIENT OF VARIANCE

The range and mean given in (Table-4.2) indicated greater variations for all twenty-two evaluated traits for the current study, which is reported in Appendix I and addressed as the below given headings:

4.1.2.1. First blossoming days

First sowing date [EN-1]- Started at 83.00 to 93.50 days, average 88.66 and a CV of 1.05%. The earliest genotype discovered was ICC-5335 (83.00 days), whereas the most late genotype discovered was ICC-3020 (93.50 days).

Second sowing date [EN-2]- Started at 85.00 to 91.00, with a mean 87.92 days and a CV of 1.03%. The earliest genotype discovered was KWR-108 (85.00 days), whereas the most late genotype discovered was PUSA 3043 (91.00 days).

Third sowing date [EN-3]- Started at 76.50 to 85.50, a mean of 81.68 days and a CV of 0.99%. The earliest genotype discovered was KWR-108 (76.50 days), whereas the most late genotype discovered was PUSA 3043 (85.50 days).

Pooled- Ranged from 79.5 days for IPC 05-28 and as high as 90.66 days for IPC-07-56, with a mean value 86.08 days and a CV of 2.68%.

4.1.2.2. 50% blossoming days

First sowing date [EN-1]- Ranged from 92.50 to 100 days, with an average 95.94 days and a CV of 1.03%. The earliest genotype discovered was PBG-5 (92.50 days), whereas the most late genotype discovered was ICC-3020 (100 days).

Second sowing date [EN-2]- Started at 91.00 to 98.00 days, with an average 94.68 days and a CV of 1.15%. The earliest genotype discovered was KWR-108 (91.00 days), whereas the most late genotype discovered was RSG-888 (98.00 days).

Third sowing date [EN-3]- Ranged from 82.50 to 92.00 days, average 87.84 days, CV 0.89%. The earliest genotype discovered was KWR-108 (82.50 days), whereas the most late genotype discovered was JG 14 (92.00 days).

Pooled- Ranged from 86.00 days for IPC 05-28 and as high as 97.33 days for IPC-07-56, with an average 92.82 days and a CV of 2.42% in the pooled analysis.

4.1.2.3. Harvest maturity days

First sowing date [EN-1]- Ranged from 159.50 to 173.00, with a mean 166.92 days and a CV of 0.63%. The earliest genotype discovered was BG-212 (159.50 days), whereas the most late genotype discovered was IPC-07-56 (173.00 days).

Second sowing date [EN-2]- Started from 164.00 to 176.50, average of 166.92, and CV 0.68%. The earliest genotype discovered was KWR-108 (164.00 days), whereas the most late genotype discovered was RSG-888 (176.50 days).

Third sowing date [EN-3]- Ranged at 139.50 to 149.00, a mean of 144.86 days and a CV of 0.49%. The earliest genotype discovered was KWR-108 (139.50 days), whereas the most late genotype discovered was PBG-5 (149.00 days).

Pooled- Ranged from 142.50 days for IPC 05-28 and as high as 175.83 days for IPC-07-56, with a mean value 160.82 days and a CV of 2.71% in the pooled analysis.

4.1.2.4. Plant height

First sowing date [EN-1]- IPC 05-28 measured the shortest at 31.03 cm and the tallest at 46.54 cm by ICC 5434 among the genotypes. Average height was 38.51 cm, with a CV of 3.41%.

Second sowing date [EN-2]- RSG 945 measured the shortest at 30.42 cm and the tallest at 45.55 cm by ICC 5335 among the genotypes. Average height was 37.58 cm, with a CV of 2.29%.

Third sowing date [EN-3]- RSG 931 measured the shortest at 16.00 cm and the tallest at 37.36 cm by IPC 06-77 among the genotypes. Average height was 26.87 cm with a CV of 2.55%.

Pooled- Average observed in the pooled analysis was 34.32 cm. IPC 06-77 recorded the tallest (42.33 cm) while RSG 945 recorded the shortest (21.81 cm) with a CV of 13.77%.

4.1.2.5. Primary offshoots plant^{-1}

First sowing date [EN-1]- Ranged from IPC 05-28 was 3.1 and the maximum was 4.7 by ICC 5434, with an average of 3.87 and CV 3.24%.

Second sowing date [EN-2]- PUSA 3043 displayed the minimum (3.1) and IPC 07-56 had the maximum (4.4), with an average of 3.75 and a CV of 4.73%.

Third sowing date [EN-3]- IPC 05-28 had the minimum (2.7) and KWR 108 and GNG 469 had the maximum (3.7), with an average of 3.31 and CV of 4.34%.

Pooled- SADABAHAR had the minimum (3.1) and IPC 06-77 had the maximum (4.4), with an average of 3.64 and a CV of 9.67% in the pooled analysis.

4.1.2.6. Secondary offshoots plant^{-1}

First sowing date [EN-1]- IPC 05-28 had the minimum (5.1) by and IPC 06-77 had the maximum (7.4), with an average of 6.5 and CV 2.22%.

Second sowing date [EN-2]- PUSA 3043 had the minimum (5.1) and IPC 07-56 had the maximum (7.1), with an average of 6.18 and a CV of 4.75%.

Third sowing date [EN-3]- IPC 05-28 had the minimum (4.7) and GNG 469 had the most (5.7), with an average of 5.31 and CV 3.16%.

Pooled- SADABAHAR had the minimum (5.1) and KWR 108 had the maximum (69.6), with an average of 5.99 and a CV of 8.40% in the pooled analysis.

4.1.2.7. Capsules plant^{-1}

First sowing date [EN-1]- K 850 had lowest (49.1) and SADABAHAR had the maximum (67.1), with an average of 59.09 and CV 1.79%.

Second sowing date [EN-2]- ICC 3020 had lowest (51.1) and GNG 469 had the maximum (69.4), with an average of 59.52 and CV 3.11%.

Third sowing date [EN-3]- RSG 888 had lowest (32.1) and IPC 07-56 had the maximum (44.9), with an average of 39.04 and CV 3.19%.

Pooled- PBG 5 had lowest (33.83) and the maximum by ICC 5439 (63.03), with an average of 52.55 and a CV of 10.00% in the pooled analysis.

4.1.2.8. Full capsules plant^{-1}

First sowing date [EN-1]- K 850 had the minimum (37.2) and SADABAHAR had the maximum (59.2), with an average of 50.00 and CV 2.35%.

Second sowing date [EN-2]- ICC 244 263 had the minimum (39.9) and the maximum number by GNG 469 (59.2), with an average of 48.60 and CV 4.29%.

Third sowing date [EN-3]- RSG 888 had the minimum (19.9) and the maximum by BG 212 (34.8), with an average of 26.99 and CV 4.38%.

Pooled- PBG 5 had the minimum (22.73) and the maximum was by IPC 06-77 (53.2), with an average of 41.86 and CV 14.49% In the pooled analysis.

4.1.2.9. Empty capsules plant^{-1}

First sowing date [EN-1]- ICC 5335 had lowest (5.2) and RSG 931 had the maximum (13.1), with an average of 9.08 and CV 6.73%.

Second sowing date [EN-2]- ICC 5335 had lowest (9.00) and PBG 5 had the maximum (12.5), with an average of 10.91 and CV 4.63%.

Third sowing date [EN-3]- BG 212 had lowest (9.7) and ICC 3020 the maximum (16.4), with an average of 12.05 and CV 4.27%.

Pooled- IPC 06-77 had lowest (6.83) and IPC 05-28 had the maximum (13.1), with an average of 10.68 and CV 14.93% in the pooled analysis.

4.1.2.10. Seeds capsule^{-1}

First sowing date [EN-1]- IPC 05-28, PUSA 3043, and RSG 945 had lowest (1.3) while KPG-59 and PBG-5 had the maximum (2.7), with an average of 1.83 and CV 9.13%.

Second sowing date [EN-2]- IPC 05-28 and RSG 945 had lowest (1.3) while ICC-3020, IPC-06-77, and ICC-5434 had the maximum (2.1), with an average of 1.74 and CV 8.92%.

Third sowing date [EN-3]- ICC-5439, PDG-4, and RSG 945 had lowest (1.3), whereas IPC-07-56 had the maximum (2.5), with an average of 1.65 and CV 9.88%.

Pooled- SADABAHAR had lowest recorded (1.4) and IPC-06-77 had the maximum (2.26), with an average of 1.74 and CV 17.05% in the pooled analysis.

4.1.2.11. Test weight (gm)

First sowing date [EN-1]- Among the genotypes, minimum was 8 by RSG-888 and maximum 14.6 by GNG 469 with an average of 10.87 and CV 2.15 %.

Second sowing date [EN-2]- Among the genotypes, minimum was 8.2 by IPC 05-28 & RSG 945 and maximum 14.2 by GNG 469 with an average of 10.49 and CV 2.48 %.

Third sowing date [EN-3]- Among the genotypes, minimum was 6.9 by PBG-5 and maximum 15.2 PUSA 3043 with an average of 9.95 and CV 2.76 %.

Pooled- In the pooled analysis, minimum was 7.45 by JG 14 and maximum 12.45 by ICC 3525 with an average of 10.44 and CV 15.13 %.

4.1.2.12. Biological yield plant^{-1}

First sowing date [EN-1]- Ranged from 15.4g (RSG 945) to 25.33g (BG-212) with an average of 19.63g and a CV of 3.50 %.

Second sowing date [EN-2]- Ranged from 16.07g (RSG 945) to 25.97g (BG-212) with an average of 19.22g and a CV of 4.88 %.

Third sowing date [EN-3]- Ranged from 6.99g (ICC-5439) to 12.32 g (ICC-5335) with an average of 9.95g and a CV of 3.67 %.

Pooled- In the pooled analysis, minimum recorded was 9.36 by GNG 469 and maximum 22.45 by IPC-06-77 with an average of 16.24 and a CV of 11.11 %.

4.2.1.13. Harvest index (%)

First sowing date [EN-1]- Ranged from 31.97g (RSG-888) to 55.40g (BG-212) with an average of 43.27g and a CV of 3.49 %.

Second sowing date [EN-2]- Ranged from 33.53g (RSG-888) to 52.92g (ICC-5335) with an average of 42.59g and a CV of 3.19 %.

Third sowing date [EN-3]- Ranged from 30.97g (PUSA 3043) to 52.48g (ICC-5335) with an average of 43.24g and a CV of 3.02 %.

Pooled- In the pooled analysis, minimum was 35.98g by IPC-07-56 and maximum 47.41g by IPC-06-77 with a mean 43.03 and a CV of 15.97 %.

4.1.2.14. Total chlorophyll content (mg/ml)

First sowing date [EN-1]- Ranged from 1.17 (RSG-888) to 2.51 (KPG 59) with an average of 1.74 and a CV of 5.54 %.

Second sowing date [EN-2]- Ranged from 0.88 (ICC 3525) to 2.4 (IPC 06-77) with an average of 1.67 and a CV of 3.99 %.

Third sowing date [EN-3]- Ranged from 0.88 (ICC 3525) to 2.51 (GNG 469) with an average of 1.63 and a CV of 9.28 %.

Pooled- In the pooled analysis, minimum was 1.095 (IPC-07-56) and maximum 2.09 (BG 212) with an average of 1.68 and a CV of 22.60 %.

4.1.2.15. Relative leaf water content (%)

First sowing date [EN-1]- Ranged from 31.32% (BPM) to 58.52% (ICC 5434) with an average of 43.91 and a CV of 1.22 %.

Second sowing date [EN-2]- Ranged from 31.66% (BPM) to 58.65% (KWR 108) with an average of 43.98 and a CV of 1.62 %.

Third sowing date [EN-3]- Ranged from 31.54% (ICC 244 263) to 49.54% (ICC 5434) with an average of 39.57 and a CV of 1.57 %.

Pooled- In the pooled analysis, minimum was 33.89% (IPC-07-56) and maximum 53.60% (BG 212) with an average of 42.49 and a CV of 17.33 %.

4.1.2.16. Lipid Peroxidation (nmol/ml)

First sowing date [EN-1]- Ranged from 13.27 (GNG 469) to 24.9 (PBG 5) with an average of 20.39 and a CV of 2.00 %.

Second sowing date [EN-2]- Ranged from 14.37 (GNG 469) to 28.94 (ICC 5439) with an average of 21.85 and a CV of 2.92 %.

Third sowing date [EN-3]- Ranged from 17.19 (KPG 59) to 31.32 (PUSA 3043) with an average of 25.14 and a CV of 1.97 %.

Pooled- In the pooled analysis, minimum was 16.89 (K 850) and maximum 27.26 (RSG 945) with an average of 22.46 and a CV 14.59 %.

4.1.2.17. Electrolyte leakage index (%)

First sowing date [EN-1]- Ranged from 25.895 (KPG 59) to 61.25 (ICC 3020) with an average of 46.93 and a CV of 1.28 %.

Second sowing date [EN-2]- Ranged from 28.72 (GNG 469) to 61.76 (PBG 7) with an average of 47.47 and a CV of 1.28 %.

Third sowing date [EN-3]- Ranged from 32.16 (GNG 469) to 61.47 (IPC 9767) with an average of 50.44 and a CV of 0.78 %.

Pooled- In the pooled analysis, minimum was 41.32 (ICC 5335) and maximum 55.65 (JG 14) with a mean 48.28 and a CV of 18.81 %.

4.1.2.18. Proline content (mg/gm)

First sowing date [EN-1]- Ranged from 0.77 (RSG 931) to 2.60 (PDG 4) with an average of 1.27 and a CV of 7.73 %.

Second sowing date [EN-2]- Ranged from 0.71 (IPC 05-28) to 2.29 (GNG 469) with an average of 1.45 and a CV of 9.34 %.

Third sowing date [EN-3]- Ranged from 1.31 (ICC 5439) to 3.09 (PDG 4) with an average of 1.89 and a CV of 7.18 %.

Pooled- In the pooled analysis, minimum was 0.74 (IPC 07-56) and maximum 2.18 (PUSA 3043) with a mean1.54 and a CV of 30.90 %.

4.1.2.19. Ascorbic acid content (mg)

First sowing date [EN-1]- Ranged from 27.7 (PBG 5) to 37.69 (ICC 3525) with an average of 31.46 and a CV of 6.37 %.

Second sowing date [EN-2]- Ranged from 26.16 (PBG 7) to 36.30 (IPC 07-56) with an average of 30.95 and a CV of 7.03 %.

Third sowing date [EN-3]- Ranged from 24.23 (IPC 05-28) to 44.61 (PDG 4) with an average of 31.35 and a CV of 4.75 %.

Pooled- In the pooled analysis, minimum was 28.72 (ICC 244-263) and maximum 34.86 (SADABAHAR) with an average of 31.25 and a CV of 11.46 %.

4.1.2.20. Pollen viability (%)

First sowing date [EN-1]- Ranged from 68.9 (IPC 05-28) to 83.7 (ICC 5434) with an average of 75.58 and a CV of 2.26 %.

Second sowing date [EN-2]- Ranged from 71.1 (GNG 469) to 85.4 (IPC 06-77) with an average of 76.19 and a CV of 2.22 %.

Third sowing date [EN-3]- Ranged from 58.4 (IPC 05-28) to 74.00 (BG 212) with an average of 66.34 and a CV of 2.32 %.

Pooled- In the pooled analysis, minimum was 61.73 (SADABAHAR) and maximum 79.43 (IPC 06-77) with an average of 72.70 and a CV of 6.35 %.

4.1.2.21. Flower drop (%)

First sowing date [EN-1]- Ranged from 21.71 (GNG 469) to 36.34 (BPM) with an average of 28.71 and a CV of 4.02 %.

Second sowing date [EN-2]- Ranged from 19.01 (GNG 469) to 35.49 (ICC 5439) with an average of 28.32 and a CV of 5.90 %.

Third sowing date [EN-3]- Ranged from 21.99 (PDG 4) to 38.51 (RSG 888) with an average of 31.14 and a CV of 4.96 %.

Pooled- In the pooled analysis, minimum was 25.71 (RSG 931) and maximum 33.24 (PBG 5) with an average of 29.39 and a CV of 16.70 %.

4.1.2.22. Seed yield plant^{-1}

First sowing date [EN-1]- Ranged from 5.80g (RSG 945) to 14g (BG 212) with an average of 8.51g and a CV of 3.54 %.

Second sowing date [EN-2]- Ranged from 5.73 (RSG 888) to 13.59 (BG 212) with an average of 8.27 and a CV of 6.34 %.

Third sowing date [EN-3]- Ranged from 2.55 (ICC 5439) to 6.48 (ICC 5335) with an average of 4.33 and a CV of 3.48 %.

Pooled- In the pooled analysis, minimum was 3.53 (SADABAHAR) and maximum 10.67 (IPC 06-77) with an average of 7.04 and a CV of 22.51 %.

VARIABILITY, HAERITABILITY AND GENETIC ADVANCE

4.1.3 PCV & GCV

First date sowing [EN-1]

Table 4.2 shows the coefficients of phenotypic and genotypic variation for yield and its traits under investigation. The PCV was significantly higher for every trait in every analysis than the GCV. Magnitude of PCV and GCV was high for proline content (mg/gm) (36.97, 37.37), seeds capsule^{-1} (22.89, 23.78), empty capsules plant^{-1} (22.16, 22.66) and relative leaf water content (%) (20.56, 20.58). Moderate PCV and GCV was recorded electrolyte leakage index (%)(19.62, 19.64), total chlorophyll content (mg/ml) (18.06, 18.48), lipid peroxidation (nmol/ml) (16.05, 16.11), harvest index (%) (15.75, 15.95), flower drop (%) (15.44, 15.70), test weight (gm) (15.24, 15.32), full capsules plant^{-1} (13.06, 13.17), plant height (12.18, 12.42), primary offshoots plant^{-1} (11.91, 12.13), secondary offshoots plant^{-1} (10.17, 10.29), biological yield plant^{-1} (10.11, 10.41). Low magnitude of PCV and GCV was noted in capsules plant^{-1} (9.33, 9.41), ascorbic acid content (mg) (7.22, 8.51), pollen viability (%) (5.91, 6.12), first blossoming days (2.64, 2.75), harvest maturity days (2.23, 2.28), 50% blossoming days (1.97, 2.10).

Second date sowing [EN-2]

Table 4.3 shows the coefficients of phenotypic and genotypic variation for yield and its traits under investigation. The PCV was significantly higher for every trait in every analysis than the GCV. Magnitude of PCV and GCV was high for proline content (mg/gm) (30.99, 31.68), total chlorophyll content (mg/ml) (27.63, 27.77), seed yield plant^{-1} (23.78, 24.20), electrolyte leakage index (%) (20.03, 20.05). Moderate PCV and GCV was recorded for relative leaf water content (%) (19.56, 19.59), lipid peroxidation (nmol/ml) (16.56, 16.69), flower drop (%) (16.30, 16.83), harvest index (%) (15.00, 15.17), test weight (gm) (14.73, 14.84), plant height (13.27, 13.37), full capsules plant^{-1} (12.35, 12.72), seeds capsule^{-1} (10.69, 12.41). Biological yield plant^{-1} recoded low value for GCV and moderate for PCV (9.63, 10.23). primary offshoots plant^{-1} (9.47, 10.05), capsules plant^{-1} (9.45, 9.70), empty capsules plant^{-1} (8.90, 9.48), secondary offshoots plant^{-1} (8.45, 9.09), ascorbic acid content (mg) (5.99, 7.78), pollen viability (%) (5.70, 5.91), first blossoming days (1.87, 2.02), 50% blossoming days (1.75, 1.93) and harvest maturity days (1.74, 1.81) recoded lower estimates for PCV and GCV.

Third date sowing [EN-3]

Table 4.4 shows the coefficients of phenotypic and genotypic variation for yield and its traits under investigation. The PCV was significantly higher for every trait in every analysis than the GCV. Magnitude of PCV & GCV was high for seed yield plant^{-1} (28.98, 29.08), proline content^{-1} (25.37, 25.87), total chlorophyll content (mg/ml) (22.32, 23.26) and plant height (21.1, 21.17). test weight (gm) (19.20, 19.30), electrolyte leakage index (%)(16.98, 16.99), harvest index (%) (16.86, 17.00), lipid peroxidation (nmol/ml) (15.76, 15.83), full capsules plant^{-1} (15.63, 15.93), relative leaf water content (%) (15.46, 15.50), flower drop (%) (15.24, 15.64), ascorbic acid content (mg) (14.99, 15.36), biological yield (14.83, 15.05), seeds capsule^{-1} (13.20, 14.94), empty capsules plant^{-1} (13.10, 13.44) recorded moderate estimates. Low estimates were recorded for capsules plant^{-1} (9.35, 9.62), pollen viability (%) (7.07, 7.26), primary offshoots plant^{-1} (6.35, 7.05), secondary offshoots plant^{-1} (3.62, 4.25), first blossoming days (2.46, 2.56), 50% blossoming days (2.44, 2.52) and harvest maturity days (1.74, 1.77).

Pooled

Table 4.5 shows the coefficients of phenotypic and genotypic variation for yield and its traits under investigation. The PCV was significantly higher for every trait in every analysis than the GCV. Magnitude of PCV & GCV was high for seed yield plant^{-1} (29.45, 30.85), biological yield (28.52, 28.88), full capsules plant^{-1} (25.38, 26.06). capsules plant^{-1} (18.46, 18.91), proline content^{-1} (17.92, 21.91), plant height (16.91, 17.82), empty capsules plant^{-1} (12.53, 13.94), lipid peroxidation (nmol/ml) (11.59, 13.04) recorded moderate estimates. seeds capsule^{-1} (9.66, 11.91), relative leaf water content (%) (8.89, 11.37) and total chlorophyll content (mg/ml) (7.89, 12.14) recorded low estimates of GCV whereas counterpart PCV was Moderate. Low estimates were recorded for secondary offshoots plant^{-1} (9.06, 9.69), primary offshoots plant^{-1} (7.84, 8.78), test weight (gm) (7.62, 9.81), harvest maturity days (7.00,7.09), pollen viability (%)(6.55, 7.04), 50% blossoming days (3.83, 3.96), first blossoming days (3.63, 3.79), electrolyte leakage index (%)(3.35, 8.38), harvest index (%) (2.97, 7.16), flower drop (%) (2.92, 7.41) and ascorbic acid content (mg) (2.72, 5.41).

4.1.4 Heritability (bs) (%)

Based on an estimation, broad-sense heritability (the ratio of total genotypic variance to total phenotypic variance) was categorized as high (>60%), medium (30-60%), and low (30%) throughout the course of the current investigation.

First sowing date [EN-1]

Heritability for every assessed trait is illustrated in Table- 4.2, with a range of 72.00 to 99.8% observed. All the characters claimed high heritability. electrolyte leakage index (%)(99.8 %) recorded highest estimate followed by relative leaf water content (%) (99.8 %) followed by lipid peroxidation (nmol/ml) (99.2 %), test weight (gm) (99 %), seed yield plant^{-1} (98.6 %), full capsules plant^{-1} (98.4 %), capsules plant^{-1} (98.2 %), proline (97.9 %), secondary offshoots plant^{-1} (97.7 %), harvest index (%) (97.6 %), flower drop (%) (96.7 %), primary offshoots plant^{-1} (96.4 %), plant height (96.2 %), harvest maturity days (96.2 %), empty capsules plant^{-1} (95.6 %), total chlorophyll content (mg/ml) (95.5 %), biological yield (94.3 %), pollen viability (%)(93.2 %), first blossoming days (92.7 %), seeds capsule^{-1} (92.6 %), 50% blossoming days (88 %) and ascorbic acid content (mg) (72 %).

Second sowing date [EN-2]

Heritability for every assessed trait is illustrated in Table-4.3, with a range of 59.20 to 99.8% observed. Majority of the characters claimed high heritability. electrolyte leakage index (%)(99.8 %) followed by relative leaf water content (%) (99.7 %) recorded highest estimate followed by total chlorophyll content (mg/ml) (99 %), test weight (gm) (98.6 %), lipid peroxidation (nmol/ml) (98.5 %), plant height (98.5 %), harvest index (%) (97.8 %), seed yield plant^{-1} (96.6 %), proline (95.6 %), capsules plant^{-1} (94.8 %),full capsules plant^{-1} (94.3 %), flower drop (%) (93.9 %), pollen viability (%)(92.9 %), harvest maturity days (92.8 %), primary offshoots plant^{-1} (88.9 %), biological yield (88.6 %), empty capsules plant^{-1} (88 %), first blossoming days (86.3 %), secondary offshoots plant^{-1} (86.3 %), 50% blossoming days (82 %) and seeds capsule^{-1} (74.1%). Moderate heritability was recorded by ascorbic acid content (mg) (59.2 %).

Third sowing date [EN-3]

Heritability for every assessed trait is illustrated in Table-4.4, with a range of 72.40 to 99.90% observed. All the characters claimed high heritability. electrolyte leakage index (%)(99.9 %) had the highest estimate followed by relative leaf water content (%) (99.5 %), plant height (99.3 %), seed yield plant^{-1} (99.3 %), lipid peroxidation (nmol/ml) (99.2 %), test weight (gm) (99 %), harvest index (%) (98.4 %), biological yield (97 %), full capsules plant^{-1} (96.2 %), harvest maturity days (96.1 %), proline (96.1 %), ascorbic acid content (mg) (95.2 %), flower drop (%) (95 %), pollen viability (%)(94.9 %), empty capsules plant^{-1} (94.9 %), capsules plant^{-1} (94.5 %), 50% blossoming days (93.8 %), first blossoming days (92.5 %), total chlorophyll content (mg/ml) (92 %), primary offshoots plant^{-1} (81 %), seeds capsule^{-1} (78.1%) and secondary offshoots plant^{-1} (72.4 %).

Pooled

Heritability for every assessed trait is illustrated in Table-4.5, with a range of 15.5 to 97.6% observed. Majority of the characters claimed high heritability. harvest maturity days (97.6 %) recorded the highest estimate followed by biological yield (97.5 %), capsules plant^{-1} (95.3 %), full capsules plant^{-1} (94.8 %), 50% blossoming days (93.8 %), first blossoming days (91.7 %), seed yield plant^{-1} (91.1 %), plant height (90 %), secondary offshoots plant^{-1} (87.5 %), pollen viability (%)(86.4 %), empty capsules plant^{-1} (80.9 %), primary offshoots plant^{-1} (79.8 %) and lipid peroxidation (nmol/ml) (79.1 %). Moderate estimates were recorded for proline (66.9 %), seeds capsule^{-1} (65.8 %), relative leaf water content (%) (61.3 %), test weight (gm) (60.3 %) and total chlorophyll content (mg/ml) (42.3 %). ascorbic acid content (mg) (25.3 %), harvest index (%) (17.3 %), electrolyte leakage index (%) (16 %) and flower drop (%) (15.5 %) recorded low estimates of heritability.

Table 4.2: Genetic parameters influencing seed yield and the individual components in chickpea [EN-1]

Character	Mean	Range		Coefficient of variation		h2	GA	GA as % mean
		Min.	Max.	GCV	PCV			
First blossoming days	88.66	83.00	93.50	2.65	2.75	92.70	4.66	5.25
50% blossoming days	95.94	92.50	100.00	1.97	2.10	88.00	3.66	3.81
Harvest maturity days	166.92	159.50	173.00	2.24	2.28	96.20	7.54	4.52
Plant height	38.52	31.03	46.54	12.19	12.42	96.20	9.49	24.63
Primary offshoots plant^{-1}	3.88	3.10	4.70	11.91	12.13	96.40	0.93	24.09
Secondary offshoots plant^{-1}	6.50	5.10	7.40	10.17	10.29	97.70	1.35	20.71
Capsules plant^{-1}	59.09	49.10	67.10	9.33	9.42	98.20	11.26	19.05
Full capsules plant^{-1}	50.01	37.20	59.20	13.06	13.17	98.40	13.35	26.70
Empty capsules plant^{-1}	9.08	5.20	13.10	22.16	22.67	95.60	4.05	44.63
Seeds capsule^{-1}	1.84	1.30	2.70	22.89	23.79	92.60	0.83	45.39
Test weight (gm)	10.88	8.00	14.60	15.25	15.32	99.00	3.40	31.25
Biological yield plant^{-1}	19.63	15.40	25.33	10.12	10.42	94.30	3.97	20.25
Harvest index (%)	43.27	31.97	55.41	15.76	15.95	97.60	13.88	32.07
Total chlorophyll content (mg/ml)	1.75	1.18	2.52	18.06	18.48	95.50	0.64	36.36
Relative leaf water content (%)	43.92	31.32	58.52	20.57	20.59	99.80	18.59	42.33
Lipid Peroxidation (nmol/ml)	20.40	13.28	24.90	16.05	16.12	99.20	6.72	32.94
Electrolyte leakage index (%)	46.93	25.90	61.26	19.63	19.65	99.80	18.95	40.38
Proline content (mg/gm)	1.27	0.78	2.61	36.97	37.38	97.90	0.96	75.35
Ascorbic acid content (mg)	31.46	27.70	37.69	7.23	8.52	72.00	3.97	12.63
Pollen viability (%)	75.58	68.90	83.70	5.91	6.12	93.20	8.88	11.76
Flower drop (%)	28.71	21.72	36.34	15.45	15.71	96.70	8.99	31.29
Seed yield plant^{-1}	8.52	5.81	14.00	21.02	21.17	98.60	3.66	42.99

4.3: Genetic parameters influencing seed yield and the individual components in chickpea [EN-2]

Character	Mean	Range		Coefficient of variation		h2	GA	GA as % mean
		Min.	Max.	GCV	PCV			
First blossoming days	87.92	85.00	91.00	1.88	2.02	86.30	3.16	3.60
50% blossoming days	94.68	91.00	98.00	1.75	1.93	82.00	3.09	3.27
Harvest maturity days	170.70	164.00	176.50	1.75	1.81	92.80	5.92	3.47
Plant height	37.58	30.42	45.55	13.28	13.37	98.50	10.20	27.15
Primary offshoots plant^{-1}	3.76	3.10	4.40	9.48	10.05	88.90	0.69	18.41
Secondary offshoots plant^{-1}	6.18	5.10	7.10	8.45	9.10	86.30	1.00	16.18
Capsules plant^{-1}	59.52	51.10	69.40	9.46	9.71	94.80	11.29	18.97
Full capsules plant^{-1}	48.60	39.90	59.20	12.36	12.72	94.30	12.02	24.73
Empty capsules plant^{-1}	10.92	9.00	12.50	8.90	9.49	88.00	1.88	17.20
Seeds capsule^{-1}	1.74	1.30	2.10	10.69	12.42	74.10	0.33	18.96
Test weight (gm)	10.50	8.20	14.20	14.74	14.84	98.60	3.17	30.15
Biological yield plant^{-1}	19.23	16.07	25.97	9.64	10.24	88.60	3.59	18.69
Harvest index (%)	42.60	33.53	52.92	15.01	15.17	97.80	13.02	30.57
Total chlorophyll content (mg/ml)	1.68	0.89	2.40	27.64	27.78	99.00	0.95	56.63
Relative leaf water content (%)	43.99	31.67	58.66	19.56	19.60	99.70	17.70	40.23
Lipid Peroxidation (nmol/ml)	21.85	14.38	28.94	16.56	16.69	98.50	7.40	33.86
Electrolyte leakage index (%)	47.47	28.72	61.77	20.04	20.06	99.80	19.57	41.23
Proline content (mg/gm)	1.46	0.71	2.30	30.99	31.69	95.60	0.91	62.44
Ascorbic acid content (mg)	30.96	26.16	36.31	5.99	7.79	59.20	2.94	9.49
Pollen viability (%)	76.19	71.10	85.40	5.70	5.91	92.90	8.62	11.32
Flower drop (%)	28.32	19.01	35.49	16.31	16.83	93.90	9.22	32.55
Seed yield plant^{-1}	8.28	5.74	13.60	23.79	24.20	96.60	3.99	48.15

4.4: Genetic parameters influencing seed yield and the individual components in chickpea [EN-3]

Character	Mean	Range		Coefficient of variation		h2	GA	GA as % mean
		Min.	Max.	GCV	PCV			
First blossoming days	81.68	76.50	85.50	2.47	2.57	92.50	3.99	4.89
50% blossoming days	87.84	82.50	92.00	2.44	2.52	93.80	4.28	4.87
Harvest maturity days	144.86	139.50	149.00	1.74	1.78	96.10	5.10	3.52
Plant height	26.88	16.00	37.36	21.10	21.18	99.30	11.64	43.31
Primary offshoots plant^{-1}	3.32	2.70	3.70	6.35	7.06	81.00	0.39	11.77
Secondary offshoots plant^{-1}	5.31	4.70	5.70	3.62	4.26	72.40	0.34	6.35
Capsules plant^{-1}	39.05	32.10	44.90	9.35	9.62	94.50	7.31	18.72
Full capsules plant^{-1}	27.00	19.90	34.80	15.63	15.94	96.20	8.53	31.59
Empty capsules plant^{-1}	12.05	9.70	16.40	13.10	13.45	94.90	3.17	26.30
Seeds capsule^{-1}	1.65	1.30	2.50	13.21	14.94	78.10	0.40	24.05
Test weight (gm)	9.96	6.90	15.20	19.20	19.30	99.00	3.92	39.35
Biological yield plant^{-1}	9.88	6.99	12.32	14.83	15.06	97.00	2.98	30.10
Harvest index (%)	43.24	30.97	52.49	16.87	17.00	98.40	14.91	34.47
Total chlorophyll content (mg/ml)	1.63	0.88	2.51	22.32	23.27	92.00	0.72	44.11
Relative leaf water content (%)	39.57	31.55	49.54	15.46	15.50	99.50	12.57	31.77
Lipid Peroxidation (nmol/ml)	25.14	17.20	31.33	15.77	15.83	99.20	8.14	32.36
Electrolyte leakage index (%)	50.45	32.17	61.48	16.98	16.99	99.90	17.64	34.97
Proline content (mg/gm)	1.89	1.31	3.09	25.37	25.88	96.10	0.97	51.25
Ascorbic acid content (mg)	31.36	24.23	44.61	14.99	15.36	95.20	9.45	30.14
Pollen viability (%)	66.34	58.40	74.00	7.07	7.26	94.90	9.42	14.19
Flower drop (%)	31.14	22.00	38.52	15.24	15.64	95.00	9.53	30.60
Seed yield plant^{-1}	4.34	2.55	6.48	28.99	29.09	99.30	2.58	59.49

4.5: Genetic parameters influencing seed yield and the individual components in chickpea [POOLED]

Character	Mean	Range		Coefficient of variation		h2	GA	GA as % mean
		Min.	Max.	GCV	PCV			
First blossoming days	86.09	79.50	90.67	3.63	3.80	91.70	6.17	7.17
50% blossoming days	92.82	86.00	97.33	3.84	3.96	93.80	7.11	7.66
Harvest maturity days	160.83	142.50	175.83	7.01	7.09	97.60	22.93	14.26
Plant height	34.32	21.81	42.34	16.91	17.82	90.00	11.35	33.06
Primary offshoots plant^{-1}	3.65	3.10	4.40	7.84	8.78	79.80	0.53	14.43
Secondary offshoots plant^{-1}	6.00	5.10	6.97	9.06	9.69	87.50	1.05	17.46
Capsules plant^{-1}	52.55	33.83	63.03	18.47	18.91	95.30	19.52	37.15
Full capsules plant^{-1}	41.87	22.73	53.20	25.39	26.07	94.80	21.33	50.94
Empty capsules plant^{-1}	10.68	6.83	13.10	12.54	13.94	80.90	2.48	23.23
Seeds capsule^{-1}	1.74	1.40	2.27	9.67	11.91	65.80	0.28	16.16
Test weight (gm)	10.44	7.45	12.45	7.62	9.81	60.30	1.27	12.19
Biological yield plant^{-1}	16.25	9.37	22.46	28.52	28.88	97.50	9.43	58.03
Harvest index (%)	43.04	35.98	47.41	2.98	7.17	17.30	1.10	2.55
Total chlorophyll content (mg/ml)	1.69	1.10	2.10	7.90	12.15	42.30	0.18	10.58
Relative leaf water content (%)	42.49	33.90	53.61	8.90	11.37	61.30	6.10	14.35
Lipid Peroxidation (nmol/ml)	22.47	16.90	27.27	11.60	13.04	79.10	4.77	21.25
Electrolyte leakage index (%)	48.28	41.32	55.65	3.35	8.38	16.00	1.33	2.76
Proline content (mg/gm)	1.54	0.74	2.18	17.92	21.92	66.90	0.47	30.19
Ascorbic acid content (mg)	31.26	28.73	34.87	2.72	5.41	25.30	0.88	2.82
Pollen viability (%)	72.71	61.73	79.43	6.55	7.05	86.40	9.13	12.55
Flower drop (%)	29.39	25.72	33.24	2.92	7.42	15.50	0.70	2.37
Seed yield plant^{-1}	7.04	3.54	10.68	29.46	30.86	91.10	4.08	57.92

4.1.5 Genetic advance as % of mean

In order to make conclusions regarding these characteristics, genetic advance was defined as high (>20%), medium (10-20%), and low (10%).

First sowing date [EN-1]

It ranged from 3.81 % to 75.34 % as depicted in the table 4.2. Proline (75.34 %) recorded the highest estimate followed by seeds capsule^{-1} (45.38 %), empty capsules plant^{-1} (44.63 %), seed yield plant^{-1} (42.98 %), relative leaf water content (%) (42.33 %), electrolyte leakage index (%)(40.38 %), total chlorophyll content (mg/ml) (36.35 %), lipid peroxidation (nmol/ml) (32.94 %), harvest index (%) (32.07 %), flower drop (%) (31.29 %), test weight (gm) (31.25 %), full capsules plant^{-1} (26.69 %), plant height (24.62 %), primary offshoots plant^{-1} (24.09 %), secondary offshoots plant^{-1} (20.70 %) and biological yield (20.24 %). Capsules plant^{-1} (19.04 %), ascorbic acid content (mg) (12.63 %) and pollen viability (%) (11.75 %) recorded moderate estimates. Low estimates noted for first blossoming days (5.25 %), harvest maturity days (4.51 %) and 50% blossoming days (3.81 %).

Second sowing date [EN-2]

It ranged from 3.26 % to 2.43 % as depicted in the table 4.3. Proline (62.43 %) recorded the highest estimate followed by total chlorophyll content (mg/ml) (56.63 %), seed yield plant^{-1} (48.14 %), electrolyte leakage index (%) (41.23 %), relative leaf water content (%) (40.22 %), lipid peroxidation (nmol/ml) (33.85 %), flower drop (%) (32.54 %), harvest index (%) (30.56 %), test weight (gm) (30.14 %), plant height (27.14 %) and full capsules plant^{-1} (24.72 %). Capsules plant^{-1} (18.96 %), seeds capsule^{-1} (18.96 %), biological yield (18.68 %), primary offshoots plant^{-1} (18.40 %), empty capsules plant^{-1} (17.20 %), secondary offshoots plant^{-1} (16.17 %) and pollen viability (%) (11.31 %) recorded moderate estimates. Low estimates were recorded for ascorbic acid content (mg) (9.49 %) first blossoming days (3.59 %), harvest maturity days (4.67 %) and 50% blossoming days (3.26 %).

Third sowing date [EN-3]

It ranged from 3.51 % to 59.49 % as depicted in the table 4.4. Seed yield plant^{-1} (59.49 %) recorded the highest estimate followed by proline (51.25 %), total chlorophyll content (mg/ml) (44.11 %), plant height (43.30 %), test weight (gm) (39.35 %), electrolyte leakage index (%) (34.96 %), harvest index (%) (34.47 %), lipid peroxidation (nmol/ml) (32.35 %), relative leaf water content (%) (31.76 %), full capsules plant^{-1} (31.59 %), flower drop (%) (30.6 %), ascorbic acid content (mg) (30.13 %), biological yield (30.09 %), empty capsules plant^{-1} (26.30 %) and seeds capsule^{-1} (24.04 %). Capsules plant^{-1} (18.72 %), pollen viability (%) (14.19 %) and primary offshoots plant^{-1} (11.77 %) recorded moderate estimates. Low estimates were recorded for secondary offshoots plant^{-1} (6.34 %), first blossoming days (4.88 %), 50% blossoming days (4.87 %) and harvest maturity days (3.51 %).

Pooled

It ranged from 2.37 % to 58.02 % as depicted in the table 4.5. Biological yield (58.02 %) recorded the highest estimate followed by seed yield plant^{-1} (57.92 %), full capsules plant^{-1} (50.93 %), capsules plant^{-1} (37.14 %), plant height (33.05 %), proline (30.18 %), empty capsules plant^{-1} (23.23 %) and lipid peroxidation (nmol/ml) (21.25 %). Secondary offshoots plant^{-1} (17.45 %), seeds capsule^{-1} (16.15 %), primary offshoots plant^{-1} (14.43 %), relative leaf water content (%) (14.34 %), harvest maturity days (14.25 %), pollen viability (%) (12.55 %), test weight (gm) (12.19 %) and total chlorophyll content (mg/ml) (10.57 %) recorded moderate estimates. Low estimates noted for 50% blossoming days (7.65 %), first blossoming days (7.16 %), ascorbic acid content (mg) (2.82 %), electrolyte leakage index (%) (2.76 %), harvest index (%) (2.55 %) and flower drop (%) (2.37 %).

4.2 CORRELATION COEFFICIENT ANALYSIS

r' is a statistical term that shows the level (strength) as well as the direction of relationship between a number of parameters. The positive sign of r' shows that the shifts in each of the variables move in the identical direction, i.e., an elevated level of one attribute is associated with elevation of the other, and vice versa.

Phenotypic correlation describes the relationship between two immediately observable qualities. It takes into account both genotypic and environmental factors, hence it varies depending on the environment. The heritable association between two features is known as genotypic correlation, and it may happen as a result of phenotypic action of a gene, linkage, or, more typically, both, or pleiotropy, which refers to a gene's many effects. Whenever the connection among both traits (positive or negative) stays unchanged in both of the parents and segregating populations, the root cause of the correlation is pleiotropy, while a shift in amounts in the segregating population implies the probable trigger for the correlation seems linkage.

A favorable connection among desired qualities aids the breeder in selecting. A negative correlation, on the contrary, hinders recombinant restoration for both phenotypic and genotypic correlation coefficients have been identified in every potential combination of traits at the phenotypic and genotypic levels, considering all genotypes into account separately. The outcomes are laid out under.

4.2.1. GENOTYPIC CORRELATION COEFFICIENT

First sowing date [EN-1]

Table 4.6 illustrates the correlation coefficients.

4.2.1.1. First blossoming days

It showed a strong positive correlation for 50% blossoming days (0.885), harvest maturity days (0.774) and flower drop (%) (0.487) while significant negative association was with harvest index (%) (-0.405), capsules plant^{-1} (-0.402) and proline (-0.399).

4.2.1.2. 50% blossoming days

It showed a strong positive correlation for harvest maturity days (0.772) while negatively significant association was with proline (-0.448).

4.2.1.3. Harvest maturity days

A strong negative correlation was discovered for plant height (-0.435) and proline (-0.432).

4.2.1.4. Plant height

It showed a strong positive correlation for full capsules plant^{-1} (0.773) followed by capsules plant^{-1} (0.739), secondary offshoots plant^{-1} (0.690), primary offshoots plant^{-1} (0.616), seeds capsule^{-1} (0.545), pollen viability (%) (0.428) and harvest index (%) (0.420) while significant negative association with flower drop (%) (-0.578) and empty capsules plant^{-1} (-0.578).

4.2.1.5. Primary offshoots plant^{-1}

It showed a strong positive correlation for pollen viability (%) (0.849), secondary offshoots plant^{-1} (0.787), seed yield plant^{-1} (0.634), harvest index (%) (0.585), seeds capsule^{-1} (0.557), relative leaf water content (%) (0.532), full capsules plant^{-1} (0.482), capsules plant^{-1} (0.478) and biological yield (0.424).

4.2.1.6. Secondary offshoots plant^{-1}

It showed a strong positive correlation for capsules plant^{-1} (0.761), full capsules plant^{-1} (0.736), seed yield plant^{-1} (0.664), harvest index (%) (0.642), pollen viability (%)(0.597), relative leaf water content (%) (0.572), seeds capsule^{-1} (0.566), biological yield (0.448), test weight (gm) (0.410) and total chlorophyll content (mg/ml) (0.392) while negatively significant association with flower drop (%) (-0.563).

4.2.1.7. Capsules plant^{-1}

It showed a strong positive correlation for filled pods plant^{-1} (0.958), harvest index (%) (0.615), total chlorophyll content (mg/ml) (0.614), relative leaf water content (%) (0.539), seeds capsule^{-1} (0.532), seed yield plant^{-1} (0.489), proline (0.484) and pollen viability (%) (0.404) and while negatively significant association with flower drop (%) (-0.937) and electrolyte leakage index (%)(-0.574).

Table 4.6: Coefficients of genotypic correlation amongst attributes in chickpea during *rabi* 2020-21 (EN-1)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
C1	**1**	0.8856*	0.7743*	-0.3136	-0.2277	-0.2609	-0.4021*	-0.3713	0.1035	-0.2146	-0.3551	0.0884	-0.4056*	-0.3814	-0.3511	0.0896	0.3321	-0.3993*	0.2248	-0.2697	0.4878*
C2		**1**	0.7725*	-0.2286	-0.1465	-0.251	-0.2845	-0.2016	-0.1251	-0.2844	-0.3266	0.1143	-0.2931	-0.3254	-0.2729	0.0769	0.3035	-0.4485*	-0.0051	-0.1439	0.3687
C3			**1**	-0.4352*	-0.2982	-0.2834	-0.2875	-0.3187	0.2469	-0.2333	-0.3375	-0.1839	-0.3518	-0.2474	-0.2673	0.0549	0.2447	-0.4327*	-0.0424	-0.2898	0.2885
C4				**1**	0.6164*	0.6909*	0.7393*	0.7739*	-0.4862*	0.5459*	0.1108	0.1843	0.4201*	0.3247	0.273	0.0004	-0.2367	0.2613	0.1648	0.4281*	-0.5789*
C5					**1**	0.7877*	0.4789*	0.4823*	-0.2534	0.5576*	0.1466	0.4245*	0.5859*	0.1327	0.5325*	0.2844	0.1952	-0.1517	0.0316	0.8496*	-0.2524
C6						**1**	0.7614*	0.7367*	-0.305	0.5661*	0.4101*	0.4488*	0.6425*	0.3925*	0.5726*	0.1148	-0.0431	0.1282	0.1403	0.5974*	-0.5636*
C7							**1**	0.9582*	-0.3701	0.5327*	0.3326	0.1303	0.6154*	0.6144*	0.539*	-0.1534	-0.5744*	0.4849*	0.1202	0.4046*	-0.9372*
C8								**1**	-0.6206*	0.4808*	0.3757	0.2702	0.6745*	0.576*	0.4724*	-0.0856	-0.511*	0.443*	0.0671	0.4542*	-0.9045*
C9									**1**	-0.1012	-0.308	-0.5199*	-0.5029*	-0.1862	-0.0565	-0.1425	0.0848	-0.1094	0.1113	-0.3656	0.3678
C10										**1**	-0.1072	0.416*	0.2759	0.3035	0.2947	0.0205	-0.1527	0.2166	-0.3556	0.3393	-0.3438
C11											**1**	0.4366*	0.5509*	0.5189*	0.3788	-0.1911	-0.2224	0.4403*	-0.0745	0.2609	-0.4517*
C12												**1**	0.2458	0.1101	0.0765	0.2288	0.2508	0.0047	-0.0258	0.2085	-0.0269
C13													**1**	0.6174*	0.7033*	-0.0063	-0.2848	0.2877	-0.2317	0.8335*	-0.6047*
C14														**1**	0.6555*	-0.4873*	-0.6357*	0.7444*	-0.1707	0.2413	-0.7338*
C15															**1**	-0.2268	-0.3725	0.4205*	-0.0055	0.631*	-0.5753*
C16																**1**	0.6681*	-0.7205*	-0.3584	0.2043	0.2688
C17																	**1**	-0.8413*	-0.1989	0.0428	0.7284*
C18																		**1**	0.1296	-0.1016	-0.6116*
C19																			**1**	-0.1429	-0.1266
C20																				**1**	-0.306
C21																					**1**
C22	-0.2551	-0.1515	-0.3706	0.3608	0.6344*	0.6647*	0.4894*	0.6051*	-0.623*	0.393	0.6468*	0.6874*	0.8667*	0.4926*	0.5555*	0.089	-0.0889	0.2224	-0.2235	0.7348*	-0.4327*

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17-Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

4.2.1.8. Full capsules plant^{-1}

It showed a strong positive correlation for harvest index (%) (0.674), seed yield plant^{-1} (0.605), total chlorophyll content (mg/ml) (0.576), seeds capsule^{-1} (0.480), relative leaf water content (%) (0.472), pollen viability (%) (0.454) and proline (0.443), while significant negative association was with flower drop (%) (-0.904), empty capsules plant^{-1} (-0.620) and electrolyte leakage index (%) (-0.511).

4.2.1.9. Empty capsules plant^{-1}

It showed strong negative correlation for seed yield plant^{-1} (-0.623), biological yield (-0.519) and harvest index (%) (-0.502).

4.2.1.10. Seeds capsule^{-1}

It exhibited significant positive correlation with biological yield (0.416).

4.2.1.11. Test weight (gm)

It showed a strong positive correlation for seed yield plant^{-1} (0.646), harvest index (%) (0.550), total chlorophyll content (mg/ml) (0.518), proline (0.440) and biological yield (0.436) while significant negative correlation with flower drop (%) (-0.451).

4.2.1.12. Biological yield plant^{-1}

It showed a strong positive correlation for seed yield plant^{-1} (0.687).

4.2.1.13. Harvest index (%)

It showed a strong positive correlation for seed yield plant^{-1} (0.866), pollen viability (%) (0.833), relative leaf water content (%) (0.703) and total chlorophyll content (mg/ml) (0.617), and while negative significant correlation was with flower drop (%) (-0.604).

4.2.1.14. Total chlorophyll content (mg/ml)

It showed a strong positive correlation for proline (0.744), relative leaf water content (%) (0.655) and seed yield plant^{-1} (0.492) while negative correlation was for flower drop (%) (-0.733), electrolyte leakage index (%) (-0.635) and lipid peroxidation (nmol/ml) (-0.487).

4.2.1.15. Relative leaf water content (%)

It exhibited positive significant correlation with pollen viability (%) (0.631), seed yield plant^{-1} (0.555) and proline (0.420) while negatively significant correlation was with flower drop (%) (-0.575).

4.2.1.16. Lipid Peroxidation (nmol/ml)

It exhibited positive significant correlation with electrolyte leakage index (%) (0.668) while significant negative correlation was with proline (-0.720).

4.2.1.17. Electrolyte leakage index (%)

It exhibited significant positive correlation with flower drop (%) (0.728) while significant negative correlation was with proline (-0.841).

4.2.1.18. Proline content (mg/gm)

It exhibited negative significant correlation with flower drop (%) (-0.611).

4.2.1.19. Ascorbic acid content (mg)

It exhibited no significant association.

4.2.1.20. Pollen viability (%)

It exhibited positive significant correlation seed yield plant^{-1} (0.734).

4.2.1.21. Flower drop (%)

It exhibited significant negative correlation with seed yield plant^{-1} (-0.432).

4.2.1.22. Seed yield plant^{-1}

It expressed a positive strong association for harvest index (%) (0.866), pollen viability (%)(0.734), biological yield (0.687), secondary offshoots plant^{-1} (0.664), test weight (gm) (0.646), primary offshoots plant^{-1} (0.634), full capsules plant^{-1} (0.605), relative leaf water content (%) (0.555), total chlorophyll content (mg/ml) (0.492) and capsules plant^{-1} (0.489) while negative significant correlation was with empty capsules plant^{-1} (-0.623) and flower drop (%) (-0.432).

Second sowing date [EN-2]

Table 4.7 illustrates the correlation coefficients.

4.2.1.1. First blossoming days

It recorded positive significant correlation with 50% blossoming days (0.952), harvest maturity days (0.93) and flower drop (%) (0.554) while negative significant correlation was with plant height (-0.889), seeds capsule^{-1} (-0.872), relative leaf water content (%) (-0.864), total chlorophyll content (mg/ml) (-0.832), proline (-0.765), seed yield (-0.760), capsules plant^{-1} (-0.743), harvest index (%) (-0.736), biological yield (-0.723), full capsules plant^{-1} (-0.722), secondary offshoots plant^{-1} (-0.654), primary offshoots plant^{-1} (-0.574), pollen viability (%)(-0.565) and test weight (gm) (-0.549).

4.2.1.2. 50% blossoming days

It revealed showed a strong positive correlation for harvest maturity days (0.998) and flower drop (%) (0.713) while significant negative correlation was with total chlorophyll content (mg/ml) (-0.891), plant height (-0.886), relative leaf water content (%) (-0.868), capsules plant^{-1} (-0.861), seeds capsule^{-1} (-0.852), full capsules plant^{-1} (-0.840), proline (-0.823), harvest index (%) (-0.748), seed yield (-0.709), secondary offshoots plant^{-1} (-0.663), primary offshoots plant^{-1} (-0.627), biological yield (-0.617), pollen viability (%) (-0.508) and test weight (gm) (-0.498).

4.2.1.3. Harvest maturity days

It showed a strong positive correlation for flower drop (%) (0.593) while negatively significant association for plant height (-0.855), relative leaf water content (%) (-0.803), total chlorophyll content (mg/ml) (-0.788), harvest index (%) (-0.778), capsules plant^{-1} (-0.759), proline (-0.758), full capsules plant^{-1} (-0.739), seed yield (-0.726), secondary offshoots plant^{-1} (-0.723), seeds capsule^{-1} (-0.674), primary offshoots plant^{-1} (-0.639), biological yield plant^{-1} (-0.586), pollen viability (%)(-0.553) and test weight (gm) (-0.447).

4.2.1.4. Plant height

It showed a strong positive correlation for seed yield (0.855), harvest index (%) (0.845), total chlorophyll content (mg/ml) (0.831), full capsules plant^{-1} (0.815), capsules plant^{-1}

(0.804), biological yield (0.780), relative leaf water content (%) (0.767), proline (0.755), pollen viability (%)(0.670), secondary branches per plant (0.666), seeds capsule^{-1} (0.652), primary offshoots plant^{-1} (0.589) and number of test weight (gm) (0.549) while significant negative association was with flower drop (%) (-0.595).

4.2.1.5. Primary offshoots plant^{-1}

It showed a strong positive association for secondary offshoots plant^{-1} (0.990), total chlorophyll content (mg/ml) (0.788), proline (0.753), relative leaf water content (%) (0.672), harvest index (%) (0.578), full capsules plant^{-1} (0.519), capsules plant^{-1} (0.512), seeds capsule^{-1} (0.460), ascorbic acid (0.454), seed yield (0.441) and pollen viability (%)(0.413) while negatively significant association with flower drop (%) (-0.507) and electrolyte leakage index (%)(-0.440).

4.2.1.6. Secondary offshoots plant^{-1}

It showed a strong positive correlation for total chlorophyll content (mg/ml) (0.761), proline (0.746), relative leaf water content (%) (0.735), harvest index (%) (0.646), seed yield (0.591), seeds capsule^{-1} (0.495), pollen viability (%) (0.490), biological yield (0.485), full capsules plant^{-1} (0.444), ascorbic acid (0.440) and capsules plant-1 (0.439).

4.2.1.7. Capsules plant^{-1}

It showed a strong positive correlation for full capsules plant^{-1} (0.988), harvest index (%) (0.765), seed yield (0.753), total chlorophyll content (mg/ml) (0.741), proline (0.723), biological yield (0.665), relative leaf water content (%) (0.571), seeds capsule^{-1} (0.502), pollen viability (%) (0.477) and test weight (gm) (0.415) while significant negative association was with flower drop (%) (-0.686).

4.2.1.8. Full capsules plant^{-1}

It showed a strong positive correlation for harvest index (%) (0.804), seed yield (0.787), total chlorophyll content (mg/ml) (0.750), proline (0.718), biological yield (0.689), relative leaf water content (%) (0.604), pollen viability (%)(0.558), seeds capsule^{-1} (0.511) and test weight (gm) (0.469) while negatively significant association with flower drop (%) (-0.715), electrolyte leakage index (%)(-0.465) and empty capsules plant^{-1} (-0.458).

Table 4.7: Coefficients of genotypic correlation amongst attributes in chickpea during rabi 2020-21 (EN-2)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
C1	1	0.9529*	0.93*	-0.8899*	-0.5745*	-0.6547*	-0.7436*	-0.7223*	0.1578	-0.8728*	-0.5494*	-0.723*	-0.7367*	-0.8326*	-0.8642*	0.1535	0.3505	-0.7658*	0.0238	-0.5654*	0.5541*
C2		1	0.9984*	-0.8861*	-0.6276*	-0.6631*	-0.8618*	-0.8402*	0.2021	-0.8526*	-0.4985*	-0.6176*	-0.7489*	-0.8918*	-0.8689*	0.205	0.3544	-0.8239*	0.1114	-0.5087*	0.7134*
C3			1	-0.8551*	-0.6397*	-0.7238*	-0.759*	-0.7398*	0.1769	-0.6742*	-0.4478*	-0.5862*	-0.7788*	-0.788*	-0.8031*	0.1289	0.2197	-0.7587*	-0.1107	-0.5536*	0.5939*
C4				1	0.5893*	0.6663*	0.8049*	0.8154*	-0.3789	0.6521*	0.5491*	0.7802*	0.8456*	0.8313*	0.7678*	-0.1489	-0.3965	0.7554*	-0.0453	0.6702*	-0.5959*
C5					1	0.9901*	0.5124*	0.5197*	-0.2451	0.4606*	0.386	0.2375	0.5787*	0.788*	0.6725*	-0.1705	-0.4402*	0.7531*	0.4542*	0.4131*	-0.507*
C6						1	0.439*	0.444*	-0.2019	0.4958*	0.3891	0.4859*	0.646*	0.7613*	0.7359*	0.0545	-0.3327	0.7469*	0.4409*	0.4906*	-0.3802
C7							1	0.9882*	-0.3165	0.5027*	0.4155*	0.6657*	0.7656*	0.741*	0.571*	-0.2962	-0.426	0.7234*	0.1167	0.4775*	-0.6866*
C8								1	-0.4583*	0.5117*	0.4691*	0.6892*	0.8048*	0.7503*	0.6048*	-0.2977	-0.4656*	0.7185*	0.1319	0.5581*	-0.715*
C9									1	-0.2512	-0.4932*	-0.4049*	-0.5404*	-0.3463	-0.4313*	0.1247	0.4108*	-0.2514	-0.1394	-0.6841*	0.4433*
C10										1	0.4022*	0.4909*	0.5765*	0.6694*	0.6485*	-0.0899	-0.3182	0.6612*	0.3683	0.4747	-0.471*
C11											1	0.429*	0.4665*	0.5882*	0.4373*	-0.2215	-0.4012*	0.6451*	0.1731	0.2163	-0.5072*
C12												1	0.7503*	0.6058*	0.5269*	0.0139	-0.2305	0.5628*	0.0039	0.581*	-0.3117
C13													1	0.7315*	0.7114*	-0.0749	-0.3711	0.6873*	0.3148	0.7803*	-0.4758*
C14														1	0.7849*	-0.3738	-0.5964*	0.8992*	0.2841	0.5272*	-0.77*
C15															1	-0.2455	-0.5486*	0.7253*	-0.0095	0.6364*	-0.6498*
C16																1	0.6152*	-0.4541*	0.2057	-0.0028	0.7623*
C17																	1	-0.7171*	-0.1775	-0.1501	0.7635*
C18																		1	0.2605	0.2711	-0.8018*
C19																			1	-0.1735	0.066
C20																				1	-0.2806
C21																					1
C22	-0.7602*	-0.709*	-0.7269*	0.8553*	0.4414*	0.5919*	0.7538*	0.7877*	-0.5032*	0.542*	0.4574*	0.9177*	0.949*	0.7017*	0.6589*	-0.0456	-0.3265	0.6508*	0.1892	0.745*	-0.4153*

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17- Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

4.2.1.9. Empty capsules plant^{-1}

It showed a strong positive correlation for flower drop (%) (0.443) and electrolyte leakage index (%) (0.410). while negative significant correlation was with pollen viability (%) (-0.684), harvest index (%) (-0.540), seed yield plant^{-1} (-0.503), test weight (gm) (-0.493), relative leaf water content (%) (-0.431) and biological yield plant^{-1} (-0.404).

4.2.1.10. Seeds capsule^{-1}

It showed a strong positive correlation for total chlorophyll content (mg/ml) (0.669), proline (0.661), relative leaf water content (%) (0.648), harvest index (%) (0.576), seed yield (0.542), biological yield (0.490), pollen viability (%) (0.474) and test weight (gm) (0.402) and while negatively significant association with flower drop (%) (-0.471).

4.2.1.11. Test weight (gm)

It showed a strong positive correlation for proline (0.645), total chlorophyll content (mg/ml) (0.588), harvest index (%) (0.466), seed yield (0.457), relative leaf water content (%) (0.437) and biological yield plant^{-1} (0.429) while negatively significant correlation was with flower drop (%) (-0.507) and electrolyte leakage index (%) (-0.401).

4.2.1.12. Biological yield plant^{-1}

It showed a strong positive correlation for seed yield plant^{-1} (0.917), harvest index (%) (0.750), total chlorophyll content (mg/ml) (0.605), pollen viability (%) (0.581), proline (0.562) and relative leaf water content (%) (0.526).

4.2.1.13. Harvest index (%)

It exhibited positive significant correlation with seed yield (0.949), pollen viability (%) (0.780), total chlorophyll content (mg/ml) (0.731), relative leaf water content (%) (0.711) and proline (0.687) while negative significant correlation was with flower drop (%) (-0.475).

4.2.1.14. Total chlorophyll content (mg/ml)

It showed a strong positive correlation for proline (0.899), relative leaf water content (%) (0.784), seed yield (0.701) and pollen viability (%) (0.527) while significant negative correlation was with flower drop (%) (-0.77) and electrolyte leakage index (%) (-0.596).

4.2.1.15. Relative leaf water content (%)

It exhibited significant positive correlation with proline (0.725), seed yield (0.658) and pollen viability (%) (0.636) while significant negative correlation was with flower drop (%) (-0.649) and electrolyte leakage index (%) (-0.548).

4.2.1.16. Lipid Peroxidation (nmol/ml)

It exhibited positive significant correlation with flower drop (%) (0.762) and electrolyte leakage index (%) (0.615) while negative significant correlation was with proline (-0.454).

4.2.1.17. Electrolyte leakage index (%)

It exhibited significant positive correlation with flower drop (%) (0.763) while negative significant correlation was with proline (-0.717).

4.2.1.18. Proline content (mg/gm)

It showed a strong positive correlation for seed yield plant^{-1} (0.650) while significant negative correlation was with flower drop (%) (-0.801).

4.2.1.19. Ascorbic acid content (mg)

It exhibited no significant estimates for any of the characters.

4.2.1.20. Pollen viability (%)

It showed a strong positive correlation for seed yield plant^{-1} (0.745).

4.2.1.21. Flower drop (%)

It exhibited significant negative correlation with seed yield plant^{-1} (-0.415).

4.2.1.22. Seed yield plant^{-1}

It showed a strong positive correlation for harvest index (%) (0.949), biological yield plant^{-1} (0.917), plant height (0.855), full capsules plant^{-1} (0.787), capsules plant^{-1} (0.753), pollen viability (%)(0.745), total chlorophyll content (mg/ml) (0.701), relative leaf water content (%) (0.658), proline (0.650), secondary offshoots plant^{-1} (0.591), seeds capsule^{-1} (0.542), test weight (gm) (0.457) and primary offshoots plant^{-1} (0.441) while significant negative correlation was with first blossoming days (-0.760), harvest maturity days (-

0.726), 50% blossoming days (-0.709), empty capsules plant^{-1} (-0.503) and flower drop (%) (-0.415).

Third sowing date [EN-3]

Table 4.8 illustrates the correlation coefficients.

4.2.1.1. First blossoming days

It showed a strong positive correlation for 50% blossoming days (0.850), lipid peroxidation (nmol/ml) (0.694), harvest maturity days (0.622), flower drop (%) (0.492) and electrolyte leakage index (%)(0.459) while significant negative correlation was with full capsules plant^{-1} (-0.533), proline (-0.530), harvest index (%) (-0.518), plant height (-0.516), relative leaf water content (%) (-0.506), seed yield plant^{-1} (-0.501), capsules plant^{-1} (-0.492), pollen viability (%)(-0.482) and total chlorophyll content (mg/ml) (-0.400).

4.2.1.2. 50% blossoming days

It showed a strong positive correlation for harvest maturity days (0.805) lipid peroxidation (nmol/ml) (0.637), flower drop (%) (0.532) and electrolyte leakage index (%) (0.468) while negative significant correlation was with proline (-0.516), full capsules plant^{-1} (-0.505), capsules plant^{-1} (-0.501), relative leaf water content (%) (-0.453) and test weight (gm) (-0.451).

4.2.1.3. Harvest maturity days

It showed a strong positive correlation for lipid peroxidation (nmol/ml) (0.546), flower drop (%) (0.494) and electrolyte leakage index (%)(0.396) while significant negative correlation was with secondary offshoots plant^{-1} (-0.581), primary offshoots plant^{-1} (-0.547), full capsules plant^{-1} (-0.538), capsules plant^{-1} (-0.499), relative leaf water content (%) (-0.495), pollen viability (%)(-0.437), harvest index (%) (-0.433), seed yield plant^{-1} (-0.429), total chlorophyll content (mg/ml) (-0.414) and test weight (gm) (-0.397).

4.2.1.4. Plant height

It exhibited showed a strong positive correlation for biological yield plant^{-1} (0.659), seed yield plant^{-1} (0.627), full capsules plant^{-1} (0.610), pollen viability (%) (0.565), relative leaf water content (%) (0.523), harvest index (%) (0.482) and capsules plant^{-1} (0.469) while negative significant correlation was with empty capsules plant^{-1} (-0.574) and lipid peroxidation (nmol/ml) (-0.489).

4.2.1.5. Primary offshoots plant^{-1}

It showed a strong positive correlation for primary offshoots plant^{-1} (0.962), capsules plant^{-1} (0.654), full capsules plant^{-1} (0.611), relative leaf water content (%) (0.558), pollen viability (%)(0.538), ascorbic acid (0.497), harvest index (%) (0.437), total chlorophyll content (mg/ml) (0.424), proline (0.421) and seed yield plant^{-1} (0.412) while negative significant correlation was with flower drop (%) (-0.597) and electrolyte leakage index (%)(-0.441).

4.2.1.6. Secondary offshoots plant^{-1}

It showed a strong positive correlation for capsules plant^{-1} (0.714), full capsules plant^{-1} (0.639), ascorbic acid (0.609), relative leaf water content (%) (0.557), pollen viability (%) (0.530) and proline (0.448) while negative significant correlation was with flower drop (%) (-0.609) and electrolyte leakage index (%) (-0.549).

4.2.1.7. Capsules plant^{-1}

It showed a strong positive correlation for pollen viability (%) (0.943), full capsules plant^{-1} (0.932), seed yield (0.760), harvest index (%) (0.678), biological yield (0.663), seeds capsule^{-1} (0.446) and relative leaf water content (%) (0.443).

4.2.1.8. Full capsules plant^{-1}

It showed a strong positive correlation for pollen viability (%) (0.975), seed yield (0.856), harvest index (%) (0.772), biological yield (0.746) and relative leaf water content (%) (0.604) while negative significant correlation was with empty capsules plant^{-1} (-0.535) and lipid peroxidation (nmol/ml) (-0.421).

4.2.1.9. Empty capsules plant^{-1}

It showed a strong positive correlation for lipid peroxidation (nmol/ml) (0.490) while significant negative correlation was with relative leaf water content (%) (-0.627), seed yield (-0.559), total chlorophyll content (mg/ml) (-0.545), harvest index (%) (-0.524), biological yield (-0.484) and pollen viability (%) (-0.447).

4.2.1.10. Seeds capsule^{-1}

It showed a strong positive correlation for biological yield plant^{-1} (0.461).

4.2.1.11. Test weight (gm)

It exhibited positive significant correlation with ascorbic acid (0.437).

4.2.1.12. Biological yield plant^{-1}

It showed a strong positive correlation for seed yield (0.897), pollen viability (%) (0.853) and harvest index (%) (0.663).

4.2.1.13. Harvest index (%)

It showed a strong positive correlation for seed yield (0.920), pollen viability (%) (0.823) and relative leaf water content (%) (0.668) while negative significant correlation was with lipid peroxidation (nmol/ml) (-0.594).

4.2.1.14. Total chlorophyll content (mg/ml)

It exhibited positive significant correlation with proline (0.828), ascorbic acid content (mg) (0.734) and relative leaf water content (%) (0.672) while negative significant correlation was with lipid peroxidation (nmol/ml) (-0.776), electrolyte leakage index (%) (-0.756) and flower drop (%) (-0.618).

4.2.1.15. Relative leaf water content (%)

It exhibited positive significant correlation with proline (0.637), seed yield plant^{-1} (0.592), pollen viability (%) (0.552) and ascorbic acid (0.464) while significant negative correlation was with lipid peroxidation (nmol/ml) (-0.821), electrolyte leakage index (%) (-0.746) and flower drop (%) (-0.554).

4.2.1.16. Lipid Peroxidation (nmol/ml)

It exhibited positive significant correlation with electrolyte leakage index (%) (0.753) and flower drop (%) (0.621) while significant negative correlation was with proline (-0.836), ascorbic acid (-0.583) and seed yield plant^{-1} (-0.488).

4.2.1.17. Electrolyte leakage index (%)

It exhibited significant positive correlation with flower drop (%) (0.544) while significant negative correlation was with proline (-0.821) and ascorbic acid (-0.662).

4.2.1.18. Proline content (mg/gm)

It exhibited significant positive correlation with ascorbic acid (0.671) while significant negative correlation was with flower drop (%) (-0.752).

4.2.1.19. Ascorbic acid content (mg)

It exhibited significant negative correlation with Flower drop (%) (-0.619).

4.2.1.20. Pollen viability (%)

It showed a strong positive correlation for seed yield plant^{-1} (0.935).

4.2.1.21. Flower drop (%)

It exhibited no significant correlation with any of the characters.

4.2.1.22. Seed yield plant^{-1}

It showed a strong positive correlation for pollen viability (%)(0.935), harvest index (%) (0.920), biological yield plant^{-1} (0.897), full capsules plant^{-1} (0.856), capsules plant^{-1} (0.760), plant height (0.627), relative leaf water content (%) (0.592) and primary offshoots plant^{-1} (0.412) while negative significant correlation was with empty capsules plant^{-1} (-0.559), first blossoming days (-0.501), lipid peroxidation (nmol/ml) (-0.488) and harvest maturity days (-0.429).

Table 4.8: Coefficients of genotypic correlation amongst attributes in chickpea during rabi 2020-21 (EN-3)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
C1	1	0.8507*	0.6225*	-0.5165*	-0.2325	-0.2038	-0.4923*	-0.5333*	0.3223	0.047	-0.2281	-0.3434	-0.5182*	-0.4006*	-0.5062*	0.6949*	0.4599*	-0.5301*	-0.3021	-0.4825*	0.4925*
C2		1	0.8053*	-0.394	-0.3622	-0.3973	-0.5013*	-0.5051*	0.224	0.0772	-0.4515*	-0.2713	-0.3294	-0.3644	-0.4534*	0.6373*	0.4682*	-0.5167*	-0.3295	-0.3598	0.5323*
C3			1	-0.347	-0.5471*	-0.5817*	-0.4996*	-0.5382*	0.302	0.0312	-0.397*	-0.329	-0.4339*	-0.414*	-0.4951*	0.5466*	0.3966*	-0.3666	-0.3122	-0.4374*	0.4946*
C4				1	0.1778	0.1597	0.4698*	0.6102*	-0.5745*	0.231	0.2349	0.6592*	0.4825*	0.1987	0.5239*	-0.4899*	-0.3321	0.1997	0.1977	0.5651*	-0.1063
C5					1	0.9629*	0.6546*	0.6118*	-0.1893	0.1154	0.2633	0.3271	0.4371*	0.4244*	0.558*	-0.3472	-0.4411*	0.421*	0.4978*	0.5383*	-0.5973*
C6						1	0.7142*	0.6397*	-0.083	0.1096	0.3586	0.3404	0.3674	0.37	0.5573*	-0.3381	-0.5499*	0.4488*	0.6098*	0.5301*	-0.6091*
C7							1	0.932*	-0.1931	0.4463*	0.1746	0.6634*	0.6782*	-0.0909	0.4431*	-0.2793	-0.1431	-0.0012	0.1212	0.9433*	-0.1651
C8								1	-0.5356*	0.3766	0.2523	0.7463*	0.7725*	0.1143	0.604*	-0.4219*	-0.2559	0.126	0.2181	0.9756*	-0.2221
C9									1	0.0037	-0.2807	-0.4842*	-0.5245*	-0.5451*	-0.627*	0.4902*	0.3787	-0.3523	-0.287	-0.4477*	0.1959
C10										1	-0.0452	0.4617*	0.1155	-0.2762	0.0375	0.0804	0.066	-0.0816	-0.247	0.3954	0.2101
C11											1	0.3744	0.0963	0.2768	0.2189	-0.1821	-0.3209	0.2344	0.4372*	0.1594	-0.1582
C12												1	0.663*	0.0195	0.3745	-0.267	-0.2701	0.056	0.1303	0.8533*	0.1518
C13													1	0.2783	0.6687*	-0.5942*	-0.2676	0.3089	0.2074	0.8237*	-0.2567
C14														1	0.6721*	-0.7767*	-0.7565*	0.8281*	0.7347*	0.0558	-0.6189*
C15															1	-0.8219*	-0.7461*	0.6377*	0.4648*	0.5524*	-0.5541*
C16																1	0.7531*	-0.8365*	-0.5832*	-0.3827	0.6214*
C17																	1	-0.8216*	-0.6623*	-0.1924	0.5444*
C18																		1	0.6713*	0.035	-0.7522*
C19																			1	0.1269	-0.6198*
C20																				1	-0.0584
C21																					1
C22	-0.5018*	-0.3472	-0.4293*	0.6276*	0.4126*	0.3817	0.7606*	0.8561*	-0.5599*	0.3286	0.225	0.8971*	0.9207*	0.162	0.592*	-0.488*	-0.2943	0.1979	0.1652	0.9356*	-0.0613

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17- Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

Pooled

Table 4.9 illustrates the correlation coefficients.

4.2.1.1. First blossoming days

It showed a strong positive correlation for 50% blossoming days (0.992), full capsules plant^{-1} (0.964), biological yield plant^{-1} (0.952), seed yield plant^{-1} (0.947), harvest maturity days (0.942), pollen viability (%)(0.941), capsules plant^{-1} (0.933), secondary offshoots plant^{-1} (0.911), plant height (0.861), primary offshoots plant^{-1} (0.846), relative leaf water content (%) (0.562), test weight (gm) (0.406), seeds capsule^{-1} (0.332) and harvest index (%) (0.288) while negative significant correlation was with flower drop (%) (-0.964), proline (-0.918), empty capsules plant^{-1} (-0.908), electrolyte leakage index (%)(-0.838) and lipid peroxidation (nmol/ml) (-0.666).

4.2.1.2. 50% blossoming days

It showed a strong positive correlation for biological yield plant^{-1} (0.948), full capsules plant^{-1} (0.945), harvest maturity days (0.936), seed yield plant^{-1} (0.932), pollen viability (%) (0.929), capsules plant^{-1} (0.910), secondary offshoots plant^{-1} (0.881), plant height (0.846), primary offshoots plant^{-1} (0.825), relative leaf water content (%) (0.509), test weight (gm) (0.381), seeds capsule^{-1} (0.326) and total chlorophyll content (mg/ml) (0.258) while significant negative correlation was with proline (-0.929), empty capsules plant^{-1} (-0.921), flower drop (%) (-0.803), electrolyte leakage index (%)(-0.747) and lipid peroxidation (nmol/ml) (-0.671).

4.2.1.3. Harvest maturity days

It showed a strong positive correlation for pollen viability (%)(0.972), full capsules plant^{-1} (0.961), capsules plant^{-1} (0.957), biological yield plant^{-1} (0.956), seed yield plant-1 (0.926), plant height (0.895), secondary offshoots plant^{-1} (0.847), primary offshoots plant^{-1} (0.785), relative leaf water content (%) (0.542), test weight (gm) (0.411), seeds capsule^{-1} (0.344) and total chlorophyll content (mg/ml) (0.256) while significant negative correlation was with flower drop (%) (-0.949), proline (-0.847), electrolyte leakage index (%)(-0.770), empty capsules plant^{-1} (-0.705) and lipid peroxidation (nmol/ml) (-0.693).

4.2.1.4. Plant height

It showed a strong positive correlation for biological yield plant^{-1} (0.946), full capsules plant^{-1} (0.947), capsules plant^{-1} (0.941), seed yield plant^{-1} (0.908), pollen viability (%) (0.899), secondary offshoots plant^{-1} (0.898), primary offshoots plant^{-1} (0.842), relative leaf water content (%) (0.564), test weight (gm) (0.546), seeds capsule^{-1} (0.433) and total chlorophyll content (mg/ml) (0.416) while significant negative correlation was with flower drop (%) (-0.925), proline (-0.742), empty capsules plant^{-1} (-0.707) and lipid peroxidation (nmol/ml) (-0.693).

4.2.1.5. Primary offshoots plant^{-1}

It showed a strong positive correlation for secondary offshoots plant^{-1} (0.953), seed yield plant^{-1} (0.925), full capsules plant^{-1} (0.915), pollen viability (%)(0.901), capsules plant^{-1} (0.895), biological yield (0.893), seeds capsule^{-1} (0.790), relative leaf water content (%) (0.757), harvest index (%) (0.670), total chlorophyll content (mg/ml) (0.375) and test weight (gm) (0.309) while negative significant correlation was with flower drop (%) (-0.998), empty capsules plant^{-1} (-0.793), proline (-0.752), lipid peroxidation (nmol/ml) (-0.730), ascorbic acid content (mg) (-0.508) and electrolyte leakage index (%)(-0.491).

4.2.1.6. Secondary offshoots plant^{-1}

It showed a strong positive correlation for seed yield plant^{-1} (0.965), full capsules plant^{-1} (0.950), biological yield plant^{-1} (0.947), pollen viability (%)(0.944), capsules plant^{-1} (0.931), relative leaf water content (%) (0.811), seeds capsule^{-1} (0.678), harvest index (%) (0.549), test weight (gm) (0.443) and total chlorophyll content (mg/ml) (0.407) while significant negative correlation was with flower drop (%) (-0.904), proline (-0.839), empty capsules plant^{-1} (-0.800), lipid peroxidation (nmol/ml) (-0.684) and electrolyte leakage index (%)(-0.554).

4.2.1.7. Capsules plant^{-1}

It showed a strong positive correlation for full capsules plant^{-1} (0.995), biological yield plant^{-1} (0.975), seed yield plant^{-1} (0.944), pollen viability (%)(0.991), relative leaf water content (%) (0.568), seeds capsule^{-1} (0.444) and test weight (gm) (0.418) while significant negative correlation was with flower drop (%) (-0.900), proline (-0.881), lipid peroxidation (nmol/ml) (-0.680), empty capsules plant^{-1} (-0.671) and electrolyte leakage index (%)(-0.599).

4.2.1.8. Full capsules plant^{-1}

It showed a strong positive correlation for pollen viability (%)(0.991), biological yield plant^{-1}(0.975), seed yield plant^{-1} (0.944), relative leaf water content (%) (0.568), seeds capsule^{-1} (0.444) and test weight (gm) (0.418) while negative significant correlation was with flower drop (%) (-0.887), proline (-0.881), lipid peroxidation (nmol/ml) (-0.680), empty capsules plant^{-1} (-0.671) and electrolyte leakage index (%)(-0.599).

4.2.1.9. Empty capsules plant^{-1}

It showed a strong positive correlation for proline content (0.900), flower drop (%) (0.610), lipid peroxidation (nmol/ml) (0.507) and electrolyte leakage index (%)(0.242) while negative correlation was with biological yield plant^{-1} (-0.825), seed yield plant^{-1} (-0.799), pollen viability (%)(-0.687), test weight (gm) (-0.558), relative leaf water content (%) (-0.455), seeds capsule^{-1} (-0.376) and total chlorophyll content (mg/ml) (-0.357).

4.2.1.10. Seeds capsule^{-1}

It showed a strong positive correlation for harvest index (%) (0.909), relative leaf water content (%) (0.843), total chlorophyll content (mg/ml) (0.712), pollen viability (%) (0.632), seed yield plant^{-1} (0.598) and biological yield (0.469) while significant negative correlation was with flower drop (%) (-0.768) and lipid peroxidation (nmol/ml) (-0.406).

4.2.1.11. Test weight (gm)

It showed a strong positive correlation for total chlorophyll content (mg/ml) (0.884), relative leaf water content (%) (0.546), biological yield (0.522), seed yield plant^{-1} (0.505) and pollen viability (%) (0.355) while significant negative correlation was with flower drop (%) (-0.803), electrolyte leakage index (%) (-0.465), lipid peroxidation (nmol/ml) (-0.365) and ascorbic acid content (mg) (-0.342).

4.2.1.12. Biological yield plant^{-1}

It showed a strong positive correlation for pollen viability (%) (0.989), seed yield plant^{-1} (0.994), relative leaf water content (%) (0.630), total chlorophyll content (mg/ml) (0.389) and harvest index (%) (0.295) while significant negative correlation was with flower drop

(%) (-0.902), proline (-0.845), electrolyte leakage index (%) (-0.810) and lipid peroxidation (nmol/ml) (-0.673).

4.2.1.13. Harvest index (%)

It showed a strong positive correlation for electrolyte leakage index (%) (0.993), flower drop (%) (0.936), lipid peroxidation (nmol/ml) (0.818) and seed yield plant^{-1} (0.397) while significant negative correlation was with ascorbic acid content (mg) (-0.952) and proline (-0.508).

4.2.1.14. Total chlorophyll content (mg/ml)

It showed a strong positive correlation for electrolyte leakage index (%) (0.925), relative leaf water content (%) (0.716) and seed yield plant^{-1} (0.397) while significant negative correlation was with ascorbic acid content (mg) (-0.616).

4.2.1.15. Relative leaf water content (%)

It exhibited positive significant correlation seed yield plant^{-1} (0.610) and pollen viability (%) (0.585) while significant negative correlation was with flower drop (%) (-0.843), ascorbic acid content (mg) (-0.714), proline (-0.518) and lipid peroxidation (nmol/ml) (-0.495).

4.2.1.16. Lipid Peroxidation (nmol/ml)

It exhibited significant positive correlation with electrolyte leakage index (%) (0.941), flower drop (%) (0.749) and proline (0.567) while significant negative correlation was with pollen viability (%) (-0.619), seed yield plant^{-1} (-0.557) and ascorbic acid (-0.264).

4.2.1.17. Electrolyte leakage index (%)

It exhibited positive significant correlation with proline (0.923) while significant negative correlation was with flower drop (%) (-0.643), ascorbic acid content (-0.500), pollen viability (%) (-0.354) and seed yield plant^{-1} (-0.288).

4.2.1.18. Proline content (mg/gm)

It exhibited significant positive correlation with flower drop (%) (0.845) while significant negative correlation was with pollen viability (%) (-0.942) and seed yield plant^{-1} (-0.849).

Table 4.9: Coefficients of genotypic correlation amongst attributes in chickpea during rabi 2020-21 (Pooled)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
C1	1	0.9928*	0.9424*	0.8618*	0.8468*	0.9116*	0.933*	0.9642*	-0.9089*	0.3323*	0.4067*	0.9527*	0.2885*	0.2254	0.5626*	-0.666*	-0.8386*	-0.9188*	0.0336	0.9416*	-0.9644*
C2		1	0.9361*	0.8469*	0.8254*	0.881*	0.9108*	0.9458*	-0.9214*	0.3265*	0.3813*	0.948*	0.23	0.2585*	0.5097*	-0.6719*	-- 0.7474*	-0.9295*	0.143	0.9298*	-0.8031*
C3			1	0.8953*	0.7858*	0.8475*	0.9579*	0.9612*	-0.7057*	0.3443*	0.4117*	0.9568*	0.0875	0.256*	0.5429*	-0.6931*	-- 0.7709*	-0.8478*	-0.0575	0.9721*	-0.9497*
C4				1	0.8429*	0.8982*	0.9416*	0.9472*	-0.7071*	0.4333*	0.5464*	0.9469*	-0.108	0.4166*	0.5644*	-0.6934*	-0.5928*	-0.7423*	0.0783	0.8994*	-0.9256*
C5					1	0.9539*	0.8955*	0.9155*	-0.7931*	0.7909*	0.3095*	0.8937*	0.6701*	0.3752*	0.7572*	-0.7306*	-0.4912*	-0.752*	-0.5087*	0.901*	-0.9984*
C6						1	0.9316*	0.9502*	-0.8004*	0.6784*	0.4433*	0.9473*	0.549*	0.4078*	0.8116*	-0.684*	-0.5542*	-0.8397*	-0.2187	0.9442*	-0.9049*
C7							1	0.9956*	-0.6713*	0.4446*	0.418*	0.9752*	0.1356	0.2178	0.5688*	-0.6801*	-0.5996*	-0.8819*	-0.1743	0.9912*	-0.9005*
C8								1	-0.7377*	0.4524*	0.4531*	0.9928*	0.1091	0.2445	0.5755*	-0.6838*	-0.5801*	-0.9169*	-0.1725	0.9901*	-0.8879*
C9									1	-0.3767*	-0.5587*	-0.8259*	0.137	-0.3576*	-0.4559*	0.5074*	0.2424*	0.9009*	0.1524	-0.6872*	0.6102*
C10										1	0.1882	0.4699*	0.909*	0.7124*	0.8435*	-0.4068*	0.1262	-0.2099	-0.0732	0.6321*	-0.7688*
C11											1	0.5227*	-0.114	0.8841*	0.546*	-0.3659*	-0.4654*	-0.1502	-0.3429*	0.3552*	-0.8032*
C12												1	0.2951*	0.3894*	0.6305*	-0.6736*	-0.8102*	-0.845*	-0.0619	0.9896*	-0.9023*
C13													1	0.0312	-0.0513*	0.8188*	0.9931*	-0.5089*	-0.9522*	0.1622	0.9361*
C14														1	0.7164*	-0.1903	0.9255*	-0.0924	-0.6169*	0.2132	-0.0246
C15															1	-0.4952*	0.1739	-0.5188*	-0.714*	0.5854*	-0.8433*
C16																1	0.9414*	0.5671*	-0.2648*	-0.6194*	1.098*
C17																	1	0.9236*	-0.5009*	-0.3549*	-0.6435*
C18																		1	0.1581	-0.9421*	0.8458*
C19																			1	-0.5879*	0.9819*
C20																				1	-0.8059*
C21																					1
C22	0.9474*	0.9327*	0.926*	0.9083*	0.9252*	0.9651*	0.9444*	0.9618*	-0.7999*	0.5981*	0.5055*	0.9942*	0.3977*	0.3974*	0.6107*	-0.5578*	-0.2884*	-0.8491*	-0.234*	0.9602*	-0.9327*

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17- Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

4.2.1.19. Ascorbic acid content (mg)

It exhibited significant positive correlation with flower drop (%) (0.981) while negative significant correlation was with pollen viability (%) (-0.587) and seed yield plant^{-1} (-0.234).

4.2.1.20. Pollen viability (%)

It showed a strong positive correlation for seed yield plant^{-1} (0.960) while significant negative correlation was with flower drop (%) (-0.805).

4.2.1.21. Flower drop (%)

It showed no significant correlation with any of the characters.

4.2.1.22. Seed yield plant-1

It showed a strong positive correlation for biological yield plant^{-1} (0.994), secondary offshoots plant^{-1} (0.965), full capsules plant^{-1} (0.961), pollen viability (%)(0.960), first blossoming days (0.947), capsules plant^{-1} (0.944), 50% blossoming days (0.932), harvest maturity days (0.926), primary offshoots plant^{-1} (0.925), plant height (0.908), relative leaf water content (%) (0.610), seeds capsule^{-1} (0.598), test weight (gm) (0.505), harvest index (%) (0.397) and total chlorophyll content (mg/ml) (0.397) while negative significant correlation was with flower drop (%) (-0.932), proline (-0.849), empty capsules plant^{-1} (-0.799), lipid peroxidation (nmol/ml) (-0.557), electrolyte leakage index (%)(-0.288) and ascorbic acid content (mg) (-0.234).

Phenotypic correlation coefficients

First sowing date [EN-1]

Table 4.10 illustrates the correlation coefficients.

4.2.1.1. First blossoming days

It showed a strong positive correlation for 50% blossoming days (0.842), harvest maturity days (0.748) and flower drop (%) (0.448) while negative significant correlation was with proline (-0.366).

4.2.1.2. 50% blossoming days

It showed a strong positive correlation for harvest maturity days (0.727) while significant negative correlation was with proline content (-0.4).

4.2.1.3. Harvest maturity days

A significant negative correlation was observed with plant height (-0.421) and proline content (-0.418).

4.2.1.4. Plant height

It showed a strong positive correlation for full capsules plant^{-1} (0.752) followed by capsules plant^{-1} (0.716), secondary offshoots plant^{-1} (0.676), primary offshoots plant^{-1} (0.590), seeds capsule^{-1} (0.528), pollen viability (%) (0.416) and harvest index (%) (0.396) while negative significant correlation was with flower drop (%) (-0.564) and empty capsules plant^{-1} (-0.468).

4.2.1.5. Primary offshoots plant^{-1}

It showed a strong positive correlation for secondary offshoots plant^{-1} (0.771), capsules plant^{-1} (0.467), full capsules plant^{-1} (0.470), seeds capsule^{-1} (0.527), biological yield plant^{-1} (0.416), harvest index (%) (0.572), relative leaf water content (%) (0.524), pollen viability (%) (0.813) and seed yield plant-1 (0.626).

4.2.1.6. Secondary offshoots plant^{-1}

It showed a strong positive correlation for capsules plant^{-1} (0.746), full capsules plant^{-1} (0.724), seeds capsule^{-1} (0.546), test weight (gm) (0.406), biological yield plant^{-1} (0.430), harvest index (%) (0.634), relative leaf water content (%) (0.565), pollen viability (%) (0.573) and seed yield plant^{-1} (0.657) whereas, significant negative correlation was with flower drop (%) (-0.550).

4.2.1.7. Capsules plant^{-1}

It showed a strong positive correlation for full capsules plant^{-1} (0.956), harvest index (%) (0.602), total chlorophyll content (mg/ml) (0.600), relative leaf water content (%) (0.534), seeds capsule^{-1} (0.518), seed yield plant^{-1} (0.480) and proline (0.476) while negative significant correlation was with flower drop (%) (-0.937) and electrolyte leakage index (%) (-0.574).

4.2.1.8. Full capsules plant^{-1}

It showed a strong positive correlation for harvest index (%) (0.664), seed yield plant^{-1} (0.593), total chlorophyll content (mg/ml) (0.564), seeds capsule^{-1} (0.469), relative leaf water content (%) (0.468), pollen viability (%)(0.440) and proline (0.439) while negative significant correlation was with flower drop (%) (-0.895), empty capsules plant^{-1} (-0.613) and electrolyte leakage index (%)(-0.507).

4.2.1.9. Empty capsules plant^{-1}

It showed a strong positive correlation for seed yield plant^{-1} (-0.599), harvest index (%) (-0.494) and biological yield plant^{-1} (-0.470).

4.2.1.10. Seeds capsule^{-1}

It exhibited no significant correlation with any of the characters.

4.2.1.11. Test weight (gm)

It showed a strong positive correlation for seed yield plant^{-1} (0.641), harvest index (%) (0.543), total chlorophyll content (mg/ml) (0.509), proline (0.431) and biological yield (0.425) while negative significant correlation was with flower drop (%) (-0.440).

4.2.1.12. Biological yield plant^{-1}

It showed a strong positive correlation for seed yield plant^{-1} (0.674).

Table 4.10: Coefficients of phenotypic correlation amongst attributes in chickpea during rabi 2020-21 (EN-1)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
C1	1	0.8423*	0.7483*	-0.2853	-0.2272	-0.231	-0.3825	-0.3461	0.0731	-0.1894	-0.3461	0.07	-0.3843	-0.3479	-0.3416	0.0793	0.3207	-0.3665*	0.2091	-0.2534	0.4486*
C2		1	0.7277*	-0.2134	-0.1553	-0.2331	-0.2595	-0.179	-0.1286	-0.2268	-0.3091	0.0877	-0.2786	-0.2989	-0.2607	0.0701	0.2849	-0.4*	0.0149	-0.1628	0.3197
C3			1	-0.4213*	-0.2956	-0.274	-0.2835	-0.3147	0.2404	-0.2175	-0.3261	-0.178	-0.3385	-0.2339	-0.2655	0.0582	0.2408	-0.4181*	0.0167	-0.2817	0.2852
C4				1	0.5906*	0.6766*	0.7164*	0.752*	-0.4689*	0.5286*	0.1131	0.1842	0.3967*	0.3188	0.2667	-0.0038	-0.2306	0.2548	0.1602	0.4162*	-0.5648*
C5					1	0.771*	0.4676*	0.4701*	-0.2397	0.5279*	0.1484	0.4163*	0.5724*	0.1284	0.5244*	0.2775	0.1907	-0.1418	0.0355	0.8135*	-0.2458
C6						1	0.7463*	0.7247*	-0.3007	0.5462*	0.4068*	0.4303*	0.6345*	0.3901	0.565*	0.1096	-0.0424	0.1312	0.1352	0.5739*	-0.5501*
C7							1	0.9564*	-0.356	0.5185*	0.3286	0.1244	0.6029*	0.6002*	0.534*	-0.1521	-0.5685*	0.4766*	0.1045	0.3934	-0.9252*
C8								1	-0.6135*	0.469*	0.3696	0.2523	0.664*	0.5644*	0.4683*	-0.0877	-0.5072*	0.4391*	0.066	0.4409*	-0.895*
C9									1	-0.0985	-0.294	-0.4707*	-0.4944*	-0.183	-0.0547	-0.1306	0.0859	-0.1163	0.0712	-0.3469	0.3619
C10										1	-0.0965	0.3798	0.2668	0.2926	0.2852	0.0228	-0.1458	0.2176	-0.2273	0.2914	-0.3285
C11											1	0.425*	0.5432*	0.5092*	0.3767	-0.1902	-0.2203	0.4317*	-0.045	0.2457	-0.4402*
C12												1	0.2168	0.1053	0.0749	0.2155	0.247	-0.0004	-0.047	0.2085	-0.0309
C13													1	0.5995*	0.6948*	-0.0044	-0.2816	0.284	-0.1854	0.7909*	-0.5848*
C14														1	0.6413*	-0.4771*	-0.6203*	0.7223*	-0.1092	0.23	-0.7129*
C15															1	-0.2259	-0.3717	0.4149*	-0.0083	0.606	-0.5648*
C16																1	0.6641*	-0.7113*	-0.2918	0.1927	0.2696
C17																	1	-0.8306*	-0.167	0.0424	0.7147*
C18																		1	0.1236	-0.0992	-0.6081*
C19																			1	-0.1301	-0.0934
C20																				1	-0.2971
C21																					1
C22	-0.2495	-0.1559	-0.3599	0.347	0.6266*	0.6573*	0.4804*	0.5933*	-0.5993*	0.3741	0.6418*	0.6744*	0.8604*	0.4817*	0.5519*	0.0873	-0.0869	0.2187	-0.1929	0.7066*	-0.422*

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17-Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

4.2.1.13. Harvest index (%)

It showed a strong positive correlation for seed yield plant^{-1} (0.860), pollen viability (%) (0.790), relative leaf water content (%) (0.694) and total chlorophyll content (mg/ml) (0.599) while negative significant correlation was with flower drop (%) (-0.584).

4.2.1.14. Total chlorophyll content (mg/ml)

It showed a strong positive correlation for proline (0.722), elative leaf water content (0.641) and seed yield plant^{-1} (0.481) while negative significant correlation was with flower drop (%) (-0.712), electrolyte leakage index (%) (-0.620) and lipid peroxidation (nmol/ml) (-0.477).

4.2.1.15. Relative leaf water content (%)

It showed a strong positive correlation for pollen viability (%) (0.606), seed yield plant^{-1} (0.551) and proline (0.414) while significant negative correlation was with flower drop (%) (-0.564).

4.2.1.16. Lipid Peroxidation (nmol/ml)

It showed a strong positive correlation for electrolyte leakage index (%) (0.664) whereas significant negative correlation was with proline (-0.711).

4.2.1.17. Electrolyte leakage index (%)

It showed a strong positive correlation for flower drop (%) (0.714) while significant negative correlation was with proline (-0.830).

4.2.1.18. Proline content (mg/gm)

It showed strong negative correlation for flower drop (%) (-0.608).

4.2.1.19. Ascorbic acid content (mg)

It exhibited no significant correlation.

4.2.1.20. Pollen viability (%)

It showed a strong positive correlation for seed yield plant^{-1} (0.706).

4.2.1.21. Flower drop (%)

It showed negative significant correlation with seed yield plant^{-1} (-0.422).

4.2.1.22. Seed yield plant^{-1}

It showed a strong positive correlation for harvest index (%) (0.860), pollen viability (%)(0.706), biological yield (0.674), secondary offshoots plant^{-1} (0.657), test weight (gm) (0.641), primary offshoots plant^{-1} (0.626), full capsules plant^{-1} (0.593), relative leaf water content (%) (0.551), total chlorophyll content (mg/ml) (0.481) and capsules plant^{-1} (0.480) where significant negative correlation was with empty capsules plant^{-1} (-0.599).

Second sowing date [EN-2]

Table 4.11. illustrates the correlation coefficients.

4.2.1.1. First blossoming days

It showed a strong positive correlation for 50% blossoming days (0.904), harvest maturity days (0.864) and flower drop (%)(0.505) while negative significant correlation was with plant height (-0.820), seeds capsule^{-1} (-0.631), relative leaf water content (%) (-0.801), total chlorophyll content (mg/ml) (-0.773), proline (-0.713), seed yield (-0.713), capsules plant^{-1} (-0.661), harvest index (%) (-0.679), biological yield plant^{-1} (-0.672), full capsules plant^{-1} (-0.644), secondary offshoots plant^{-1} (-0.586), primary offshoots plant^{-1} (-0.486), pollen viability (%)(-0.518) and test weight (gm) (-0.502).

4.2.1.2. 50% blossoming days

It showed a strong positive correlation for harvest maturity days (0.928) and flower drop (%)(0.633) while significant negative correlation was with total chlorophyll content (mg/ml) (-0.791), plant height (-0.795), relative leaf water content (%) (-0.784), capsules plant^{-1} (-0.743), seeds capsule^{-1} (-0.645), full capsules plant^{-1} (-0.723), proline (-0.728), harvest index (%) (-0.677), seed yield (-0.650), secondary offshoots plant^{-1} (-0.591), primary offshoots plant^{-1} (-0.530), biological yield (-0.559), pollen viability (%)(-0.429) and test weight (gm) (-0.467).

4.2.1.3. Harvest maturity days

It showed a strong positive correlation for flower drop (%)(0.552) while significant negative correlation was with plant height (-0.809), relative leaf water content (%) (-0.771), total chlorophyll content (mg/ml) (-0.753), harvest index (%) (-0.755), capsules plant^{-1} (-0.714), proline (-0.702), full capsules plant^{-1} (-0.696), seed yield (-0.697), secondary offshoots plant^{-1} (-0.654), seeds capsule^{-1} (-0.573), primary offshoots plant^{-1} (-

0.583), biological yield (-0.538), pollen viability (%)(-0.512) and test weight (gm) (-0.429).

4.2.1.4. Plant height

It showed a strong positive correlation for seed yield (0.832), harvest index (%) (0.827), total chlorophyll content (mg/ml) (0.818), full capsules plant^{-1} (0.777), capsules plant^{-1} (0.769), biological yield (0.729), relative leaf water content (%) (0.761), proline (0.744), pollen viability (%)(0.650), secondary offshoots plant^{-1} (0.614), seeds capsule^{-1} (0.561), primary offshoots plant^{-1} (0.566) and test weight (gm) (0.542) while significant negative correlation was with flower drop (%)(-0.595).

4.2.1.5. Primary offshoots plant^{-1}

It showed a strong positive correlation for secondary offshoots plant^{-1} (0.910), total chlorophyll content (mg/ml) (0.732), proline (0.687), relative leaf water content (%) (0.631), harvest index (%) (0.540), full capsules plant^{-1} (0.474), capsules plant^{-1} (0.465) and seed yield plant^{-1} (0.411) while significant negative correlation was with flower drop (%)(-0.463) and electrolyte leakage index (%)(-0.413).

4.2.1.6. Secondary offshoots plant^{-1}

It showed a strong positive correlation for total chlorophyll content (mg/ml) (0.715), proline (0.678), relative leaf water content (%) (0.675), harvest index (%) (0.606), seed yield (0.726), seeds capsule^{-1} (0.430), pollen viability (%) (0.431), biological yield (0.405), full capsules plant^{-1} (0.412), ascorbic acid (0.440) and capsules plant^{-1} (0.408).

4.2.1.7. Capsules plant^{-1}

It showed a strong positive correlation for full capsules plant^{-1} (0.987), harvest index (%) (0.750), seed yield (0.726), total chlorophyll content (mg/ml) (0.725), proline (0.678), biological yield plant^{-1} (0.604), relative leaf water content (%) (0.549), seeds capsule^{-1} (0.463), pollen viability (%)(0.431) and test weight (gm) (0.406) while significant negative correlation was with flower drop (%)(-0.673) and electrolyte leakage index (%)(-0.412).

4.2.1.8. Full capsules plant^{-1}

It showed a strong positive correlation for harvest index (%) (0.783), seed yield (0.753), total chlorophyll content (mg/ml) (0.732), proline (0.669), biological yield (0.620), relative leaf water content (%) (0.581), pollen viability (%)(0.506), seeds capsule^{-1} (0.472) and test weight (gm) (0.457) while significant negative correlation was with flower drop (%)(-0.697), electrolyte leakage index (%)(-0.449) and empty capsules plant^{-1} (-0.462).

4.2.1.9. Empty capsules plant^{-1}

It showed a strong positive correlation for flower drop (%) (0.408) while significant negative correlation was with pollen viability (%) (-0.616), harvest index (%) (-0.492), seed yield (-0.445), test weight (gm) (-0.464), relative leaf water content (%) (-0.405).

4.2.1.10. Seeds capsule^{-1}

It showed a strong positive correlation for total chlorophyll content (mg/ml) (0.569), proline (0.550), relative leaf water content (%) (0.555), harvest index (%) (0.482) and seed yield (0.431) while significant negative correlation was with flower drop (%) (-0.422).

4.2.1.11. Test weight (gm)

It showed a strong positive correlation for proline (0.620), total chlorophyll content (mg/ml) (0.577), harvest index (%) (0.460), seed yield (0.447), relative leaf water content (%) (0.433) and biological yield plant^{-1} (0.399) while significant negative correlation was with flower drop (%) (-0.487) and electrolyte leakage index (%) (-0.397).

4.2.1.12. Biological yield plant^{-1}

It showed a strong positive correlation for seed yield (0.904), harvest index (%) (0.714), total chlorophyll content (mg/ml) (0.558), pollen viability (%) (0.541), proline (0.517) and relative leaf water content (%) (0.496).

4.2.1.13. Harvest index (%)

It showed a strong positive correlation for seed yield (0.941), pollen viability (%) (0.737), total chlorophyll content (mg/ml) (0.723), relative leaf water content (%) (0.697) and proline (0.661) while significant negative correlation was with flower drop (%) (-0.470).

4.2.1.14. Total chlorophyll content (mg/ml)

It showed a strong positive correlation for proline (0.871), relative leaf water content (%) (0.777), seed yield plant^{-1} (0.684) and pollen viability (%) (0.499) while significant negative correlation was with flower drop (%) (-0.741) and electrolyte leakage index (%) (-0.593).

4.2.1.15. Relative leaf water content (%)

It showed a strong positive correlation for proline (0.707), seed yield (0.643) and pollen viability (%) (0.615) while significant negative correlation was with flower drop (%) (-0.624) and electrolyte leakage index (%) (-0.547).

4.2.1.16. Lipid Peroxidation (nmol/ml)

It showed a strong positive correlation for flower drop (%) (0.725) and electrolyte leakage index (%) (0.610) while significant negative correlation was with proline (-0.440).

4.2.1.17. Electrolyte leakage index

It showed a strong positive correlation for flower drop (%) (0.740) while significant negative correlation was with proline (-0.700).

4.2.1.18. Proline content (mg/gm)

It showed a strong positive correlation for seed yield plant^{-1} (0.623) while significant negative correlation was with Flower drop (%) (-0.759).

4.2.1.19. Ascorbic acid content (mg)

It exhibited no significant estimates for any of the characters.

4.2.1.20. Pollen viability

It showed a strong positive correlation for seed yield plant^{-1} (0.707).

4.2.1.21. Flower drop (%)

It exhibited significant negative correlation with seed yield plant^{-1} (-0.417).

4.2.1.22. Seed yield plant^{-1}

It showed a strong positive correlation for harvest index (%) (0.941), biological yield (0.904), plant height (0.832), full capsules plant^{-1} (0.753), capsules plant^{-1} (0.726), pollen viability (%)(0.707), total chlorophyll content (mg/ml) (0.684), relative leaf water content (%) (0.643), proline (0.623), secondary offshoots plant^{-1} (0.541), seeds capsule^{-1} (0.431), test weight (gm) (0.447) and primary offshoots plant^{-1} (0.411) while significant negative correlation was with first blossoming days (-0.713), harvest maturity days (-0.697), 50% blossoming days (-0.650), empty capsules plant^{-1} (-0.445) and flower drop (%)(-0.417).

Table 4.11: Coefficients of genotypic correlation amongst attributes in chickpea during rabi 2020-21 (EN-2)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
C1	1	0.904*	0.8643*	-0.8201*	-0.4866*	-0.5868*	-0.661*	-0.6441*	0.158	-0.6315*	-0.5029*	-0.6724*	-0.6794*	-0.7736*	-0.8016*	0.1371	0.3258	-0.7134*	-0.0276	-0.5182*	0.5051*
C2		1	0.9289*	-0.7957*	-0.5306*	-0.5919*	-0.7431*	-0.7234*	0.1732	-0.6458*	-0.4673*	-0.5593*	-0.6776*	-0.7914*	-0.7845*	0.168	0.3228	-0.728*	0.0026	-0.4294*	0.6331*
C3			1	-0.8092*	-0.5839*	-0.6549*	-0.7143*	-0.696*	0.1699	-0.5732*	-0.4299*	-0.5384*	-0.7555*	-0.7536*	-0.7713*	0.125	0.2146	-0.7023*	-0.0918	-0.5126*	0.5521*
C4				1	0.5667*	0.6146*	0.7696*	0.7772*	-0.3465	0.561*	0.5422*	0.7291*	0.8278*	0.8185*	0.7614*	-0.1407	-0.3919	0.7449*	-0.0135	0.6501*	-0.5715*
C5					1	0.9108*	0.4658*	0.4744*	-0.2336	0.3801	0.3589	0.2195	0.5405*	0.7327*	0.6312*	-0.1542	-0.4136*	0.6875*	0.3781	0.3755	-0.4632*
C6						1	0.4086*	0.412*	-0.1798	0.4307*	0.3568	0.4058*	0.6068*	0.7157*	0.6756*	0.0607	-0.3118	0.678*	0.332	0.4249*	-0.3465
C7							1	0.9873*	-0.3153	0.4639*	0.4063*	0.6045*	0.7501*	0.7252*	0.549*	-0.2922	-0.4121*	0.6786*	0.0879	0.4316*	-0.6732*
C8								1	-0.4621*	0.4724*	0.4574*	0.6202*	0.7834*	0.7323*	0.581*	-0.2912	-0.4493*	0.669*	0.1021	0.5065*	-0.6975*
C9									1	-0.2321	-0.4641*	-0.3301	-0.4928*	-0.326	-0.4055*	0.1084	0.3833	-0.2079	-0.1189	-0.6161*	0.4086*
C10										1	0.3444	0.3483	0.4824*	0.5694*	0.5555*	-0.0667	-0.2705	0.5505*	0.1098	0.356	-0.4222*
C11											1	0.3993*	0.4605*	0.5775*	0.433*	-0.2165	-0.3973*	0.6204*	0.158	0.2103	-0.4879*
C12												1	0.7146*	0.5585*	0.4962*	0.0216	-0.2168	0.5175*	0.0194	0.5419*	-0.3165
C13													1	0.7231*	0.6971*	-0.0722	-0.3678	0.6613*	0.2525	0.7379*	-0.4704*
C14														1	0.7776*	-0.3729	-0.593*	0.8718*	0.2109	0.4994*	-0.7414*
C15															1	-0.244	-0.547*	0.707*	-0.011	0.6154*	-0.6241*
C16																1	0.6106*	-0.4402*	0.1639	-0.0009	0.725*
C17																	1	-0.7004*	-0.1368	-0.1427	0.7403*
C18																		1	0.2044	0.2747	-0.7596*
C19																			1	-0.1014	0.0669
C20																				1	-0.251
C21																					1
C22	-0.713*	-0.6507*	-0.6976*	0.8328*	0.4111*	0.5414*	0.7265*	0.7535*	-0.4455*	0.4317*	0.4476*	0.9047*	0.9416*	0.6845*	0.6435*	-0.0407	-0.321	0.6233*	0.1592	0.7077*	-0.4171*

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17-Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

Third sowing date [EN-3]

Table 4.12. illustrates the correlation coefficients.

4.2.1.1. First blossoming days

It showed a strong positive correlation for 50% blossoming days (0.836), lipid peroxidation (nmol/ml) (0.670), harvest maturity days (0.610), flower drop (%)(0.472) and electrolyte leakage index (%)(0.441) while significant negative correlation was with full capsules plant^{-1} (-0.507), proline (-0.498), harvest index (%) (-0.497), plant height (-0.492), relative leaf water content (%) (-0.486), seed yield plant^{-1} (-0.480), capsules plant^{-1} (-0.462) and pollen viability (%)(-0.441).

4.2.1.2. 50% blossoming days

It showed a strong positive correlation for harvest maturity days (0.800) lipid peroxidation (nmol/ml) (0.619), flower drop (%) (0.508) and electrolyte leakage index (%) (0.454) while significant negative correlation was with proline (-0.497), full capsules plant^{-1} (-0.477), capsules plant^{-1} (-0.464), relative leaf water content (%) (-0.444), test weight (gm) (-0.438).

1.2.1.3 Harvest maturity days

It showed a strong positive correlation for lipid peroxidation (nmol/ml) (0.532) and flower drop (%)(0.469) while significant negative correlation was with secondary offshoots plant^{-1} (-0.512), primary offshoots plant^{-1} (-0.511), full capsules plant^{-1} (-0.518), capsules plant^{-1} (-0.475), relative leaf water content (%) (-0.489), pollen viability (%)(-0.431), harvest index (%) (-0.419) and seed yield plant^{-1} (-0.419).

4.2.1.4. Plant height

It showed a strong positive correlation for biological yield (0.591), seed yield plant^{-1} (0.622), full capsules plant^{-1} (0.591), pollen viability (%) (0.549), relative leaf water content (%) (0.519), harvest index (%) (0.476) and capsules plant^{-1} (0.451) while significant negative correlation was with empty capsules plant^{-1} (-0.558) and lipid peroxidation (nmol/ml) (-0.487).

4.2.1.5. Primary offshoots plant^{-1}

It showed a strong positive correlation for secondary offshoots plant^{-1} (0.941), capsules plant^{-1} (0.548), full capsules plant^{-1} (0.525), relative leaf water content (%) (0.508), pollen viability (%) (0.480), ascorbic acid (0.442), while significant negative correlation was with flower drop (%) (-0.539).

4.2.1.6. Secondary offshoots plant^{-1}

It showed a strong positive correlation for capsules plant^{-1} (0.574), full capsules plant^{-1} (0.521), ascorbic acid (0.499), relative leaf water content (%) (0.484), pollen viability (%) (0.445) while significant negative correlation was with flower drop (%) (-0.544) and electrolyte leakage index (%) (-0.465).

4.2.1.7. Capsules plant^{-1}

It showed a strong positive correlation for pollen viability (%) (0.880), full capsules plant^{-1} (0.929), seed yield (0.737), harvest index (%) (0.644), biological yield plant^{-1} (0.650) and relative leaf water content (%) (0.433).

4.2.1.8. Full capsules plant^{-1}

It showed a strong positive correlation for pollen viability (%) (0.915), seed yield (0.838), harvest index (%) (0.745), biological yield plant^{-1} (0.734) and relative leaf water content (%) (0.593) while significant negative correlation was with empty capsules plant^{-1} (-0.516) and lipid peroxidation (nmol/ml) (-0.412).

4.2.1.9. Empty capsules plant^{-1}

It showed a strong positive correlation for lipid peroxidation (nmol/ml) (0.481) while significant negative correlation was with relative leaf water content (%) (-0.607), seed yield plant^{-1} (-0.544), total chlorophyll content (mg/ml) (-0.515), harvest index (%) (-0.507), biological yield plant^{-1} (-0.463) and pollen viability (%) (-0.419).

4.2.1.10. Seeds capsule^{-1}

It exhibited no significant correlation with any of the characters.

4.2.1.11. Test weight (gm)

It exhibited no significant correlation with any of the characters.

4.2.1.12. Biological yield plant^{-1}

It showed a strong positive correlation for seed yield plant^{-1} (0.889), pollen viability (%) (0.814) and harvest index (%) (0.638).

4.2.1.13. Harvest index (%)

It showed a strong positive correlation for seed yield plant^{-1} (0.914), Pollen viability (%) (0.792) and Relative leaf water content (%) (0.662) while significant negative correlation was with Lipid Peroxidation (nmol/ml) (-0.587).

4.2.1.14. Total chlorophyll content (mg/ml)

It showed a strong positive correlation for proline content (mg/gm) (0.785), ascorbic acid (0.682) and relative leaf water content (%) (0.645) while significant negative correlation was with lipid peroxidation (nmol/ml) (-0.750), electrolyte leakage index (%) (-0.724) and flower drop (%) (-0.561).

1.2.1.15 Relative leaf water content (%)

It showed a strong positive correlation for proline content (mg/gm) (0.625), seed yield plant^{-1} (0.590), pollen viability (%) (0.539) and ascorbic acid content (mg) (0.453) while significant negative correlation was with lipid peroxidation (nmol/ml) (-0.817), electrolyte leakage index (%) (-0.744) and flower drop (%) (-0.543).

4.2.1.16. Lipid Peroxidation (nmol/ml)

It showed a strong positive correlation for electrolyte leakage index (%) (0.749) and flower drop (%) (0.605) while significant negative correlation was with proline (-0.822), ascorbic acid (-0.560) and seed yield plant^{-1} (-0.487).

4.2.1.17. Electrolyte leakage index

It showed a strong positive correlation for flower drop (%) (0.531) while significant negative correlation was with proline (-0.805) and ascorbic acid (-0.644).

4.2.1.18. Proline content (mg/gm)

It showed a strong positive correlation for ascorbic acid (0.638) while significant negative correlation was with flower drop (%) (-0.733).

4.2.1.19. Ascorbic acid content (mg)

It exhibited negative significant correlation with flower drop (%) (-0.584).

4.2.1.20. Pollen viability

It showed a strong positive correlation for seed yield plant^{-1} (0.903).

4.2.1.21. Flower drop (%)

It exhibited no significant correlation with any of the characters.

4.2.1.22. Seed yield plant^{-1}

It showed a strong positive correlation for pollen viability (%) (0.903), harvest index (%) (0.914), biological yield plant^{-1} (0.889), full capsules plant^{-1} (0.838), capsules plant^{-1} (0.737), plant height (0.622) and relative leaf water content (%) (0.590) while significant negative correlation was with empty capsules plant^{-1} (-0.544), first blossoming days (-0.480), lipid peroxidation (nmol/ml) (-0.487) and harvest maturity days (-0.419).

Table 4.12: Coefficients of phenotypic correlation amongst attributes in chickpea during rabi 2020-21 (EN-3)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
C1	1	0.8362*	0.6106*	-0.4928*	-0.2185	-0.1894	-0.4623*	-0.5072*	0.3081	-0.0027	-0.2237	-0.3195	-0.4979*	-0.3665	-0.4863*	0.6703*	0.4414*	-0.4982*	-0.2712	-0.441*	0.4727*
C2		1	0.8006*	-0.3783	-0.3364	-0.3453	-0.4643*	-0.4779*	0.2188	0.0501	-0.4388*	-0.2592	-0.3226	-0.3447	-0.4443*	0.6194*	0.4541*	-0.4971*	-0.3195	-0.3373*	0.508*
C3			1	-0.3352	-0.5112*	-0.5122*	-0.4755*	-0.5184*	0.2922	0.0218	-0.3872	-0.318	-0.4192*	-0.3888	-0.4898*	0.5325*	0.3892	-0.3495	-0.3092	-0.4314*	0.4693*
C4				1	0.1495	0.132	0.4517*	0.5917*	-0.5587*	0.2116	0.2325	0.591*	0.4762*	0.1904	0.5194*	-0.4879*	-0.3308	0.1947	0.1899	0.5494*	-0.1057
C5					1	0.9417*	0.5481*	0.5257*	-0.1748	0.086	0.2403	0.2712	0.4029*	0.3538	0.5086*	-0.3106	-0.3943	0.3616	0.4426*	0.4806*	-0.5393*
C6						1	0.5748*	0.5218*	-0.0837	0.0481	0.3029	0.2643	0.3225	0.2997	0.4845*	-0.2855	-0.4656*	0.3549	0.4996*	0.4452*	-0.544*
C7							1	0.9291*	-0.1685	0.3562	0.1665	0.6507*	0.6444*	-0.0962	0.4332*	-0.2682	-0.1405	0.0136	0.1219	0.8801*	-0.1886
C8								1	-0.5163*	0.3101	0.2483	0.7345*	0.7458*	0.1024	0.5931*	-0.4129*	-0.2515	0.1333	0.2197	0.9154*	-0.2353
C9									1	-0.007	-0.2781	-0.4632*	-0.5079*	-0.5152*	-0.6073*	0.4815*	0.3663	-0.3307	-0.2766	-0.4199*	0.1825
C10										1	-0.0248	0.3873	0.1048	-0.2313	0.0314	0.0767	0.0611	-0.0845	-0.1988	0.3543	0.196
C11											1	0.3628	0.0959	0.2586	0.2176	-0.1814	-0.3196	0.2263	0.43	0.1518	-0.1541
C12												1	0.6387*	0.0081	0.372	-0.2662	-0.2676	0.0648	0.1202	0.814*	0.134
C13													1	0.2781	0.6627*	-0.5879*	-0.2652	0.2991	0.2049	0.7928*	-0.2448
C14														1	0.6459*	-0.7507*	-0.7243*	0.785*	0.6822*	0.0409	-0.5618*
C15															1	-0.817*	-0.7449*	0.6257*	0.4538*	0.5398*	-0.5438*
C16																1	0.7498*	-0.8227*	-0.5602*	-0.3626	0.6051*
C17																	1	-0.8055*	-0.6449*	-0.1882	0.5318*
C18																		1	0.6383*	0.0139	-0.7333*
C19																			1	0.1296	-0.5845*
C20																				1	-0.0424
C21																					1
C22	-0.4809*	-0.3409	-0.419*	0.6228*	0.3693	0.3209	0.7373*	0.8388*	-0.5441*	0.284	0.2213	0.8896*	0.9146*	0.1574	0.5906*	-0.4871*	-0.2936	0.1984	0.1608	0.9036*	-0.0625

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17- Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

Pooled

Table 4.13. illustrates the correlation coefficients.

4.2.1.1. First blossoming days

It showed a strong positive correlation for 50% blossoming days (0.982), harvest maturity days (0.927), biological yield plant^{-1} (0.898), full capsules plant^{-1} (0.883), capsules plant^{-1} (0.859), seed yield plant^{-1} (0.828), pollen viability (%)(0.804) secondary offshoots plant^{-1} (0.790), plant height (0.750), primary offshoots plant^{-1} (0.690), relative leaf water content (%) (0.330), test weight (gm) (0.248) and seeds capsule^{-1} (0.233), while significant negative correlation was with proline (-0.801), empty capsules plant^{-1} (-0.749), lipid peroxidation (nmol/ml) (-0.541), flower drop (%)(-0.411) and electrolyte leakage index (%)(-0.339).

4.2.1.2. 50% blossoming days

It showed a strong positive correlation for harvest maturity days (0.928), biological yield plant^{-1} (0.907), full capsules plant^{-1} (0.884), capsules plant^{-1} (0.855), seed yield plant^{-1} (0.837), pollen viability (%)(0.815), secondary offshoots plant^{-1} (0.778), plant height (0.758), primary offshoots plant^{-1} (0.685), relative leaf water content (%) (0.319), seeds capsule^{-1} (0.241) and test weight (gm) (0.233) while significant negative correlation was with proline (-0.809), empty capsules plant^{-1} (-0.782), lipid peroxidation (nmol/ml) (-0.558), flower drop (%)(-0.408) and electrolyte leakage index (%)(-0.329).

4.2.1.3. Harvest maturity days

It showed a strong positive correlation for biological yield plant^{-1} (0.935), capsules plant^{-1} (0.923), full capsules plant^{-1} (0.922), pollen viability (%)(0.878), seed yield plant^{-1} (0.859), plant height (0.826), secondary offshoots plant^{-1} (0.772),primary offshoots plant^{-1} (0.676), relative leaf water content (%) (0.385), test weight (gm) (0.288) and seeds capsule^{-1} (0.261) while significant negative correlation was with proline (-0.723), empty capsules plant^{-1} (-0.609), lipid peroxidation (nmol/ml) (-0.601), flower drop (%)(-0.541) and electrolyte leakage index (%)(-0.389).

Table 4.13: Coefficients of phenotypic correlation amongst attributes in chickpea during rabi 2020-21 (Pooled)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21
C1	1	0.9821*	0.9275*	0.7505*	0.6903*	0.7909*	0.859*	0.883*	-0.7493*	0.2332*	0.2484*	0.8985*	-0.0322	0.0489	0.3301*	-0.5419*	-0.3396*	-0.8017*	-0.0057	0.8046*	-0.4111*
C2		1	0.9285*	0.7589*	0.6856*	0.7783*	0.8555*	0.8846*	-0.7829*	0.2417*	0.2339*	0.9074*	-0.0143	0.0842	0.3194*	-0.5589*	-0.329*	-0.8091*	0.0227	0.8158*	-0.4089*
C3			1	0.826*	0.6764*	0.7721*	0.9239*	0.9228*	-0.6098*	0.2617*	0.2886*	0.9356*	-0.031	0.1226	0.3857*	-0.601*	-0.3898*	-0.7233*	-0.046	0.8789*	-0.5416*
C4				1	0.7841*	0.8575*	0.9159*	0.925*	-0.6775*	0.4128*	0.4575*	0.9107*	0.1345	0.3666*	0.5307*	-0.629*	-0.3463*	-0.5153*	0.0677	0.8622*	-0.6612*
C5					1	0.9187*	0.8218*	0.838*	-0.6698*	0.6504*	0.2968*	0.8065*	0.4218*	0.3609*	0.6759*	-0.5754*	-0.2561*	-0.491*	-0.0968	0.8345*	-0.6737*
C6						1	0.8929*	0.9087*	-0.7081*	0.587*	0.4052*	0.8927*	0.3522*	0.3793*	0.7036*	-0.5712*	-0.2941*	-0.5781*	-0.019	0.8712*	-0.6623*
C7							1	0.9943*	-0.625*	0.4023*	0.3645*	0.9572*	0.1637	0.2224	0.5086*	-0.6242*	-0.3352*	-0.6583*	-0.0636	0.9368*	-0.6749*
C8								1	-0.7045*	0.4083*	0.3968*	0.9729*	0.1711	0.2459*	0.5163*	-0.6307*	-0.3348*	-0.6807*	-0.0553	0.9393*	-0.6611*
C9									1	-0.3109*	-0.4709*	-0.7517*	-0.1575	-0.3175*	-0.3979*	0.463*	0.2153	0.6031*	0.0033	-0.6413*	0.351*
C10										1	0.1376	0.3986*	0.5392*	0.4252*	0.5921*	-0.2791*	-0.0551	-0.0935	-0.0928	0.5105*	-0.3465*
C11							`				1	0.4349*	0.1843	0.6212*	0.4573*	-0.3219*	-0.3398*	0.0331	0.041	0.3141*	-0.534*
C12												1	0.1669	0.2709*	0.5103*	-0.6017*	-0.3378*	-0.6749*	-0.0288	0.9329*	-0.5874*
C13													1	0.3896*	0.4002*	0.138	0.4421*	0.0704	-0.3341*	0.3057*	-0.1827
C14														1	0.6851*	-0.3286*	-0.2678*	0.2868*	0.0528	0.209	-0.4813*
C15															1	-0.4711*	-0.3145*	-0.1076	-0.1403	0.567*	-0.7551*
C16																1	0.7761*	0.2402*	-0.2259	-0.5381*	0.6274*
C17																	1	0.0035	-0.346*	-0.1988	0.4871*
C18																		1	0.2331	-0.6952*	0.1778
C19																			1	-0.2347*	0.0871
C20																				1	-0.6375*
C21																					1
C22	0.8287*	0.8378*	0.8593*	0.8833*	0.8482*	0.9133*	0.9228*	0.9413*	-0.7474*	0.5023*	0.4625*	0.971*	0.3887*	0.3566*	0.5775*	-0.514*	-0.2163	-0.6003*	-0.0895	0.9327*	-0.5854*

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17-Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

4.2.1.4. Plant height

It showed a strong positive correlation for biological yield plant^{-1} (0.946), full capsules plant^{-1} (0.947), capsules plant^{-1} (0.941), seed yield plant^{-1} (0.908), pollen viability (%) (0.899), secondary offshoots plant^{-1} (0.898), primary offshoots plant^{-1} (0.842), relative leaf water content (%) (0.564), test weight (gm) (0.546), seeds capsule^{-1} (0.433) and total chlorophyll content (mg/ml) (0.416) while significant negative correlation was with proline flower drop (%)(-1.455), proline (-0.742), empty capsules plant^{-1} (-0.707) and lipid peroxidation (nmol/ml) (-0.693).

4.2.1.5. Primary offshoots plant^{-1}

It showed a strong positive correlation for secondary offshoots plant^{-1} (0.918), seed yield plant^{-1} (0.848), pollen viability (%) (0.834), full capsules plant^{-1} (0.838), capsules plant^{-1} (0.821), biological yield plant^{-1} (0.806), relative leaf water content (%) (0.675), seeds capsule^{-1} (0.650), harvest index (%) (0.421), total chlorophyll content (mg/ml) (0.360) and test weight (gm) (0.296) while significant negative correlation was with empty capsules plant^{-1} (-0.669), flower drop (%)(-0.673), lipid peroxidation (nmol/ml) (-0.575), proline (-0.491) and electrolyte leakage index (%)(-0.256).

4.2.1.6. Secondary offshoots plant^{-1}

It showed a strong positive correlation for yield plant^{-1} (0.913), full capsules plant^{-1} (0.908), capsules plant^{-1} (0.892), biological yield plant^{-1} (0.892), pollen viability (%)(0.871), relative leaf water content (%) (0.703), seeds capsule^{-1} (0.587), test weight (gm) (0.405), total chlorophyll content (mg/ml) (0.379) and harvest index (%) (0.352) while significant negative correlation was with empty capsules plant^{-1} (-0.708), flower drop (%)(-0.662), proline (-0.578), lipid peroxidation (nmol/ml) (-0.571) and electrolyte leakage index (%)(-0.294).

4.2.1.7. Capsules plant^{-1}

It showed a strong positive correlation for full capsules plant^{-1} (0.994), biological yield (0.957), pollen viability (%)(0.936), seed yield plant^{-1} (0.922), relative leaf water content (%) (0.508), seeds capsule^{-1} (0.402) and test weight (gm) (0.364) while significant negative correlation was with flower drop (%) (-0.674), proline (-0.658), empty capsules plant^{-1} (-0.625), lipid peroxidation (nmol/ml) (-0.624) and electrolyte leakage index (%)(-0.335).

4.2.1.8. Full capsules plant^{-1}

It showed a strong positive correlation for biological yield plant^{-1} (0.972), seed yield plant^{-1} (0.941), pollen viability (%)(0.939), relative leaf water content (%) (0.516), seeds capsule^{-1} (0.408), test weight (gm) (0.396) and total chlorophyll content (mg/ml) (0.245) while significant negative correlation was with empty capsules plant^{-1} (-0.704), proline (-0.680), flower drop (%) (-0.661), lipid peroxidation (nmol/ml) (-0.630) and electrolyte leakage index (%)(-0.334).

4.2.1.9. Empty capsules plant^{-1}

It showed a strong positive correlation for proline (0.603), lipid peroxidation (nmol/ml) (0.463) and flower drop (%) (0.351) while significant negative correlation was with seed yield plant^{-1} (-0.747), biological yield plant^{-1} (-0.751), pollen viability (%)(-0.641), test weight (gm) (-0.470), relative leaf water content (%) (-0.397), total chlorophyll content (mg/ml) (-0.317) and seeds capsule^{-1} (-0.310).

4.2.1.10. Seeds capsule^{-1}

It showed a strong positive correlation for relative leaf water content (%) (0.592), harvest index (%) (0.539), pollen viability (%) (0.510), seed yield plant^{-1} (0.502), total chlorophyll content (mg/ml) (0.425) and biological yield plant^{-1} (0.398) while significant negative correlation was with lipid peroxidation (nmol/ml) (-0.279).

4.2.1.11. Test weight (gm)

It showed a strong positive correlation for total chlorophyll content (mg/ml) (0.621), seed yield plant^{-1} (0.462), relative leaf water content (%) (0.457), biological yield plant^{-1} (0.434) and pollen viability (%) (0.314) while significant negative correlation was with flower drop (%) (-0.534), electrolyte leakage index (%) (-0.339) and ascorbic acid content (mg) (-0.321).

4.2.1.12. Biological yield plant^{-1}

It showed a strong positive correlation for seed yield plant^{-1} (0.971), pollen viability (%) (0.932), relative leaf water content (%) (0.510) and total chlorophyll content (mg/ml)

(0.270) while significant negative correlation was with proline (-0.674), lipid peroxidation (nmol/ml) (-0.601), flower drop (%) (-0.587) and electrolyte leakage index (%) (-0.337).

4.2.1.13. Harvest index (%)

It showed a strong positive correlation for electrolyte leakage index (%) (0.442), relative leaf water content (%) (0.400), total chlorophyll content (mg/ml) (0.389), seed yield plant^{-1} (0.388) and pollen viability (%) (0.305) while significant negative correlation was with ascorbic acid content (mg) (-0.334).

4.2.1.14. Total chlorophyll content (mg/ml)

It showed a strong positive correlation for relative leaf water content (%) (0.685), seed yield plant^{-1} (0.356) and proline (0.286) while significant negative correlation was with flower drop (%) (-0.481), lipid peroxidation (nmol/ml) (-0.328) and electrolyte leakage index (%) (-0.267).

4.2.1.15. Relative leaf water content (%)

It showed a strong positive correlation for pollen viability (%) (0.567) and seed yield plant^{-1} (0.577) while significant negative correlation was with flower drop (%) (-0.755), lipid peroxidation (nmol/ml) (-0.471) and electrolyte leakage index (%) (-0.314).

1.2.1.16 Lipid Peroxidation (nmol/ml)

It showed a strong positive correlation for electrolyte leakage index (%) (0.776), flower drop (%) (0.627) and proline (0.240) while significant negative correlation was with pollen viability (%) (-0.538) and seed yield plant^{-1} (-0.514).

4.2.1.17. Electrolyte leakage index

It showed a strong positive correlation for flower drop (%) (0.487) while significant negative correlation was with ascorbic acid (-0.346).

4.2.1.18. Proline content (mg/gm)

It showed a strong positive correlation for ascorbic acid content (mg) (0.233) while significant negative correlation was with pollen viability (%) (-0.695) and seed yield plant^{-1} (-0.600).

4.2.1.19. Ascorbic acid content (mg)

It showed strong negative correlation for pollen viability (%) (-0.234).

4.2.1.20. Pollen viability

It showed a strong positive correlation for seed yield plant^{-1} (0.932) while significant negative correlation was with flower drop (%) (-0.637).

4.2.1.21. Flower drop (%)

It showed strong negative correlation for seed yield plant^{-1} (-0.585).

4.2.1.22. Seed yield plant^{-1}

It content biological yield plant^{-1} (0.971), full capsules plant^{-1} (0.941), pollen viability (%)(0.932), capsules plant^{-1} (0.922), secondary offshoots plant^{-1} (0.913), plant height (0.883),harvest maturity days (0.859), primary offshoots plant^{-1} (0.848), 50% blossoming days (0.837), first blossoming days (0.828), relative leaf water content (%) (0.577), seeds capsule^{-1} (0.502), test weight (gm) (0.462), harvest index (%) (0.388) and total chlorophyll content (mg/ml) (0.356) while negative correlation significant was with empty capsules plant^{-1} (-0.747), proline content (-0.600), flower drop (%)(-0.585) and lipid peroxidation (nmol/ml) (-0.514).

1.3 PATH COEFFICIENT ANALYSIS

Path coefficient analysis computes the indirect & direct impacts of numerous independent traits onto a dependant one. It suggests the impact of each of these independent factors on seed yield plant-1 (dependent character) is possibly direct or indirect through other component factors.

PATH COEFFICIENT ANALYSIS (GENOTYPIC)

First sowing date [EN-1]

Table 4.14 illustrates the path coefficient analysis estimates

4.3.1. Direct impact of various characters on seed yield plant^{-1}

Full capsules plant^{-1} (1.2358), harvest index (%) (0.6304), biological yield plant^{-1} (0.4281), empty capsules plant^{-1} (0.3684), pollen viability (%)(0.1458), flower drop (%)(0.0985), test weight (gm) (0.0978), 50% blossoming days (0.0935), seeds capsule^{-1} (0.0543), proline content (0.0521), first blossoming days (0.0285), electrolyte leakage index (%)(0.0247) imposed direct positive impacts on seed yield plant^{-1} whereas, capsules plant^{-1} (-0.8602), plant height (-0.1402), harvest maturity days (-0.1271), secondary offshoots plant^{-1} (-0.0404), relative leaf water content (%) (-0.032), total chlorophyll content (mg/ml) (-0.0295), ascorbic acid content (mg) (-0.0226), primary offshoots plant^{-1} (-0.0206), lipid peroxidation (nmol/ml) (-0.0183) had direct negative impact on seed yield plant$^{-1.}$

4.3.2. Indirect impacts of various characters on seed yield plant^{-1}

4.3.2.1. First blossoming days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* 50% blossoming days (0.0253), harvest maturity days (0.0221), flower drop (%) (0.0139), electrolyte leakage index (%) (0.0095), ascorbic acid content (mg) (0.0064), empty capsules plant^{-1} (0.003), lipid peroxidation (nmol/ml) (0.0026), biological yield plant^{-1} (0.0025). however, indirect negative impacts *via.,* harvest index (%) (-0.0116), capsules plant^{-1} (-0.0115), proline content (-0.0114), total chlorophyll content (mg/ml) (-0.0109), full capsules plant^{-1} (-0.0106), test weight (gm) (-0.0101), relative leaf water content (%) (-0.01), plant height (-0.0089), pollen viability (%)(-0.0077), secondary offshoots plant^{-1} (-0.0074), primary offshoots plant^{-1} (-0.0065) and seeds capsule^{-1} (-0.0061).

Table-4.14: Coefficients of genotypic path depicting direct and indirect impacts on seed yield plant^{-1} (EN-1)

Character	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	**0.0285**	0.0253	0.0221	-0.0089	-0.0065	-0.0074	-0.0115	-0.0106	0.003	-0.0061	-0.0101	0.0025	-0.0116	-0.0109	-0.01	0.0026	0.0095	-0.0114	0.0064	-0.0077	0.0139	-0.2551
C2	0.0828	**0.0935**	0.0722	-0.0214	-0.0137	-0.0235	-0.0266	-0.0188	-0.0117	-0.0266	-0.0305	0.0107	-0.0274	-0.0304	-0.0255	0.0072	0.0284	-0.0419	-0.0005	-0.0135	0.0345	-0.1515
C3	-0.0984	-0.0982	**-0.1271**	0.0553	0.0379	0.036	0.0365	0.0405	-0.0314	0.0297	0.0429	0.0234	0.0447	0.0315	0.034	-0.007	-0.0311	0.055	0.0054	0.0368	-0.0367	-0.3706
C4	0.044	0.0321	0.061	**-0.1402**	-0.0864	-0.0969	-0.1037	-0.1085	0.0682	-0.0766	-0.0155	-0.0259	-0.0589	-0.0455	-0.0383	-0.0001	0.0332	-0.0366	-0.0231	-0.06	0.0812	0.3608
C5	0.0047	0.003	0.0062	-0.0127	**-0.0206**	-0.0163	-0.0099	-0.01	0.0052	-0.0115	-0.003	-0.0088	-0.0121	-0.0027	-0.011	-0.0059	-0.004	0.0031	-0.0007	-0.0175	0.0052	0.6344
C6	0.0105	0.0101	0.0115	-0.0279	-0.0318	**-0.0404**	-0.0308	-0.0298	0.0123	-0.0229	-0.0166	-0.0181	-0.026	-0.0159	-0.0231	-0.0046	0.0017	-0.0052	-0.0057	-0.0242	0.0228	0.6647
C7	0.3459	0.2448	0.2473	-0.636	-0.4119	-0.655	**-0.8602**	-0.8242	0.3184	-0.4582	-0.2861	-0.1121	-0.5294	-0.5285	-0.4637	0.132	0.4941	-0.4171	-0.1034	-0.3481	0.8062	0.4894
C8	-0.4588	-0.2491	-0.3939	0.9564	0.596	0.9104	1.1841	**1.2358**	-0.7669	0.5942	0.4643	0.3339	0.8335	0.7118	0.5838	-0.1058	-0.6315	0.5475	0.083	0.5613	-1.1177	0.6051
C9	0.0381	-0.0461	0.091	-0.1791	-0.0933	-0.1124	-0.1364	-0.2286	**0.3684**	-0.0373	-0.1135	-0.1915	-0.1853	-0.0686	-0.0208	-0.0525	0.0313	-0.0403	0.041	-0.1347	0.1355	-0.623
C10	-0.0117	-0.0154	-0.0127	0.0296	0.0303	0.0307	0.0289	0.0261	-0.0055	**0.0543**	-0.0058	0.0226	0.015	0.0165	0.016	0.0011	-0.0083	0.0118	-0.0193	0.0184	-0.0187	0.393
C11	-0.0347	-0.0319	-0.033	0.0108	0.0143	0.0401	0.0325	0.0368	-0.0301	-0.0105	**0.0978**	0.0427	0.0539	0.0508	0.0371	-0.0187	-0.0218	0.0431	-0.0073	0.0255	-0.0442	0.6468
C12	0.0378	0.0489	-0.0787	0.0789	0.1818	0.1921	0.0558	0.1157	-0.2226	0.1781	0.1869	**0.4281**	0.1052	0.0471	0.0327	0.0979	0.1074	0.002	-0.011	0.0893	-0.0115	0.6874
C13	-0.2557	-0.1848	-0.2218	0.2648	0.3693	0.405	0.388	0.4252	-0.317	0.174	0.3473	0.1549	**0.6304**	0.3892	0.4433	-0.0039	-0.1795	0.1814	-0.1461	0.5254	-0.3812	0.8667
C14	0.0113	0.0096	0.0073	-0.0096	-0.0039	-0.0116	-0.0181	-0.017	0.0055	-0.009	-0.0153	-0.0033	-0.0182	**-0.0295**	-0.0194	0.0144	0.0188	-0.022	0.005	-0.0071	0.0217	0.4926
C15	0.0112	0.0087	0.0086	-0.0087	-0.017	-0.0183	-0.0172	-0.0151	0.0018	-0.0094	-0.0121	-0.0024	-0.0225	-0.021	**-0.032**	0.0073	0.0119	-0.0135	0.0002	-0.0202	0.0184	0.5555
C16	-0.0016	-0.0014	-0.001	0	-0.0052	-0.0021	0.0028	0.0016	0.0026	-0.0004	0.0035	-0.0042	0.0001	0.0089	0.0042	**-0.0183**	-0.0122	0.0132	0.0066	-0.0037	-0.0049	0.089
C17	0.0082	0.0075	0.006	-0.0058	0.0048	-0.0011	-0.0142	-0.0126	0.0021	-0.0038	-0.0055	0.0062	-0.007	-0.0157	-0.0092	0.0165	**0.0247**	-0.0208	-0.0049	0.0011	0.018	-0.0889
C18	-0.0208	-0.0234	-0.0225	0.0136	-0.0079	0.0067	0.0253	0.0231	-0.0057	0.0113	0.0229	0.0002	0.015	0.0388	0.0219	-0.0375	-0.0438	**0.0521**	0.0068	-0.0053	-0.0319	0.2224
C19	-0.0051	0.0001	0.001	-0.0037	-0.0007	-0.0032	-0.0027	-0.0015	-0.0025	0.008	0.0017	0.0006	0.0052	0.0039	0.0001	0.0081	0.0045	-0.0029	**-0.0226**	0.0032	0.0029	-0.2235
C20	-0.0393	-0.021	-0.0423	0.0624	0.1239	0.0871	0.059	0.0662	-0.0533	0.0495	0.038	0.0304	0.1216	0.0352	0.092	0.0298	0.0062	-0.0148	-0.0208	**0.1458**	-0.0446	0.7348
C21	0.048	0.0363	0.0284	-0.057	-0.0248	-0.0555	-0.0923	-0.0891	0.0362	-0.0339	-0.0445	-0.0027	-0.0595	-0.0723	-0.0566	0.0265	0.0717	-0.0602	-0.0125	-0.0301	**0.0985**	-0.4327

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17- Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

4.3.2.2. 50% blossoming days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* first blossoming days (0.0828), harvest maturity days (0.0722), flower drop (%)(0.0345), electrolyte leakage index (%)(0.0284), biological yield plant^{-1} (0.0107) and lipid peroxidation (nmol/ml) (0.0072) whereas indirect negative impacts *via.,* proline content (-0.0419), test weight (gm) (-0.0305), total chlorophyll content (mg/ml) (-0.0304), harvest index (%) (-0.0274), seeds capsule^{-1} (-0.0266), capsules plant^{-1} (-0.0266), relative leaf water content (%) (-0.0255), secondary offshoots plant-1 (-0.0235), plant height (-0.0214), full capsules plant^{-1} (-0.0188), primary offshoots plant^{-1} (-0.0137), pollen viability (%)(-0.0135), empty capsules plant^{-1} (-0.0117) and ascorbic acid content (mg) (-0.0005).

4.3.2.3. Harvest maturity days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* plant height (0.0553), proline content (mg/gm) (0.055), harvest index (%) (0.0447), test weight (gm) (0.0429), full capsules plant^{-1} (0.0405), primary offshoots plant^{-1} (0.0379), pollen viability (%)(0.0368), capsules plant-1 (0.0365), secondary offshoots plant^{-1} (0.036), relative leaf water content (%) (0.034), total chlorophyll content (mg/ml) (0.0315), seeds capsule^{-1} (0.0297), biological yield plant^{-1} (0.0234) and ascorbic acid content (mg) (0.0054) whereas indirect negative impacts *via.,* first blossoming days (-0.0984), 50% blossoming days (-0.0982), flower drop (%)(-0.0367), empty capsules plant^{-1} (-0.0314), electrolyte leakage index (%)(-0.0311) and lipid peroxidation (nmol/ml) (-0.007).

4.3.2.4. Plant height

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(0.0812), empty capsules plant^{-1} (0.0682), harvest maturity days (0.061), first blossoming days (0.044), electrolyte leakage index (%)(0.0332) and 50% blossoming days (0.0321) whereas indirect negative impacts *via.,* full capsules plant^{-1} (-0.1085), capsules plant^{-1} (-0.1037), secondary offshoots plant^{-1} (-0.0969), primary offshoots plant^{-1} (-0.0864), seeds capsule^{-1} (-0.0766), pollen viability (%)(-0.06), harvest index (%) (-0.0589), total chlorophyll content (mg/ml) (-0.0455), relative leaf water content (%) (-0.0383), proline content (-0.0366), biological yield plant^{-1} (-0.0259), ascorbic acid content (mg) (-0.0231), test weight (gm) (-0.0155) and lipid peroxidation (nmol/ml) (-0.0001).

4.3.2.5. Primary offshoots plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* harvest maturity days (0.0062), empty capsules plant^{-1} (0.0052), flower drop (%) (0.0052), first blossoming days (0.0047), proline content (0.0031) and 50% blossoming days (0.003) whereas indirect negative impacts *via.,* pollen viability (%)(-0.0175), secondary offshoots plant^{-1} -0.0163), plant height (-0.0127), harvest index (%) (-0.0121), seeds capsule^{-1} (-0.0115), relative leaf water content (%) (-0.011), full capsules plant^{-1} (-0.01), capsules plant^{-1} (-0.0099), biological yield plant^{-1} (-0.0088), lipid peroxidation (nmol/ml) (-0.0059), electrolyte leakage index (%)(-0.004), test weight (gm) (-0.003), total chlorophyll content (mg/ml) (-0.0027) and ascorbic acid content (mg) (-0.0007).

4.3.2.6. Secondary offshoots plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%) (0.0228), empty capsules plant^{-1} (0.0123), harvest maturity days (0.0115), first blossoming days (0.0105), 50% blossoming days (0.0101) and electrolyte leakage index (%)(0.0017) whereas indirect negative impacts *via.,* primary offshoots plant^{-1} (-0.0318), capsules plant^{-1} (-0.0308), full capsules plant^{-1} (-0.0298), plant height (-0.0279), harvest index (%) (-0.026), pollen viability (%)(-0.0242), relative leaf water content (%) (-0.0231), seeds capsule^{-1} (-0.0229), biological yield plant^{-1} (-0.0181), test weight (gm) (-0.0166), total chlorophyll content (mg/ml) (-0.0159), ascorbic acid content (mg) (-0.0057), proline content (-0.0052) and lipid peroxidation (nmol/ml) (-0.0046).

4.3.2.7. Capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%) (0.8062), electrolyte leakage index (%)(0.4941), first blossoming days (0.3459), empty capsules plant^{-1} (0.3184), harvest maturity days (0.2473), 50% blossoming days (0.2448) and lipid peroxidation (nmol/ml) (0.132) whereas indirect negative impacts *via.,* full capsules plant^{-1} (-0.8242), primary offshoots plant^{-1} (-0.655), plant height (-0.636), seeds capsule^{-1} (-0.4582), harvest index (%) (-0.5294), total chlorophyll content (mg/ml) (-0.5285), relative leaf water content (%) (-0.4637), proline content (-0.4171), primary offshoots plant^{-1} (-0.4119), pollen viability (%)(-0.3481), test weight (gm) (-0.2861), biological yield plant^{-1} (-0.1121) and ascorbic acid content (mg) (-0.1034).

4.3.2.8. Full capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* capsules plant^{-1} (1.1841), plant height (0.9564), secondary offshoots plant^{-1} (0.9104), harvest index (%) (0.8335), total chlorophyll content (mg/ml) (0.7118), primary offshoots plant^{-1} (0.596), seeds capsule^{-1} (0.5942), relative leaf water content (%) (0.5838), pollen viability (%)(0.5613), proline content (0.5475), test weight (gm) (0.4643), biological yield plant^{-1} (0.3339) and ascorbic acid content (mg) (0.083) whereas indirect negative impacts *via.,* flower drop (%)(-1.1177), empty capsules plant^{-1} (-0.7669), electrolyte leakage index (%)(-0.6315), first blossoming days (-0.4588), harvest maturity days (-0.3939), 50% blossoming days (-0.2491) and lipid peroxidation (nmol/ml) (-0.1058).

4.3.2.9. Empty capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(0.1355), harvest maturity days (0.091), ascorbic acid content (mg) (0.041), first blossoming days (0.0381) and electrolyte leakage index (%)(0.0313) whereas indirect negative impacts *via.,* full capsules plant^{-1} (-0.2286), biological yield plant^{-1} (-0.1915), harvest index (%) (-0.1853), plant height (-0.1791), capsules plant^{-1} (-0.1364), pollen viability (%)(-0.1347), test weight (gm) (-0.1135), secondary offshoots plant^{-1} (-0.1124), primary offshoots plant^{-1} (-0.0933), total chlorophyll content (mg/ml) (-0.0686), lipid peroxidation (nmol/ml) (-0.0525), 50% blossoming days (-0.0461), proline content (-0.0403), seeds capsule^{-1} (-0.0373) and relative leaf water content (%) (-0.0208).

4.3.2.10. Seeds capsule^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* secondary offshoots plant^{-1} (0.0307), primary offshoots plant^{-1} (0.0303), plant height (0.0296), capsules plant^{-1} (0.0289), full capsules plant^{-1} (0.0261), biological yield plant^{-1} (0.0226), pollen viability (%)(0.0184), total chlorophyll content (mg/ml) (0.0165), relative leaf water content (%) (0.016), harvest index (%) (0.015), proline content (0.0118) and lipid peroxidation (nmol/ml) (0.0011) whereas indirect negative impacts *via.,* ascorbic acid content (mg) (-0.0193), flower drop (%)(-0.0187), 50% blossoming days (-0.0154), harvest maturity days (-0.0127), first blossoming days (-0.0117), electrolyte leakage index (%)(-0.0083), test weight (gm) (-0.0058) and empty capsules plant^{-1} (-0.0055).

4.3.2.11. Test weight (gm)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* harvest index (%) (0.0539), total chlorophyll content (mg/ml) (0.0508), proline content (0.0431), biological yield plant^{-1} (0.0427), secondary offshoots plant^{-1} (0.0401), relative leaf water content (%) (0.0371), full capsules plant^{-1} (0.0368), capsules plant^{-1} (0.0325), pollen viability (%)(0.0255), primary offshoots plant^{-1} (0.0143) and plant height (0.0108) whereas indirect negative impacts *via.,* flower drop (%)(-0.0442), first blossoming days (-0.0347), harvest maturity days (-0.033), 50% blossoming days (-0.0319), empty capsules plant^{-1} (-0.0301),), electrolyte leakage index (%)(-0.0218), lipid peroxidation (nmol/ml) (-0.0187), seeds capsule^{-1} (-0.0105) and ascorbic acid content (mg) (-0.0073).

4.3.2.12. Biological yield plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* secondary offshoots plant^{-1} (0.1921), test weight (gm) (0.1869), primary offshoots plant^{-1} (0.1818), seeds capsule^{-1} (0.1781), full capsules plant^{-1} (0.1157), electrolyte leakage index (%)(0.1074), harvest index (%) (0.1052), lipid peroxidation (nmol/ml) (0.0979), pollen viability (%)(0.0893), plant height (0.0789), capsules plant^{-1} (0.0558), 50% blossoming days (0.0489), total chlorophyll content (mg/ml) (0.0471), first blossoming days (0.0378), relative leaf water content (%) (0.0327) and proline content (0.002) whereas indirect negative impacts *via.,* empty capsules plant^{-1} (-0.2226), harvest maturity days (-0.0787), flower drop (%)(-0.0115) and ascorbic acid content (mg) (-0.011).

4.3.2.13. Harvest index (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* pollen viability (%)(0.5254), relative leaf water content (%) (0.4433), full capsules plant^{-1} (0.4252), secondary offshoots plant^{-1} (0.405), total chlorophyll content (mg/ml) (0.3892), capsules plant^{-1} (0.388), primary offshoots plant^{-1} (0.3693 test weight (gm) (0.3473), plant height (0.2648), proline content (0.1814), seeds capsule^{-1} (0.174) and biological yield plant^{-1} (0.1549) whereas indirect negative impacts *via.,* flower drop (%)(-0.3812), empty capsules plant^{-1} (-0.317), first blossoming days (-0.2557), harvest maturity days (-0.2218), 50% blossoming days (-0.1848), electrolyte leakage index (%)(-0.1795), ascorbic acid content (mg) (-0.1461) and lipid peroxidation (nmol/ml) (-0.0039).

4.3.2.14. Total chlorophyll content (mg/ml)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(0.0217), electrolyte leakage index (%)(0.0188), lipid peroxidation (nmol/ml) (0.0144), first blossoming days (0.0113), 50% blossoming days (0.0096), harvest maturity days (0.0073), empty capsules plant^{-1} (0.0055) and ascorbic acid content (mg) (0.005) whereas indirect negative impacts *via.,* proline content (-0.022), relative leaf water content (%) (-0.0194), harvest index (%) (-0.0182), capsules plant^{-1} (-0.0181), full capsules plant^{-1} (-0.017), test weight (gm) (-0.0153), secondary offshoots plant^{-1} (-0.0116), plant height (-0.0096), seeds capsule^{-1} (-0.009), pollen viability (%)(-0.0071), primary offshoots plant^{-1} (-0.0039) and biological yield plant^{-1} (-0.0033).

4.3.2.15. Relative leaf water content (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(0.0184), electrolyte leakage index (%)(0.0119), first blossoming days (0.0112), 50% blossoming days (0.0087), harvest maturity days (0.0086), lipid peroxidation (nmol/ml) (0.0073), empty capsules plant^{-1} (0.0018) and ascorbic acid content (mg) (0.0002) whereas indirect negative impacts *via.,* harvest index (%) (-0.0225), total chlorophyll content (mg/ml) (-0.021), pollen viability (%)(-0.0202), secondary offshoots plant^{-1} (-0.0183), capsules plant^{-1} (-0.0172), primary offshoots plant^{-1} (-0.017), full capsules plant^{-1} (-0.0151), proline content (-0.0135), test weight (gm) (-0.0121), seeds capsule^{-1} (-0.0094), plant height (-0.0087) and biological yield plant^{-1} (-0.0024).

4.3.2.16. Lipid Peroxidation (nmol/ml)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* proline content (0.0132), total chlorophyll content (mg/ml) (0.0089), ascorbic acid content (mg) (0.0066), lipid peroxidation (nmol/ml) (0.0042), test weight (gm) (0.0035), capsules plant^{-1} (0.0028), empty capsules plant^{-1} (0.0026), full capsules plant^{-1} (0.0016), harvest index (%) (0.0001) and plant height (0.0001) whereas indirect negative impacts *via.,* electrolyte leakage index (%)(-0.0122), primary offshoots plant^{-1} (-0.0052), flower drop (%)(-0.0049), biological yield plant^{-1} (-0.0042), pollen viability (%)(-0.0037), secondary offshoots plant^{-1} (-0.0021), first blossoming days (-0.0016), 50% blossoming days (-0.0014), harvest maturity days (-0.001) and seeds capsule^{-1} (-0.0004).

4.3.2.17. Electrolyte leakage index

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(0.018), lipid peroxidation (nmol/ml) (0.0165), first blossoming days (0.0082), 50% blossoming days (0.0075), biological yield plant^{-1} (0.0062), harvest maturity days (0.006), primary offshoots plant^{-1} (0.0048), empty capsules plant^{-1} (0.0021) and pollen viability (%)(0.0011) whereas indirect negative impacts *via.,* proline content (-0.0208), total chlorophyll content (mg/ml) (-0.0157), capsules plant^{-1} (-0.0142), full capsules plant^{-1} (-0.0126), relative leaf water content (%) (-0.0092), harvest index (%) (-0.007), plant height (-0.0058), test weight (gm) (-0.0055), ascorbic acid content (mg) (-0.0049), seeds capsule^{-1} (-0.0038) and secondary offshoots plant^{-1} (-0.0011).

4.3.2.18. Proline content (mg/gm)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* total chlorophyll content (mg/ml) (0.0388), capsules plant^{-1} (0.0253), full capsules plant^{-1} (0.0231), test weight (gm) (0.0229), relative leaf water content (%) (0.0219), harvest index (%) (0.015), plant height 0.0136), seeds capsule^{-1} (0.0113), ascorbic acid content (mg) (0.0068), secondary offshoots plant^{-1} (0.0067) and biological yield plant^{-1} (0.0002) whereas indirect negative impacts *via.,* electrolyte leakage index (%)(-0.0438), lipid peroxidation (nmol/ml) (-0.0375), flower drop (%)(-0.0319), 50% blossoming days (-0.0234), harvest maturity days (-0.0225), first blossoming days (-0.0208), primary offshoots plant^{-1} (-0.0079), empty capsules plant^{-1} (-0.0057) and pollen viability (%)(-0.0053).

4.3.2.19. Ascorbic acid content (mg)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* lipid peroxidation (nmol/ml) (0.0081), seeds capsule^{-1} (0.008), harvest index (%) (0.0052), electrolyte leakage index (%)(0.0045), total chlorophyll content (mg/ml) (0.0039), pollen viability (%)(0.0032), flower drop (%)(0.0029), test weight (gm) (0.0017), harvest maturity days (0.001), biological yield plant^{-1} (0.0006), 50% blossoming days (0.0001) and relative leaf water content (%) (0.0001) whereas indirect negative impacts *via.,* first blossoming days (-0.0051), plant height (-0.0037), secondary offshoots plant^{-1} (-0.0032), proline content (-0.0029), capsules plant^{-1} (-0.0027), empty capsules plant^{-1} (-0.0025), full capsules plant^{-1} (-0.0015) and primary offshoots plant^{-1} (-0.0007).

4.3.2.20. Pollen viability

It imposed positive indirect impact on seed yield plant^{-1} *via.,* primary offshoots plant^{-1} (0.1239), harvest index (%) (0.1216), relative leaf water content (%) (0.092), secondary offshoots plant^{-1} (0.0871), electrolyte leakage index (%)(0.0662), plant height (0.0624), capsules plant^{-1} (0.059), seeds capsule^{-1} (0.0495), test weight (gm) (0.038), total chlorophyll content (mg/ml) (0.0352), biological yield plant^{-1} (0.0304), lipid peroxidation (nmol/ml) (0.0298) and electrolyte leakage index (%)(0.0062) whereas indirect negative impacts *via.,* empty capsules plant^{-1} (-0.0533), flower drop (%)(-0.0446), harvest maturity days (-0.0423), first blossoming days (-0.0393), 50% blossoming days (-0.021), ascorbic acid content (mg) (-0.0208) and proline content (-0.0148).

4.3.2.21. Flower drop (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* electrolyte leakage index (%)(0.0717), first blossoming days (0.048), 50% blossoming days (0.0363), empty capsules plant^{-1} (0.0362), harvest maturity days (0.0284) and lipid peroxidation (nmol/ml) (0.0265) whereas indirect negative impacts *via.,* capsules plant^{-1} (-0.0923), full capsules plant^{-1} (-0.0891), total chlorophyll content (mg/ml) (-0.0723), proline content (-0.0602), harvest index (%) (-0.0595), plant height (-0.057), relative leaf water content (%) (-0.0566), secondary offshoots plant^{-1} (-0.0555), test weight (gm) (-0.0445), seeds capsule^{-1} (-0.0339), pollen viability (%)(-0.0301), primary offshoots plant^{-1} (-0.0248), ascorbic acid content (mg) (-0.0125) and biological yield plant^{-1} (-0.0027).

Second sowing date [EN-2]

Table 4.15 illustrates the path coefficient analysis estimates

4.3.1. Direct impact of various characters on seed yield plant^{-1}

Full capsules plant^{-1} (1.4058), harvest index (%) (0.4784), biological yield plant^{-1} (0.4648), empty capsules plant^{-1} (0.2028), 50% blossoming days (0.1507), pollen viability (%)(0.1026), flower drop (%)(0.0706), ascorbic acid content (mg) (0.0387), secondary offshoots plant^{-1} (0.0215), total chlorophyll content (mg/ml) (0.0168) and proline content (0.0097) imposed direct positive impacts on seed yield plant^{-1} whereas, capsules plant^{-1} (-1.32), harvest maturity days (-0.2821), electrolyte leakage index (%)(-

0.1238), first blossoming days (-0.1112), relative leaf water content (%) (-0.1022), primary offshoots plant^{-1} (-0.0852), seeds capsule^{-1} (-0.0809), plant height (-0.0422), test weight (gm) (-0.0283) and lipid peroxidation (nmol/ml) (-0.0267) had direct negative impacts on seed yield plant^{-1}.

4.3.2. Indirect impacts of various characters on seed yield plant^{-1}

4.3.2.1. First blossoming days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* plant height (0.099), seeds capsule^{-1} (0.0971), relative leaf water content (%) (0.0961), total chlorophyll content (mg/ml) (0.0926), proline content (0.0852), capsules plant^{-1} (0.0827), harvest index (%) (0.0819), biological yield plant^{-1} (0.0804), full capsules plant-1 (0.0803), secondary offshoots plant^{-1} (0.0728), primary offshoots plant^{-1} (0.0639), pollen viability (%)(0.0629) and test weight (gm) (0.0611) whereas indirect negative impacts *via.,* 50% blossoming days (-0.106), harvest maturity days (-0.1034), flower drop (%)(-0.0616), electrolyte leakage index (%)(-0.039), empty capsules plant^{-1} (-0.0175), lipid peroxidation (nmol/ml) (-0.0171) and ascorbic acid content (mg) (-0.0027).

4.3.2.2. 50% blossoming days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* first blossoming days (0.1436), harvest maturity days (0.1519), flower drop (%)(0.1075), electrolyte leakage index (%)(0.0534), lipid peroxidation (nmol/ml) (0.0309), empty capsules plant^{-1} (0.0305) and ascorbic acid content (mg) (0.0168) however, negative impacts *via.,* total chlorophyll content (mg/ml) (-0.1344), plant height (-0.1335), relative leaf water content (%) (-0.1309), capsules plant^{-1} (-0.1299), seeds capsule^{-1} (-0.1285), full capsules plant^{-1} (-0.1266), proline content (-0.1241), harvest index (%) (-0.1128), secondary offshoots plant^{-1} (-0.0999), primary offshoots plant^{-1} (-0.0946), biological yield plant^{-1} (-0.093), pollen viability (%)(-0.0767) and test weight (gm) (-0.0751).

4.3.2.3. Harvest maturity days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* plant height (0.2413), relative leaf water content (%) (0.2266), total chlorophyll content (mg/ml) (0.2223), harvest index (%) (0.2197), capsules plant^{-1} (0.2141), proline content (0.2141), full capsules plant^{-1} (0.2087), secondary offshoots plant-1 (0.2042), seeds capsule^{-1} (0.1902), primary offshoots plant^{-1} (0.1805), biological yield plant^{-1} (0.1654), pollen viability (%)(0.1562), test weight (gm) (0.1263) and ascorbic acid content (mg) (0.0312) whereas indirect negative impacts *via.,* 50% blossoming days (-0.2845), first blossoming days (-0.2624), flower drop (%)(-0.1676), electrolyte leakage index (%)(-0.062), empty capsules plant^{-1} (-0.0499) and lipid peroxidation (nmol/ml) (-0.0364).

4.3.2.4. Plant height

It imposed positive indirect impact on seed yield plant^{-1} *via.,* first blossoming days (0.0376), 50% blossoming days (0.0374), harvest maturity days (0.0361), flower drop (%)(0.0252), electrolyte leakage index (%)(0.0167), empty capsules plant^{-1} (0.016), lipid peroxidation (nmol/ml) (0.0063) and ascorbic acid content (mg) (0.0019) whereas indirect negative impacts *via.,* total chlorophyll content (mg/ml) (-0.0351), harvest index (%) (-0.0357), full capsules plant^{-1} (-0.0344), capsules plant^{-1} (-0.034), biological yield plant^{-1} (-0.033), relative leaf water content (%) (-0.0324), proline content (-0.0319), pollen viability (%)(-0.0283), secondary offshoots plant^{-1} (-0.0281), seeds capsule^{-1} (-0.0275), primary offshoots plant^{-1} (-0.0249) and test weight (gm) (-0.0232).

Table 4.15: Coefficients of genotypic path depicting direct and indirect impacts on seed yield plant^{-1} (EN-2)

Character	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	**-0.1112**	-0.106	-0.1034	0.099	0.0639	0.0728	0.0827	0.0803	-0.0175	0.0971	0.0611	0.0804	0.0819	0.0926	0.0961	-0.0171	-0.039	0.0852	-0.0027	0.0629	-0.0616	-0.7602
C2	0.1436	**0.1507**	0.1519	-0.1335	-0.0946	-0.0999	-0.1299	-0.1266	0.0305	-0.1285	-0.0751	-0.093	-0.1128	-0.1344	-0.1309	0.0309	0.0534	-0.1241	0.0168	-0.0767	0.1075	-0.709
C3	-0.2624	-0.2845	**-0.2821**	0.2413	0.1805	0.2042	0.2141	0.2087	-0.0499	0.1902	0.1263	0.1654	0.2197	0.2223	0.2266	-0.0364	-0.062	0.2141	0.0312	0.1562	-0.1676	-0.7269
C4	0.0376	0.0374	0.0361	**-0.0422**	-0.0249	-0.0281	-0.034	-0.0344	0.016	-0.0275	-0.0232	-0.033	-0.0357	-0.0351	-0.0324	0.0063	0.0167	-0.0319	0.0019	-0.0283	0.0252	0.8553
C5	0.0489	0.0535	0.0545	-0.0502	**-0.0852**	-0.0912	-0.0436	-0.0443	0.0209	-0.0392	-0.0329	-0.0202	-0.0493	-0.0671	-0.0573	0.0145	0.0375	-0.0642	-0.0387	-0.0352	0.0432	0.4414
C6	-0.0141	-0.0142	-0.0155	0.0143	0.023	**0.0215**	0.0094	0.0095	-0.0043	0.0107	0.0084	0.0104	0.0139	0.0164	0.0158	0.0012	-0.0071	0.016	0.0095	0.0105	-0.0082	0.5919
C7	0.9816	1.1376	1.0019	-1.0625	-0.6763	-0.5795	**-1.32**	-1.3044	0.4177	-0.6636	-0.5484	-0.8787	-1.0106	-0.9782	-0.7538	0.391	0.5623	-0.9549	-0.1541	-0.6303	0.9063	0.7538
C8	-1.0154	-1.1811	-1.04	1.1463	0.7306	0.6242	1.3891	**1.4058**	-0.6442	0.7193	0.6594	0.9688	1.1313	1.0548	0.8502	-0.4185	-0.6545	1.0101	0.1854	0.7845	-1.0052	0.7877
C9	0.032	0.041	0.0359	-0.0769	-0.0497	-0.041	-0.0642	-0.093	**0.2028**	-0.051	-0.1	-0.0821	-0.1096	-0.0702	-0.0875	0.0253	0.0833	-0.051	-0.0283	-0.1388	0.0899	-0.5032
C10	0.0706	0.069	0.0546	-0.0528	-0.0373	-0.0401	-0.0407	-0.0414	0.0203	**-0.0809**	-0.0326	-0.0397	-0.0467	-0.0542	-0.0525	0.0073	0.0258	-0.0535	-0.0298	-0.0384	0.0381	0.542
C11	0.0155	0.0141	0.0127	-0.0155	-0.0109	-0.011	-0.0118	-0.0133	0.014	-0.0114	**-0.0283**	-0.0121	-0.0132	-0.0166	-0.0124	0.0063	0.0114	-0.0183	-0.0049	-0.0061	0.0143	0.4574
C12	-0.336	-0.287	-0.2725	0.3626	0.1104	0.2259	0.3094	0.3203	-0.1882	0.2282	0.1994	**0.4648**	0.3487	0.2816	0.2449	0.0065	-0.1072	0.2616	0.0018	0.2701	-0.1449	0.9177
C13	-0.3525	-0.3583	-0.3726	0.4046	0.2769	0.3091	0.3663	0.385	-0.2585	0.2758	0.2232	0.359	**0.4784**	0.35	0.3404	-0.0358	-0.1776	0.3288	0.1506	0.3733	-0.2276	0.949
C14	-0.014	-0.015	-0.0133	0.014	0.0133	0.0128	0.0125	0.0126	-0.0058	0.0113	0.0099	0.0102	0.0123	**0.0168**	0.0132	-0.0063	-0.01	0.0151	0.0048	0.0089	-0.013	0.7017
C15	0.0883	0.0888	0.0821	-0.0785	-0.0687	-0.0752	-0.0584	-0.0618	0.0441	-0.0663	-0.0447	-0.0539	-0.0727	-0.0802	**-0.1022**	0.0251	0.0561	-0.0741	0.001	-0.065	0.0664	0.6589
C16	-0.0041	-0.0055	-0.0034	0.004	0.0046	-0.0015	0.0079	0.008	-0.0033	0.0024	0.0059	-0.0004	0.002	0.01	0.0066	**-0.0267**	-0.0165	0.0121	-0.0055	0.0001	-0.0204	-0.0456
C17	-0.0434	-0.0439	-0.0272	0.0491	0.0545	0.0412	0.0527	0.0576	-0.0509	0.0394	0.0497	0.0285	0.0459	0.0738	0.0679	-0.0762	**-0.1238**	0.0888	0.022	0.0186	-0.0945	-0.3265
C18	-0.0074	-0.008	-0.0073	0.0073	0.0073	0.0072	0.007	0.0069	-0.0024	0.0064	0.0062	0.0054	0.0066	0.0087	0.007	-0.0044	-0.0069	**0.0097**	0.0025	0.0026	-0.0077	0.6508
C19	0.0009	0.0043	-0.0043	-0.0018	0.0176	0.0171	0.0045	0.0051	-0.0054	0.0142	0.0067	0.0002	0.0122	0.011	-0.0004	0.008	-0.0069	0.0101	**0.0387**	-0.0067	0.0026	0.1892
C20	-0.058	-0.0522	-0.0568	0.0688	0.0424	0.0503	0.049	0.0573	-0.0702	0.0487	0.0222	0.0596	0.0801	0.0541	0.0653	-0.0003	-0.0154	0.0278	-0.0178	**0.1026**	-0.0288	0.745
C21	0.0391	0.0504	0.0419	-0.0421	-0.0358	-0.0268	-0.0485	-0.0505	0.0313	-0.0332	-0.0358	-0.022	-0.0336	-0.0543	-0.0459	0.0538	0.0539	-0.0566	0.0047	-0.0198	**0.0706**	-0.4153

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17- Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

4.3.2.5. Primary offshoots plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* harvest maturity days (0.0545), 50% blossoming days (0.0535), first blossoming days (0.0489), flower drop (%)(0.0432), electrolyte leakage index (%)(0.0375), empty capsules plant^{-1} (0.0209) and lipid peroxidation (nmol/ml) (0.0145) whereas indirect negative impacts *via.,* secondary offshoots plant^{-1} (-0.0912), total chlorophyll content (mg/ml) (-0.0671), proline content (-0.0642), relative leaf water content (%) (-0.0573), plant height (-0.0502), harvest index (%) (-0.0493), full capsules plant^{-1} (-0.0443), capsules plant^{-1} (-0.0436), seeds capsule^{-1} (-0.0392), ascorbic acid content (mg) (-0.0387), pollen viability (%)(-0.0352), test weight (gm) (-0.0329) and biological yield plant^{-1} (-0.0202).

4.3.2.6. Secondary offshoots plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* primary offshoots plant^{-1} (0.023), total chlorophyll content (mg/ml) (0.0164), proline content (0.016), relative leaf water content (%) (0.0158), plant height (0.0143), harvest index (%) (0.0139), seeds capsule^{-1} (0.0107), pollen viability (%)(0.0105), biological yield plant^{-1} (0.0104), full capsules plant^{-1} (0.0095), ascorbic acid content (mg) (0.0095), capsules plant^{-1} (0.0094), test weight (gm) (0.0084) and lipid peroxidation (nmol/ml) (0.0012) whereas indirect negative impacts *via.,* harvest maturity days (-0.0155), 50% blossoming days (-0.0142), first blossoming days (-0.0141), flower drop (%)(-0.0082), electrolyte leakage index (%)(-0.0071) and empty capsules plant^{-1} (-0.0043).

4.3.2.7. Capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* 50% blossoming days (1.1376), harvest maturity days (1.0019), first blossoming days (0.9816), flower drop (%)(0.9063), electrolyte leakage index (%)(0.5623), empty capsules plant^{-1} (0.4177) and lipid peroxidation (nmol/ml) (0.391) whereas indirect negative impacts *via.,* full capsules plant^{-1} (-1.3044), plant height (-1.0625), harvest index (%) (-1.0106), total chlorophyll content (mg/ml) (-0.9782), proline content (-0.9549), biological yield plant^{-1} (-0.8787), relative leaf water content (%) (-0.7538), primary offshoots plant^{-1} (-0.6763), seeds capsule^{-1} (-0.6636), pollen viability (%)(-0.6303), secondary offshoots plant^{-1} (-0.5795), test weight (gm) (-0.5484) and ascorbic acid content (mg) (-0.1541).

4.3.2.8. Full capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* capsules plant^{-1} (1.3891), plant height (1.1463), harvest index (%) (1.1313), total chlorophyll content (mg/ml) (1.0548), proline content (1.0101), biological yield plant^{-1} (0.9688), relative leaf water content (%) (0.8502), pollen viability (%)(0.7845), primary offshoots plant^{-1} (0.7306), seeds capsule^{-1} (0.7193), test weight (gm) (0.6594), secondary offshoots plant^{-1} (0.6242) and ascorbic acid content (mg) (0.1854) whereas indirect negative impacts *via.,* 50% blossoming days (-1.1811), harvest maturity days (-1.04), first blossoming days (-1.0154), flower drop (%)(-1.0052), electrolyte leakage index (%)(-0.6545), empty capsules plant^{-1} (-0.6442) and lipid peroxidation (nmol/ml) (-0.4185).

4.3.2.9. Empty capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%) (0.0899), electrolyte leakage index (%) (0.0833), 50% blossoming days (0.041), harvest maturity days (0.0359), first blossoming days (0.032) and lipid peroxidation (nmol/ml) (0.0253) whereas indirect negative impacts *via.* pollen viability (%)(-0.1388), harvest index (%) (-0.1096), test weight (gm) (-0.1), full capsules plant^{-1} (-0.093), relative leaf water content (%) (-0.0875), biological yield plant^{-1} (-0.0821), plant height (-0.0769), total chlorophyll content (mg/ml) (-0.0702), capsules plant^{-1} (-0.0642), proline content (-0.051), primary offshoots plant^{-1} (-0.0497), secondary offshoots plant^{-1} (-0.041) and ascorbic acid content (mg) (-0.0283).

4.3.2.10. Seeds capsule^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* first blossoming days (0.0706), 50% blossoming days (0.069), harvest maturity days (0.0546), flower drop (%)(0.0381), electrolyte leakage index (%)(0.0258), empty capsules plant^{-1} (0.0203) and lipid peroxidation (nmol/ml) (0.0073) whereas indirect negative impacts *via.,* total chlorophyll content (mg/ml) (-0.0542), proline content (-0.0535), plant height (-0.0528), relative leaf water content (%) (-0.0525), harvest index (%) (-0.0467), full capsules plant^{-1} (-0.0414), capsules plant^{-1} (-0.0407), secondary offshoots plant^{-1} (-0.0401), biological yield plant^{-1} (-0.0397), pollen viability (%)(-0.0384), primary offshoots plant^{-1} (-0.0373), test weight (gm) (-0.0326) and ascorbic acid content (mg) (-0.0298).

4.3.2.11. Test weight (gm)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* first blossoming days (0.0155), flower drop (%)(0.0143), 50% blossoming days (0.0141), empty capsules plant^{-1} (0.014), harvest maturity days (0.0127), electrolyte leakage index (%)(0.0114) and lipid peroxidation (nmol/ml) (0.0063) whereas indirect negative impacts *via.,* proline content (-0.0183), total chlorophyll content (mg/ml) (-0.0166), plant height (-0.0155), full capsules plant^{-1} (-0.0133), harvest index (%) (-0.0132), relative leaf water content (%) (-0.0124), biological yield plant^{-1} (-0.0121), capsules plant^{-1} (-0.0118), seeds capsule^{-1} (-0.0114), secondary offshoots plant^{-1} (-0.011), primary offshoots plant^{-1} (-0.0109), pollen viability (%)(-0.0061) and ascorbic acid content (mg) (-0.0049).

4.3.2.12. Biological yield plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* plant height (0.3626), harvest index (%) (0.3487), full capsules plant^{-1} (0.3203), capsules plant^{-1} (0.3094), total chlorophyll content (mg/ml) (0.2816), pollen viability (%)(0.2701), proline content (0.2616), relative leaf water content (%) (0.2449), seeds capsule^{-1} (0.2282), secondary offshoots plant^{-1} (0.2259), test weight (gm) (0.1994), primary offshoots plant^{-1} (0.1104), lipid peroxidation (nmol/ml) (0.0065) and ascorbic acid content (mg) (0.0018) whereas indirect negative impacts *via.,* first blossoming days (-0.336), 50% blossoming days (-0.287), harvest maturity days (-0.2725), empty capsules plant^{-1} (-0.1882), flower drop (%)(-0.1449) and electrolyte leakage index (%)(-0.1072).

4.3.2.13. Harvest index (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* plant height (0.4046), full capsules plant^{-1} (0.385), pollen viability (%)(0.3733), capsules plant^{-1} (0.3663), biological yield plant^{-1} (0.359), total chlorophyll content (mg/ml) (0.35), relative leaf water content (%) (0.3404), proline content (0.3288), secondary offshoots plant^{-1} (0.3091), primary offshoots plant^{-1} (0.2769), seeds capsule^{-1} (0.2758), test weight (gm) (0.2232) and ascorbic acid content (mg) (0.1506) whereas indirect negative impacts *via.,* harvest maturity days (-0.3726), 50% blossoming days (-0.3583), first blossoming days (-0.3525), empty capsules plant^{-1} (-0.2585), flower drop (%)(-0.2276), electrolyte leakage index (%)(-0.1776), and lipid peroxidation (nmol/ml) (-0.0358).

4.3.2.14. Total chlorophyll content (mg/ml)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* proline content (0.0151), plant height (0.014), primary offshoots plant^{-1} (0.0133), relative leaf water content (%) (0.0132), secondary offshoots plant^{-1} (0.0128), full capsules plant^{-1} (0.0126), capsules plant^{-1} (0.0125), harvest index (%) (0.0123), seeds capsule^{-1} (0.0113), biological yield plant^{-1} (0.0102), test weight (gm) (0.0099), pollen viability (%)(0.0089) and ascorbic acid content (mg) (0.0048) whereas indirect negative impacts *via.,* 50% blossoming days (-0.015), first blossoming days (-0.014), harvest maturity days (-0.0133), flower drop (%)(-0.013), electrolyte leakage index (%)(-0.01), lipid peroxidation (nmol/ml) (-0.0063) and empty capsules plant^{-1} (-0.0058).

4.3.2.15. Relative leaf water content (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* 50% blossoming days (0.0888), first blossoming days (0.0883), harvest maturity days (0.0821), flower drop (%)(0.0664), electrolyte leakage index (%)(0.0561), empty capsules plant^{-1} (0.0441), lipid peroxidation (nmol/ml) (0.0251) and ascorbic acid content (mg) (0.001) whereas indirect negative impacts *via.,* total chlorophyll content (mg/ml) (-0.0802), plant height (-0.0785), secondary offshoots plant^{-1} (-0.0752), proline content (-0.0741), harvest index (%) (-0.0727), primary offshoots plant^{-1} (-0.0687), seeds capsule^{-1} (-0.0663), pollen viability (%)(-0.065), full capsules plant^{-1} (-0.0618), capsules plant^{-1} (-0.0584), biological yield plant^{-1} (-0.0539) and test weight (gm) (-0.0447).

4.3.2.16. Lipid Peroxidation (nmol/ml)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* proline content (0.0121), total chlorophyll content (mg/ml) (0.01), full capsules plant^{-1} (0.008), capsules plant^{-1} (0.0079), relative leaf water content (%) (0.0066), test weight (gm) (0.0059), primary offshoots plant^{-1} (0.0046), plant height (0.004), seeds capsule^{-1} (0.0024), 50% blossoming days (-0.0055), harvest index (%) (0.002) and pollen viability (%)(0.0001) whereas indirect negative impacts *via.,* flower drop (%)(-0.0204), electrolyte leakage index (%)(-0.0165), ascorbic acid content (mg) (-0.0055), first blossoming days (-0.0041), harvest maturity days (-0.0034), empty capsules plant^{-1} (-0.0033), secondary offshoots plant^{-1} (-0.0015) and biological yield plant^{-1} (-0.0004).

4.3.2.17. Electrolyte leakage index

It imposed positive indirect impact on seed yield plant^{-1} *via.,* proline content (0.0888), total chlorophyll content (mg/ml) (0.0738), relative leaf water content (%) (0.0679), full capsules plant^{-1} (0.0576), primary offshoots plant^{-1} (0.0545), capsules plant^{-1} (0.0527), test weight (gm) (0.0497), plant height (0.0491), harvest index (%) (0.0459), secondary offshoots plant^{-1} (0.0412), seeds capsule^{-1} (0.0394), biological yield plant^{-1} (0.0285), ascorbic acid content (mg) (0.022) and pollen viability (%)(0.0186) whereas indirect negative impacts *via.,* flower drop (%)(-0.0945), lipid peroxidation (nmol/ml) (-0.0762), empty capsules plant^{-1} (-0.0509), 50% blossoming days (-0.0439), first blossoming days (-0.0434) and harvest maturity days (-0.0272).

4.3.2.18. Proline content (mg/gm)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* total chlorophyll content (mg/ml) (0.0087), primary offshoots plant^{-1} (0.0073), plant height (0.0073), secondary offshoots plant^{-1} (0.0072), relative leaf water content (%) (0.007), capsules plant^{-1} (0.007), full capsules plant^{-1} (0.0069), harvest index (%) (0.0066), seeds capsule^{-1} (0.0064), test weight (gm) (0.0062), biological yield plant^{-1} (0.0054), pollen viability (%)(0.0026) and ascorbic acid content (mg) (0.0025) whereas indirect negative impacts *via.,* 50% blossoming days (-0.008), flower drop (%)(-0.0077), first blossoming days (-0.0074), harvest maturity days (-0.0073), electrolyte leakage index (%)(-0.0069), lipid peroxidation (nmol/ml) (-0.0044) and empty capsules plant^{-1} (-0.0024).

4.3.2.19. Ascorbic acid content (mg)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* primary offshoots plant^{-1} (0.0176), secondary offshoots plant^{-1} (0.0171), seeds capsule^{-1} (0.0142), harvest index (%) (0.0122), total chlorophyll content (mg/ml) (0.011), proline content (0.0101), lipid peroxidation (nmol/ml) (0.008), test weight (gm) (0.0067), full capsules plant^{-1} (0.0051), capsules plant^{-1} (0.0045), 50% blossoming days (0.0043), flower drop (%)(0.0026), first blossoming days (0.0009) and biological yield plant^{-1}(0.0002) whereas indirect negative impacts *via.,* electrolyte leakage index (%)(-0.0069), pollen viability (%)(-0.0067), empty capsules plant^{-1} (-0.0054), harvest maturity days (-0.0043), plant height (-0.0018) and relative leaf water content (%) (-0.0004).

4.3.2.20. Pollen viability

It imposed positive indirect impact on seed yield plant^{-1} *via.,* harvest index (%) (0.0801), plant height (0.0688), relative leaf water content (%) (0.0653), biological yield plant^{-1} (0.0596), full capsules plant^{-1} (0.0573), total chlorophyll content (mg/ml) (0.0541), secondary offshoots plant^{-1} (0.0503), capsules plant^{-1} (0.049), seeds capsule^{-1} (0.0487), primary offshoots plant^{-1} (0.0424), proline content (0.0278) and test weight (gm) (0.0222) whereas indirect negative impacts *via.,* empty capsules plant^{-1}(-0.0702), first blossoming days (-0.058), harvest maturity days (-0.0568), 50% blossoming days (-0.0522), flower drop (%)(-0.0288), ascorbic acid content (mg) (-0.0178), electrolyte leakage index (%)(-0.0154) and lipid peroxidation (nmol/ml) (-0.0003).

4.3.2.21. Flower drop (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* electrolyte leakage index (%)(0.0539), lipid peroxidation (nmol/ml) (0.0538), 50% blossoming days (0.0504), harvest maturity days (0.0419), first blossoming days (0.0391), empty capsules plant^{-1} (0.0313) and ascorbic acid content (mg) (0.0047) whereas indirect negative impacts *via.,* proline content (-0.0566), total chlorophyll content (mg/ml) (-0.0543), full capsules plant^{-1} (-0.0505), capsules plant^{-1} (-0.0485), relative leaf water content (%) (-0.0459), plant height (-0.0421), test weight (gm) (-0.0358), harvest index (%) (-0.0336), seeds capsule^{-1} (-0.0332), secondary offshoots plant^{-1} (-0.0268), biological yield plant^{-1} (-0.022) and pollen viability (%)(-0.0198).

Third sowing date [EN-3]

Table 4.16 illustrates the path coefficient analysis estimates.

4.3.1. Direct impact of various characters on seed yield plant^{-1}

Harvest index (%) (0.5695), biological yield plant^{-1} (0.4463), full capsules plant^{-1} (0.2007), lipid peroxidation (nmol/ml) (0.0861), total chlorophyll content (mg/ml) (0.0661), empty capsules plant^{-1} (0.0579), flower drop (%)(0.0514), relative leaf water content (%) (0.0419), secondary offshoots plant^{-1} (0.0355), seeds capsule^{-1} (0.0297), pollen viability (%)(0.0097), proline content (0.007), harvest maturity days (0.0052) and plant height (0.0019) imposed direct positive impacts on seed yield plant^{-1} whereas., capsules plant^{-1} (-0.1075), primary offshoots plant^{-1} (-0.0704), 50% blossoming days (-

0.0409), test weight (gm) (-0.0354), first blossoming days (-0.0313), electrolyte leakage index (%) (-0.0101) and ascorbic acid content (mg) (-0.0092) had direct negative impacts.

4.3.2. Indirect impacts of various characters on seed yield plant^{-1}

4.3.2.1. First blossoming days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* full capsules plant^{-1} (0.0167), proline content (0.0166), plant height (0.0162), harvest index (%) (0.0162), relative leaf water content (%) (0.0158), capsules plant^{-1} (0.0154), pollen viability (%)(0.0151), total chlorophyll content (mg/ml) (0.0125), biological yield plant^{-1} (0.0108), ascorbic acid content (mg) (0.0095), primary offshoots plant^{-1} (0.0073), test weight (gm) (0.0071) and secondary offshoots plant^{-1} (0.0064) whereas indirect negative impacts *via.,* 50% blossoming days (-0.0266), lipid peroxidation (nmol/ml) (-0.0218), harvest maturity days (-0.0195), flower drop (%)(-0.0154), electrolyte leakage index (%)(-0.0144), empty capsules plant^{-1} (-0.0101) and seeds capsule^{-1} (-0.0015).

4.3.2.2. 50% blossoming days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* proline content (0.0212), full capsules plant^{-1} (0.0207), capsules plant^{-1} (0.0205), relative leaf water content (%) (0.0186), test weight (gm) (0.0185), secondary offshoots plant^{-1} (0.0163), plant height (0.0161), total chlorophyll content (mg/ml) (0.0149), primary offshoots plant^{-1} (0.0148), pollen viability (%)(0.0147), harvest index (%) (0.0135), ascorbic acid content (mg) (0.0135) and biological yield plant^{-1} (0.0111) however, negative impacts *via.,* first blossoming days (-0.0348), harvest maturity days (-0.033), lipid peroxidation (nmol/ml) (-0.0261), flower drop (%)(-0.0218), electrolyte leakage index (%)(-0.0192), empty capsules plant^{-1} (-0.0092) and seeds capsule^{-1} (-0.0032).

4.3.2.3. Harvest maturity days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* 50% blossoming days (0.0042), first blossoming days (0.0032), lipid peroxidation (nmol/ml) (0.0028), flower drop (%)(0.0026), electrolyte leakage index (%)(0.0021), empty capsules plant^{-1} (0.0016) and seeds capsule^{-1} (0.0002) whereas indirect negative impacts *via.,* secondary offshoots plant^{-1} (-0.003), full capsules plant^{-1} (-0.0028), primary offshoots plant^{-1} (-0.0028), capsules plant^{-1} (-0.0026), relative leaf water content (%) (-0.0026), pollen viability (%)(-

0.0023), harvest index (%) (-0.0022), test weight (gm) (-0.0021), total chlorophyll content (mg/ml) (-0.0021), proline content (-0.0019), plant height (-0.0018), biological yield plant^{-1} (-0.0017) and ascorbic acid content (mg) (-0.0016).

4.3.2.4. Plant height

It imposed positive indirect impact on seed yield plant^{-1} *via.,* biological yield plant^{-1} (0.0012), full capsules plant^{-1} (0.0011), pollen viability (%)(0.0011), relative leaf water content (%) (0.001), capsules plant^{-1} (0.0009), harvest index (%) (0.0009), seeds capsule^{-1} (0.0004), test weight (gm) (0.0004), total chlorophyll content (mg/ml) (0.0004), proline content (0.0004), ascorbic acid content (mg) (0.0004), primary offshoots plant^{-1} (0.0003) and secondary offshoots plant^{-1} (0.0003) whereas indirect negative impacts *via.,* empty capsules plant^{-1} (-0.0011), first blossoming days (-0.001), 50% blossoming days (-0.0007), harvest maturity days (-0.0007), electrolyte leakage index (%)(-0.0006) and flower drop (%)(-0.0002).

Table 4.16: Coefficients of genotypic path depicting direct and indirect impacts on seed yield plant^{-1} (EN-3)

Character	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	**-0.0313**	-0.0266	-0.0195	0.0162	0.0073	0.0064	0.0154	0.0167	-0.0101	-0.0015	0.0071	0.0108	0.0162	0.0125	0.0158	-0.0218	-0.0144	0.0166	0.0095	0.0151	-0.0154	-0.5018
C2	-0.0348	**-0.0409**	-0.033	0.0161	0.0148	0.0163	0.0205	0.0207	-0.0092	-0.0032	0.0185	0.0111	0.0135	0.0149	0.0186	-0.0261	-0.0192	0.0212	0.0135	0.0147	-0.0218	-0.3472
C3	0.0032	0.0042	**0.0052**	-0.0018	-0.0028	-0.003	-0.0026	-0.0028	0.0016	0.0002	-0.0021	-0.0017	-0.0022	-0.0021	-0.0026	0.0028	0.0021	-0.0019	-0.0016	-0.0023	0.0026	-0.4293
C4	-0.001	-0.0007	-0.0007	**0.0019**	0.0003	0.0003	0.0009	0.0011	-0.0011	0.0004	0.0004	0.0012	0.0009	0.0004	0.001	-0.0009	-0.0006	0.0004	0.0004	0.0011	-0.0002	0.6276
C5	0.0164	0.0255	0.0385	-0.0125	**-0.0704**	-0.0678	-0.0461	-0.0431	0.0133	-0.0081	-0.0185	-0.023	-0.0308	-0.0299	-0.0393	0.0244	0.0311	-0.0296	-0.035	-0.0379	0.042	0.4126
C6	-0.0072	-0.0141	-0.0206	0.0057	0.0342	**0.0355**	0.0253	0.0227	-0.0029	0.0039	0.0127	0.0121	0.013	0.0131	0.0198	-0.012	-0.0195	0.0159	0.0216	0.0188	-0.0216	0.3817
C7	0.0529	0.0539	0.0537	-0.0505	-0.0704	-0.0768	**-0.1075**	-0.1002	0.0208	-0.048	-0.0188	-0.0713	-0.0729	0.0098	-0.0476	0.03	0.0154	0.0001	-0.013	-0.1014	0.0178	0.7606
C8	-0.1071	-0.1014	-0.108	0.1225	0.1228	0.1284	0.1871	**0.2007**	-0.1075	0.0756	0.0506	0.1498	0.1551	0.0229	0.1212	-0.0847	-0.0514	0.0253	0.0438	0.1958	-0.0446	0.8561
C9	0.0187	0.013	0.0175	-0.0333	-0.011	-0.0048	-0.0112	-0.031	**0.0579**	0.0002	-0.0163	-0.028	-0.0304	-0.0316	-0.0363	0.0284	0.0219	-0.0204	-0.0166	-0.0259	0.0113	-0.5599
C10	0.0014	0.0023	0.0009	0.0069	0.0034	0.0033	0.0133	0.0112	0.0001	**0.0297**	-0.0013	0.0137	0.0034	-0.0082	0.0011	0.0024	0.002	-0.0024	-0.0073	0.0117	0.0062	0.3286
C11	0.0081	0.016	0.0141	-0.0083	-0.0093	-0.0127	-0.0062	-0.0089	0.0099	0.0016	**-0.0354**	-0.0133	-0.0034	-0.0098	-0.0078	0.0065	0.0114	-0.0083	-0.0155	-0.0056	0.0056	0.225
C12	-0.1533	-0.1211	-0.1468	0.2942	0.146	0.1519	0.2961	0.3331	-0.2161	0.2061	0.1671	**0.4463**	0.2959	0.0087	0.1671	-0.1192	-0.1205	0.025	0.0582	0.3808	0.0677	0.8971
C13	-0.2951	-0.1876	-0.2471	0.2747	0.2489	0.2092	0.3862	0.4399	-0.2987	0.0658	0.0549	0.3775	**0.5695**	0.1585	0.3808	-0.3384	-0.1524	0.1759	0.1181	0.469	-0.1462	0.9207
C14	-0.0265	-0.0241	-0.0274	0.0131	0.028	0.0245	-0.006	0.0076	-0.036	-0.0183	0.0183	0.0013	0.0184	**0.0661**	0.0444	-0.0513	-0.05	0.0547	0.0485	0.0037	-0.0409	0.162
C15	-0.0212	-0.019	-0.0207	0.0219	0.0234	0.0233	0.0186	0.0253	-0.0263	0.0016	0.0092	0.0157	0.028	0.0281	**0.0419**	-0.0344	-0.0312	0.0267	0.0195	0.0231	-0.0232	0.592
C16	0.0598	0.0549	0.0471	-0.0422	-0.0299	-0.0291	-0.024	-0.0363	0.0422	0.0069	-0.0157	-0.023	-0.0512	-0.0669	-0.0708	**0.0861**	0.0648	-0.072	-0.0502	-0.0329	0.0535	-0.488
C17	-0.0047	-0.0047	-0.004	0.0034	0.0045	0.0056	0.0014	0.0026	-0.0038	-0.0007	0.0032	0.0027	0.0027	0.0077	0.0076	-0.0076	**-0.0101**	0.0083	0.0067	0.0019	-0.0055	-0.2943
C18	-0.0037	-0.0036	-0.0026	0.0014	0.003	0.0031	0	0.0009	-0.0025	-0.0006	0.0016	0.0004	0.0022	0.0058	0.0045	-0.0059	-0.0058	**0.007**	0.0047	0.0002	-0.0053	0.1979
C19	0.0028	0.003	0.0029	-0.0018	-0.0046	-0.0056	-0.0011	-0.002	0.0026	0.0023	-0.004	-0.0012	-0.0019	-0.0068	-0.0043	0.0054	0.0061	-0.0062	**-0.0092**	-0.0012	0.0057	0.1652
C20	-0.0047	-0.0035	-0.0042	0.0055	0.0052	0.0051	0.0091	0.0094	-0.0043	0.0038	0.0015	0.0082	0.008	0.0005	0.0053	-0.0037	-0.0019	0.0003	0.0012	**0.0097**	-0.0006	0.9356
C21	0.0253	0.0274	0.0254	-0.0055	-0.0307	-0.0313	-0.0085	-0.0114	0.0101	0.0108	-0.0081	0.0078	-0.0132	-0.0318	-0.0285	0.032	0.028	-0.0387	-0.0319	-0.003	**0.0514**	-0.0613

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17- Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

4.3.2.6. Primary offshoots plant^{-1}

It imposed positive direct impacts on seed yield plant^{-1} *via.,* flower drop (%) (0.042), harvest maturity days (0.0385), electrolyte leakage index (%) (0.0311), 50% blossoming days (0.0255), lipid peroxidation (nmol/ml) (0.0244), first blossoming days (0.0164 and empty capsules plant^{-1}) (0.0133) whereas indirect negative impacts *via.,* secondary offshoots plant^{-1} (-0.0678), capsules plant^{-1} (-0.0461), full capsules plant^{-1} (-0.0431), relative leaf water content (%) (-0.0393), pollen viability (%) (-0.0379), ascorbic acid content (mg) (-0.035), harvest index (%) (-0.0308), total chlorophyll content (mg/ml) (-0.0299), proline content (mg/gm) (-0.0296), biological yield plant^{-1} (-0.023), test weight (-0.0185), plant height (-0.0124) and seeds capsule^{-1} (-0.0081).

4.3.2.6. Secondary offshoots plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* primary offshoots plant-1 (0.0342), capsules plant^{-1} (0.0253), full capsules plant^{-1} (0.0227), ascorbic acid content (mg) (0.0216), relative leaf water content (%) (0.0198), pollen viability (%)(0.0188), proline content (0.0159), total chlorophyll content (mg/ml) (0.0131), harvest index (%) (0.013), test weight (gm) (0.0127), biological yield plant^{-1} (0.0121), plant height (0.0057) and seeds capsule^{-1} (0.0039) whereas indirect negative impacts *via.,* flower drop (%)(-0.0216), harvest maturity days (-0.0206), electrolyte leakage index (%)(-0.0195), 50% blossoming days (-0.0141), lipid peroxidation (nmol/ml) (-0.012), first blossoming days (-0.0072) and empty capsules plant^{-1} (-0.0029).

4.3.2.7. Capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* 50% blossoming days (0.0539), harvest maturity days (0.0537), first blossoming days (0.0529), lipid peroxidation (nmol/ml) (0.03), empty capsules plant^{-1} (0.0208), flower drop (%)(0.0178), electrolyte leakage index (%)(0.0154), total chlorophyll content (mg/ml) (0.0098) and proline content (0.0001) whereas indirect negative impacts *via.,* pollen viability (%)(-0.1014), full capsules plant^{-1} (-0.1002), secondary offshoots plant^{-1} (-0.0768), harvest index (%) (-0.0729), biological yield plant^{-1} (-0.0713), primary offshoots plant^{-1} (-0.0704), plant height (-0.0505), seeds capsule^{-1} (-0.048), relative leaf water content (%) (-0.0476), test weight (gm) (-0.0188) and ascorbic acid content (mg) (-0.013).

4.3.2.8. Full capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* pollen viability (%)(0.1958), capsules plant^{-1} (0.1871), harvest index (%) (0.1551), biological yield plant^{-1} (0.1498), secondary offshoots plant^{-1} (0.1284), primary offshoots plant^{-1} (0.1228), plant height (0.1225), relative leaf water content (%) (0.1212), seeds capsule^{-1} (0.0756), test weight (gm) (0.0506), ascorbic acid content (mg) (0.0438), proline content (0.0253) and total chlorophyll content (mg/ml) (0.0229) whereas indirect negative impacts *via.,* harvest maturity days (-0.108), empty capsules plant^{-1} (-0.1075), first blossoming days (-0.1071), 50% blossoming days (-0.1014), lipid peroxidation (nmol/ml) (-0.0847), electrolyte leakage index (%)(-0.0514) and flower drop (%)(-0.0446).

4.3.2.9. Empty capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* lipid peroxidation (nmol/ml) (0.0284), electrolyte leakage index (%)(0.0219), first blossoming days (0.0187), harvest maturity days (0.0175), 50% blossoming days (0.013), flower drop (%)(0.0113) and seeds capsule^{-1} (0.0002) whereas indirect negative impacts *via.,* relative leaf water content (%) (-0.0363), plant height (-0.0333), total chlorophyll content (mg/ml) (-0.0316), full capsules plant^{-1} (-0.031), harvest index (%) (-0.0304), biological yield plant^{-1} (-0.028), pollen viability (%)(-0.0259), proline content (-0.0204), ascorbic acid content (mg) (-0.0166), test weight (gm) (-0.0163), capsules plant^{-1} (-0.0112), primary offshoots plant^{-1} (-0.011) and secondary offshoots plant^{-1} (-0.0048).

4.3.2.10. Seeds capsule^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* biological yield plant^{-1} (0.0137), capsules plant^{-1} (0.0133), pollen viability (%)(0.0117), full capsules plant^{-1} (0.0112), plant height (0.0069), flower drop (%)(0.0062), primary offshoots plant^{-1} (0.0034), harvest index (%) (0.0034), secondary offshoots plant^{-1} (0.0033), lipid peroxidation (nmol/ml) (0.0024), 50% blossoming days (0.0023), electrolyte leakage index (%)(0.002), first blossoming days (0.0014), relative leaf water content (%) (0.0011), harvest maturity days (0.0009) and empty capsules plant^{-1} (0.0001) whereas indirect negative impacts *via.,* total chlorophyll content (mg/ml) (-0.0082), ascorbic acid content (mg) (-0.0073), proline content (-0.0024) and test weight (gm) (-0.0013).

4.3.2.11. Test weight (gm)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* 50% blossoming days (0.016), harvest maturity days (0.0141), electrolyte leakage index (%)(0.0114), empty capsules plant^{-1} (0.0099), first blossoming days (0.0081), lipid peroxidation (nmol/ml) (0.0065), flower drop (%)(0.0056) and seeds capsule^{-1} (0.0016) whereas indirect negative impacts *via.,* ascorbic acid content (mg) (0.0016), biological yield plant^{-1} (-0.0133), secondary offshoots plant^{-1} (-0.0127), total chlorophyll content (mg/ml) (-0.0098), primary offshoots plant^{-1} (-0.0093), full capsules plant^{-1} (-0.0089), plant height (-0.0083), proline content (-0.0083), relative leaf water content (%) (-0.0078), capsules plant^{-1} (-0.0062), pollen viability (%)(-0.0056) and harvest index (%) (-0.0034).

4.3.2.12. Biological yield

It imposed positive indirect impact on seed yield plant^{-1} *via.,* pollen viability (%)(0.3808), full capsules plant^{-1} (0.3331), capsules plant^{-1} (0.2961), harvest index (%) (0.2959), plant height (0.2942), seeds capsule^{-1} (0.2061), test weight (gm) (0.1671), relative leaf water content (%) (0.1671), secondary offshoots plant^{-1} (0.1519), primary offshoots plant^{-1} (0.146), flower drop (%)(0.0677), ascorbic acid content (mg) (0.0582), proline content (0.025) and total chlorophyll content (mg/ml) (0.0087) whereas indirect negative impacts *via.,* empty capsules plant^{-1} (-0.2161), first blossoming days (-0.1533), harvest maturity days (-0.1468), 50% blossoming days (-0.1211), electrolyte leakage index (%)(-0.1205) and lipid peroxidation (nmol/ml) (-0.1192).

4.3.2.13. Harvest index (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* pollen viability (%)(0.469), full capsules plant^{-1} (0.4399), capsules plant^{-1} (0.3862), relative leaf water content (%) (0.3808), biological yield plant^{-1} (0.3775), plant height (0.2747), primary offshoots plant^{-1} (0.2489), secondary offshoots plant^{-1} (0.2092), proline content (0.1759), total chlorophyll content (mg/ml) (0.1585), ascorbic acid content (mg) (0.1181), seeds capsule^{-1} (0.0658) and test weight (gm) (0.0549) whereas indirect negative impacts *via.,* lipid peroxidation (nmol/ml) (-0.3384), empty capsules plant^{-1} (-0.2987), first blossoming days (-0.2951), harvest maturity days (-0.2471), 50% blossoming days (-0.1876), electrolyte leakage index (%)(-0.1524) and flower drop (%)(-0.1462).

4.3.2.14. Total chlorophyll content (mg/ml)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* proline content (0.0547), ascorbic acid content (mg) (0.0485), relative leaf water content (%) (0.0444), primary offshoots plant^{-1} (0.028), secondary offshoots plant^{-1} (0.0245), harvest index (%) (0.0184), test weight (gm) (0.0183), plant height (0.0131), full capsules plant^{-1} (0.0076), pollen viability (%)(0.0037) and biological yield plant^{-1} (0.0013) whereas indirect negative impacts *via.,* lipid peroxidation (nmol/ml) (-0.0513), electrolyte leakage index (%)(-0.05), flower drop (%)(-0.0409), empty capsules plant^{-1} (-0.036), harvest maturity days (-0.0274), first blossoming days (-0.0265), 50% blossoming days (-0.0241), seeds capsule^{-1} (-0.0183) and capsules plant^{-1} (-0.006).

4.3.2.15. Relative leaf water content (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* total chlorophyll content (mg/ml) (0.0281), harvest index (%) (0.028), proline content (0.0267), full capsules plant^{-1} (0.0253), primary offshoots plant^{-1} (0.0234), secondary offshoots plant^{-1} (0.0233), pollen viability (%)(0.0231), plant height (0.0219), ascorbic acid content (mg) (0.0195), capsules plant^{-1} (0.0186), biological yield plant^{-1} (0.0157), test weight (gm) (0.0092) and seeds capsule^{-1} (0.0016) whereas indirect negative impacts *via.,* lipid peroxidation (nmol/ml) (-0.0344), electrolyte leakage index (%)(-0.0312), empty capsules plant^{-1} (-0.0263), flower drop (%)(-0.0232), first blossoming days (-0.0212), harvest maturity days (-0.0207) and 50% blossoming days (-0.019).

4.3.2.16. Lipid Peroxidation (nmol/ml)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* electrolyte leakage index (%)(0.0648), first blossoming days (0.0598), 50% blossoming days (0.0549), flower drop (%)(0.0535), harvest maturity days (0.0471), empty capsules plant^{-1} (0.0422) and seeds capsule^{-1} (0.0069) whereas indirect negative impacts *via.,* proline content (-0.072), relative leaf water content (%) (-0.0708), total chlorophyll content (mg/ml) (-0.0669), harvest index (%) (-0.0512), ascorbic acid content (mg) (-0.0502), plant height (-0.0422), full capsules plant^{-1} (-0.0363), pollen viability (%)(-0.0329), primary offshoots plant^{-1} (-0.0299), secondary offshoots plant^{-1} (-0.0291), capsules plant^{-1} (-0.024), biological yield plant^{-1} (-0.023) and test weight (gm) (-0.0157).

4.3.2.17. Electrolyte leakage index (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* proline content (0.0083), total chlorophyll content (mg/ml) (0.0077), relative leaf water content (%) (0.0076), ascorbic acid content (mg) (0.0067), secondary offshoots plant^{-1} (0.0056), primary offshoots plant^{-1} (0.0045), plant height (0.0034), test weight (gm) (0.0032), biological yield plant-1 (0.0027), harvest index (%) (0.0027), full capsules plant^{-1} (0.0026), pollen viability (%)(0.0019) and capsules plant^{-1} (0.0014) whereas indirect negative impacts *via.,* lipid peroxidation (nmol/ml) (-0.0076), flower drop (%)(-0.0055), first blossoming days (-0.0047), 50% blossoming days (-0.0047), harvest maturity days (-0.004), empty capsules plant^{-1} (-0.0038) and seeds capsule^{-1} (-0.0007).

4.3.2.18. Proline content (mg/gm)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* total chlorophyll content (mg/ml) (0.0058), ascorbic acid content (mg) (0.0047), relative leaf water content (%) (0.0045), secondary offshoots plant^{-1} (0.0031), primary offshoots plant-1 (0.003), harvest index (%) (0.0022), test weight (gm) (0.0016), plant height (0.0014), full capsules plant^{-1} (0.0009), biological yield plant^{-1} (0.0004), pollen viability (%)(0.0002) and capsules plant^{-1} (0.0001) whereas indirect negative impacts *via.,* lipid peroxidation (nmol/ml) (-0.0059), electrolyte leakage index (%)(-0.0058), flower drop (%)(-0.0053), first blossoming days (-0.0037), 50% blossoming days (-0.0036), harvest maturity days (-0.0026), empty capsules plant^{-1} (-0.0025) and seeds capsule^{-1} (-0.0006).

4.3.2.19. Ascorbic acid content (mg)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* electrolyte leakage index (%)(0.0061), flower drop (%)(0.0057), lipid peroxidation (nmol/ml) (0.0054), 50% blossoming days (0.003), harvest maturity days (0.0029), first blossoming days (0.0028), empty capsules plant^{-1} (0.0026) and capsules plant^{-1} (0.0023) whereas indirect negative impacts *via.,* total chlorophyll content (mg/ml) (-0.0068), proline content (-0.0062), secondary offshoots plant^{-1} (-0.0056), primary offshoots plant^{-1} (-0.0046), relative leaf water content (%) (-0.0043), test weight (gm) (-0.004), full capsules plant^{-1} (-0.002), harvest index (%) (-0.0019), plant height (-0.0018), biological yield plant^{-1} (-0.0012), pollen viability (%)(-0.0012) and seeds capsule^{-1} (-0.0011).

4.3.2.20. Pollen viability (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* full capsules plant^{-1} (0.0094), capsules plant^{-1} (0.0091), biological yield plant^{-1} (0.0082), harvest index (%) (0.008), plant height (0.0055), relative leaf water content (%) (0.0053), primary offshoots plant^{-1} (0.0052), secondary offshoots plant^{-1} (0.0051), seeds capsule^{-1} (0.0038), test weight (gm) (0.0015), ascorbic acid content (mg) (0.0012), total chlorophyll content (mg/ml) (0.0005) and proline content (0.0003) whereas indirect negative impacts *via.,* first blossoming days (-0.0047), empty capsules plant^{-1} (-0.0043), harvest maturity days (-0.0042), lipid peroxidation (nmol/ml) (-0.0037), 50% blossoming days (-0.0035), electrolyte leakage index (%)(-0.0019) and flower drop (%)(-0.0006).

4.3.2.21. Flower drop (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* lipid peroxidation (nmol/ml) (0.032), electrolyte leakage index (%)(0.028), 50% blossoming days (0.0274), harvest maturity days (0.0254), first blossoming days (0.0253), seeds capsule^{-1} (0.0108), empty capsules plant^{-1} (0.0101) and biological yield plant^{-1} (0.0078) whereas indirect negative impacts *via.,* proline content (-0.0387), ascorbic acid content (mg) (-0.0319), total chlorophyll content (mg/ml) (-0.0318), secondary offshoots plant^{-1} (-0.0313), primary offshoots (-0.0307), relative leaf water content (%) (-0.0285), harvest index (%) (-0.0132), full capsules plant^{-1} (-0.0114), capsules plant^{-1} (-0.0085), test weight (gm) (-0.0081), plant height (-0.0055) and pollen viability (%)(-0.003).

Pooled

Table 4.17 illustrates the path coefficient analysis estimates

4.3.1. Direct impact of various characters on seed yield plant^{-1}

Capsules plant^{-1} (3.1977), biological yield plant^{-1} (1.1622), secondary offshoots plant^{-1} (0.3074), plant height (0.1497), proline content (0.1138), pollen viability (%)(0.1067), first blossoming days (0.0966), harvest index (%) (0.0883), harvest maturity days (0.0419), flower drop (%)(0.0192) and lipid peroxidation (nmol/ml) (0.0112) imposed direct positive impact on seed yield plant^{-1} whereas, full capsules plant^{-1} (-4.0085), empty capsules plant^{-1} (-0.5311), 50% blossoming days (-0.152), primary offshoots plant^{-1} (-0.1092), test weight (gm) (-0.0674), relative leaf water content (%) (-0.0449), ascorbic acid content (mg) (-0.033), seeds capsule^{-1} (-0.0327), electrolyte leakage index (%) (-0.0136) and total chlorophyll content (mg/ml) (-0.0065) had direct negative impacts.

4.3.2. Indirect impacts of various characters on seed yield plant^{-1}

4.3.2.1. First blossoming days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* 50% blossoming days (0.0959), full capsules plant^{-1} (0.0931), biological yield plant^{-1} (0.092), harvest maturity days (0.091), pollen viability (%)(0.0909), capsules plant^{-1} (0.0901), secondary offshoots plant^{-1} (0.088), plant height (0.0832), primary offshoots plant^{-1} (0.0818), relative leaf water content (%) (0.0543), test weight (gm) (0.0393), seeds capsule^{-1} (0.0321), harvest index (%) (0.0279), total chlorophyll content (mg/ml) (0.0218) and ascorbic acid content (mg) (0.0032) and whereas indirect negative impacts *via.,* flower drop (%)(-0.1318), electrolyte leakage index (%)(-0.11), proline content (-0.0887), empty capsules plant^{-1} (-0.0878) and lipid peroxidation (nmol/ml) (-0.0643).

4.3.2.2. 50% blossoming days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%) (0.1981), electrolyte leakage index (%) (0.1592), proline content (0.1413), empty capsules plant^{-1} (0.14) and lipid peroxidation (nmol/ml) (0.1021). however, negative impacts *via.,* biological yield plant^{-1} (-0.1441), full capsules plant^{-1} (-0.1438), harvest maturity days (-0.1423), pollen viability (%)(-0.1413), capsules plant^{-1} (-0.1384), secondary offshoots plant^{-1} (-0.1339), plant height (-0.1287), primary offshoots plant^{-1} (-0.1255), relative leaf water content (%) (-0.0775), test weight (gm) (-0.058), seeds capsule^{-1} (-0.0496), total chlorophyll content (mg/ml) (-0.0393), harvest index (%) (-0.035) and ascorbic acid content (mg) (-0.0217).

4.3.2.3. Harvest maturity days

It imposed positive indirect impact on seed yield plant^{-1} *via.,* pollen viability (%)(0.0408), full capsules plant^{-1} (0.0403), capsules plant^{-1} (0.0402), biological yield plant^{-1} (0.0401), first blossoming days (0.0395), 50% blossoming days (0.0392), plant height (0.0375), secondary offshoots plant^{-1} (0.0355), primary offshoots plant^{-1} (0.0329), relative leaf water content (%) (0.0228), test weight (gm) (0.0173), seeds capsule^{-1} (0.0144), total chlorophyll content (mg/ml) (0.0107) and harvest index (%) (0.0037) whereas indirect negative impacts *via.,* flower drop (%)(-0.0628), electrolyte leakage index (%)(-0.0452), proline content (-0.0355), empty capsules plant^{-1} (-0.0296), lipid peroxidation (nmol/ml) (-0.0291) and ascorbic acid content (mg) (-0.0024).

4.3.2.4. Plant height

It imposed positive indirect impact on seed yield plant^{-1} *via.,* full capsules plant^{-1} (0.1418), biological yield plant-1 (0.1418), capsules plant^{-1} (0.141), pollen viability (%)(0.1347), secondary offshoots plant^{-1} (0.1345), harvest maturity days (0.1341), first blossoming days (0.129), 50% blossoming days (0.1268), primary offshoots plant^{-1} (0.1262), relative leaf water content (%) (0.0845), test weight (gm) (0.0818), seeds capsule^{-1} (0.0649), total chlorophyll content (mg/ml) (0.0624) and ascorbic acid content (mg) (0.0117) whereas indirect negative impacts *via.,* flower drop (%)(-0.218), proline content (-0.1112), empty capsules plant^{-1} (-0.1059), lipid peroxidation (nmol/ml) (-0.1038), electrolyte leakage index (%)(-0.0888) and harvest index (%) (-0.0162).

4.3.2.5. Primary offshoots plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(0.168), empty capsules plant^{-1} (0.0866), proline content (0.0821), lipid peroxidation (nmol/ml) (0.0798), ascorbic acid content (mg) (0.0555) and electrolyte leakage index (%)(0.0536) whereas indirect negative impacts *via.,* secondary offshoots plant^{-1} (-0.1042), full capsules plant^{-1} (-0.1), pollen viability (%)(-0.0984), capsules plant^{-1} (-0.0978), biological yield plant^{-1} (-0.0976), first blossoming days (-0.0925), plant height (-0.092), 50% blossoming days (-0.0901), seeds capsule^{-1} (-0.0864), harvest maturity days (-0.0858), relative leaf water content (%) (-0.0827), harvest index (%) (-0.0732), total chlorophyll content (mg/ml) (-0.041) and test weight (gm) (-0.0338).

Table 4.17: Coefficients of genotypic path depicting direct and indirect impacts on seed yield plant^{-1} (Pooled)

Character	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	**0.0966**	0.0959	0.091	0.0832	0.0818	0.088	0.0901	0.0931	-0.0878	0.0321	0.0393	0.092	0.0279	0.0218	0.0543	-0.0643	-0.11	-0.0887	0.0032	0.0909	-0.1318	0.9474
C2	-0.1509	**-0.152**	-0.1423	-0.1287	-0.1255	-0.1339	-0.1384	-0.1438	0.14	-0.0496	-0.058	-0.1441	-0.035	-0.0393	-0.0775	0.1021	0.1592	0.1413	-0.0217	-0.1413	0.1981	0.9327
C3	0.0395	0.0392	**0.0419**	0.0375	0.0329	0.0355	0.0402	0.0403	-0.0296	0.0144	0.0173	0.0401	0.0037	0.0107	0.0228	-0.0291	-0.0452	-0.0355	-0.0024	0.0408	-0.0628	0.926
C4	0.129	0.1268	0.1341	**0.1497**	0.1262	0.1345	0.141	0.1418	-0.1059	0.0649	0.0818	0.1418	-0.0162	0.0624	0.0845	-0.1038	-0.0888	-0.1112	0.0117	0.1347	-0.218	0.9083
C5	-0.0925	-0.0901	-0.0858	-0.092	**-0.1092**	-0.1042	-0.0978	-0.1	0.0866	-0.0864	-0.0338	-0.0976	-0.0732	-0.041	-0.0827	0.0798	0.0536	0.0821	0.0555	-0.0984	0.168	0.9252
C6	0.2802	0.2708	0.2605	0.2761	0.2932	**0.3074**	0.2864	0.2921	-0.2461	0.2085	0.1363	0.2912	0.1688	0.1254	0.2495	-0.2103	-0.1704	-0.2581	-0.0672	0.2903	-0.4454	0.9651
C7	2.9833	2.9125	3.0631	3.0109	2.8634	2.9788	**3.1977**	3.1837	-2.1468	1.4216	1.3368	3.1182	0.4337	0.6966	1.8189	-2.1749	-1.9173	-2.82	-0.5574	3.1694	-4.5741	0.9444
C8	-3.8649	-3.7913	-3.8531	-3.797	-3.6696	-3.8088	-3.991	**-4.0085**	2.9572	-1.8136	-1.8165	-3.9795	-0.4372	-0.9801	-2.307	2.7408	2.3252	3.6755	0.6914	-3.969	5.5278	0.9618
C9	0.4827	0.4894	0.3748	0.3755	0.4212	0.4251	0.3565	0.3918	**-0.5311**	0.2001	0.2967	0.4386	-0.0728	0.1899	0.2421	-0.2695	-0.1287	-0.4784	-0.0809	0.365	-0.3241	-0.7999
C10	-0.0109	-0.0107	-0.0113	-0.0142	-0.0259	-0.0222	-0.0146	-0.0148	0.0123	**-0.0327**	-0.0062	-0.0154	-0.0455	-0.0233	-0.0276	0.0133	-0.0041	0.0069	0.0024	-0.0207	0.0252	0.5981
C11	-0.0274	-0.0257	-0.0278	-0.0368	-0.0209	-0.0299	-0.0282	-0.0305	0.0377	-0.0127	**-0.0674**	-0.0352	0.0077	-0.0596	-0.0368	0.0247	0.0314	0.0101	0.0231	-0.0239	0.0784	0.5055
C12	1.1073	1.1018	1.112	1.1004	1.0386	1.1009	1.1333	1.1538	-0.9598	0.5461	0.6075	**1.1622**	0.343	0.4525	0.7327	-0.7828	-0.9416	-0.9821	-0.072	1.1501	-1.7111	0.9942
C13	0.0255	0.0203	0.0077	-0.0095	0.0592	0.0485	0.012	0.0096	0.0121	0.1229	-0.0101	0.0261	**0.0883**	0.0028	-0.0045	0.0723	0.4428	-0.045	-0.2142	0.0143	0.1004	0.3977
C14	-0.0015	-0.0017	-0.0017	-0.0027	-0.0024	-0.0026	-0.0014	-0.0016	0.0023	-0.0046	-0.0057	-0.0025	-0.0002	**-0.0065**	-0.0046	0.0012	-0.006	0.0006	0.004	-0.0014	0.0002	0.3974
C15	-0.0253	-0.0229	-0.0244	-0.0254	-0.034	-0.0365	-0.0256	-0.0259	0.0205	-0.0379	-0.0245	-0.0283	0.0023	-0.0322	**-0.0449**	0.0222	-0.0078	0.0233	0.0321	-0.0263	0.0644	0.6107
C16	-0.0075	-0.0075	-0.0078	-0.0078	-0.0082	-0.0077	-0.0076	-0.0077	0.0057	-0.0046	-0.0041	-0.0076	0.0092	-0.0021	-0.0056	**0.0112**	0.0159	0.0064	-0.003	-0.0069	0.0123	-0.5578
C17	0.0154	0.0142	0.0146	0.008	0.0067	0.0075	0.0081	0.0079	-0.0033	-0.0017	0.0063	0.011	-0.068	-0.0125	-0.0024	-0.0192	**-0.0136**	-0.0179	0.0068	0.0048	0.0087	-0.2884
C18	-0.1046	-0.1058	-0.0965	-0.0845	-0.0856	-0.0956	-0.1004	-0.1043	0.1025	-0.0239	-0.0171	-0.0962	-0.0579	-0.0105	-0.059	0.0645	0.1506	**0.1138**	0.018	-0.1072	0.1987	-0.8491
C19	-0.0011	-0.0047	0.0019	-0.0026	0.0168	0.0072	0.0057	0.0057	-0.005	0.0024	0.0113	0.002	0.0799	0.0203	0.0235	0.0087	0.0165	-0.0052	**-0.033**	0.0194	-0.0554	-0.234
C20	0.1004	0.0992	0.1037	0.0959	0.0961	0.1007	0.1057	0.1056	-0.0733	0.0674	0.0379	0.1056	0.0173	0.0227	0.0625	-0.0661	-0.0379	-0.1005	-0.0627	**0.1067**	-0.1713	0.9602
C21	-0.0263	-0.0251	-0.0288	-0.028	-0.0296	-0.0279	-0.0275	-0.0265	0.0117	-0.0148	-0.0224	-0.0283	0.0219	-0.0005	-0.0276	0.0211	-0.0124	0.0336	0.0324	-0.0309	**0.0192**	-1.2927

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17- Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

4.3.2.6. Secondary offshoots plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* primary offshoots plant^{-1} (0.2932), full capsules plant^{-1} (0.2921), biological yield plant^{-1} (0.2912), pollen viability (%)(0.2903), capsules plant^{-1} (0.2864), first blossoming days (0.2802), plant height (0.2761), 50% blossoming days (0.2708), harvest maturity days (0.2605), relative leaf water content (%) (0.2495), seeds capsule^{-1} (0.2085), harvest index (%) (0.1688), test weight (gm) (0.1363) and total chlorophyll content (mg/ml) (0.1254) whereas indirect negative impacts *via.,* flower drop (%)(-0.4454), proline content (-0.2581), empty capsules plant^{-1} (-0.2461), lipid peroxidation (nmol/ml) (-0.2103), electrolyte leakage index (%)(-0.1704) and ascorbic acid content (mg) (-0.0672).

4.3.2.7. Capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* full capsules plant^{-1} (3.1837), pollen viability (%) (3.1694), biological yield plant^{-1} (3.1182), harvest maturity days (3.0631), plant height (3.0109), first blossoming days (2.9833), secondary offshoots plant^{-1} (2.9788), 50% blossoming days (2.9125), primary offshoots plant^{-1} (2.8634), relative leaf water content (%) (1.8189), seeds capsule^{-1} (1.4216), test weight (gm) (1.3368), total chlorophyll content (mg/ml) (0.6966) and harvest index (%) (0.4337) whereas indirect negative impacts *via.,* flower drop (%)(-4.5741), proline content (-2.82), lipid peroxidation (nmol/ml) (-2.1749), empty capsules plant^{-1} (-2.1468), electrolyte leakage index (%)(-1.9173) and ascorbic acid content (mg) (-0.5574).

4.3.2.8. Full capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(5.5278), proline content (3.6755), empty capsules plant^{-1} (2.9572), lipid peroxidation (nmol/ml) (2.7408), electrolyte leakage index (%)(2.3252) and ascorbic acid content (mg) (0.6914) whereas indirect negative impacts *via.,* capsules plant^{-1} (-3.991), biological yield plant^{-1} (-3.9795), pollen viability (%)(-3.969), first blossoming days (-3.8649), harvest maturity days (-3.8531), secondary offshoots plant^{-1} (-3.8088), plant height (-3.797), 50% blossoming days (-3.7913), primary offshoots plant^{-1} (-3.6696), relative leaf water content (%) (-2.307), test weight (gm) (-1.8165), seeds capsule^{-1} (-1.8136), total chlorophyll content (mg/ml) (-0.9801) and harvest index (%) (-0.4372).

4.3.2.9. Empty capsules plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* 50% blossoming days (0.4894), first blossoming days (0.4827), biological yield plant^{-1} (0.4386), secondary offshoots plant^{-1} (0.4251), primary offshoots plant^{-1} (0.4212), full capsules plant^{-1} (0.3918), plant height (0.3755), harvest maturity days (0.3748), pollen viability (%)(0.365), capsules plant^{-1} (0.3565), test weight (gm) (0.2967), relative leaf water content (%) (0.2421), seeds capsule^{-1} (0.2001) and total chlorophyll content (mg/ml) (0.1899) whereas indirect negative impacts *via.,* proline content (-0.4784), flower drop (%)(-0.3241), lipid peroxidation (nmol/ml) (-0.2695), electrolyte leakage index (%)(-0.1287), ascorbic acid content (mg) (-0.0809) and harvest index (%) (-0.0728).

4.3.2.10. Seeds capsule^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* Flower drop (%)(0.0252), Lipid Peroxidation (nmol/ml) (0.0133), empty capsules plant^{-1} (0.0123), proline content (0.0069) and Ascorbic acid content (mg) (0.0024) whereas indirect negative impacts *via.,* harvest index (%) (-0.0455), Relative leaf water content (%) (-0.0276), primary offshoots plant^{-1} (-0.0259), Total chlorophyll content (mg/ml) (-0.0233), secondary offshoots plant^{-1} (-0.0222), Pollen viability (%)(-0.0207), biological yield plant^{-1} (-0.0154), full capsules plant^{-1} (-0.0148), capsules plant^{-1} (-0.0146), plant height (-0.0142), harvest maturity days (-0.0113), first blossoming days (-0.0109), 50% blossoming days (-0.0107), test weight (gm) (-0.0062) and Electrolyte leakage index (%)(-0.0041).

4.3.2.11. Test weight (gm)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(0.0784), full capsules plant^{-1} (0.0377), electrolyte leakage index (%)(0.0314), lipid peroxidation (nmol/ml) (0.0247), ascorbic acid content (mg) (0.0231), proline content (0.0101) and harvest index (%) (0.0077) whereas indirect negative impacts *via.,* total chlorophyll content (mg/ml) (-0.0596), plant height (-0.0368), relative leaf water content (%) (-0.0368), biological yield plant^{-1} (-0.0352), empty capsules plant^{-1} (-0.0305), secondary offshoots plant^{-1} (-0.0299), capsules plant^{-1} (-0.0282), harvest maturity days (-0.0278), first blossoming days (-0.0274), 50% blossoming days (-0.0257), pollen viability (%)(-0.0239), primary offshoots plant^{-1} (-0.0209) and seeds capsule^{-1} (-0.0127).

4.3.2.12. Biological yield plant^{-1}

It imposed positive indirect impact on seed yield plant^{-1} *via.,* full capsules plant^{-1} (1.1538), pollen viability (%)(1.1501), capsules plant^{-1} (1.1333), harvest maturity days (1.112), first blossoming days (1.1073), 50% blossoming days (1.1018), secondary offshoots plant^{-1} (1.1009), plant height (1.1004), primary offshoots plant^{-1} (1.0386), relative leaf water content (%) (0.7327), test weight (gm) (0.6075), seeds capsule^{-1} (0.5461), total chlorophyll content (mg/ml) (0.4525) and harvest index (%) (0.343) whereas negative indirect impacts *via.,* flower drop (%)(-1.7111), proline content (-0.9821), empty capsules plant^{-1} (-0.9598), electrolyte leakage index (%)(-0.9416), lipid peroxidation (nmol/ml) (-0.7828) and ascorbic acid content (mg) (-0.072).

4.3.2.13. Harvest index (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* electrolyte leakage index (%)(0.4428), seeds capsule^{-1} (0.1229), flower drop (%)(0.1004), lipid peroxidation (nmol/ml) (0.0723), primary offshoots plant^{-1} (0.0592), secondary offshoots plant^{-1} (0.0485), biological yield plant-1 (0.0261), first blossoming days (0.0255), 50% blossoming days (0.0203), pollen viability (%)(0.0143), empty capsules plant^{-1} (0.0121), capsules plant^{-1} (0.012), full capsules plant^{-1} (0.0096), harvest maturity days (0.0077) and total chlorophyll content (mg/ml) (0.0028) whereas indirect negative impacts *via.,* ascorbic acid content (mg) (-0.2142), proline content (-0.045), test weight (gm) (-0.0101), plant height (-0.0095) and relative leaf water content (%) (-0.0045).

4.3.2.14. Total chlorophyll content (mg/ml)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* ascorbic acid content (mg) (0.004), empty capsules plant^{-1} (0.0023), lipid peroxidation (nmol/ml) (0.0012), proline content (0.0006) and flower drop (%)(0.0002) whereas indirect negative impacts *via.,* electrolyte leakage index (%)(-0.006), test weight (gm) (-0.0057), seeds capsule^{-1} (-0.0046), relative leaf water content (%) (-0.0046), plant height (-0.0027), secondary offshoots plant^{-1} (-0.0026), biological yield plant^{-1} (-0.0025), primary offshoots plant^{-1} (-0.0024), 50% blossoming days (-0.0017), harvest maturity days (-0.0017), full capsules plant^{-1} (-0.0016), first blossoming days (-0.0015), capsules plant^{-1} (-0.0014), pollen viability (%)(-0.0014) and harvest index (%) (-0.0002).

4.3.2.15. Relative leaf water content (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(0.0644), ascorbic acid content (mg) (0.0321), proline content (0.0233), lipid peroxidation (nmol/ml) (0.0222), empty capsules plant^{-1} (0.0205) and harvest index (%) (0.0023) whereas indirect negative impacts *via.,* seeds capsule^{-1} (-0.0379), secondary offshoots plant^{-1} (-0.0365), primary offshoots plant^{-1} (-0.034), total chlorophyll content (mg/ml) (-0.0322), biological yield plant-1 (-0.0283), pollen viability (%)(-0.0263), full capsules plant^{-1} (-0.0259), capsules plant^{-1} (-0.0256), plant height (-0.0254), first blossoming days (-0.0253), test weight (gm) (-0.0245), harvest maturity days (-0.0244), 50% blossoming days (-0.0229) and electrolyte leakage index (%)(-0.0078).

4.3.2.16. Lipid Peroxidation (nmol/ml)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* electrolyte leakage index (%)(0.0159), flower drop (%)(0.0123), harvest index (%) (0.0092), proline content (0.0064) and empty capsules plant^{-1} (0.0057) whereas indirect negative impacts *via.,* primary offshoots plant^{-1} (-0.0082), harvest maturity days (-0.0078), plant height (-0.0078), secondary offshoots plant^{-1} (-0.0077), full capsules plant^{-1} (-0.0077), capsules plant^{-1} (-0.0076), biological yield plant-1 (-0.0076), first blossoming days (-0.0075), 50% blossoming days (-0.0075), pollen viability (%)(-0.0069), relative leaf water content (%) (-0.0056), seeds capsule^{-1} (-0.0046), test weight (gm) (-0.0041), ascorbic acid content (mg) (-0.003) and total chlorophyll content (mg/ml) (-0.0021).

4.3.2.17. Electrolyte leakage index

It imposed positive indirect impact on seed yield plant^{-1} *via.,* first blossoming days (0.0154), harvest maturity days (0.0146), 50% blossoming days (0.0142), biological yield plant^{-1} (0.011), flower drop (%)(0.0087), capsules plant^{-1} (0.0081), plant height (0.008), full capsules plant^{-1} (0.0079), secondary offshoots plant^{-1} (0.0075), ascorbic acid content (mg) (0.0068), primary offshoots plant^{-1} (0.0067), test weight (gm) (0.0063) and pollen viability (%)(0.0048) whereas indirect negative impacts *via.,* harvest index (%) (-0.068), lipid peroxidation (nmol/ml) (-0.0192), proline content (-0.0179), total chlorophyll content (mg/ml) (-0.0125), empty capsules plant^{-1} (-0.0033), relative leaf water content (%) (-0.0024) and seeds capsule^{-1} (-0.0017).

4.3.2.18. Proline content (mg/gm)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* flower drop (%)(0.1987), electrolyte leakage index (%)(0.1506), empty capsules plant^{-1} (0.1025), lipid peroxidation (nmol/ml) (0.0645) and ascorbic acid content (mg) (0.018) whereas indirect negative impacts *via.,* pollen viability (%)(-0.1072), 50% blossoming days (-0.1058), first blossoming days (-0.1046), full capsules plant^{-1} (-0.1043), capsules plant^{-1} (-0.1004), harvest maturity days (-0.0965), biological yield plant^{-1} (-0.0962), secondary offshoots plant^{-1} (-0.0956), primary offshoots plant^{-1} (-0.0856), plant height (-0.0845), relative leaf water content (%) (-0.059), harvest index (%) (-0.0579), seeds capsule^{-1} (-0.0239), test weight (gm) (-0.0171) and total chlorophyll content (mg/ml) (-0.0105).

4.3.2.19. Ascorbic acid content (mg)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* harvest index (%) (0.0799), relative leaf water content (%) (0.0235), total chlorophyll content (mg/ml) (0.0203), pollen viability (%)(0.0194), primary offshoots plant^{-1} (0.0168), electrolyte leakage index (%)(0.0165), test weight (gm) (0.0113), lipid peroxidation (nmol/ml) (0.0087), secondary offshoots plant^{-1} (0.0072), capsules plant^{-1} (0.0057), full capsules plant^{-1} (0.0057), seeds capsule^{-1} (0.0024), biological yield plant^{-1} (0.002) and harvest maturity days (0.0019) whereas indirect negative impacts *via.,* flower drop (%)(-0.0554), proline content (-0.0052), empty capsules plant^{-1} (-0.005), 50% blossoming days (-0.0047), plant height (-0.0026) and first blossoming days (-0.0011).

4.3.2.20. Pollen viability

It imposed positive indirect impact on seed yield plant^{-1} *via.,* capsules plant^{-1} (0.1057), biological yield yield^{-1} (0.1056), full capsules plant^{-1} (0.1056), harvest maturity days (0.1037), secondary offshoots plant^{-1} (0.1007), first blossoming days (0.1004), 50% blossoming days (0.0992), primary offshoots plant^{-1} (0.0961), plant height (0.0959), seeds capsule^{-1} (0.0674), relative leaf water content (%) (0.0625), test weight (gm) (0.0379), total chlorophyll content (mg/ml) (0.0227) and harvest index (%) (0.0173) whereas indirect negative impacts *via.,* flower drop (%)(-0.1713), proline content (-0.1005), empty capsules plant^{-1} (-0.0733), lipid peroxidation (nmol/ml) (-0.0661), ascorbic acid content (mg) (-0.0627) and electrolyte leakage index (%)(-0.0379).

4.3.2.21. Flower drop (%)

It imposed positive indirect impact on seed yield plant^{-1} *via.,* proline content (0.0336), ascorbic acid content (mg) (0.0324), harvest index (%) (0.0219), lipid peroxidation (nmol/ml) (0.0211) and empty capsules plant^{-1} (0.0117) whereas indirect negative impacts *via.,* pollen viability (%)(-0.0309), primary offshoots (-0.0296), harvest maturity days (-0.0288), biological yield plant^{-1} (-0.0283), plant height (-0.028), secondary offshoots plant^{-1} (-0.0279), relative leaf water content (%) (-0.0276), capsules plant^{-1} (-0.0275), full capsules plant^{-1} (-0.0265), first blossoming days (-0.0263), 50% blossoming days (-0.0251), test weight (gm) (-0.0224), seeds capsule^{-1} (-0.0148), electrolyte leakage index (%)(-0.0124) and total chlorophyll content (mg/ml) (-0.0005).

1.4 Eberhart and Russell's model for stability analysis

One of the primary goals of all breeding programs is the development of a stable genotype. For commercial agricultural plant production, phenotypically stable genotypes are sought. Any breeding program must screen for and select phenotypically stable genotypes that can performs evenly in varying conditions of environment. For stability analysis, multiple models have been given. One of them Eberhart & Russell (1966), one that yields greater than mean, with regression coefficient (b=1) and deviation from regression equals zero, *i.e.,* ($s^2di=0$). A coefficient of regression (bi>1) indicates genotype suits rich environment, whilst coefficient of regression (bi<1) shows it may be adapted to poor environments.

Stability analysis might be more informative if study material is evaluated in a variety of environments that influence genotype growth and development. In the current study, 25 genotypes were examined over three sowing dates in *rabi* 2020-21.

4.4.1 Stability analysis of variance

Stability's ANOVA illustrated that variations owning to genotypes among all traits were significant (Table 4.18). Basing pooled ANOVA, the individual environment effect was significant for every trait. Assessing contrary to pooled error, the G x E interaction demonstrated significant differences amongst analysed parameters. The G x E then was split into genotype x environment (linear) & and pooled deviations. For all traits, genotypes x environment (linear) interaction and pooled deviation were significant. When examined contrary to pooled error, environment (linear) revealed a significant difference in all characteristics. Mean performance across environments, regression coefficient (bi) (R.C) & deviation from regression (S^2di) (D.F.R) were used to determine genotype's phenotypic stability.

4.4.2 Stability for individual traits

Mean performance across contexts, coefficient of regression (bi) & deviation from regression (s^2di) were employed to determine genotype phenotypic stability (Table 4.19-4.29). The character stability of genotypes is discussed further below:

Table 4.18: Three environmental stability ANOVA

Source	d.f.	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
Genotype	24	7.75*	6.68*	16.57*	42.83*	0.24*	0.50*	53.98*	76.50*	3.91*	0.15*	6.69*
Env. + (Gen. X Env.)	50	2797.48*	3253.34*	9903.005*	506.88*	5.19*	14.08*	1190.77*	844.31*	47.44*	1.23*	42.97*
Env. (Linear)	1	735.04*	949.86*	9738.64*	2090.56*	4.34*	18.93*	6842.06*	8320.24*	112.13*	0.42*	10.70*
Gen. X Env. (Linear)	24	2.55*	3.12*	4.07*	22.02*	0.08*	0.14*	15.09*	14.03*	2.88*	0.09*	1.71*
Pooled deviation	25	5563.11*	6465.68*	19412.54*	908.99*	10.13*	27.26*	2093.37*	1342.35*	87.64*	2.35*	83.88*
Pooled error dev.	72	0.27	0.31	0.34	0.33	0.01	0.02	0.68	0.79	0.10	0.01	0.02

Source	d.f.	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
Genotype	24	6.05*	129.17*	0.36*	153.49*	29.45*	212.50*	0.58*	16.02*	54.70*	52.66*	7.50*
Env. + (Gen. X Env.)	50	132.16*	717.09*	1.16*	721.20*	203.74*	920.88*	1.10*	378.12*	2024.19*	339.39*	25.65*
Env. (Linear)	1	1520.48*	7.24*	0.15*	320.15*	295.5*	178.85*	5.06*	6.67*	1522.17*	116.75*	275.07*
Gen. X Env. (Linear)	24	2.93*	4.75*	0.04*	25.33*	6.16*	15.06*	0.03*	7.90*	3.35*	10.55*	1.04*
Pooled deviation	25	200.68*	1429.34*	2.27*	1405.27*	389.74*	1820.16*	1.98*	74.516*	3984.28*	663.99*	39.31*
Pooled error dev.	72	0.17	0.65	0.00	0.13	0.09	0.10	0.01	1.22	0.91	0.72	0.04

4.4.2.1. First blossoming days

K 850, IPC-97-67, ICC 244-263, BPM and RSG 945 genotypes carried greater mean, R.C *i.e.,* (bi=1), and minimal D.F.R *i.e.,* (S^2di~0), suggesting that they were stable, not perfect.

ICC-5434, ICC-5439 and SADABAHAR on the other hand, had a lower mean value coupled with R.C lesser to unity (bi<1) and a minimal D.F.R (S^2di~0), depicting their above average stability. KWR-108, PBG-7 and IPC-06-77 on the contrary, exhibited low mean compared to grand mean paired with higher R.C (bi>1) with insignificant D.F.R (S^2di~0), demonstrating below average stability.

Any other genotypes with any bi value and a high S^2di value are unstable.

4.4.2.2. 50% blossoming days

IPC-06-77, IPC-97-67, BG-212, and GNG 469 genotypes with a minimal D.F.R (S^2di~0) and a lower mean value suggesting ideal and fair stability, whereas, PUSA 3043 recorded higher mean value, R.C *i.e.,* (bi=1), and minimal D.F.R *i.e.,* (S^2di~0) revealed stable but not ideal stability.

Genotypes ICC-5434 and SADABAHAR, on the contrary, had a low mean with a R.C smaller than unity (bi<1) and the minute D.F.R (S^2di~0), depicting above-average stability. On the contrary, PBG-7 and ICC-5335 genotypes had low mean compared to grand mean paired with higher R.C *i.e.,* (bi>1) with little D.F.R (S^2di~0) indicating below average stability.

Any other genotypes with any bi value and a high S^2di value are unstable.

4.4.2.3. Harvest maturity days

Genotypes IPC-97-67, ICC-5434, and ICC-5439 had a minimal D.F.R S2di~0) and a lower mean value, depicting ideal and fair stability, whereas, K-850, ICC-3525, and IPC 05-28 had higher mean, R.C *i.e.,* (bi=1), and a small D.F.R *i.e.,* (S^2di~0), demonstrating stable but not ideal stability.

Any other genotypes with a high S^2di value and any bi value are unstable.

4.19 Stability table for first blossoming days & 50% flowering

Sl.no	First blossoming days				50% blossoming days			
	Genotype	Mean	βi	S2Di	Genotype	Mean	βi	S2Di
1	**KWR-108**	82.83	1.449	0.0341	**KWR-108**	89.5	1.4426	1.9666
2	**PBG-7**	85.5	1.3489	0.1026	**PBG-7**	91	1.1962	-0.3342
3	**ICC-3020**	86.83	1.4058	20.6597	**ICC-3020**	93.3333	1.4513	10.6783
4	**IPC-06-77**	84.5	1.4676	-0.227	**IPC-06-77**	92	1.0896	-0.0764
5	**KPG-59**	84.66	0.9682	1.2052	**KPG-59**	91.5	1.0328	1.008
6	**K-850**	86.3333	0.9742	-0.138	**K-850**	92.6667	0.9909	3.3924
7	**ICC-5335**	82.5	0.8615	6.2777	**ICC-5335**	91.5	1.1962	-0.3342
8	**IPC-97-67**	86.8333	0.9868	-0.3635	**IPC-97-67**	92.1667	0.9341	-0.4496
9	**ICC 244-263**	87.6667	0.9304	0.3127	**ICC 244-263**	94.3333	1.1552	0.0007
10	**BG-212**	85	0.8183	1.4111	**BG-212**	92	0.9096	-0.4016
11	**ICC-3525**	88.5	1.2805	2.8877	**ICC-3525**	95.1667	1.1639	0.7354
12	**ICC-5434**	85.6667	0.4934	-0.3911	**ICC-5434**	91.6667	0.8607	0.5578
13	**ICC-5439**	85.6667	0.8495	0.5489	**ICC-5439**	92.5	1.246	2.5501
14	**BPM**	86.8333	1.0929	-0.3522	**BPM**	93.1667	0.9009	1.8625
15	**IPC-07-56**	87	1.4118	7.4953	**IPC-07-56**	93.5	1.2791	9.3684
16	**RSG 931**	86.5	0.6619	0.7199	**RSG 931**	93.1667	0.7043	1.3537
17	**PDG-4**	84.8333	1.1738	3.753	**PDG-4**	91.6667	0.9909	3.3924
18	**IPC 05-28**	87.3333	1.3051	0.6841	**IPC 05-28**	94.5	1.3928	-0.1745
19	**PUSA 3043**	89	0.7806	0.1858	**PUSA 3043**	94.6667	0.9341	-0.4496
20	**RSG-888**	87.5	0.8741	3.1355	**RSG-888**	94.5	0.9499	4.7534
21	**GNG 469**	84.8333	0.9616	1.0783	**GNG 469**	90.8333	1.0486	0.4259
22	**RSG 945**	88.3333	0.9868	-0.3635	**RSG 945**	95.5	0.7864	0.0359
23	**SADABAHAR**	85.3333	0.6433	-0.4	**SADABAHAR**	92.3333	0.5819	-0.1653
24	**PBG-5**	85.6667	0.4305	11.3181	**PBG-5**	93.1667	0.2779	5.2661
25	**JG-14**	86.5	0.8435	7.1813	**JG-14**	94.1667	0.484	3.8
Population mean			**86.08**				**92.82**	

4.20: Stability table for harvest maturity days & plant height

Sl.no	Harvest maturity days				Plant height			
	Genotype	**Mean**	**βi**	**S2Di**	**Genotype**	**Mean**	**βi**	**S2Di**
1	**KWR-108**	155.83	1.0042	6.8365	**KWR-108**	40.99	0.6773	-0.3358
2	**PBG-7**	158.83	1.0705	4.2252	**PBG-7**	33.26	0.7533	24.7375
3	**ICC-3020**	161.83	1.1126	25.9434	**ICC-3020**	31.39	1.056	12.9322
4	**IPC-06-77**	160.67	1.1193	6.5882	**IPC-06-77**	40.68	0.4345	1.7191
5	**KPG-59**	161.17	1.0198	11.5033	**KPG-59**	34.23	0.8031	28.0939
6	**K-850**	161.83	1.0519	-0.387	**K-850**	30.85	1.0886	-0.4772
7	**ICC-5335**	159.67	0.841	5.1145	**ICC-5335**	38.54	1.0146	24.9111
8	**IPC-97-67**	160.33	1.0471	0.5801	**IPC-97-67**	34.10	0.9218	2.5077
9	**ICC 244-263**	163.17	0.9923	2.0738	**ICC 244-263**	30.88	1.1886	0.1769
10	**BG-212**	157.00	0.8712	13.3056	**BG-212**	37.86	0.7966	31.558
11	**ICC-3525**	164.83	1.0851	-0.4972	**ICC-3525**	33.05	1.1687	57.5632
12	**ICC-5434**	157.17	0.926	0.6431	**ICC-5434**	39.70	1.3321	2.9717
13	**ICC-5439**	159.33	1.0519	-0.387	**ICC-5439**	32.84	1.3602	6.4955
14	**BPM**	160.83	0.9767	5.0716	**BPM**	30.17	1.8041	23.9088
15	**IPC-07-56**	160.83	1.1644	44.5162	**IPC-07-56**	38.77	0.784	0.3818
16	**RSG 931**	160.83	0.9152	5.8823	**RSG 931**	27.54	1.5651	3.5254
17	**PDG-4**	159.50	0.9141	28.49	**PDG-4**	35.74	1.0019	39.0821
18	**IPC 05-28**	164.33	1.0851	-0.4972	**IPC 05-28**	32.09	-0.2431	-0.4854
19	**PUSA 3043**	164.83	1.1183	-0.4645	**PUSA 3043**	31.15	-0.0566	-0.0708
20	**RSG-888**	161.83	1.039	46.172	**RSG-888**	31.39	1.9596	82.9895
21	**GNG 469**	158.00	1.0743	1.4128	**GNG 469**	35.26	1.3971	-0.3396
22	**RSG 945**	163.00	1.0217	2.3395	**RSG 945**	29.73	0.3884	0.1149
23	**SADABAHAR**	160.50	0.7993	4.1466	**SADABAHAR**	38.05	1.0325	0.8222
24	**PBG-5**	162.00	0.8381	11.39	**PBG-5**	32.13	1.315	21.406
25	**JG-14**	162.50	0.8607	4.8894	**JG-14**	37.74	1.4566	0.1209
Population means			**160.83**				**34.32**	

4.4.2.4. Plant height

Genotype SADABAHAR had a high mean value and a tiny D.F.R (S^2di~0), suggesting fair and ideal stability, while genotype K-850 had a lower mean value coupled with R.C *i.e.,* (bi=1), and a minor D.F.R *i.e.,* (S^2di~0), suggesting stable but not ideal stability.

Genotypes KWR 108 and IPC 07-56 on the other hand, had a higher mean with a R.C lower to unity (bi<1) and a minimal D.F.R (S2di~0), showing above average stability. On the contrary, genotype JG 14 exhibited a higher mean compared to grand mean with a higher R.C (bi>1) couple with minimal D.F.R (S^2di~0), revealing below average stability.

Any other genotypes with any bi value and a high S^2di value are unstable.

4.4.2.5. Primary offshoots plant^{-1}

Genotype RSG 931 demonstrated stability with a lower mean, a R.C close to unity (bi~1), and a minute D.F.R (S^2di~0).

Genotypes KWR-108, ICC 244-263, ICC-5439 and GNG 469 demonstrated above average stability with a higher mean, a R.C lower than unity (bi<1), and a minute D.F.R (S^2di~0). IPC-06-77, K-850, BG-212, ICC-5434, IPC-07-56, SADABAHAR, PBG-5, JG-14 on the other hand recorded higher mean paired with higher R.C *i.e.,* (bi>1), a minimal D.F.R (S^2di~0), suggesting below average stability.
Any other genotypes with any bi value and higher of S^2di value are unstable.

4.4.2.6. Secondary offshoots plant^{-1}

ICC 244-263 and ICC-5439 had higher mean values, a R.C below unity (bi<1) with a minimal D.F.R (S^2di~0), showing above average stability.

KWR-108, PBG-7, ICC-3020, IPC-06-77, K-850, BG-212, ICC-5434, IPC-07-56, GNG 469, SADABAHAR, PBG-5, JG 14 all on the other hand, have higher mean paired with higher coefficient of regression (bi>1) with small D.F.R (S^2di~0), owning below average stability.

Any other genotypes with any bi value and a high S^2di value are unstable.

4.21: Stability table for number of primary & secondary offshoots plant^{-1}

Sl.no	Primary offshoots plant^{-1}				Secondary offshoots plant^{-1}			
	Genotype	Mean	βi	S2Di	Genotype	Mean	βi	S2Di
1	KWR-108	3.90	0.6442	-0.0035	KWR-108	6.37	1.3458	0.0526
2	PBG-7	3.63	1.2117	0.02	PBG-7	6.10	1.2034	0.1009
3	ICC-3020	3.57	0.7669	-0.007	ICC-3020	6.27	1.5027	0.0741
4	IPC-06-77	4.00	1.7255	0.011	IPC-06-77	6.57	1.5762	-0.017
5	KPG-59	3.47	0.3067	0.1389	KPG-59	5.93	0.7989	0.1408
6	K-850	3.73	2.2469	-0.0025	K-850	6.17	1.2106	0.3943
7	ICC-5335	3.57	1.5491	0.0781	ICC-5335	5.83	1.1227	0.0096
8	IPC-97-67	3.43	-0.1917	-0.0111	IPC-97-67	5.70	0.3138	-0.0172
9	ICC 244-263	3.83	0.8896	0.0377	ICC 244-263	6.00	0.5341	0.3814
10	BG-212	3.97	1.6181	0.1801	BG-212	6.43	1.3531	-0.0222
11	ICC-3525	3.43	0.6595	0.2597	ICC-3525	5.70	0.6793	0.6079
12	ICC-5434	4.03	1.8098	0.1658	ICC-5434	6.47	1.4193	-0.0212
13	ICC-5439	3.67	0.4448	0.0009	ICC-5439	6.13	0.8406	0.049
14	BPM	3.30	0	-0.0114	BPM	5.57	0.4045	-0.0198
15	IPC-07-56	4.13	1.8558	-0.0035	IPC-07-56	6.57	1.451	0.0899
16	RSG 931	3.53	1.0966	0.0262	RSG 931	5.67	0.8752	0.0041
17	PDG-4	3.50	0.3681	0.2051	PDG-4	5.93	0.8406	0.049
18	IPC 05-28	3.17	1.135	0.2713	IPC 05-28	5.27	0.583	0.6067
19	PUSA 3043	3.23	-0.1227	0.0127	PUSA 3043	5.27	0.0173	0.0238
20	RSG-888	3.57	1.6871	0.3204	RSG-888	5.73	1.1328	0.4524
21	GNG 469	3.87	0.2377	0.2655	GNG 469	6.43	1.1227	0.0096
22	RSG 945	3.17	0.7669	-0.007	RSG 945	5.20	0.3872	0.0039
23	SADABAHAR	4.10	1.7945	-0.0113	SADABAHAR	6.47	1.461	0.0078
24	PBG-5	3.67	1.227	0.0535	PBG-5	6.07	1.3141	0.3964
25	JG-14	3.77	1.273	0.0535	JG-14	6.13	1.51	-0.0223
Population means		**3.65**				**6.00**		

4.22: Stability table for capsules & full capsules plant^{-1}

Sl.no	Capsules plant^{-1}				Full capsules plant^{-1}			
	Genotype	Mean	βi	S2Di	Genotype	Mean	βi	S2Di
1	KWR-108	57.97	1.0509	1.9803	KWR-108	48.03	1.0371	4.804
2	PBG-7	52.97	0.9142	0.7666	PBG-7	42.03	0.8335	0.8802
3	ICC-3020	48.87	0.792	21.0229	ICC-3020	36.97	1.0415	24.363
4	IPC-06-77	57.53	0.9955	-0.4457	IPC-06-77	47.87	0.9949	1.2344
5	KPG-59	53.27	1.4247	1.882	KPG-59	41.77	1.2702	-0.8514
6	K-850	46.40	0.5867	1.5071	K-850	33.80	0.6636	7.375
7	ICC-5335	56.43	0.9425	-0.9411	ICC-5335	48.10	1.027	1.6028
8	IPC-97-67	53.43	0.948	20.7269	IPC-97-67	43.40	1.052	10.742
9	ICC 244-263	48.87	0.5871	5.2854	ICC 244-263	36.23	0.6645	0.0457
10	BG-212	56.40	0.8865	22.9326	BG-212	47.33	0.8351	5.2145
11	ICC-3525	51.00	0.9185	-0.9397	ICC-3525	40.73	1.1203	-0.7548
12	ICC-5434	58.60	1.0977	1.6933	ICC-5434	48.83	1.1075	0.7306
13	ICC-5439	54.10	1.0159	0.7176	ICC-5439	43.53	1.048	0.3125
14	BPM	49.30	0.7924	45.659	BPM	37.93	0.764	35.6688
15	IPC-07-56	57.87	0.9566	9.1483	IPC-07-56	48.03	0.9446	5.5827
16	RSG 931	48.70	0.8516	-1.0133	RSG 931	36.17	0.7783	3.0104
17	PDG-4	52.10	1.0229	32.1003	PDG-4	42.20	1.0486	43.3871
18	IPC 05-28	46.33	0.9231	3.7994	IPC 05-28	36.50	0.933	6.4807
19	PUSA 3043	46.57	0.8193	-1.0112	PUSA 3043	35.30	0.7313	-0.921
20	RSG-888	49.17	1.2569	37.166	RSG-888	38.57	1.2741	39.5352
21	GNG 469	57.33	1.5959	0.8154	GNG 469	46.90	1.4209	12.8739
22	RSG 945	45.93	0.9135	-0.9388	RSG 945	34.50	0.7906	-0.3253
23	SADABAHAR	58.27	1.2927	-0.7387	SADABAHAR	48.50	1.2398	-0.3905
24	PBG-5	53.13	1.1492	-0.1878	PBG-5	41.07	1.1162	-0.5424
25	JG-14	53.30	1.2657	-0.8165	JG-14	42.43	1.2634	0.4866
Population mean		**52.55**				**41.87**		

4.4.2.7. Capsules plant^{-1}

Genotypes PBG-7, IPC-06-77, ICC-5335 and ICC-5439 with small D.F.R (S^2di~0) with higher mean indicated ideal and fair stability, whereas ICC-3525 and RSG 945 having low mean couple with R.C (b=1) and minimal D.F.R (S^2di~0) recorded stable but not ideal stability.

On the contrary, genotypes GNG 469, SADABAHAR, PBG-5, JG 14 had a higher mean and coefficient of regression (bi>1) coupled with a minimal D.F.R (S^2di~0), showing below average stability.

Any other genotypes with any bi value and a high S^2di value are unstable.

4.4.2.8. Full capsules plant^{-1}

The higher mean value, R.C unit (b=1) and minimal D.F.R (S^2di~0) of genotype ICC-5439 indicate that this genotype was ideal and stable.

Genotype PBG-7 exhibited higher mean and R.C (bi<1) with minimal D.F.R (S^2di~0), depicted above average stability, while, ICC-5434, SADABAHAR and JG 14 showed higher mean coupled with higher R.C *i.e.,* (bi>1) and insignificant D.F.R *i.e.,* (S^2di~0), showing below average stability.

Any other genotypes with any bi value and a high S^2di value are unstable.

4.23: Stability table for empty capsules plant^{-1} & seeds pod^{-1}

Sl.no	Empty capsules plant^{-1}				Seeds capsule^{-1}			
	Genotype	Mean	βi	S2Di	Genotype	Mean	βi	S2Di
1	**KWR-108**	9.63	0.5346	-0.1444	**KWR-108**	1.83	1.0705	-0.0059
2	**PBG-7**	11.23	0.6064	0.1277	**PBG-7**	1.53	-0.5353	-0.0113
3	**ICC-3020**	11.90	2.5285	4.1957	**ICC-3020**	1.83	-0.063	0.0934
4	**IPC-06-77**	9.67	0.7987	0.3159	**IPC-06-77**	1.87	2.6606	0.0736
5	**KPG-59**	11.50	-0.0196	0.4088	**KPG-59**	2.10	5.4786	0.0384
6	**K-850**	12.60	0.8178	3.7109	**K-850**	1.63	1.0705	-0.0059
7	**ICC-5335**	8.33	1.9046	-0.0723	**ICC-5335**	1.67	-2.7236	-0.0121
8	**IPC-97-67**	10.03	2.1382	-0.0691	**IPC-97-67**	1.67	0.488	0.0695
9	**ICC 244-263**	12.63	0.6906	3.2579	**ICC 244-263**	1.67	1.102	-0.0071
10	**BG-212**	9.07	1.2905	4.9881	**BG-212**	1.87	3.8413	0.0236
11	**ICC-3525**	10.27	2.6107	1.607	**ICC-3525**	1.80	0.0472	0.0468
12	**ICC-5434**	9.77	1.2831	-0.1475	**ICC-5434**	2.17	4.3608	-0.0086
13	**ICC-5439**	10.57	1.962	2.7517	**ICC-5439**	1.47	0.488	0.0695
14	**BPM**	11.37	0.9833	0.2404	**BPM**	1.63	-0.5825	0.0278
15	**IPC-07-56**	9.83	0.6261	-0.1008	**IPC-07-56**	2.17	-2.1096	0.0981
16	**RSG 931**	12.53	-0.1892	0.5766	**RSG 931**	1.73	-1.6688	0.0263
17	**PDG-4**	9.90	1.294	0.4	**PDG-4**	1.63	3.2431	-0.0046
18	**IPC 05-28**	9.83	0.9006	0.2997	**IPC 05-28**	1.43	-2.1411	0.0159
19	**PUSA 3043**	11.27	0.0259	0.0142	**PUSA 3043**	1.50	-2.1725	-0.0131
20	**RSG-888**	10.60	1.263	-0.084	**RSG-888**	1.80	4.3923	0.0401
21	**GNG 469**	10.43	-0.2497	-0.1025	**GNG 469**	1.50	-0.0472	0.0468
22	**RSG 945**	11.43	-0.1215	0.391	**RSG 945**	1.30	0	-0.0132
23	**SADABAHAR**	9.77	0.9988	0.6024	**SADABAHAR**	1.87	1.6215	-0.011
24	**PBG-5**	12.07	0.8608	-0.0661	**PBG-5**	2.07	4.9748	0.1743
25	**JG-14**	10.87	1.462	0.3897	**JG-14**	1.83	2.204	0.0112
Population mean		**10.68**				**1.74**		

4.4.2.9. Empty capsules plant^{-1}

Genotypes IPC 05-28 and SADABAHAR with minute D.F.R (S^2di~0) and lower mean values depicted fair and ideal stability, while genotype BPM higher mean and R.C (bi=1), and a minimal regression from deviation (S^2di~0) recorded stable but not a perfect stability.

On the other hand, genotypes KWR-108, IPC-06-77, IPC-07-56, GNG 469, and RSG 945 exhibited lower mean and R.C *i.e.,* (bi<1) and minimal D.F.R *i.e.,* (S^2di~0), depicting above average stability whereas, ICC-5335, IPC-97-67, ICC-5434, PDG-4, and RSG-888 recorded lower mean accompanied by higher R.C (bi>1) with minor D.F.R (S^2di~0) depicted below average stability.

Any other genotypes with any other bi value and a high S^2di value were unstable.

4.4.2.10. Seeds capsule^{-1}

KWR-108 had a greater mean, R.C *i.e.,* (bi=1), and minimal D.F.R *i.e.,* (S^2di~0), showing ideal stability while genotype K-850 lower mean and R.C (bi=1), and a minimal regression from deviation (S^2di~0) recorded stable but not a perfect stability.

On the other hand, genotypes ICC-3020, ICC-3525 and IPC-07-56 exhibited higher mean values with lower R.C *i.e.,* (bi<1) and a minute D.F.R *i.e.,* (S^2di~0), suggesting above average stability, whereas, IPC-06-77, KPG-59, BG-212, ICC-5434, RSG-888, SADABAHAR, PBG-5 and JG-14 had higher mean accompanied by a higher R.C (bi>1) with minimal D.F.R (S^2di~0) recording below average stability.

Any other genotypes with any bi value and a high S^2di value are unstable.

4.4.2.11. Test weight (gm)

Genotypes ICC-3020, K-850, IPC-97-67, ICC-5439 and IPC-07-56 had minimal D.F.R (S^2di~0), R.C (bi=1) with a higher mean, suggesting ideal and fair stability, whereas, KPG-59, ICC 244-263, ICC-5434 and IPC 05-28 had lower mean values, R.C (bi=1), along with small D.F.R (S^2di~0), suggesting stable but not ideal stability.

In contrary, genotypes KWR-108, IPC-06-77, ICC-5335, PDG-4 and GNG 469 had higher mean coupled with higher R.C *i.e.,* (bi>1) and minute D.F.R *i.e.,* (S^2di~0) recorded below average stability.

Any other genotype any bi value and higher S^2di value are unstable.

4.4.2.12. Biological yield plant^{-1}

Genotype PBG-7 exhibiting a higher mean value and minor D.F.R (S^2di~0) suggested fair and ideal stability, while genotype ICC 244-263, BPM, RSG 931, IPC 05-28 and GNG 469 with a lower mean, R.C *i.e.,* (bi=1), and a tiny D.F.R *i.e.,* (S^2di~0) suggested stable but not ideal stability.

In contrast, genotypes KWR-108, IPC-06-77 and IPC-07-56 displayed higher mean value alongside R.C lower than unity (bi<1) and a small D.F.R (S^2di~0) suggesting above average stability, while IPC-97-67 and BG-212 carried higher mean in combination with a higher R.C (bi>1) with insignificant D.F.R (S^2di~0) demonstrated below average stability.

Any other genotypes with any bi value and high S^2di are unstable.

4.4.2.13. Harvest index (%)

Genotypes KWR-108, IPC-06-77, ICC-5335, ICC-5434 and IPC-07-56 carried higher mean values alongside lower R.C *i.e.,* (bi<1) and minimal D.F.R *i.e.,* (S^2di~0), suggesting above average stability, whereas, PDG-4 possessed high mean value to grand mean that had greater regression coefficients (bi>1) and insignificant D.F.R (S^2di~0), showing below average stability.

Any other genotypes with any other bi and S^2di value are unstable.

4.24: Stability table for test weight (gm), Biological yield plant^{-1}

Sl.no	Test weight (gm)				Biological yield plant^{-1}			
	Genotype	Mean	βi	S2Di	Genotype	Mean	βi	S2Di
1	KWR-108	11.10	1.3116	0.188	KWR-108	16.76	0.766	0.5674
2	PBG-7	9.92	0.6696	0.8265	PBG-7	16.55	0.9599	0.1634
3	ICC-3020	11.12	1.0308	0.0834	ICC-3020	16.68	1.1434	2.3199
4	IPC-06-77	11.21	1.6514	-0.0331	IPC-06-77	16.57	0.7589	0.4019
5	KPG-59	9.84	1.0965	0.0631	KPG-59	15.92	1.1734	-0.1544
6	K-850	10.98	1.0371	0.1128	K-850	15.96	1.0936	1.5972
7	ICC-5335	13.75	1.1952	0.09	ICC-5335	18.53	0.9681	2.3515
8	IPC-97-67	11.63	0.9005	0.0409	IPC-97-67	16.65	1.1437	-0.212
9	ICC 244-263	9.42	0.9675	0.0475	ICC 244-263	15.54	0.9358	-0.2167
10	BG-212	11.85	2.9134	3.4159	BG-212	20.99	1.4612	0.5145
11	ICC-3525	9.11	1.1331	-0.0068	ICC-3525	17.22	1.2412	2.6608
12	ICC-5434	8.83	0.9487	0.228	ICC-5434	17.55	0.9045	2.5999
13	ICC-5439	10.78	1.0813	0.0676	ICC-5439	15.91	1.4036	-0.1503
14	BPM	10.32	1.2027	0.0345	BPM	15.83	1.0692	-0.2292
15	IPC-07-56	11.66	1.0838	0.0193	IPC-07-56	17.48	0.8424	-0.0792
16	RSG 931	9.77	1.1002	-0.0249	RSG 931	14.79	0.9674	0.0925
17	PDG-4	11.08	1.1698	0.0024	PDG-4	15.07	0.8965	1.0012
18	IPC 05-28	8.78	0.9106	0.0383	IPC 05-28	14.52	1.0198	-0.0572
19	PUSA 3043	11.18	-6.8359	4.1509	PUSA 3043	15.07	0.5933	-0.172
20	RSG-888	8.55	-1.4985	0.0099	RSG-888	15.41	1.0552	3.7539
21	GNG 469	14.12	1.1444	-0.0325	GNG 469	15.61	1.0205	-0.1266
22	RSG 945	8.70	0.683	0.0071	RSG 945	14.00	0.5402	0.1487
23	SADABAHAR	9.13	1.2521	0.102	SADABAHAR	16.08	0.7655	2.8763
24	PBG-5	8.70	4.3113	0.7847	PBG-5	15.39	1.1613	5.2093
25	JG-14	9.57	4.5401	0.7887	JG-14	16.12	1.1155	-0.2295
Population mean		**10.44**				**16.25**		

4.4.2.14. Total chlorophyll content (mg/ml)

Genotypes IPC-06-77, KPG-59, BG-212, ICC-5439, IPC-07-56, PDG-4 and GNG 469 displayed higher mean values alongside R.C *i.e.,* (bi<1) and a small D.F.R *i.e.,* (S^2di~0) demonstrating above average stability, while genotypes KWR-108, ICC-5335, ICC-5434, SADABAHAR and JG 14 possessed higher mean together with a high R.C (bi>1) with insignificant D.F.R (S^2di~0) indicated below average stability.

Any other genotypes with any other bi and S^2di value are unstable.

4.4.2.15. Relative leaf water content (%)

Genotypes PDG-4 carried higher mean values with lower R.C *i.e.,* (bi<1) and minimal D.F.R *i.e.,* (S^2di~0), suggesting above average stability, while, KWR-108, ICC-5335, BG-212, IPC-07-56 and SADABAHAR possessed higher mean paired with higher regression coefficients (bi>1) and insignificant D.F.R (S^2di~0), demonstrating below average stability.

Any other genotypes with any bi value and S^2di value are unstable.

4.4.2.16. Lipid Peroxidation (nmol/ml)

The higher mean value and R.C *i.e.,* (bi=1), minimal D.F.R *i.e.,* (S^2di~0) of genotype ICC 244-263 indicated stable, not ideal stability.

On the contrary, KWR-108, IPC-06-77, KPG-59, ICC-5335, BG-212, IPC-07-56, PDG-4, and SADABAHAR demonstrated lower mean alongside R.C *i.e.,* (bi<1) and a small D.F.R *i.e.,* (S^2di~0), suggesting above average stability, while, RSG 931, IPC 05-28, and GNG 469 experienced lower mean paired with higher R.C *i.e.,* (bi>1) and insignificant D.F.R *i.e.,* (S^2di~0) revealed below average stability.

Any other genotypes with any bi or S^2di values are unstable.

4.25: Stability table for harvest index (%), Total chlorophyll content (mg/ml)

Sl.no	Harvest index (%)				Total chlorophyll content (mg/ml)			
	Genotype	Mean	βi	S2Di	Genotype	Mean	βi	S2Di
1	**KWR-108**	51.52	-1.5053	-0.8991	**KWR-108**	1.96	2.2121	0.0249
2	**PBG-7**	42.94	2.2756	0.1032	**PBG-7**	1.51	0.6916	0.0055
3	**ICC-3020**	38.16	5.3124	8.8829	**ICC-3020**	1.63	-0.7738	-0.0037
4	**IPC-06-77**	52.08	-0.2181	-0.0418	**IPC-06-77**	2.03	0.836	0.2126
5	**KPG-59**	40.20	-0.9569	6.3581	**KPG-59**	2.43	0.557	0.0205
6	**K-850**	39.89	-1.1496	-0.9174	**K-850**	1.41	4.623	-0.001
7	**ICC-5335**	53.12	0.5198	0.0633	**ICC-5335**	1.81	4.7897	0.1298
8	**IPC-97-67**	43.15	6.9069	38.0958	**IPC-97-67**	1.63	3.7215	0.092
9	**ICC 244-263**	37.17	1.2747	3.4044	**ICC 244-263**	1.58	3.8027	0.0271
10	**BG-212**	52.95	1.5247	8.2632	**BG-212**	1.91	-0.0656	0.0382
11	**ICC-3525**	35.10	-2.368	5.4257	**ICC-3525**	1.12	6.7661	0.0405
12	**ICC-5434**	50.70	-0.6958	-0.9748	**ICC-5434**	1.90	2.52	0.0549
13	**ICC-5439**	41.31	-6.1542	21.3198	**ICC-5439**	1.78	0.8573	0.0171
14	**BPM**	43.01	0.3025	0.7337	**BPM**	1.48	0.2849	0.1902
15	**IPC-07-56**	51.54	-1.5123	-0.8939	**IPC-07-56**	1.83	0.6271	0.0036
16	**RSG 931**	39.15	2.0842	1.0124	**RSG 931**	1.43	1.3865	0.0567
17	**PDG-4**	44.58	6.2942	-0.0487	**PDG-4**	2.17	-2.6404	0.0537
18	**IPC 05-28**	36.08	-5.4975	-0.836	**IPC 05-28**	1.32	0.6526	0.0419
19	**PUSA 3043**	33.91	-4.3446	7.0594	**PUSA 3043**	1.28	-2.8015	0.0851
20	**RSG-888**	32.61	-2.1152	-0.9322	**RSG-888**	1.24	-2.1379	0.0354
21	**GNG 469**	43.51	3.7395	16.1881	**GNG 469**	2.32	-2.233	0.0134
22	**RSG 945**	39.55	7.9836	31.2583	**RSG 945**	1.33	-2.4685	0.0923
23	**SADABAHAR**	52.39	4.2676	6.5121	**SADABAHAR**	1.95	2.1135	0.0669
24	**PBG-5**	36.33	-0.3856	23.8616	**PBG-5**	1.34	-0.6678	0.019
25	**JG-14**	45.00	9.4174	31.79	**JG-14**	1.74	2.347	0.0266
Population mean		**43.04**				**1.69**		

4.4.2.17. Electrolyte leakage index (%)

With a minimal D.F.R ($S^2di \sim 0$) and lower mean, genotype GNG 469 demonstrated fair to perfect stability.

On the other hand, genotypes IPC-06-77 and BG-212 possessed a lower mean value alongside lower R.C *i.e.,* ($bi<1$) and a minimal D.F.R *i.e.,* ($S^2di \sim 0$), demonstrating above average stability, while genotypes KWR-108 and SADABAHAR experienced a lower mean value to grand mean accompanied by a higher R.C *i.e.,* ($bi>1$) and an insignificant D.F.R *i.e.,* ($S^2di \sim 0$), suggesting below average stability.

Any other genotypes with any bi and S^2di value are unstable.

4.4.2.18. Proline content (mg/gm)

Genotypes ICC-5335, IPC-07-56, PDG-4 and SADABAHAR exhibiting a high mean values and minimal D.F.R ($S^2di \sim 0$) suggested fair and ideal stability, while genotypes IPC 05-28, PUSA 3043 and RSG 945 that had lower mean, R.C *i.e.,* ($bi=1$), and tiny D.F.R *i.e.,* ($S^2di \sim 0$) suggested stable but not ideal stability.

Conversely, genotypes BG-212 and ICC-5434 displayed higher mean alongside lower R.C *i.e.,* ($bi<1$) & a small D.F.R *i.e.,* ($S^2di \sim 0$), suggesting above average stability, while KWR-108, IPC-06-77, KPG-59 and GNG 469 displayed higher mean in combination with higher R.C *i.e.,* ($bi>1$) and insignificant D.F.R *i.e.,* ($S^2di \sim 0$) revealed below average stability.

Any other genotypes with any bi and S^2di value are unstable.

4.26: Stability table for Relative leaf water content (%), Lipid Peroxidation (nmol/ml)

Sl.no	Relative leaf water content (%)				Lipid Peroxidation (nmol/ml)			
	Genotype	**Mean**	**βi**	**S2Di**	**Genotype**	**Mean**	**βi**	**S2Di**
1	**KWR-108**	53.58	3.4054	-0.197	**KWR-108**	21.08	0.3827	0.2733
2	**PBG-7**	44.20	3.5459	-0.0758	**PBG-7**	24.74	-0.4316	2.7624
3	**ICC-3020**	43.77	3.7279	3.8491	**ICC-3020**	23.69	0.6783	1.3805
4	**IPC-06-77**	52.15	1.8858	4.6134	**IPC-06-77**	21.42	0.3376	0.6639
5	**KPG-59**	50.38	0.6234	10.0235	**KPG-59**	15.40	0.6963	-0.0376
6	**K-850**	43.28	2.9743	8.9702	**K-850**	24.88	1.0366	31.9325
7	**ICC-5335**	48.65	1.4249	-0.1951	**ICC-5335**	21.40	0.3803	-0.1316
8	**IPC-97-67**	35.79	-1.1756	0.9418	**IPC-97-67**	23.75	0.6759	5.2332
9	**ICC 244-263**	38.40	2.2994	140.0113	**ICC 244-263**	25.69	0.9212	0.7342
10	**BG-212**	49.31	1.2599	0.1052	**BG-212**	21.04	0.8277	-0.0698
11	**ICC-3525**	36.48	-0.0285	7.7636	**ICC-3525**	24.70	2.4654	7.1528
12	**ICC-5434**	53.21	1.2357	24.5891	**ICC-5434**	21.77	0.3735	1.4102
13	**ICC-5439**	38.69	-1.2914	-0.1044	**ICC-5439**	26.16	0.5352	15.1386
14	**BPM**	32.24	-0.5117	-0.1257	**BPM**	26.54	1.4	3.6904
15	**IPC-07-56**	47.99	1.4381	0.4503	**IPC-07-56**	22.37	0.4572	-0.1169
16	**RSG 931**	37.35	0.1689	1.4952	**RSG 931**	21.69	2.0691	0.756
17	**PDG-4**	48.73	0.6021	-0.1315	**PDG-4**	15.90	0.785	-0.0964
18	**IPC 05-28**	33.21	-0.1817	0.239	**IPC 05-28**	22.08	1.6484	0.1766
19	**PUSA 3043**	34.04	0.05	4.8133	**PUSA 3043**	24.27	2.4826	2.5746
20	**RSG-888**	33.34	0.5759	4.6681	**RSG-888**	26.14	1.6546	0.6351
21	**GNG 469**	48.58	0.0319	1.7078	**GNG 469**	15.38	1.1234	0.0185
22	**RSG 945**	35.57	0.0468	-0.198	**RSG 945**	21.13	1.925	2.2503
23	**SADABAHAR**	48.46	2.061	-0.195	**SADABAHAR**	22.43	0.2923	0.3544
24	**PBG-5**	34.35	0.8895	-0.0345	**PBG-5**	24.99	1.3203	22.4999
25	**JG-14**	40.56	-0.0581	137.9785	**JG-14**	22.98	0.9629	1.4704
Population means		**42.49**				**22.47**		

4.27: Stability table for electrolyte leakage index, Proline content (mg/gm)

Sl.no	Electrolyte leakage index				Proline content (mg/gm)			
	Genotype	**Mean**	**βi**	**S2Di**	**Genotype**	**Mean**	**βi**	**S2Di**
1	**KWR-108**	42.91	1.8821	0.6651	**KWR-108**	1.71	1.409	0.0531
2	**PBG-7**	55.43	0.7684	84.128	**PBG-7**	1.44	1.4655	-0.0045
3	**ICC-3020**	55.66	-3.2413	3.4724	**ICC-3020**	1.25	1.4478	-0.0072
4	**IPC-06-77**	43.96	0.4852	-0.1313	**IPC-06-77**	1.56	1.1635	0.0741
5	**KPG-59**	30.06	2.0485	4.6312	**KPG-59**	2.45	1.4845	0.0434
6	**K-850**	54.68	-0.6117	73.6326	**K-850**	1.35	0.6081	0.0146
7	**ICC-5335**	44.91	0.7665	18.4471	**ICC-5335**	1.66	1.0272	0.015
8	**IPC-97-67**	55.22	3.0954	14.3221	**IPC-97-67**	1.45	1.2091	-0.0063
9	**ICC 244-263**	53.26	1.3095	21.7197	**ICC 244-263**	1.46	1.3655	0.0051
10	**BG-212**	46.07	0.4054	0.0834	**BG-212**	1.75	-0.1106	0.0065
11	**ICC-3525**	49.01	-2.0768	0.6607	**ICC-3525**	1.20	1.1467	0.0763
12	**ICC-5434**	43.55	-0.1968	17.8395	**ICC-5434**	1.78	0.6703	0.0185
13	**ICC-5439**	53.41	0.4659	93.2613	**ICC-5439**	1.30	0.1423	0.0242
14	**BPM**	56.00	0.9735	-0.093	**BPM**	1.39	0.8124	0.0229
15	**IPC-07-56**	43.78	1.9628	3.6413	**IPC-07-56**	1.68	1.0736	0.0838
16	**RSG 931**	57.50	1.152	3.7982	**RSG 931**	1.28	1.3803	0.0519
17	**PDG-4**	30.21	1.4978	1.4869	**PDG-4**	2.59	1.0615	0.2836
18	**IPC 05-28**	54.93	3.1314	11.6863	**IPC 05-28**	1.13	0.9647	0.1752
19	**PUSA 3043**	49.66	1.7474	0.5621	**PUSA 3043**	1.03	0.9207	0.0785
20	**RSG-888**	48.32	3.1005	42.5594	**RSG-888**	1.09	1.1068	0.0522
21	**GNG 469**	29.92	1.0127	0.0968	**GNG 469**	2.61	1.1499	0.0701
22	**RSG 945**	51.98	0.9412	72.1304	**RSG 945**	1.10	0.9159	0.0525
23	**SADABAHAR**	44.03	1.3136	-0.0246	**SADABAHAR**	1.70	0.9163	0.1027
24	**PBG-5**	56.84	1.1451	-0.1131	**PBG-5**	1.17	1.1185	0.0364
25	**JG-14**	55.77	1.9215	45.9646	**JG-14**	1.40	0.5507	0.0761
Population means		**48.28**				**1.54**		

4.4.2.19. Ascorbic acid content (mg)

Genotype IPC-06-77, K-850 and ICC-5439 with a higher mean value and lower R.C *i.e.,* (bi<1) & a minimal D.F.R *i.e.,* (S^2di~0), displayed above average stability whereas, PBG-7 and ICC-3020 displayed higher mean in combination with higher R.C *i.e.,* (bi>1) & insignificant D.F.R *i.e.,* (S^2di~0) revealed below average stability.

Any other genotypes with any other bi and S^2di values are unstable.

4.4.2.20. Pollen viability (%)

Genotypes KWR-108, SADABAHAR and JG-14 with a slight D.F.R (S^2di~0) coupled with higher mean suggested ideal and fair stability, while, IPC-97-67, RSG 931 and RSG 945 displaying lower mean with R.C (bi=1), with a minimal D.F.R (S^2di~0) demonstrated stable but not ideal stability.

Any other genotypes with any bi value and S^2di value ae unstable.

4.4.2.21 Flower drop (%)

RSG 931, PBG-5, and JG-14 genotypes showed higher mean, R.C *i.e.,* (bi=1), & a small D.F.R *i.e.,* (S^2di~0), suggesting stable, not ideal.

Conversely, genotype PBG-7 and PDG-4 had a lower mean value alongside a lower R.C *i.e.,* (bi<1) & a minimal D.F.R *i.e.,* (S^2di~0), suggesting above average stability, while KWR-108, IPC-06-77 and IPC-07-56 were having a low mean value to grand mean accompanied by a higher R.C *i.e.,* (bi>1) & an insignificant D.F.R *i.e.,* (S^2di~0) revealed below average stability.

Any other genotypes with any bi and S2di value are unstable.

4.28: Stability table for Ascorbic acid content (mg), pollen viability (%)

Sl.no	Ascorbic acid content (mg)				Pollen viability			
	Genotype	**Mean**	**βi**	**S2Di**	**Genotype**	**Mean**	**βi**	**S2Di**
1	**KWR-108**	30.26	-2.7704	-1.6019	**KWR-108**	79.57	0.9366	-1.3275
2	**PBG-7**	31.92	18.5929	-0.6741	**PBG-7**	72.63	0.8287	-0.6513
3	**ICC-3020**	31.59	5.8601	0.0171	**ICC-3020**	71.30	1.1636	3.732
4	**IPC-06-77**	32.05	-1.3686	-0.8053	**IPC-06-77**	79.53	0.8983	14.6469
5	**KPG-59**	30.00	3.5495	7.3417	**KPG-59**	68.70	1.1333	4.4548
6	**K-850**	31.42	-1.0751	-0.4227	**K-850**	72.80	1.2073	5.6462
7	**ICC-5335**	28.89	1.4559	-1.825	**ICC-5335**	79.67	1.0649	4.2579
8	**IPC-97-67**	30.12	-1.9169	-1.6611	**IPC-97-67**	71.33	0.9693	0.8326
9	**ICC 244-263**	29.87	-13.4067	2.5125	**ICC 244-263**	70.13	0.8904	-0.9074
10	**BG-212**	30.54	-2.1409	-1.8014	**BG-212**	79.37	0.8285	3.1701
11	**ICC-3525**	31.75	5.9251	57.4936	**ICC-3525**	68.40	1.0383	-1.3513
12	**ICC-5434**	30.38	-0.574	-0.6918	**ICC-5434**	79.40	1.0081	2.3374
13	**ICC-5439**	32.56	-11.5022	0.9121	**ICC-5439**	70.17	0.8345	0.2795
14	**BPM**	29.80	0.9447	-1.4215	**BPM**	69.37	0.8162	-1.0436
15	**IPC-07-56**	33.64	-8.7969	-1.8236	**IPC-07-56**	77.17	0.5546	26.393
16	**RSG 931**	30.31	5.4069	19.2702	**RSG 931**	72.13	1.0178	0.3017
17	**PDG-4**	36.54	12.0202	77.3584	**PDG-4**	69.33	0.947	-1.3257
18	**IPC 05-28**	27.18	-3.8267	9.2495	**IPC 05-28**	69.70	1.8357	68.1924
19	**PUSA 3043**	32.75	7.6254	6.7239	**PUSA 3043**	69.83	0.9805	3.1491
20	**RSG-888**	30.82	3.0114	27.8398	**RSG-888**	68.63	1.3576	3.2423
21	**GNG 469**	36.21	14.1182	14.8225	**GNG 469**	67.90	0.7906	-0.944
22	**RSG 945**	30.00	-7.9298	17.9733	**RSG 945**	69.43	0.9086	0.0106
23	**SADABAHAR**	35.44	2.0233	13.1645	**SADABAHAR**	78.63	0.9885	-0.3749
24	**PBG-5**	29.10	1.9221	6.5669	**PBG-5**	69.67	0.9983	-1.234
25	**JG-14**	28.34	-2.1476	0.538	**JG-14**	72.83	1.0026	-0.4009
Population mean		**31.26**				**72.71**		

4.4.2.22 Seed yield plant^{-1}

Genotypes KWR-108, PBG-7, IPC-06-77, ICC-5434, IPC-07-56, SADABAHAR and JG-14 alongside little D.F.R (S^2di~0) together with a higher mean stated ideal and fair stability, while, K-850, BPM and IPC 05-28 through a small D.F.R (S^2di~0) suggested stable but not ideal stability.

On the contrary, genotypes ICC-5335 and BG-212 displayed higher mean values alongside higher R.C *i.e.,* (bi>1) & a minimal D.F.R *i.e.,* (S^2di~0), suggesting below average stability.

Any other genotypes with any bi and S^2di value are unstable.

4.29: Stability table for Flower drop (%), seed yield plant^{-1}

Sl.no	Flower drop (%)				Seed yield plant^{-1}			
	Genotype	Mean	βi	S2Di	Genotype	Mean	βi	S2Di
1	KWR-108	25.06	1.2173	0.7868	KWR-108	8.64	0.9495	0.3333
2	PBG-7	27.68	-1.0612	0.7406	PBG-7	7.07	0.9103	0.0499
3	ICC-3020	33.02	2.1954	0.1248	ICC-3020	6.43	1.1063	1.8237
4	IPC-06-77	26.83	1.32	0.2644	IPC-06-77	8.63	0.9608	0.1303
5	KPG-59	21.82	0.3354	3.0738	KPG-59	6.48	1.2094	-0.0182
6	K-850	34.22	-1.1246	1.8999	K-850	6.36	1.0251	0.0698
7	ICC-5335	27.57	3.6651	7.3596	ICC-5335	9.86	1.2366	0.535
8	IPC-97-67	25.69	1.0231	5.5593	IPC-97-67	6.97	0.8746	-0.0484
9	ICC 244-263	31.88	-0.2296	-0.8566	ICC 244-263	5.71	0.7331	-0.0637
10	BG-212	31.15	2.4089	0.607	BG-212	11.18	1.9326	-0.0632
11	ICC-3525	31.49	-0.0389	-1.0011	ICC-3525	6.13	1.1411	0.2463
12	ICC-5434	27.67	2.0553	-1.0126	ICC-5434	8.91	1.0825	0.8933
13	ICC-5439	30.19	-2.2098	19.3598	ICC-5439	6.78	1.561	-0.0517
14	BPM	33.06	-1.6266	7.1764	BPM	6.77	1.0338	-0.0576
15	IPC-07-56	26.58	2.4438	0.8626	IPC-07-56	9.01	1.0233	-0.0647
16	RSG 931	33.04	1.0376	-0.8954	RSG 931	5.75	0.8295	-0.0196
17	PDG-4	21.86	0.1385	-0.0642	PDG-4	6.65	0.8499	-0.063
18	IPC 05-28	34.74	2.0055	1.7804	IPC 05-28	5.29	0.9177	0.3638
19	PUSA 3043	34.33	0.4641	-1.0178	PUSA 3043	5.17	0.6165	0.0141
20	RSG-888	33.40	2.7081	11.5598	RSG-888	5.03	0.8183	0.1091
21	GNG 469	21.17	1.0204	1.6216	GNG 469	6.65	0.867	-0.0239
22	RSG 945	35.13	1.9014	-0.9894	RSG 945	5.45	0.2515	-0.0642
23	SADABAHAR	27.51	3.3681	3.1657	SADABAHAR	8.40	0.9907	0.118
24	PBG-5	29.70	1.0384	-0.5311	PBG-5	5.74	1.1696	1.4599
25	JG-14	30.00	0.9442	-1.0861	JG-14	7.05	0.9094	0.0329
Population means		**29.39**				**7.04**		

4.5 Parameters of genetic variability (hybrids and parents)

4.5.1. Analysis of variance

Table 4.30 illustrated ANOVA results for every trait in the study. The genetic variability estimate was observed for twenty-two characters among thirty-one genotypes. ANOVA results demonstrated genotypes MSS was significant for every investigated character, proving that there is enough genetic variation in the experimental genotypes for the various attributes.

The ANOVA for the experimental design indicated substantial variations among genotypes for each of the twenty-two characters, indicating availability of significant variability for every concerned character. With the exception of secondary offshoots plant^{-1} among parents, mean squares owing to genotypic variance were likewise substantial for every character, according to a further split of variance *i.e.,* hybrids & parents. Likewise, MSS attributed to parent vs. hybrids were noteworthy for nearly every metric, except for ascorbic acid content (mg), harvest index (%), and seeds capsule^{-1}. (Table 4.31).

4.5.2 PER SE PERFORMANCE OF PARENTS AND THEIR CROSSES

The mean (Appendix II) contains the performances pertaining to crosses & parents for various characters. Average and range also exhibited more diversity across all twenty-two traits. The key characteristics of each character are covered under subsequent subheads:

4.5.2.1 First blossoming days

Ranged at (84.5 to 102.5 days), a general mean of 94.38 days. Among parents, ICC-5335 (84.5 days) recorded earliest whereas, most late genotype was IPC 07-56 (92.5 days) owning a mean of 88.45 days. Amongst hybrids, SADABAHAR x GNG 469 (91 days) was recognized earliest and most late hybrid was KWR 108 X GNG 469 (102.5 days) with a mean value 97.21 days. The C.V(FS) value was 11.67%.

4.5.2.2 50% blossoming days

Exhibited range of (91.5 to 110 days) with a general average value of 101.59 days. Among parents, genotype ICC-5335 (91.5 days) recorded earliest whereas, most late genotype was IPC 07-56 (100 days) with an average value of 95.65 days. Amongst hybrids, SADABAHAR x GNG 469 (97.5 days) was recognized earliest and most late hybrid was ICC 5335 X GNG 469 (110 days) with a mean value 104.42 days. The C.V(FS) value was 15.73%.

4.5.2.3 Harvest maturity days

Ranged at (146.5 to 165.5 days) with a general average of 155.61 days. Among parents, genotype SADABAHAR (149 days) recorded earliest whereas, most late was ICC 5434 (159 days) with an average of 153.60 days. Amongst hybrids, ICC 5335 X PDG 4 (146.5 days) recorded earliest and most late hybrid was ICC 5434 X KPG 59 (165.5 days) with a mean value 156.57 days. The C.V(FS) value was 23.43%.

4.5.2.4 Plant height

Ranged at (38.47 to 49.03 days) with a general average of 44.54 days. Among parents, genotype GNG 469 (38.47 cm) had minimum height, where genotype BG 212 (45.71 cm) had maximum height with a parental mean value of 43.20 cm. Among the crosses, IPC 06-77 X GNG 469 (39.85 cm) had minimum height and SADABAHAR X GNG 469 (49.03 cm) had maximum height along with mean value 45.18 cm. The C.V (FS) value was 4.89%.

4.5.2.5 Primary offshoots plant^{-1}

Exhibited range of 3.3 to 4.6 with a mean 3.91. Among parents, ICC 5335 (3.5) showed minimum variation and BG 212 (4.6) showed maximum variation with mean value 4.06. Among hybrids, minimum variation showed by ICC 5434 X KPG 59 (3.3) and maximum value showed by ICC 5434 X GNG 469 (4.6), average of 3.84 and the C.V 0.10%.

4.5.2.6 Secondary offshoots plant^{-1}

Ranged 5.4 to 7.4 alongside a mean 6.35. Among parents, ICC 5335 (5.6) showed minimum variation and BG 212 (6.8) showed maximum variation with mean value 6.17. Among hybrids, minimum variation showed by ICC 5434 X KPG 59 (5.4) and maximum value showed by IPC 06-77 X KPG 59 (7.4), average of 6.43 and the C.V 0.27%.

4.30: Randomized Block Design ANOVA

Sov	d.f	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
Replication	1	0.14	1.3	7.8	6.15	0.002	0.005	17.56	10.4	0.93	0.041	0.1
Genotypes	30	54.59*	56.54*	42.49*	14.28*	0.3*	0.69*	28.57*	25.3*	1.73*	0.078*	6.37*
Error	30	1.34	1.03	2.4	2.43	0.046	0.16	5.41	6.68	0.44	0.023	0.1
Total	61	27.51	28.34	22.2	8.32	0.17	0.42	17	15.9	1.08	0.051	3.19

Sov	d.f	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
Replication	1	0.63	4.43	0.014	1.79	1.49*	0.15	0	0.44	18.42	4.35	0.0005
Genotypes	30	24.47*	16.88*	0.68*	107.51*	7.55*	104.59*	0.22*	34.61*	42.88*	34.97*	7.2*
Error	30	1.32	2.37	0.061	3.67	0.33	1.3	0.003	3.13	10.32	2.48	0.32
Total	61	12.7	9.54	0.36	54.71	3.9	52.08	0.11	18.57	26.47	18.49	3.7

4.31: Parents and crosses ANOVA details

Sov	d.f.	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
Blocks	1	0.14	1.3	7.8	6.15	0.002	0.005	17.56	10.4	0.93	0.041	0.1
Parents	9	10.97*	10.78*	25.75*	6.93*	0.31*	0.3	15.6*	18.2*	1.05*	0.073*	6.79*
Males	2	3.16	6*	2.16	19.48*	0.28*	0.24	0.02	0.78	1.04	0.08*	0.69*
Female	6	15.33*	14.14*	37.9*	1.96	0.37*	0.36	19.02*	18.96*	0.67	0.082*	9.59*
Male vs. Female	1	0.46	0.19	0.038	11.64*	0.046	0.04	26.24*	48.55*	3.4*	0.0008	2.17*
Crosses	20	24.32*	27.76*	46.16*	15.66*	0.28*	0.86*	30.34*	26.33*	1.87*	0.084*	6.44*
Parents vs. Crosses	1	1052.59*	1044.08*	119.62*	52.91*	0.66*	0.9*	110.04*	68.5*	4.9*	0.01	1.34*
Error	30	1.34	1.03	2.4	2.43	0.046	0.16	5.41	6.68	0.44	0.023	0.1
Total	61	27.51	28.34	22.2	8.32	0.17	0.42	17	15.9	1.08	0.051	3.19

Sov	d.f.	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
Blocks	1	0.63	4.43	0.014	1.79	1.49*	0.15	0	0.44	18.42	4.35	0.0005
Parents	9	19.51*	24.63*	0.47*	74.19*	8.74*	102.85*	0.13*	35.61*	22.82	18.66*	6.2*
Males	2	9.6*	16.55*	1.21*	58.21*	0.014	107.64*	0.24*	6.55	37.93*	24.34*	1.06*
Female	6	26*	1.53	0.22*	86.79*	9.57*	35.73*	0.003	49.85*	20.96	18.93*	7.26*
Male vs. Female	1	0.43	179.41*	0.48*	30.58*	21.25*	496.01*	0.66*	8.29	3.73	5.68	10.12*
Crosses	20	25.8*	13.98*	0.78*	87.02*	5.47*	75.62*	0.21*	35.86*	50.47*	38.71*	7.66*
Parents vs. Crosses	1	42.61*	4.96	0.62*	817.14*	38.57*	699.61*	1.29*	0.75	71.78*	106.83*	7.12*
Error	30	1.32	2.37	0.061	3.67	0.33	1.3	0.003	3.13	10.32	2.48	0.32
Total	61	12.7	9.54	0.36	54.71	3.9	52.08	0.11	18.57	26.47	18.49	3.7

4.5.2.7 Capsules plant^{-1}

Expressed a range of 61.7 to 76.2 with mean of 69.28. Among parents, ICC 5335 (62.2) showed minimum variation and BG 212 (71.8) showed maximum variation with mean value 67.35. Among hybrids, minimum variation showed by ICC 5335 X KPG 59 (61.7) and maximum value showed by ICC 5335 X PDG 4 (76.2), average of 70.20 and the C.V 12.78%.

4.5.2.8 Full capsules plant^{-1}

Expressed a range of 52.3 to 65.4 with an average value of 58.80. Among parents, ICC 5335 (52.3) showed minimum variation and IPC 07-56 (61.1) showed maximum variation with mean value 57.28. Among hybrids, minimum variation showed by IPC 07-56 X KPG 59 (52.4) and maximum value showed by ICC 5335 X PDG 4 (65.4), average of 59.53 and the C.V 10.4%.

4.5.2.9 Empty capsules plant^{-1}

Expressed a range of 8.5 to 12.1 with a mean of 10.48. Among parents, IPC 07-56 (9.1) showed minimum variation and KPG 59 (11.3) showed maximum variation with mean value 10.07. Among hybrids, minimum variation showed by ICC 5335 X KPG 59 (8.5) and maximum value showed by IPC 07-56 X GNG 469 (12.1), average of 10.67 and the C.V 0.60%.

4.5.2.9 Seeds capsule^{-1}

Expressed a range of 1.3 to 2.1 with a mean of 1.73. Among parents, ICC 5335 (1.3) showed minimum variation and PDG 4 (1.9) showed maximum variation with mean value 1.71. Among hybrids, minimum variation showed by IPC 07-56 X KPG 59 (1.4) and maximum value showed by IPC 06-77 X KPG 59 (2.1), average of 1.74 and the C.V 0.02%.

4.5.2.11 Test weight (gm)

Average of 12.02 g and range varied from (8.65 to 14.95 g). Among parents, minimum weight was recorded in ICC 5434 (9g) whereas, maximum weight recorded in BG 212 (14.95g) among parents with mean value 11.80 g. Among hybrids, minimum and maximum weight was recorded in BG 212 X GNG 469 (8.65 g) and BG 212 X KPG 59 (14.7 g) along with mean value 12.12 g and the C.V(FS) value 2.11%.

4.5.2.12 Biological yield plant^{-1}

Average of 22.14 g and range varied from (15.74 to 27.605 g). Among parents, minimum weight was recorded in ICC 5434 (16.11g) whereas, maximum weight recorded in BG 212 (26.97g) among parents with mean value 20.94 g. Among hybrids, minimum and maximum weight was recorded in IPC 07-56 X KPG 59 (15.74 g) and SADABAHAR X GNG 469 (27.60 g) along with mean value 22.72 g and the C.V(FS) value 8.24 %.

4.5.2.13 Harvest index (%)

Recorded a range of (41.00 to 50.59 %) with a mean of 47.38 %. Among parents, minimum variation was noticed in genotype KPG 59 (41.00 %) and maximum variation was observed in KWR 108 (50.45 %) with mean value 47.79%. Among hybrids, minimum and maximum variation was observed in genotype BG 212 X GNG 469 (43.08 %) and ICC 5335 X PDG 4 (50.59 %) respectively and mean value 47.19%. The value of C.V(FS) was 4.50%.

4.5.2.14 Total chlorophyll content (mg/ml)

Recorded a range of 1.53 to 4.405 with a mean of 2.52. Among parents, KWR 108 (1.74) showed minimum variation and PDG 4 (3.50) showed maximum variation with mean value 2.37. Among hybrids, minimum variation showed by BG 212 X GNG 469 (1.53) and maximum value showed by IPC 06-77 X KPG 59 (4.405), average of 2.58 and the C.V 0.31%.

4.5.2.15 Relative leaf water content (%)

Recorded a range of 32.7 to 63.91 % with a mean of 46.05. Among parents, IPC 06-77 (32.7 %) showed minimum variation and GNG 469 (48.74 %) showed maximum variation with mean value 40.79. Among hybrids, minimum variation showed by ICC 5434 X PDG 4 (36.55 %) and maximum value showed by ICC 5335 X PDG 4 (63.91 %), average of 48.55 and the C.V 30.61 %.

4.5.2.16 Lipid Peroxidation (nmol/ml)

Recorded a range of 7.37 to14.86 with a mean of 10.82. Among parents, KWR 108 (9.06) showed minimum variation and ICC 5335 (14.865) showed maximum variation with mean value 11.96. Among hybrids, minimum variation showed by SADABAHAR X GNG 469 (7.37) and maximum value showed by BG 212 X KPG 59 (13.46), average of 10.28 and the C.V 2.79 %.

4.5.2.17 Electrolyte Leakage Index

Recorded a range of 28.41 to 53.84 with a mean of 40.10. Among parents, PDG 4 (30.82) showed minimum variation and BG 212 (53.84) showed maximum variation with mean value 44.97. Among hybrids, minimum variation showed by ICC 5434 X PDG 4 (28.41) and maximum value showed by BG 212 X PDG 4 (48.31), average of 37.38 and the C.V 31.59 %.

4.5.2.18 Proline content (mg/gm)

Recorded a range of 1.35 to 2.42 with a mean of 1.84. Among parents, ICC 5434 (1.44) showed minimum variation and KPG 51 (2.19) showed maximum variation with mean value 1.63. Among hybrids, minimum variation showed by SADABAHAR X KPG 59 (1.35) and maximum value showed by ICC 5335 X GNG 469 (2.42), average of 1.94 and the C.V 0.09 %.

4.5.2.19 Ascorbic acid content (mg)

Recorded a range of 21.30 to 36.52 with a mean of 27.38. Among parents, SADABAHAR (21.30) showed minimum variation and KWR 108 (35.21) showed maximum variation with mean value 27.22. Among hybrids, minimum variation showed by IPC 06-77 X GNG 469 (21.74) and maximum value showed by SADABAHAR X GNG 469 (36.52), average of 27.45 and the C.V 14.93 %.

4.5.2.20 Pollen Viability

Recorded a range of 67.6 to 86.7 % with a mean of 73.52. Among parents, PDG 4 (67.6 %) showed minimum variation and BG 212 (77.4 %) showed maximum variation with mean value 71.96. Among hybrids, minimum variation showed by BG 212 X GNG 469 (67.6 %) and maximum value showed by ICC 5434 X KPG 59 (86.7 %), average of 74.26 and the C.V 14.93 %.

4.5.2.21 Flower drop (%)

Recorded a range of 15.41 to 29.44 % with a mean of 23.45. Among parents, IPC 06-77 (19.54 %) showed minimum variation and ICC 5335 (29.44 %) showed maximum variation with mean value 25.36. Among hybrids, minimum variation showed by IPC 06-77 X PDG 4 (15.41 %) and maximum value showed by BG 212 X KPG 59 (28.39 %), average of 22.5 and the C.V 19.53 %.

4.5.2.22 Seed yield plant^{-1}

Recorded a range of (6.91 to 13.48 g), average of 10.51 g. Among parents, minimum variation was noticed in genotype ICC 5434 (7.72 g) and maximum variation showed in genotype BG 212 (13.48 g) with a mean value of 10.02g. Among hybrids, minimum and maximum variation was observed by IPC 07-56 X KPG 59 (6.91 g) and IPC 06-77 X PDG 4 (13.3 g) respectively along with mean value 10.75 g. The C.V (FS) value 2.68 %.

4.6 ESTIMATION OF HETEROSIS, HETEROBELTIOSIS AND STANDARD HETEROSIS

Harvesting crops with heterosis is one of the major advances in plant breeding. A percentage increase (positive) or drop (negative) in the hybrid's average performance above that of the three heterosics: relative (midparent), better (parent), and economic (standard) heterosis was used to define heterosis. For every aspect that was taken into account, the degree of heterosis, or relative heterosis (RH) and heterobeltiosis (HB), was evaluated. In contrast to heterobeltiosis, which was determined over better parental value, and standard heterosis, which was calculated over standard check variety, relative heterosis (RH) was calculated over the mid parent value.

Positive gene effects were thought to be advantageous for the characters *viz.*, plant height, primary offshoots plant^{-1}, secondary offshoots plant^{-1}, capsules plant^{-1}, full capsules plant^{-1}, seeds capsule^{-1}, test weight (gm), biological yield plant^{-1}, harvest index (%), total chlorophyll content (mg/ml), relative leaf water content (%), proline content (mg/gm), ascorbic acid content (mg), pollen viability, seed yield plant^{-1} whereas, negative affects were thought to be beneficial to characters first blossoming days, 50% blossoming days, harvest maturity days, full capsules plant^{-1}, lipid peroxidation (nmol/ml), electrolyte leakage index (%)and flower drop (%).

The following are the key findings for each character under consideration.

4.6.1 First blossoming days

Average heterosis ranged from 4.60 (SADABAHAR X GNG 469) to 18.84 per cent (ICC 5335 X GNG 469). All 21 crosses had positive significant heterosis. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (4.60 %), ICC 5434 X GNG 469 (5.03%) and BG 212 X GNG 469 (5.68 %).

Heterobeltiosis ranged from 3.30 * (ICC 5434 X GNG 469) to 16.48 * per cent (ICC 5335 X GNG 469). All 21 crosses had positive significant heterosis. The top three crosses which are desirable for these particular trait, ICC 5434 X GNG 469 (3.30 %), SADABAHAR X GNG 469 (3.41 %) and ICC 5335 X PDG 4 (5.17 %).

Standard heterosis ranged from 1.68 (SADABAHAR X GNG 469) to 14.53 per cent (KWR 108 X GNG 469). All 21 crosses had positive significant heterosis. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (1.68 %), ICC 5335 X PDG 4 (2.23 %), BG 212 X GNG 469 (3.91 %).

4.6.2 50% blossoming days

Average heterosis ranged from 3.45 (SADABAHAR X GNG 469) to 18.28 per cent (ICC 5335 X GNG 469). All 21 crosses had positive significant heterosis. Top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (3.45 %), IPC 06-77 X PDG 4 (5.26 %) and BG 212 X GNG 469 (5.26 %).

Heterobeltiosis ranged from 3.17 (SADABAHAR X GNG 469) to 16.40 per cent (ICC 5335 X GNG 469). All 21 crosses had positive significant heterosis. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (3.17 %), BG 212 X KPG 59 (3.59 %) and ICC 5434 X GNG 469 (4.10 %).

Standard heterosis ranged from -2.01 (SADABAHAR X GNG 469) to 10.55 per cent (ICC 5335 X GNG 469). 2 crosses recorded negative significance heterosis and positive heterosis was significant for 19 crosses among the 21 crosses. The top crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (-2.01 %) and ICC 5335 X PDG 4 (-0.50 %).

4.6.3 Harvest maturity days

Average heterosis ranged from -4.15 (ICC 5434 X GNG 469) to 6.58 per cent (KWR 108 X GNG 469). The significant negative heterosis was for 2 crosses and positive for 12 crosses among the 21 crosses. The top crosses which are desirable for these particular trait, ICC 5434 X GNG 469 (-4.15 %) and ICC 5335 X PDG 4 (-3.93 %).

Heterobeltiosis ranged from -5.66 (ICC 5434 X GNG 469) to 5.19 per cent (KWR 108 X GNG 469). The negative heterosis was significant for 5 crosses and positive for 8 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X GNG 469 (-5.66 %), ICC 5335 X PDG 4 (-3.93 %) and BG 212 X GNG 469 (-2.60 %).

Standard heterosis ranged from -0.34 (ICC 5335 X PDG 4) to 12.59 per cent (ICC 5434 X KPG 59). The negative heterosis was significant for 1 cross and positive heterosis was significant for 11 crosses among the 21 crosses. The top cross which is desirable for this particular trait, ICC 5335 X PDG 4 (-0.34 %).

Table 4.32: Relative, heterobeltiosis & standard heterosis estimates

Hybrids	First blossoming days			50% blossoming days			Harvest maturity days			Plant height		
	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H
KWR 108 X GNG 469	15.49 *	14.53 *	14.53*	14.44 *	13.54 *	9.55*	6.58 *	5.19 *	10.20*	13.43 *	6.32	3.41
KWR 108 X KPG 59	9.50 *	9.50 *	9.50*	9.04 *	8.21 *	6.03*	2.46 *	0.97	6.12	3.86	3.14	0.31
KWR 108 X PDG 4	9.35 *	7.82 *	7.82*	8.14 *	7.29 *	3.52*	3.14 *	2.30 *	6.12*	2.07	1.74	-0.4
ICC 5335 X GNG 469	18.84 *	16.48 *	14.53*	18.28 *	16.40 *	10.55*	5.06 *	4.55 *	9.52*	17.53 *	10.91 *	6.32*
ICC 5335 X KPG 59	11.49 *	8.38 *	8.38*	12.70 *	9.23 *	7.04*	4.23 *	3.56 *	8.84*	-3.83	-3.85	-7.78
ICC 5335 X PDG 4	6.71 *	5.17 *	2.23*	6.45 *	4.76 *	-0.50*	-3.93 *	-3.93 *	-0.34*	10.66 *	9.51 *	7.21*
ICC 5434 X GNG 469	5.03 *	3.30 *	5.03*	5.73 *	4.10 *	2.01*	-4.15 *	-5.66 *	2.04*	12.59 *	5.99	2.15
ICC 5434 X KPG 59	12.47 *	11.54 *	13.41*	11.28 *	11.28 *	9.05*	5.58 *	4.09 *	12.59*	-5.68	-5.91	-9.32
ICC 5434 X PDG 4	8.43 *	6.04 *	7.82*	6.77 *	5.13 *	3.02*	2.09 *	0	8.16	-5.83	-6.56	-8.52
BG 212 X GNG 469	5.68 *	5.68 *	3.91*	5.26 *	4.71 *	0.50*	-1.15	-2.60 *	2.04*	8.07 *	-0.49	0.6
BG 212 X KPG 59	7.04 *	6.15 *	6.15*	4.66 *	3.59 *	1.51*	0.33	-1.29	3.74	-0.32	-2.88	-1.81
BG 212 X PDG 4	13.14 *	12.50 *	10.61*	11.05 *	10.47 *	6.03*	2.65 *	1.64	5.44	3.06	1.43	2.54
IPC 07-56 X GNG 469	12.47 *	9.73 *	13.41*	12.08 *	9.00 *	9.55*	3.68 *	2.21 *	10.20*	-1.7	-7.54	-10.75
IPC 07-56 X KPG 59	8.79 *	7.03 *	10.61*	9.37 *	8.00 *	8.54*	2.56 *	1.26	9.18	8.64 *	8.29	4.53
IPC 07-56 X PDG 4	9.19 *	5.95 *	9.50*	8.48 *	5.50 *	6.03*	0.96	-0.95	6.8	8.51 *	7.75	5.48
IPC 06-77 X GNG 469	13.07 *	13.07 *	11.17*	11.58 *	10.99 *	6.53*	3.06 *	2.24 *	8.84*	-1.74	-6.55	-11.88
IPC 06-77 X KPG 59	10.42 *	9.50 *	9.50*	9.33 *	8.21 *	6.03*	-0.96	-1.6	4.76	4.78	3.91	-0.34
IPC 06-77 X PDG 4	6.86 *	6.25 *	4.47*	5.26 *	4.71 *	0.50*	-0.65	-1.92 *	4.42*	10.38 *	8.36 *	6.08
SADABAHAR X GNG 469	4.60 *	3.41 *	1.68*	3.45 *	3.17 *	-2.01*	1.65	0	4.76	20.38 *	14.05 *	8.43*
SADABAHAR X KPG 59	13.96 *	11.73 *	11.73*	12.79 *	10.77 *	8.54*	5.77 *	3.88 *	9.18*	8.11 *	7.63	3.23*
SADABAHAR X PDG 4	8.67 *	8.05 *	5.03*	7.69 *	7.41 *	2.01*	1.49	0.33	4.08	2.18	0.7	-1.42
no.of sig"+ve"	21	21	21	21	21	19	12	8	11	9	4	4
no.of sig"-ve"	0	0	0	0	0	2	2	5	1	0	0	0

Table 4.32: Relative, heterobeltiosis & standard heterosis estimates

Hybrids	Primary offshoots plant^{-1}			Secondary offshoots plant^{-1}			Capsules plant^{-1}			Full capsules plant^{-1}		
	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H
KWR 108 X GNG 469	-10.26	-14.63 *	0.01*	2.52	-1.61	-8.96	9.86 *	8.47 *	2.67*	13.80 *	10.94 *	6.50*
KWR 108 X KPG 59	-20.00 *	-22.73 *	-2.86*	0.8	0	-5.97	4.66	3.42	-2.11	6.96	3.99	-0.17
KWR 108 X PDG 4	-4.76	-6.98	14.29	8.8	7.94	1.49	5.12	3.71	-1.83	4.95	3.13	-1
ICC 5335 X GNG 469	5.56	2.7	8.57	11.5	10.53	-5.97	2.5	-0.15	-7.88	3.93	1.65	-7.33
ICC 5335 X KPG 59	13.92 *	2.27	28.57	19.33 *	12.7	5.97	-3.52	-6.09	-13.22	-0.28	-2.21	-11.33
ICC 5335 X PDG 4	0	-9.3	11.43	2.52	-3.17	-8.96	19.34 *	16.34 *	7.17*	21.22 *	17.63 *	9.00*
ICC 5434 X GNG 469	24.32 *	24.32 *	31.43*	25.86 *	23.73 *	8.96*	3.2	0.87	-2.53	2.37	-1.36	-3
ICC 5434 X KPG 59	-18.52 *	-25.00 *	-5.71*	-11.48	-14.29	-19.4	0.3	-1.89	-5.2	0.35	-3.56	-5.17
ICC 5434 X PDG 4	-7.5	-13.95 *	5.71*	0	-3.17	-8.96	-3.43	-5.68	-8.86	-2.62	-5.42	-7
BG 212 X GNG 469	3.61	-6.52	22.86	12	2.94	4.48	5.53	0.97	1.97	6.92	1.48	3
BG 212 X KPG 59	-6.67	-8.7	20	5.34	1.47	2.99	-1.09	-5.29	-4.36	-1.99	-7.22	-5.83
BG 212 X PDG 4	-16.85 *	-19.57 *	5.71*	-14.50 *	-17.65 *	-16.42*	4.01	-0.56	0.42	3.18	-1.31	0.17
IPC 07-56 X GNG 469	1.23	-6.82	17.14	17.07 *	9.09	7.46	5.15	1.71	0.42	2.42	-2.95	-1.17
IPC 07-56 X KPG 59	-11.36 *	-11.36	11.43	8.53	6.06	4.48	-5.22	-8.26 *	-9.42*	-9.26	-14.24 *	-12.67*
IPC 07-56 X PDG 4	-17.24 *	-18.18 *	2.86*	6.98	4.55	2.99	6.56	2.99	1.69	4.54	-0.16	1.67
IPC 06-77 X GNG 469	1.37	0	5.71	0	-1.69	-13.43	5.43	4.33	-1.69	5.46	3.33	-1.83
IPC 06-77 X KPG 59	7.5	-2.27	22.86	21.31 *	17.46 *	10.45*	7.61 *	6.57	0.42	8.26	5.79	0.5
IPC 06-77 X PDG 4	-6.33	-13.95 *	5.71*	11.48	7.94	1.49	14.26 *	12.99 *	6.47*	15.45 *	14.04 *	8.33*
SADABAHAR X GNG 469	-10	-16.28 *	2.86*	-2.48	-7.81	-11.94	8.96 *	5.9	3.52	9.66 *	4.65	5
SADABAHAR X KPG 59	-21.84 *	-22.73 *	-2.86*	-13.39 *	-14.06	-17.91	12.28 *	9.21 *	6.75*	11.87 *	6.48	6.83
SADABAHAR X PDG 4	-20.93 *	-20.93 *	-2.86*	-13.39 *	-14.06	-17.91	4.3	1.29	-0.98	2.59	-1.33	-1
no.of sig"+ve"	2	1	7	4	2	2	6	4	4	5	3	3
no.of sig"-ve"	7	10	4	3	1	1	0	1	1	0	1	1

Table 4.32: Relative, heterobeltiosis & standard heterosis estimates

Hybrids	Empty capsules plant^{-1}			Seeds capsule^{-1}			Test weight (gm)			Biological yield plant^{-1}		
	R.H	**HB.**	**S.H**	**R.H**	**HB.**	**S.H**	**R.H**	**HB.**	**S.H**	**R.H**	**HB.**	**S.H**
KWR 108 X GNG 469	-11.65 *	-16.51 *	-20.18*	0.00	0.00	6.25	1.26	-4.74	8.56	12.70 *	3.14	-0.75
KWR 108 X KPG 59	-7.62	-14.16 *	-14.91	6.25	0.00	6.25	19.40 *	10.67 *	26.13*	15.14 *	9.32	5.2
KWR 108 X PDG 4	6.12	5.05	-8.77	-5.56	-10.53	6.25	-14.63 *	-17.00 *	-5.41*	-9.14	-10.11	-11.61
ICC 5335 X GNG 469	-4.81	-9.17	-13.16	13.33	0.00	6.25	10.10 *	-1.42	25.23	16.62 *	6.52	2.96
ICC 5335 X KPG 59	-19.81 *	-24.78 *	-25.44	7.14	0.00	-6.25	-2.81	-14.18 *	9.01*	-1.17	-6.37	-9.5
ICC 5335 X PDG 4	9.09	9.09	-5.26*	31.25 *	10.53	31.25	-2.88	-10.28 *	13.96*	11.28 *	10.33	8.5
ICC 5434 X GNG 469	7.77	1.83	-2.63	-11.11	-15.79	0.00	5.21	-4.93	-4.5	17.87 *	9.54	-12.46
ICC 5434 X KPG 59	0	-7.08	-7.89	-5.88	-15.79	0.00	18.18 *	8.33 *	5.41*	14.13 *	2.34	-11.48
ICC 5434 X PDG 4	-8.16	-9.09	-21.05	0.00	0.00	18.75	36.52 *	19.67 *	28.83*	20.96 *	2.69	0.98
BG 212 X GNG 469	-1.83	-1.83	-6.14	11.76	11.76	18.75	-33.72 *	-42.14 *	-22.07*	-20.42 *	-32.54 *	-22.49*
BG 212 X KPG 59	3.6	1.77	0.88	-6.25	-11.76	-6.25	14.17 *	-1.67	32.43	10.59 *	-3.08	11.35
BG 212 X PDG 4	8.65	3.67	-0.88	-5.56	-10.53	6.25	-14.13 *	-22.74 *	4.05*	-12.24 *	-18.56 *	-6.43*
IPC 07-56 X GNG 469	21.00 *	11.01	6.14	-14.29	-16.67	-6.25	-0.28	-3.87	4.05	10.89 *	5.54	-6.65
IPC 07-56 X KPG 59	17.65 *	6.19	5.26*	-15.15	-22.22 *	-12.5*	-20.23 *	-24.26 *	-18.02*	-23.33 *	-24.18 *	-32.93*
IPC 07-56 X PDG 4	18.95 *	14.14 *	-0.88	2.70	0.00	18.75	12.66 *	12.36 *	21.62*	23.95 *	17.72 *	15.76*
IPC 06-77 X GNG 469	5.26	0.92	-3.51	-5.56	-10.53	6.25	22.67 *	18.71 *	27.48*	26.33 *	20.26 *	6.33*
IPC 06-77 X KPG 59	4.23	-1.77	-2.63	23.53 *	10.53	31.25	-12.41 *	-16.53 *	-10.36*	-10.89 *	-11.85	-22.07
IPC 06-77 X PDG 4	7.54	7	-6.14*	0.00	0.00	18.75	15.63 *	15.48 *	24.32*	20.89 *	14.79 *	12.89*
SADABAHAR X GNG 469	4.95	-2.75	-7.02	17.65 *	17.65	25	28.81 *	19.28 *	19.82*	52.68 *	47.15 *	17.59*
SADABAHAR X KPG 59	14.56 *	4.42	3.51	18.75 *	11.76	18.75	21.67 *	14.35 *	11.26*	46.11 *	35.66 *	17.34*
SADABAHAR X PDG 4	14.58 *	11.11	-3.51	-16.67 *	-21.05 *	-6.25*	-5.83	-15.48 *	-9.01*	-19.28 *	-29.22 *	-30.39*
no.of sig"+ve"	5	1	1	4	0	0	10	8	11	14	5	5
no.of sig"-ve"	2	3	3	1	2	2	6	7	5	5	4	4

Table 4.32: Relative, heterobeltiosis & standard heterosis estimates

Hybrids	Harvest index (%)			Total chlorophyll content (mg/ml)			Relative leaf water content (%)			Lipid Peroxidation (nmol/ml)			Electrolyte leakage index (%)		
	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H
KWR 108 X GNG 469	3.95	-0.16	2.84	-10.73	-18.03	4.7	16.64 *	-1.46	-6.47	7.07	0.63	-3.98	-23.45 *	-33.18 *	-10.46*
KWR 108 X KPG 59	9.63 *	-0.63	2.35	9.8	-2.46	34.17	57.93 *	48.07 *	10.75*	12.74 *	5.16	1.99	-32.92 *	-34.95 *	-12.82*
KWR 108 X PDG 4	-2.74	-10.71 *	-8.03*	-15.92	-37.09 *	35.40*	40.11 *	27.67 *	1.62*	7.81	0.96	-2.92	-7.76 *	-24.39 *	1.33*
ICC 5335 X GNG 469	1.19	-2.55	-0.18	3.41	-7.09	48.91	12.56 *	8.92	3.38	-11.60 *	-25.16 *	3.01*	-4.77 *	-18.66 *	14.78*
ICC 5335 X KPG 59	-3.12	-11.98 *	-9.83*	16.29	8.05	73.16	6.86	-1.56	-12.61	-29.40 *	-39.83 *	-17.18*	-28.62 *	-32.47 *	-4.70*
ICC 5335 X PDG 4	9.55 *	0.82	3.27	-14.31	-25.25 *	60.88*	47.83 *	40.18 *	24.45*	-29.70 *	-40.30 *	-17.82*	-25.47 *	-40.11 *	-15.49*
ICC 5434 X GNG 469	-7.72 *	-9.10 *	-11.12*	57.00 *	46.96 *	115.23*	13.81 *	13.22 *	7.46*	-17.48 *	-24.47 *	-13.24*	-15.73 *	-24.03 *	-5.45*
ICC 5434 X KPG 59	6.69	-0.99	-3.19	16.54	13	65.49	30.98 *	17.64 *	10.50*	1.53	-6.37	7.55	-7.61 *	-8.14 *	15.66*
ICC 5434 X PDG 4	12.32 *	5.62	3.27	-22.07 *	-34.52 *	40.93*	-17.97 *	-24.23 *	-28.83*	-27.29 *	-33.21 *	-23.29*	-24.84 *	-36.55 *	-21.03*
BG 212 X GNG 469	-10.65 *	-13.77 *	-12.06*	-26.71 *	-26.97 *	-6.05*	-3.81	-8.29	-12.96	-27.76 *	-33.03 *	-25.19*	-5.94 *	-21.56 *	17.40*
BG 212 X KPG 59	3.24	-6.01	-4.15	13.26	9.6	50.75	2.2	-4.49	-17.8	19.43 *	11.56 *	24.63*	-28.47 *	-34.15 *	-1.45*
BG 212 X PDG 4	5.09	-3.09	-1.17	-11.25	-29.10 *	52.59*	1.09	-2.71	-16.27	2.76	-4.39	6.81	14.13 *	-10.27 *	34.30*
IPC 07-56 X GNG 469	-1.9	-5.68	-3.04	35.22 *	23.75 *	90.36*	-1.65	-8.26	-12.93	-27.42 *	-37.88 *	-16.71*	-29.18 *	-38.30 *	-16.95*
IPC 07-56 X KPG 59	-3.98	-12.90 *	-10.46*	-1.58	-6.79	43.38	8.76	3.89	-14.65	-21.66 *	-32.49 *	-9.49*	-6.71 *	-9.73 *	21.52*
IPC 07-56 X PDG 4	-2.27	-10.21 *	-7.70*	-20.30 *	-31.67 *	47.07*	19.15 *	17.29 *	-3.64*	-3.8	-17.40 *	10.74*	11.96 *	-8.39 *	23.32*
IPC 06-77 X GNG 469	4.2	0.58	2.54	4.53	-5.27	48.91	17.68 *	-1.68	-6.69	-2.33	-5	-4.12	-13.53 *	-18.87 *	-7.49*
IPC 06-77 X KPG 59	7.85 *	-1.8	0.11	83.54 *	72.07 *	170.49*	27.16 *	17.70 *	-11.97*	-12.94 *	-14.63 *	-13.84*	-1.99	-6.61 *	17.58*
IPC 06-77 X PDG 4	9.16 *	0.68	2.64	-29.93 *	-39.37 *	30.49*	11.60 *	0.44	-20.06	20.65 *	17.80 *	18.89*	16.45 *	1.97	16.27
SADABAHAR X GNG 469	-5.45	-8.34 *	-7.39*	68.23 *	64.18 *	109.70*	5.92	-10.85 *	-15.39*	-41.02 *	-49.81 *	-31.76*	-3.77	-17.64 *	15.66*
SADABAHAR X KPG 59	-1.12	-9.60 *	-8.67*	17.77	10.94	52.59	49.41 *	39.48 *	4.32*	-24.68 *	-35.48 *	-12.27*	0.42	-4.78 *	33.73*
SADABAHAR X PDG 4	-0.72	-8.05 *	-7.11*	-3.19	-24.25 *	63.03*	42.87 *	29.64 *	3.18*	0.16	-14.50 *	16.25*	-20.80 *	-36.24 *	-10.46*
no.of sig"+ve"	5	0	0	4	4	11	13	9	7	3	2	5	3	0	10
no.of sig"-ve"	2	9	9	4	7	1	1	2	4	11	13	10	15	20	10

Table 4.32: Relative, heterobeltiosis & standard heterosis estimates

Hybrids	Proline content			Ascorbic acid content (mg)			Pollen viability			Flower drop (%)			Seed yield plant^{-1}		
	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H	R.H	HB.	S.H
KWR 108 X GNG 469	20.89 *	6.90 *	15.13*	-10.13	-23.44 *	-4.60*	-4.28	-5.91	-4.28	-34.18 *	-37.39 *	-13.83*	16.71 *	2.98	7.69
KWR 108 X KPG 59	-1.33	-15.53 *	-1.85*	-12.33 *	-20.99 *	-1.54*	-4.52	-6.67	-8.29	17.30 *	11.73 *	38.77*	25.50 *	8.59	13.56
KWR 108 X PDG 4	41.56 *	39.74 *	15.66*	-7.13	-19.74 *	0.01*	7.73	3.4	1.6	3.82	-4.02	40.41	-11.63 *	-18.05 *	-14.31*
ICC 5335 X GNG 469	36.53 *	19.21 *	28.39*	2.61	1.72	-9.22	-5.36	-6.04	-4.41	-1.12	-4.77	41.52	17.88 *	4.13	8.61
ICC 5335 X KPG 59	20.11 *	1.6	18.04*	4.07	-1.54	-1.52	-4.55	-7.6	-7.35	-29.52 *	-38.11 *	-8.02*	-4.79	-17.53 *	-13.99*
ICC 5335 X PDG 4	16.64 *	16.45 *	-6.1	12.83	11.87	1.55	6.45	1.2	1.47	-27.54 *	-28.11 *	6.84*	21.77 *	13.05 *	17.91*
ICC 5434 X GNG 469	1.15	-13.55 *	-6.89*	4.92	-1.54	-1.52	10.91 *	6.83	8.69	-2.03	-4.9	30.9	8.85	2.58	-17.97
ICC 5434 X KPG 59	-7.16 *	-23.06 *	-10.61*	18.43 *	18.43 *	18.45*	23.24 *	22.98 *	15.91*	10.82 *	3.47	34.08	22.33 *	17.82 *	-10.00*
ICC 5434 X PDG 4	5.74	2.96	-16.97*	-11.29	-15.39 *	-15.38*	0.8	-1.28	-6.95	-31.73 *	-35.63 *	-5.83*	37.32 *	23.03 *	9.93*
BG 212 X GNG 469	25.25 *	9.36 *	17.78	-16.66 *	-26.65 *	-15.38*	-11.92 *	-12.66 *	-9.63*	-17.26 *	-18.83 *	11.71*	-29.52 *	-41.95 *	-28.28*
BG 212 X KPG 59	-7.69 *	-21.92 *	-9.28*	-8.56	-14.64 *	-1.52*	6.91	1.94	5.48	17.12 *	8.27	43.34	12.58 *	-8.9	12.55
BG 212 X PDG 4	51.57 *	51.32 *	22.02*	-23.88 *	-31.99 *	-21.53*	-0.14	-6.46	-3.21	-36.85 *	-39.86 *	-12.01*	-8.44	-21.11 *	-2.53*
IPC 07-56 X GNG 469	4.26	-9.61 *	-2.65*	-7.28	-10.53	-21.53	8.93 *	5.78	7.62	-5.15	-6.69	28.42	8.34	-0.62	-4.77
IPC 07-56 X KPG 59	17.39 *	-1.37	14.59*	25.39 *	13.82	13.83	7.96	6.83	2.41	6.33	-1.95	30.54	-26.40 *	-33.86 *	-36.62*
IPC 07-56 X PDG 4	-5.32	-6.25	-24.4	23.20 *	16.94 *	6.15*	3.09	0.14	-4.01	-38.90 *	-41.65 *	-14.64*	21.70 *	17.60 *	12.68*
IPC 06-77 X GNG 469	26.84 *	12.32 *	20.96*	-17.36 *	-21.88 *	-23.07*	-1.72	-6.31	-4.68	-13.36 *	-25.64 *	2.35*	31.38 *	20.98 *	14.93*
IPC 06-77 X KPG 59	-3.33	-17.12 *	-3.71*	-19.39 *	-20.01 *	-20.00*	2.3	1.42	-4.81	16.11 *	9.01	22.52	-4.01	-13.41 *	-17.74*
IPC 06-77 X PDG 4	47.16 *	45.05 *	20.43*	18.67 *	14.03	12.29	1.46	0.43	-7.35	-36.46 *	-46.81 *	-22.18*	32.24 *	28.32 *	21.90*
SADABAHAR X GNG 469	-13.40 *	-24.38 *	-18.56*	58.47 *	47.35 *	29.22*	5.87	0.66	2.41	-0.29	-7.74	26.99	44.46 *	43.55 *	14.79*
SADABAHAR X KPG 59	-26.86 *	-38.13 *	-28.11*	31.55 *	15.35 *	15.37*	5.04	3.85	-2.54	-25.29 *	-26.78 *	-14.28*	45.07 *	42.72 *	12.68*
SADABAHAR X PDG 4	49.92 *	49.67 *	20.70*	-3.71	-11.87	-20	17.33 *	16.47 *	6.82*	-6.86	-16.17 *	22.64*	-19.47 *	-24.15 *	-32.22*
no.of sig"+ve"	11	9	9	6	4	5	4	2	2	4	1	5	12	8	7
no.of sig"-ve"	4	8	8	5	8	7	1	1	1	10	11	7	4	7	8

4.6.4 Plant height

Average heterosis ranged at -5.83 (ICC 5434 X PDG 4) to 20.38 per cent (SADABAHAR X GNG 469). The was no negative significance heterosis for any crosses and positive for 9 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (20.38 %), ICC 5335 X GNG 469 (17.53 %) and KWR 108 X GNG 469 (13.43%).

Heterobeltiosis ranged from -7.54 (IPC 07-56 X GNG 469) to 14.05 per cent (SADABAHAR X GNG 469). The was no negative significance heterosis for any crosses and positive for 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (14.05 %), ICC 5335 X GNG 469 (10.91 %) and ICC 5335 X PDG 4 (9.51 %).

Standard heterosis ranged from -11.88 (IPC 06-77 X GNG 469) to 8.43 (SADABAHAR X GNG 469). The was no negative significance heterosis for any crosses and positive for 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (8.43 %), ICC 5335 X PDG 4 (7.21 %) and ICC 5335 X GNG 469 (6.32 %).

4.6.5 Primary offshoots plant^{-1}

Average heterosis ranged at -21.84 (SADABAHAR X KPG 59) to 24.32 per cent (ICC 5434 X GNG 469). The negative heterosis was significant for 7 crosses and positive for 2 crosses among the 21 crosses. The top crosses which are desirable for these particular trait, ICC 5434 X GNG 469 (24.32 %) and ICC 5335 X KPG 59 (13.92 %).

Heterobeltiosis ranged from -25.00 (ICC 5434 X KPG 59) to 24.32 per cent (ICC 5434 X GNG 469). The negative heterosis was significant for 10 crosses and positive heterosis was significant for 1 cross among the 21 crosses. The top cross for desirable for this character is ICC 5434 X GNG 469 (24.32).

Standard heterosis ranged from -5.71 (ICC 5434 X KPG 59) to 31.43 (ICC 5434 X GNG 469). The negative heterosis was significant for 4 crosses and positive for 7 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X GNG 469 (31.43 %), BG 212 X PDG 4 and ICC 5434 X PDG 4 (5.71 %) and IPC 07-56 X PDG 4 (2.86 %).

4.6.6 Secondary offshoots plant^{-1}

Average heterosis ranged -14.50 (BG 212 X PDG 4) to 25.86 per cent (ICC 5434 X GNG 469). The negative heterosis was significant for 3 crosses and positive for 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X GNG 469 (24.32 %), ICC 5335 X KPG 59 (21.31 %) and ICC 5335 X KPG 59 (19.33 %).

Heterobeltiosis ranged from -17.65 (BG 212 X PDG 4) to 23.73 per cent (ICC 5434 X GNG 469). The negative heterosis was significant for 1 cross and positive heterosis was significant for 2 crosses among the 21 crosses. The top crosses which are desirable for these particular trait, ICC 5434 X GNG 469 (23.73%) and ICC 5335 X KPG 59 (17.46%).

Standard heterosis ranged from -16.42 (BG 212 X PDG 4) to 10.45 per cent (IPC 06-77 X KPG 59). The negative heterosis was significant for 1 cross and positive heterosis was significant for 2 crosses among the 21 crosses. The top crosses which are desirable for these particular trait, IPC 06-77 X KPG 59 (10.45 %) and ICC 5434 X GNG 469 (8.96 %).

4.6.7 Capsules plant^{-1}

Average heterosis ranged from -5.22 (IPC 07-56 X KPG 59) to 19.34 per cent (ICC 5335 X PDG 4). The was no negative significance heterosis for any crosses and positive for 6 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X PDG 4 (19.34 %), IPC 06-77 X PDG 4 (14.26 %) and SADABAHAR X KPG 59 (12.28 %).

Heterobeltiosis ranged from -8.26 (IPC 07-56 X KPG 59) to 16.34 per cent (ICC 5335 X PDG 4). The negative heterosis was significant for 1 cross and positive heterosis was significant for 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X PDG 4 (16.34 %), IPC 06-77 X PDG 4 (12.99 %) and SADABAHAR X KPG 59 (9.21 %).

Standard heterosis ranged from -9.42 (IPC 07-56 X KPG 59) to 7.17 (ICC 5335 X PDG 4). The negative heterosis was significant for 1 cross and positive heterosis was significant for 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X PDG 4 (7.17 %), SADABAHAR X KPG 59 (6.75 %) and IPC 06-77 X PDG 4 (6.47 %).

4.6.8 Full capsules plant^{-1}

Average heterosis ranged from -9.26 (IPC 07-56 X KPG 59) to 21.22 per cent (ICC 5335 X PDG 4). The was no negative significance heterosis for any crosses and positive for 5 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X PDG 4 (21.22 %), IPC 06-77 X PDG 4 (15.45 %) and KWR 108 X GNG 469 (13.80 %).

Heterobeltiosis ranged from -14.24 (IPC 07-56 X KPG 59) to 17.63 per cent (ICC 5335 X PDG 4). The negative heterosis was significant for 1 cross and positive heterosis was significant for 3 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X PDG 4 (17.63 %), IPC 06-77 X PDG 4 (14.04 %) and KWR 108 X GNG 469 (9.21 %).

Standard heterosis ranged from -12.67 (IPC 07-56 X KPG 59) to 9.00 (ICC 5335 X PDG 4). The negative heterosis was significant for 1 cross and positive heterosis was significant for 3 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X PDG 4 (9.00 %), IPC 06-77 X PDG 4 (8.33 %) and KWR 108 X GNG 469 (6.50 %).

4.6.9 Empty capsules plant^{-1}

Average heterosis ranged from -19.81 (ICC 5335 X KPG 59) to 21.00 per cent (IPC 07-56 X GNG 469). The significant negative heterosis was for 2 crosses and positive for 5 crosses among the 21 crosses. The top crosses which are desirable for these particular trait, ICC 5335 X KPG 59 (-19.81 %) and KWR 108 X GNG 469 (-11.65 %).

Heterobeltiosis ranged from -24.78 (ICC 5335 X KPG 59) to 14.14 per cent (IPC 07-56 X PDG 4). The negative heterosis was significant for 3 crosses and positive heterosis was significant for 1 cross among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X KPG 59 (-24.78 %), KWR 108 X GNG 469 (-16.51%) and KWR 108 X KPG 59 (-14.16 %).

Standard heterosis ranged from -6.14 (IPC 06-77 X PDG 4) to 5.26 (IPC 07-56 X KPG 59). The negative heterosis was significant for 3 crosses and positive heterosis was significant for 1 cross among the 21 crosses. The top three crosses which are desirable for these particular trait, KWR 108 X GNG 469 (-20.18 %), IPC 06-77 X PDG 4 (-6.14 %) and ICC 5335 X PDG 4 (5.26 %).

4.6.10 Seeds capsule^{-1}

Average heterosis ranged from -16.67 (SADABAHAR X PDG 4) to 31.25 per cent (ICC 5335 X PDG 4). The negative heterosis was significant for 1 cross and positive heterosis was significant for 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X PDG 4 (31.25 %), IPC 06-77 X KPG 59 (23.53 %) and SADABAHAR X KPG 59 (18.75 %).

Heterobeltiosis ranged from -22.22 (IPC 07-56 X KPG 59) to 17.65 per cent (SADABAHAR X GNG 469). The significant negative heterosis was for 2 crosses and there was no positive significance for any crosses among the 21 crosses.

Standard heterosis ranged from -12.50 (IPC 07-56 X KPG 59) to 31.25 per cent (ICC 5335 X PDG 4). The significant negative heterosis was for 2 crosses and there was no positive significance for any crosses among the 21 crosses.

4.6.11 Test weight (gm)

Average heterosis ranged from -33.72 (BG 212 X GNG 469) to 36.52 per cent (ICC 5434 X PDG 4). The negative heterosis was significant for 6 crosses and positive for 10 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X PDG 4 (36.52 %), SADABAHAR X GNG 469 (28.81 %) and IPC 06-77 X GNG 469 (22.67 %).

Heterobeltiosis ranged from -42.14 (BG 212 X GNG 469) to 19.67 per cent (ICC 5434 X PDG 4). The negative heterosis was significant for 7 crosses and positive for 8 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X PDG 4 (19.67 %), SADABAHAR X GNG 469 (19.28 %) and IPC 06-77 X GNG 469 (18.71%).

Standard heterosis ranged from -22.07 (BG 212 X GNG 469) to 28.83 (ICC 5434 X PDG 4). The negative heterosis was significant for 5 crosses and positive for 11 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X PDG 4 (28.83 %), IPC 06-77 X GNG 469 (27.48 %) and KWR 108 X KPG 59 (26.13 %).

4.6.12 Biological yield plant^{-1}

Average heterosis ranged from -23.33 (IPC 07-56 X KPG 59) to 52.68 per cent (SADABAHAR X GNG 469). The negative heterosis was significant for 5 crosses and positive heterosis was significant for 14 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (52.68 %), SADABAHAR X KPG 59 (46.11 %) and IPC 06-77 X GNG 469 (26.33 %).

Heterobeltiosis ranged from -32.54 (BG 212 X GNG 469) to 47.15 per cent (SADABAHAR X GNG 469). The negative heterosis was significant for 4 crosses and positive for 5 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (47.15 %), SADABAHAR X KPG 59 (35.66 %) and IPC 06-77 X GNG 469 (20.26 %).

Standard heterosis ranged from -32.93 (IPC 07-56 X KPG 59) to 17.59 per cent (SADABAHAR X GNG 469). The negative heterosis was significant for 4 crosses and positive for 5 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (17.59 %), SADABAHAR X KPG 59 (17.34 %) and IPC 07-56 X PDG 4 (15.76 %).

4.6.13 Harvest index (%)

Average heterosis ranged -10.65 (BG 212 X GNG 469) to 12.32 per cent (ICC 5434 X PDG 4). Observed significance negative for 2 crosses and positive for 5 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X PDG 4 (12.32 %), KWR 108 X KPG 59 (9.63 %) and ICC 5335 X PDG 4 (9.55 %).

Heterobeltiosis ranged from -13.77 (BG 212 X GNG 469) to 5.62 per cent (ICC 5434 X PDG 4). Observed significance negative for 9 crosses and no positives among the 21 crosses.

Standard heterosis ranged from -12.06 (BG 212 X GNG 469) to 3.27 (ICC 5434 X PDG 4). Observed significance negative for 9 crosses and no positives among the 21 crosses.

4.6.14 Total chlorophyll content (mg/ml)

Average heterosis ranged from -29.93 (IPC 06-77 X PDG 4) to 83.54 per cent (IPC 06-77 X KPG 59). The negative heterosis was significant for 4 crosses and positive for 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, IPC 06-77 X KPG 59 (83.54 %), SADABAHAR X GNG 469 (68.23 %) and ICC 5434 X GNG 469 (57.00 %).

Heterobeltiosis ranged from -39.37 (IPC 06-77 X PDG 4) to 72.07 per cent (IPC 06-77 X KPG 59). The negative heterosis was significant for 7 crosses and positive for 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, IPC 06-77 X KPG 59 (72.07 %), SADABAHAR X GNG 469 (64.18 %) and ICC 5434 X GNG 469 (46.96 %).

Standard heterosis ranged from -6.05 (BG 212 X GNG 469) to 170.49 (IPC 06-77 X KPG 59). The negative heterosis was significant for 1 cross and positive heterosis was significant for 11 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, IPC 06-77 X KPG 59 (170.49 %), ICC 5434 X GNG 469 (115.23 %) and SADABAHAR X GNG 469 (109.70 %).

4.6.15 Relative leaf water content (%)

Average heterosis ranged from -17.97 (ICC 5434 X PDG 4) to 57.93 per cent (KWR 108 X KPG 59). The negative heterosis was significant for 1 cross and positive heterosis was significant for 13 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, KWR 108 X KPG 59 (57.93 %), SADABAHAR X KPG 59 (49.41 %) and ICC 5335 X PDG 4 (47.83 %).

Heterobeltiosis ranged from -24.23 (ICC 5434 X PDG 4) to 48.07 per cent (KWR 108 X KPG 59). The negative significant heterosis was for 2 crosses and positive for 9 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, KWR 108 X KPG 59 (48.07 %), ICC 5335 X PDG 4 (40.18 %) and SADABAHAR X KPG 59 (39.48 %).

Standard heterosis ranged from -28.83 (ICC 5434 X PDG 4) to 24.45 per cent (ICC 5335 X PDG 4). The negative heterosis was significant for 4 crosses and positive for 7 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X PDG 4 (24.45 %), KWR 108 X KPG 59 (10.75 %) and ICC 5434 X KPG 59 (10.50 %).

4.6.16 Lipid Peroxidation (nmol/ml)

Average heterosis ranged from -41.02 (SADABAHAR X GNG 469) to 20.65 per cent (IPC 06-77 X PDG 4). The negative heterosis was significant for 11 cross and positive heterosis was significant for 3 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (-41.02

%), IPC 06-77 X PDG 4 (-29.70%) and ICC 5335 X KPG 59 (-29.40%).

Heterobeltiosis ranged from -49.81 (SADABAHAR X GNG 469) to 17.80 per cent (IPC 06-77 X PDG 4). The negative heterosis was significant for 13 crosses and positive for 2 amongst 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (-49.81 %), IPC 06-77 X PDG 4 (-40.30 %) and ICC 5335 X KPG 59 (-39.83 %).

Standard heterosis ranged from -31.76 (SADABAHAR X GNG 469) to 18.89 (IPC 06-77 X PDG 4). The negative heterosis was significant for 10 crosses and positive for 5 amongst 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (-31.76 %), BG 212 X GNG 469 (-25.19 %) and ICC 5434 X PDG 4 (-23.29 %).

4.6.17 Electrolyte Leakage Index (%)

Average heterosis ranged from -32.92 (KWR 108 X KPG 59) to 16.45 per cent (IPC 06-77 X PDG 4). The negative heterosis was significant for 15 cross and positive heterosis was significant for 3 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 -32.92 %), IPC 07-56 X GNG 469 (-29.18 %) and ICC 5335 X KPG 59 (-28.62 %).

Heterobeltiosis ranged from -40.11 (ICC 5335 X PDG 4) to 1.97 per cent (IPC 06-77 X PDG 4). The negative heterosis was significant for 20 crosses and no positive among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (-49.81 %), IPC 07-56 X GNG 469 (-38.30 %) and ICC 5434 X PDG 4 (-36.55 %).

Standard heterosis ranged from -21.03 (ICC 5434 X PDG 4) to 34.30 per cent (BG 212 X PDG 4). The negative heterosis was significant for 10 crosses and positive for 10 amongst 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X PDG 4 (-21.03 %), IPC 07-56 X GNG 469 (-16.95 %) and ICC 5335 X PDG 4 (-15.49 %).

4.6.18 Proline content (mg/gm)

Average heterosis ranged from -26.86 (SADABAHAR X KPG 59) to 51.57 per cent (BG 212 X PDG 4). The negative heterosis was significant for 4 cross and positive heterosis was significant for 11 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (51.57 %), SADABAHAR X PDG 4 (49.92 %) and IPC 06-77 X PDG 4 (47.16 %).

Heterobeltiosis ranged from -38.13 (SADABAHAR X KPG 59) to 51.32 per cent (BG 212 X PDG 4). The negative heterosis was significant for 8 crosses and positive for 9 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (51.32 %), SADABAHAR X PDG 4 (49.67 %) and IPC 06-77 X PDG 4 (45.05 %).

Standard heterosis ranged from -28.11 (SADABAHAR X KPG 59) to 28.39 per cent (ICC 5335 X GNG 469). The negative heterosis was significant for 8 crosses and positive for 9 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5335 X GNG 469 (28.39 %), BG 212 X PDG 4 (22.02 %) and IPC 06-77 X GNG 469 (20.96 %).

4.6.19 Ascorbic acid content (mg)

Average heterosis ranged from -23.88 (BG 212 X PDG 4) to 58.47 per cent (SADABAHAR X GNG 469). The negative heterosis was significant for 5 cross and positive heterosis was significant for 6 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (58.47 %), SADABAHAR X KPG 59 (31.55 %) and IPC 07-56 X KPG 59 (25.39 %).

Heterobeltiosis ranged from -31.99 (BG 212 X PDG 4) to 47.35 per cent (SADABAHAR X GNG 469). The negative heterosis was significant for 8 crosses and positive 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (47.35 %), ICC 5434 X KPG 59 (18.43 %) and IPC 07-56 X PDG 4 (16.94 %).

Standard heterosis ranged from -23.07 (IPC 06-77 X GNG 469) to 29.22 per cent (SADABAHAR X GNG 469). The negative heterosis was significant for 7 crosses and positive for 5 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (29.22 %), ICC 5434 X KPG 59 (18.45 %) and SADABAHAR X KPG 59 (15.37 %).

4.6.20 Pollen viability (%)

Average heterosis ranged from -11.92 (BG 212 X GNG 469) to 23.24 per cent (ICC 5434 X KPG 59). The negative heterosis was significant for 1 cross and positive heterosis was significant for 4 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X KPG 59 (23.24 %), SADABAHAR X PDG 4 (17.33 %) and ICC 5434 X GNG 469 (10.91%).

Heterobeltiosis ranged from -12.66 (BG 212 X GNG 469) to 22.98 per cent (ICC 5434 X KPG 59). The negative heterosis was significant for 1 cross and positive for 2 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, ICC 5434 X KPG 59 (22.98 %) and SADABAHAR X PDG 4 (16.47 %).

Standard heterosis ranged from -9.63 (BG 212 X GNG 469) to 15.91 per cent (ICC 5434 X KPG 59). The negative heterosis was significant for 1 cross and positive for 2 crosses among the 21 crosses. The top crosses which are desirable for these particular trait, ICC 5434 X KPG 59 (15.91 %) and SADABAHAR X PDG 4 (6.82 %).

4.6.21 Flower drop (%)

Average heterosis ranged from -38.90 (IPC 07-56 X PDG 4) to 17.30 per cent (KWR 108 X KPG 59). The negative heterosis was significant for 10 crosses and positive for 4 amongst 21 crosses. The top three crosses which are desirable for these particular trait, IPC 07-56 X PDG 4 (-38.90 %), BG 212 X PDG 4 (-36.85 %) and IPC 06-77 X PDG 4 (-36.46 %).

Heterobeltiosis ranged from -46.81 (IPC 06-77 X PDG 4) to 11.73 per cent (KWR 108 X KPG 59). Observed negative significance for 11 and positive for 1 cross among the 21 crosses. The top three crosses which are desirable for these particular trait, IPC 06-77 X PDG 4 (-46.81 %), IPC 07-56 X PDG 4 (-41.65 %) and BG 212 X PDG 4 (-39.86 %).

Standard heterosis ranged from -22.18 (IPC 06-77 X PDG 4) to 38.77 per cent (KWR 108 X KPG 59). The negative heterosis was significant for 7 crosses and positive for 5 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, IPC 06-77 X PDG 4 (-22.18 %), IPC 07-56 X PDG 4 (-14.64 %) and SADABAHAR X KPG 59 (-14.28 %).

4.6.22 Seed yield plant^{-1}

Average heterosis ranged from -29.52 (BG 212 X GNG 469) to 45.07 per cent (SADABAHAR X KPG 59). The negative heterosis was significant for 4 crosses and positive for 12 crosses among the 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X KPG 59 (45.07%), SADABAHAR X GNG 469 (44.46 %) and ICC 5434 X PDG 4 (37.32%).

Heterobeltiosis ranged from -41.95 (BG 212 X GNG 469) to 43.55 per cent (SADABAHAR X GNG 469). The negative heterosis was significant for 7 crosses and positive for 8 amongst 21 crosses. The top three crosses which are desirable for these particular trait, SADABAHAR X GNG 469 (43.55%), SADABAHAR X KPG 59 (42.72 %) and IPC 06-77 X PDG 4 (28.32 %).

Standard heterosis ranged from -36.62 (IPC 07-56 X KPG 59) to 21.90 per cent (IPC 06-77 X PDG 4). The negative heterosis was significant for 8 crosses and positive for 7 amongst 21 crosses. The top three crosses which are desirable for these particular trait, IPC 06-77 X PDG 4 (21.90 %), ICC 5335 X PDG 4 (17.91 %) and SADABAHAR X GNG 469 (14.79 %).

4.7 COMBINING ABILITY ANALYSIS

The selection of parents and the breeding protocol used are critical components of every successful breeding operation. Combining ability is a useful tool for selecting appropriate parental lines for a hybridization program and for differentiating between good and poor combiners. Additionally, it offers details on particular promising pairings to take advantage of heterosis for appropriate advancement, it is crucial to choose parents that have acceptable characteristics and a general good combining ability concerning yield and its component features.

4.7.1. ANOVA for combining ability

Employing procedure recommended by Kempthorne in 1957, an ANOVA of combining ability was performed to divide the entire genetic variance into general combining ability (GCA: representing an additive type of gene activity) & specific combining ability (SCA: a measure of non-additive gene action). Table.4.33 illustrates the ANOVA for combining ability for all the traits.

ANOVA expressed all treatments and crosses were statistically significant. The replication showed significance for capsules plant^{-1} and flower drop (%).

4.7.2. Combining ability (GCA and SCA) effects estimation

Tables 4.35 and 4.36 give the estimations of the GCA impacts of the parents & SCA of the crosses for each of the twenty-two qualities. The following is a presentation of the key findings on the combination of ability impacts for various characters:

4.7.2.1. First blossoming days

It's thought that early flowering is preferable. For this characteristic, genotypes with negative GCA and SCA values should be taken into consideration. For GCA, ranged varied from -1.643 (PDG 4) to 2.286 percent (IPC 07-56) with standard error of GCA effects (lines) 0.4871, (testers) 0.3189. Negative significant GCA impacts for first blossoming days were recorded for 2 parents, where positively significant GCA effects were showed for 3 parents. Top desirable parents were PDG 4 (-1.64 %) and BG 212 (-1.54 %).

For SCA, ranged varied from -4.500 (SADABAHAR X GNG 469), to 5.000 percent (ICC 5335 X GNG 469) with standard error 0.8437. Among 21 crosses, 7 crosses were negatively significant, and 6 crosses were positively significant for SCA effect. Top three desirable crosses were SADABAHAR X GNG 469 (-4.500%), ICC 5335 X PDG 4 (-3.857 %), ICC 5434 X GNG 469 (-3.833%).

4.7.2.2. 50% blossoming days

It's thought that early flowering is preferable. For this characteristic, genotypes with negative GCA and SCA values should be taken into consideration. For GCA, ranged varied from -2.262 (BG 212) to 3.071 percent (IPC 07-56) with standard error of GCA effects (lines) 0.4432, (testers) 0.2901. Negative significant GCA impacts for 50% blossoming days were recorded for 3 parents, where positively significant GCA effects were showed for 3 parents. Top desirable parents were BG 212 (-2.26 %), SADABAHAR (-2.09 %) and PDG 4 (-2.00 %).

For SCA, ranged varied from -5.119 (SADABAHAR X GNG 469), to 5.333 percent (BG 212 X PDG 4) with standard error 0.7676. Among 21 crosses, 7 crosses were negatively significant, and 6 were positively significant for SCA effect. Top three desirable crosses were SADABAHAR X GNG 469 (-5.119 %), ICC 5335 X PDG 4 (-4.167 %), ICC 5434 X GNG 469 (-2.952%).

4.7.2.3. Harvest maturity days

It's thought that early maturity is preferable. For this characteristic, genotypes with negative GCA and SCA values should be taken into consideration. For GCA, ranged varied from -4.071 (BG 212) to 3.262 percent (IPC 07-56) with standard error of GCA effects (lines) 0.5722, (testers) 0.3746. Negative significant GCA impacts were recorded for 2 parents, where positively significant GCA effects were showed for 4 parents. Top desirable parents were BG 212 (-4.07%) and PDG 4 (-2.28 %).

For SCA, ranged varied from -8.595 (ICC 5434 X GNG 469), to 5.476 percent (ICC 5434 X KPG 59) with standard error 0.991. Among 21 crosses, 6 crosses showed negatively significant, and 7 crosses showed positively significant for SCA effect. Top three desirable crosses were ICC 5434 X GNG 469 (-8.595 %), ICC 5335 X PDG 4 (-7.048 %), KWR 108 X KPG 59 (-3.857 %).

4.33: Combining ability ANOVA

Sov	d.f.	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
Blocks	1	0.024	3.429	7.714	9.419	0.015	0.015	35.109 *	24.687	0.915	0.001	0.095
Crosses	20	24.329 *	27.764 *	46.164 *	15.667 *	0.285 *	0.862 *	30.344 *	26.338 *	1.878 *	0.085 *	6.440 *
Line	6	15.817	21.881	33.437	9.88	0.29	1.092	30.364	25.381	3.783 *	0.054	1.677
Tester	2	29.786	49.143	62	7.23	0.187	0.309	38.297	40.56	0.034	0.072	0.532
Line * Tester	12	27.675 *	27.143 *	49.889 *	19.968 *	0.299 *	0.840 *	29.008 *	24.447 *	1.233 *	0.102 *	9.806 *
Error	20	1.424	1.179	1.964	3.023	0.059	0.203	6.853	8.939	0.407	0.025	0.121
Total	41	12.563	14.202	23.666	9.347	0.168	0.52	19.001	17.81	1.137	0.054	3.203

Sov	d.f.	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
Blocks	1	4.294	3.561	0.018	0.248	0.639	0.179	0	1.16	1.167	7.468 *	0.398
Crosses	20	25.802 *	13.985 *	0.786 *	87.030 *	5.471 *	75.620 *	0.214 *	35.864 *	50.475 *	38.715 *	7.664 *
Line	6	5.076	17.136	0.784	95.383	1.884	65.548	0.246	23.458	57.421	10.625	2.561
Tester	2	4.58	6.585	0.483	2.883	9.03	36.867	0.15	32.196	6.247	56.867	2.456
Line * Tester	12	39.703 *	13.643 *	0.838 *	96.878 *	6.671 *	87.115 *	0.209 *	42.679 *	54.373 *	49.735 *	11.083 *
Error	20	1.413	3.406	0.067	4.848	0.401	1.187	0.003	3.61	10.805	1.144	0.347
Total	41	13.38	8.57	0.417	44.825	2.88	37.471	0.106	19.284	29.921	19.626	3.917

4.34: Details of covariance and standard error

Source of variation	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
COV FS	11.6753	15.7395	23.4327	4.8921	0.1003	0.2706	12.7825	10.4967	0.6046	0.0266	2.1174
S. Square (GCA)	2.1378	3.4333	4.5754	0.5532	0.0179	0.0497	2.7478	2.4032	0.1501 *	0.0038	0.0984
S. Square (SCA)	13.1254 *	12.9821 *	23.9623 *	8.4724 *	0.1198 *	0.3182 *	11.0778 *	7.7540 *	0.4130 *	0.0387 *	4.8425 *
S. Square (Additive)(F=1)	4.2756	6.8667	9.1508	1.1064	0.0358	0.0994	5.4956	4.8064	0.3003	0.0077	0.1967
S. Square (Dominance)(F=1)	13.1254	12.9821	23.9623	8.4724	0.1198	0.3182	11.0778	7.7540	0.4130	0.0387	4.8425
Standard error for GCA lines	0.4871	0.4432	0.5722	0.7098	0.0994	0.1840	1.0687	1.2206	0.2605	0.0645	0.1421
Standard error for GCA testers	0.3189	0.2901	0.3746	0.4647	0.0650	0.1205	0.6996	0.7990	0.1706	0.0422	0.0931
Standard error for SCA crosses	0.8437	0.7676	0.9910	1.2294	0.1721	0.3188	1.8510	2.1141	0.4512	0.1117	0.2462

Source of variation	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
COV FS	8.2439	4.5067	0.3197	30.6129	2.7931	31.5938	0.0992	14.9388	14.4742	19.5399	2.6877
S. Square (GCA)	0.3415	0.8455	0.0566	4.4285	0.5056	5.0021	0.0195	2.4217	2.1029	3.2602	0.2161
S. Square (SCA)	19.1450 *	5.1187 *	0.3852 *	46.0149 *	3.1354 *	42.9643 *	0.1030 *	19.5343 *	21.7843 *	24.2958 *	5.3677 *
S. Square (Additive)(F=1)	0.683	1.691	0.1132	8.8571	1.0113	10.0042	0.0391	4.8435	4.2058	6.5204	0.4322
S. Square (Dominance)(F=1)	19.145	5.1187	0.3852	46.0149	3.1354	42.9643	0.103	19.5343	21.7843	24.2958	5.3677
Standard error for GCA lines	0.4853	0.7534	0.106	0.8989	0.2584	0.4447	0.0219	0.7757	1.3419	0.4366	0.2406
Standard error for GCA testers	0.3177	0.4932	0.0694	0.5885	0.1691	0.2911	0.0143	0.5078	0.8785	0.2858	0.1575
Standard error for SCA crosses	0.8405	1.305	0.1837	1.5569	0.4475	0.7703	0.038	1.3435	2.3243	0.7562	0.4168

4.7.2.4. Plant height

Ranged from -2.325 (ICC 5434) to 1.585 per cent (SADABAHAR) with standard error of GCA effects (lines) 0.7098, (testers) 0.4647. 1 parent showed negatively significant, and 1 parent showed positively significant for GCA effects. Desirable parents were SADABAHAR (1.585 %).

SCA effects ranged from -4.680 (IPC 07-56 X GNG 469) to 3.406 percent (ICC 5434 X GNG 469) with standard error 1.229. Among 21 crosses, 4 showed negatively significant. Where, 3 crosses showed positively significant. Top three desirable significant crosses were ICC 5434 X GNG 469 (3.406 %), IPC 06-77 X PDG 4 (2.924%), IPC 07-56 X KPG 59 (2.841%).

4.7.2.5. Primary offshoots plant^{-1}

Range of -0.371 (SADABAHAR) to 0.229 per cent (ICC 5335) with standard error of GCA effects (lines) 0.0994, (testers) 0.065. 2 parents showed negatively significant, and 2 parent showed positively significant for GCA effects. Desirable parents were ICC 5335 (0.229 %) and BG 212 (0.229 %).

SCA effects ranged from -0.586 (ICC 5434 X KPG 59) to 0.629 percent (ICC 5434 X GNG 469) with standard error 0.1721. Among 21 crosses, 2 showed negatively significant. Where, 4 crosses showed positively significant. Top three desirable significant crosses were ICC 5434 X GNG 469 (0.629 %), KWR 108 X PDG 4 (0.490 %), ICC 5335 X KPG 59 (0.414 %).

4.7.2.6. Secondary offshoots plant^{-1}

Range of -0.795 (SADABAHAR) to 0.605 per cent (IPC 07-56) with standard error of GCA effects (lines) 0.1840, (testers) 0.1205. 1 parent showed negatively significant, and 1 parent showed positively significant for GCA effects. Desirable parents were IPC 07-56 (0.605 %).

SCA effects ranged from -0.952 (ICC 5434 X KPG 59) to 0.948 percent (ICC 5434 X GNG 469) with standard error 0.3188. Among 21 crosses, 3 showed negatively significant. Where, 1 cross showed positively significant. Top desirable significant cross was ICC 5434 X GNG 469 (0.948 %).

4.7.2.7. Capsules plant^{-1}

Ranged from -3.033 (ICC 5434) to 3.100 per cent (SADABAHAR) with standard error of GCA effects (lines) 1.0687, (testers) 0.6996. 3 parents showed negatively significant, and 2 parents showed positively significant for GCA effects.

Desirable parents were SADABAHAR (3.100 %) and PDG 4 (1.314 %).

SCA effects ranged from -4.243 (ICC 5335 X KPG 59) to 7.086 percent (ICC 5335 X PDG 4) with standard error 1.851. Among 21 crosses, 2 showed negatively significant. Where, 2 crosses showed positively significant. Top desirable significant crosses were ICC 5335 X PDG 4 (7.086 %) and SADABAHAR X KPG 59 (4.457 %).

4.7.2.8. Full capsules plant^{-1}

Ranged from -2.562 (ICC 5434) to 2.638 per cent (SADABAHAR) with standard error of GCA effects (lines) 1.2206, (testers) 0.7990. 2 parents showed negatively significant, and 1 parent showed positively significant for GCA effects. Desirable parents were SADABAHAR (2.638 %).

SCA effects ranged from -4.11 (SADABAHAR X PDG 4) to 5.990 percent (ICC 5335 X PDG 4) with standard error 2.1141. Among 21 crosses, there were no negatively significant. Where, 1 cross showed positively significant. Top desirable significant cross was ICC 5335 X PDG 4 (5.990 %).

4.7.2.9. Empty capsules plant^{-1}

Less amount is considered desirable, ranged from -0.938 (KWR 108) to 1.129 per cent (IPC 07-56) with standard error of GCA effects (lines) 0.2605, (testers) 0.1706. 2 parents showed negatively significant, and 1 parent showed positively significant for GCA effects. Desirable parents were KWR 108 (-0.938 %) and ICC 5335 (-0.938 %).

SCA effects ranged from -1.290 (ICC 5335 X KPG 59) to 1.095 percent (ICC 5335 X PDG 4) with standard error 0.4512. Among 21 crosses, 2 showed negatively significant. Where, 1 cross showed positively significant. Top desirable significant crosses were ICC 5335 X PDG 4 (-1.290 %) and ICC 5434 X PDG 4 (-1.171 %).

4.7.2.10. Seeds capsule^{-1}

Ranged from -0.138 (IPC 07-56) to 0.162 per cent (IPC 06-77) with standard error of GCA effects (lines) 0.0645, (testers) 0.0422. 1 parent showed negatively significant, and 2 parents showed positively significant for GCA effects. Desirable parents were IPC 06-77 (0.162 %) and PDG 4 (0.076 %).

SCA effects ranged from -0.376 (SADABAHAR X PDG 4) to 0.267 percent (IPC 06-77 X KPG 59) with standard error 0.1117. Among 21 crosses, 1 cross showed negatively significant. Where, 2 crosses showed positively significant. Top desirable significant crosses were IPC 06-77 X KPG 59 (0.267 %) and ICC 5335 X PDG 4 (0.257

%).

4.7.2.11. Test weight (gm)

Ranged from -0.736 (IPC 07-56) to 0.764 per cent (ICC 5335) with standard error of GCA effects (lines) 0.1421, (testers) 0.0931. 2 parents showed negatively significant, and 3 parents showed positively significant for GCA effects. The top three desirable parents were ICC 5335 (0.764 %), IPC 06-77 (0.514%) and PDG 4 (0.224 %).

SCA effects ranged from -2.893 (BG 212 X GNG 469) to 3.200 percent (BG 212 X KPG 59) with standard error 0.2462. Among 21 crosses, 6 crosses showed negatively significant. Where, 9 crosses showed positively significant. Top desirable significant crosses were BG 212 X KPG 59 (3.200 %), KWR 108 X KPG 59 (1.950 %) and IPC 07-56 X PDG 4 (1.893 %).

4.7.2.12. Biological yield plant^{-1}

Ranged from -1.105 (IPC 07-56) to 1.114 per cent (SADABAHAR) with standard error of GCA effects (lines) 0.4853, (testers) 0.3177. 3 parents showed negatively significant, and 1 parent showed positively significant for GCA effects. The desirable parent was SADABAHAR (1.114 %).

SCA effects ranged from -7.903 (SADABAHAR X PDG 4) to 5.150 percent (IPC 07-56 X PDG 4) with standard error 0.8405. Among 21 crosses, 5 crosses showed negatively significant. Where, 6 crosses showed positively significant. Top desirable significant crosses were IPC 07-56 X PDG 4 (5.150 %), BG 212 X KPG 59 (4.693 %) and SADABAHAR X KPG 59 (4.368 %).

4.7.2.13. Harvest index (%)

Ranged from -1.985 (SADABAHAR) to 2.662 per cent (IPC 06-77) with standard error of GCA effects (lines) 0.7534, (testers) 0.4932. 2 parents showed negatively significant, and 1 parent showed positively significant for GCA effects. The desirable parent was IPC 06-77 (2.662 %).

SCA effects ranged from -4.231 (KWR 108 X PDG 4) to 2.644 percent (ICC 5434 X PDG 4) with standard error 1.305. Among 21 crosses, 4 crosses showed negatively significant. Where, no crosses showed positively significant.

4.35: General combining ability estimates concerning different traits in chickpea

Parents	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108	1.786 *	1.405 *	1.429 *	0.542	-0.205	-0.029	0.6	1.538	-0.938 *	-0.038	0.064
ICC 5335	-0.214	0.738	-0.738	0.908	0.229 *	0.071	-2.400 *	-1.462	-0.938 *	0.029	0.764 *
ICC 5434	0.119	-0.262	1.595 *	-2.325 *	0.029	-0.162	-3.033 *	-2.562 *	-0.471	-0.038	0.081
BG 212	-1.548 *	-2.262 *	-4.071 *	0.242	0.229 *	0.071	0.433	-0.062	0.495	-0.038	-0.486 *
IPC 07-56	2.286 *	3.071 *	3.262 *	-0.068	0.029	0.605 *	-0.833	-1.962	1.129 *	-0.138 *	-0.736 *
IPC 06-77	-0.214	-0.595	-0.738	-0.883	0.062	0.238	2.133	1.871	0.262	0.162 *	0.514 *
SADABAHAR	-0.214	-2.095 *	-0.738	1.585 *	-0.371 *	-0.795 *	3.100 *	2.638 *	0.462	0.062	-0.202
GNG 469	0.5	0.286	0.429	-0.07	0.105	0.086	0.543	0.571	-0.029	-0.01	-0.09
KPG 59	1.143 *	1.714 *	1.857 *	-0.681	0.019	0.086	-1.857 *	-1.914 *	0.057	-0.067	-0.133
PDG 4	-1.643 *	-2.000 *	-2.286 *	0.751	-0.124 *	-0.171	1.314 *	1.343	-0.029	0.076 *	0.224 *
Std.error (LINES)	0.4871	0.4432	0.5722	0.7098	0.0994	0.1840	1.0687	1.2206	0.2605	0.0645	0.1421
Std.error (TESTERS)	0.3189	0.2901	0.3746	0.4647	0.0650	0.1205	0.6996	0.7990	0.1706	0.0422	0.0931
no.of sig"+ve"	**3**	**3**	**4**	**1**	**2**	**1**	**2**	**1**	**1**	**2**	**3**
no.of sig"-ve"	**2**	**3**	**2**	**1**	**2**	**1**	**3**	**2**	**2**	**1**	**2**

4.35: General combining ability estimates concerning different traits in chickpea

Parents	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
KWR 108	0.199	1.332	-0.552 *	3.811 *	0.348	-4.435 *	0.124 *	0.229	-2.195	1.578 *	0.415
ICC 5335	0.912	0.698	0.038	5.408 *	-0.627 *	-2.451 *	0.195 *	-0.059	-2.029	-0.074	0.618 *
ICC 5434	-1.038 *	-0.003	0.248 *	0.941	-0.519	-3.101 *	-0.275 *	0.952	4.938 *	1.168 *	-0.494
BG 212	-0.616	-1.038	-0.427 *	-5.247 *	0.749 *	4.222 *	0.134 *	-2.814 *	-1.295	0.104	-0.502 *
IPC 07-56	-1.105 *	-1.665 *	0.026	-2.542 *	-0.032	1.542 *	-0.136 *	0.661	2.038	0.189	-0.882 *
IPC 06-77	0.535	2.662 *	0.401 *	-3.824 *	0.558 *	1.357 *	0.179 *	-2.093 *	-3.662 *	-2.561 *	0.856 *
SADABAHAR	1.114 *	-1.985 *	0.268 *	1.453	-0.476	2.865 *	-0.221 *	3.124 *	2.205	-0.404	-0.01
GNG 469	0.24	-0.19	0.002	-0.396	-0.895 *	-1.418 *	0.088 *	-1.055 *	0.081	0.886 *	0.084
KPG 59	-0.653 *	-0.57	0.185 *	0.495	0.237	1.770 *	-0.114 *	1.738 *	0.624	1.420 *	-0.455 *
PDG 4	0.413	0.761	-0.187 *	-0.099	0.658 *	-0.352	0.026 *	-0.683	-0.705	-2.307 *	0.370 *
Std.error (LINES)	0.4853	0.7534	0.106	0.8989	0.2584	0.4447	0.0219	0.7757	1.3419	0.4366	0.2406
Std.error (TESTERS)	0.3177	0.4932	0.0694	0.5885	0.1691	0.2911	0.0143	0.5078	0.8785	0.2858	0.1575
no.of sig"+ve"	**1**	**1**	**4**	**2**	**3**	**5**	**6**	**2**	**1**	**4**	**3**
no.of sig"-ve"	**3**	**2**	**3**	**3**	**2**	**4**	**4**	**3**	**1**	**2**	**3**

4.36: Specific combining ability estimates concerning different traits in chickpea

Hybrids	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108 X GNG 469	3.000 *	2.881 *	3.571 *	1.11	-0.238	-0.386	1.657	2.262	-0.605	0.01	-0.043
KWR 108 X KPG 59	-2.143 *	-2.048 *	-3.857 *	0.321	-0.252	-0.186	0.657	0.748	-0.09	0.067	1.950 *
KWR 108 X PDG 4	-0.857	-0.833	0.286	-1.431	0.490 *	0.571	-2.314	-3.01	0.695	-0.076	-1.907 *
ICC 5335 X GNG 469	5.000 *	4.548 *	4.738 *	2.063	-0.371 *	-0.286	-2.843	-3.038	0.195	-0.057	1.107 *
ICC 5335 X KPG 59	-1.143	-0.381	2.310 *	-3.705 *	0.414 *	0.514	-4.243 *	-2.952	-1.290 *	-0.2	-0.650 *
ICC 5335 X PDG 4	-3.857 *	-4.167 *	-7.048 *	1.642	-0.043	-0.229	7.086 *	5.990 *	1.095 *	0.257 *	-0.457
ICC 5434 X GNG 469	-3.833 *	-2.952 *	-8.595 *	3.406 *	0.629 *	0.948 *	1.59	0.662	0.929	-0.09	-1.510 *
ICC 5434 X KPG 59	3.024 *	2.619 *	5.476 *	-1.167	-0.586 *	-0.952 *	2.09	1.848	0.243	-0.033	-0.367
ICC 5434 X PDG 4	0.81	0.333	3.119 *	-2.239	-0.043	0.005	-3.681	-2.51	-1.171 *	0.124	1.876 *
BG 212 X GNG 469	-3.167 *	-2.452 *	-2.929 *	0.14	0.129	0.414	1.324	1.762	-0.438	0.21	-2.893 *
BG 212 X KPG 59	-1.810 *	-2.881 *	-1.857	-0.339	0.114	0.314	-0.776	-1.052	0.276	-0.133	3.200 *
BG 212 X PDG 4	4.976 *	5.333 *	4.786 *	0.199	-0.243	-0.729 *	-0.548	-0.71	0.162	-0.076	-0.307
IPC 07-56 X GNG 469	1.5	1.214	1.738	-4.680 *	0.129	0.081	1.49	1.162	0.329	-0.09	0.257
IPC 07-56 X KPG 59	-1.643	-1.214	-1.19	2.841 *	0.014	-0.119	-3.11	-3.252	0.143	-0.133	-2.150 *
IPC 07-56 X PDG 4	0.143	0	-0.548	1.839	-0.143	0.038	1.619	2.09	-0.471	0.224	1.893 *
IPC 06-77 X GNG 469	2.000 *	1.881 *	3.738 *	-4.375 *	-0.305	-0.952 *	-2.976	-3.071	0.095	-0.19	1.607 *
IPC 06-77 X KPG 59	-0.143	-0.048	-3.690 *	1.451	0.381 *	0.648	0.924	0.814	0.11	0.267 *	-2.550 *
IPC 06-77 X PDG 4	-1.857 *	-1.833 *	-0.048	2.924 *	-0.076	0.305	2.052	2.257	-0.205	-0.076	0.943 *
SADABAHAR X GNG 469	-4.500 *	-5.119 *	-2.262 *	2.336	0.029	0.181	-0.243	0.262	-0.505	0.21	1.474 *
SADABAHAR X KPG 59	3.857 *	3.952 *	2.810 *	0.598	-0.086	-0.219	4.457 *	3.848	0.61	0.167	0.567 *
SADABAHAR X PDG 4	0.643	1.167	-0.548	-2.934 *	0.057	0.038	-4.214 *	-4.11	-0.105	-0.376 *	-2.040 *
Std.error	0.8437	0.7676	0.991	1.2294	0.1721	0.3188	1.851	2.1141	0.4512	0.1117	0.2462
no.of sig"+ve"	**6**	**6**	**7**	**3**	**4**	**1**	**2**	**1**	**1**	**2**	**9**
no.of sig"-ve"	**7**	**7**	**6**	**4**	**2**	**3**	**2**	**0**	**2**	**1**	**6**

4.36: Specific combining ability estimates concerning different traits in chickpea

Hybrids	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
KWR 108 X GNG 469	0.145	2.045	-0.329	-3.937 *	0.642	0.288	0.015	0.332	-0.548	-7.941 *	0.503
KWR 108 X KPG 59	2.433 *	2.185	-0.031	4.017 *	0.155	-3.750 *	-0.102 *	-1.596	-4.09	1.945 *	1.681 *
KWR 108 X PDG 4	-2.578 *	-4.231 *	0.36	-0.08	-0.796	3.462 *	0.087 *	1.265	4.638	5.997 *	-2.184 *
ICC 5335 X GNG 469	0.302	1.204	-0.199	-0.474	2.372 *	7.385 *	0.194 *	-0.685	-0.814	4.675 *	0.399
ICC 5335 X KPG 59	-1.73	-3.146 *	0.014	-9.575 *	-0.940 *	-2.813 *	0.201 *	-1.303	-3.557	-5.674 *	-1.527 *
ICC 5335 X PDG 4	1.429	1.942	0.185	10.049 *	-1.431 *	-4.572 *	-0.395 *	1.988	4.371	0.998	1.128 *
ICC 5434 X GNG 469	-1.368	-3.455 *	0.671 *	6.088 *	0.508	0.755	-0.001	0.478	2.019	1.329	-1.389 *
ICC 5434 X KPG 59	-0.245	0.81	-0.321	6.757 *	1.621 *	5.162 *	0.131 *	3.330 *	6.876 *	1.425	0.02
ICC 5434 X PDG 4	1.614	2.644	-0.35	-12.845 *	-2.130 *	-5.917 *	-0.130 *	-3.809 *	-8.895 *	-2.753 *	1.370 *
BG 212 X GNG 469	-4.145 *	-2.880 *	-0.629 *	1.791	-2.050 *	1.651 *	0.055	0.33	-5.448 *	-1.408	-2.506 *
BG 212 X KPG 59	4.693 *	1.375	0.114	-1.585	2.198 *	-8.316 *	-0.252 *	1.452	5.310 *	4.323 *	2.488 *
BG 212 X PDG 4	-0.548	1.504	0.515 *	-0.206	-0.148	6.665 *	0.197 *	-1.782	0.138	-2.915 *	0.018
IPC 07-56 X GNG 469	0.063	2.162	0.488 *	-0.899	-0.353	-8.024 *	-0.06	-4.885 *	4.119	1.817 *	0.439
IPC 07-56 X KPG 59	-5.214 *	-1.093	-0.460 *	-2.675	-0.705	2.629 *	0.468 *	2.317	-0.324	1.703 *	-2.497 *
IPC 07-56 X PDG 4	5.150 *	-1.069	-0.028	3.574 *	1.059 *	5.395 *	-0.408 *	2.568	-3.795	-3.520 *	2.058 *
IPC 06-77 X GNG 469	1.468	0.57	-0.562 *	3.588 *	0.417	-4.439 *	0.07	-2.567	0.619	-0.598	0.851
IPC 06-77 X KPG 59	-4.304 *	-0.24	1.235 *	-0.013	-1.765 *	1.394	-0.192 *	-4.490 *	-0.024	2.863 *	-2.175 *
IPC 06-77 X PDG 4	2.835 *	-0.331	-0.673 *	-3.575 *	1.349 *	3.045 *	0.122 *	7.056 *	-0.595	-2.265 *	1.325 *
SADABAHAR X GNG 469	3.535 *	0.352	0.561 *	-6.159 *	-1.535 *	2.383 *	-0.275 *	6.997 *	0.052	2.125 *	1.703 *
SADABAHAR X KPG 59	4.368 *	0.107	-0.551 *	3.075	-0.562	5.695 *	-0.252 *	0.289	-4.19	-6.584 *	2.011 *
SADABAHAR X PDG 4	-7.903 *	-0.459	-0.01	3.084	2.097 *	-8.078 *	0.527 *	-7.285 *	4.138	4.458 *	-3.714 *
Std.error	**0.8405**	**1.305**	**0.1837**	**1.5569**	**0.4475**	**0.7703**	**0.038**	**1.3435**	**2.3243**	**0.7562**	**0.4168**
no.of sig"+ve"	**6**	**0**	**5**	**6**	**5**	**10**	**8**	**3**	**2**	**9**	**8**
no.of sig"-ve"	**5**	**4**	**5**	**5**	**6**	**8**	**8**	**4**	**2**	**7**	**7**

4.7.2.14. Total chlorophyll content (mg/ml)

Ranged from -0.552 (KWR 108) to 0.401 per cent (IPC 06-77) with standard error of GCA effects (lines) 0.106, (testers) 0.0694. 3 parents showed negatively significant, and 4 parents showed positively significant for GCA effects. The top three desirable parents were IPC 06-77 (0.401 %), SADABAHAR (0.268 %) and ICC 5434 (0.248 %).

SCA effects ranged from -0.673 (IPC 06-77 X PDG 4) to 1.235 percent (IPC 06-77 X KPG 59) with standard error 0.1837. Among 21 crosses, 5 crosses showed negatively significant. Where, 5 crosses showed positively significant. Top three desirable significant crosses were IPC 06-77 X KPG 59 (1.235 %), ICC 5434 X GNG 469 (0.671 %) and SADABAHAR X GNG 469 (0.561 %).

4.7.2.15. Relative leaf water content (%)

Ranged from -5.247 (BG 212) to 5.408 per cent (ICC 5335) with standard error of GCA effects (lines) 0.8989, (testers) 0.5885. 3 parents showed negatively significant, and 2 parents showed positively significant for GCA effects. The top desirable parents were ICC 5335 (5.408 %) and KWR 108 (3.811 %).

SCA effects ranged from -12.845 (ICC 5434 X PDG 4) to 10.049 percent (ICC 5335 X PDG 4) with standard error 1.5569. Among 21 crosses, 5 crosses showed negatively significant. Where, 6 crosses showed positively significant. Top three desirable significant crosses were ICC 5335 X PDG 4 (10.049%), ICC 5434 X KPG 59 (6.757 %) and ICC 5434 X GNG 469 (6.088 %).

4.7.2.16. Lipid Peroxidation (nmol/ml)

Ranged from -0.895 (GNG 469) to 0.749 per cent (BG 212) with standard error of GCA effects (lines) 0.2584, (testers) 0.1691. 2 parents showed negatively significant, and 3 parents showed positively significant for GCA effects. The top desirable parents were GNG 469 (-0.895 %) and ICC 5335 (-0.627 %).

SCA effects ranged from -2.130 (ICC 5434 X PDG 4) to 2.372 percent (ICC 5335 X GNG 469) with standard error 0.4475. Among 21 crosses, 6 crosses showed negatively significant. Where, 5 crosses showed positively significant. Top three desirable significant crosses were ICC 5434 X PDG 4 (-2.130 %), BG 212 X GNG 469 (-2.050 %) and IPC 06-77 X KPG 59 (-1.765 %).

4.7.2.17. Electrolyte leakage index

Ranged from -4.435 (KWR 108) to 4.222 per cent (BG 212) with standard error of GCA effects (lines) 0.4447, (testers) 0.2911. 4 parents showed negatively significant, and 5 parents showed positively significant for GCA effects. The top three desirable parents were KWR 108 (-4.435%), ICC 5434 (-3.101 %) and ICC 5335 (-2.451%).

SCA effects ranged from -8.316 (BG 212 X KPG 59) to 7.385 percent (ICC 5335 X GNG 469) with standard error 0.7703. Among 21 crosses, 8 crosses showed negatively significant. Where, 10 crosses showed positively significant. Top three desirable significant crosses were BG 212 X KPG 59 (-8.316 %), SADABAHAR X PDG 4 (-8.078%) and IPC 07-56 X GNG 469 (-8.024 %).

4.7.2.18. Proline

Ranged from -0.275 (ICC 5434) to 0.195 per cent (ICC 5335) with standard error of GCA effects (lines) 0.0219, (testers) 0.0143. 4 parents showed negatively significant, and 6 parents showed positively significant for GCA effects. The top three desirable parents were ICC 5335 (0.195 %), IPC 06-77 (0.179 %) and BG 212 (0.134%).

SCA effects ranged from -0.408 (IPC 07-56 X PDG 4) to 0.527 percent (SADABAHAR X PDG 4) with standard error 0.038. Among 21 crosses, 8 crosses showed negatively significant. Where, 8 crosses showed positively significant. Top three desirable significant crosses were SADABAHAR X PDG 4 (0.527 %), IPC 07-56 X KPG 59 (0.468 %) and ICC 5335 X KPG 59 (0.201 %).

4.7.2.19. Ascorbic acid content (mg)

Ranged from -2.814 (BG 212) to 3.124 per cent (SADABAHAR) with standard error of GCA effects (lines) 0.7757, (testers) 0.5078. 3 parents showed negatively significant, and 2 parents showed positively significant for GCA effects. The top desirable parents were SADABAHAR (3.124 %) and KPG 59 (1.738 %).

SCA effects ranged from -7.285 (SADABAHAR X PDG 4) to 7.056 percent (IPC 06-77 X PDG 4) with standard error 1.3435. Among 21 crosses, 4 crosses showed negatively significant. Where, 3 crosses showed positively significant. Top three desirable significant crosses were IPC 06-77 X PDG 4 (7.056 %), SADABAHAR X GNG 469 (6.997 %) and ICC 5434 X KPG 59 (3.330 %).

4.7.2.20. Pollen viability

Ranged from -3.662 (IPC 06-77) to 4.938 per cent (ICC 5434) with standard error of GCA effects (lines) 1.3419, (testers) 0.8785. 1 parent showed negatively significant, and 1 parent showed positively significant for GCA effects. The top desirable parent ICC 5434 (4.938 %).

SCA effects ranged from -8.895 (ICC 5434 X PDG 4) to 6.876 percent (ICC 5434 X KPG 59) with standard error 2.3243. Among 21 crosses, 2 crosses showed negatively significant. Where, 2 crosses showed positively significant. Top desirable significant crosses were ICC 5434 X KPG 59 (6.876 %) and BG 212 X KPG 59 (5.310 %).

4.7.2.21. Flower drop (%)

Ranged from -2.561 (IPC 06-77) to 1.578 per cent (KWR 108) with standard error of GCA effects (lines) 0.4366, (testers) 0.2858. 2 parents showed negatively significant, and 4 parents showed positively significant for GCA effects. The top desirable parents were IPC 06-77 (-2.561%) and PDG 4 (-2.307 %).

SCA effects ranged from -7.941 (KWR 108 X GNG 469) to 5.997 percent (KWR 108 X PDG 4) with standard error 0.7562. Among 21 crosses, 7 crosses showed negatively significant. Where, 9 crosses showed positively significant. The top three desirable significant crosses were KWR 108 X GNG 469 (-7.941 %), SADABAHAR X KPG 59 (-6.584 %) and ICC 5335 X KPG 59 (-5.674 %).

4.7.2.22. Seed yield plant^{-1}

Ranged from -0.882 (IPC 07-56) to 0.856 per cent (IPC 06-77) with standard error of GCA effects (lines) 0.2406, (testers) 0.1575. 3 parents showed negatively significant, and 3 parents showed positively significant for GCA effects. The top three desirable parents were IPC 06-77 (0.856 %), ICC 5335 (0.618 %) and PDG 4 (0.370 %).

SCA effects ranged from -3.714 (SADABAHAR X PDG 4) to 2.488 percent (BG 212 X KPG 59) with standard error 0.4168. Among 21 crosses, 7 crosses showed negatively significant. Where, 8 crosses showed positively significant. The top three desirable significant crosses were BG 212 X KPG 59 (2.488 %), IPC 07-56 X PDG 4 (2.058 %) and SADABAHAR X KPG 59 (2.011%).

4.8 ESTIMATION OF GENE ACTION

Table 4.37 provides estimates of the variances regarding GCA and SCA (σ^2 gca and σ^2 sca), correspondingly, alongside the gene action. The variance resulting from GCA is smaller compared to that of SCA, as demonstrated by the following table, therefore the GCA-SCA variance ratio is expected to be below one. As a result, each trait within study proved non-additive form of gene action.

Many genes regulate the yield trait, which manifests itself in a complicated way. Breeders need to comprehend how genes function in order to choose the best breeding strategies and eventually increase the productivity of the crop and traits that contribute to yield. There are three kinds of gene actions that influence trait expression: additive, dominance, and epistasis. Improvement of crops and selection techniques are advised when additive gene action is controlling. Conversely, allelic & non-allelic interactions between genes are linked to dominance & epistasis gene effects. Creating composite varieties or taking advantage of heterosis can be helpful in certain circumstances. Therefore, while choosing suitable breeding techniques, breeders can benefit much from the understanding of gene action.

4.37: Contributions of lines, testers & Line X Tester for gene action

Trait	Line %	Tester %	Line x Tester %	Var GCA	Var SCA	Gene action
First blossoming days	19.50	12.24	68.25	2.13	13.12	**Non-Additive**
50% blossoming days	23.64	17.70	58.65	3.43	12.98	**Non-Additive**
Harvest maturity days	21.72	13.43	64.84	4.57	23.96	**Non-Additive**
Plant height	18.91	4.61	76.46	0.55	8.47	**Non-Additive**
Primary offshoots plant^{-1}	30.51	6.55	62.93	0.017	0.119	**Non-Additive**
Secondary offshoots plant^{-1}	37.99	3.57	58.42	0.049	0.318	**Non-Additive**
Capsules plant^{-1}	30.02	12.62	57.35	2.74	11.07	**Non-Additive**
Full capsules plant^{-1}	28.90	15.39	55.69	2.40	7.75	**Non-Additive**
Empty capsules plant^{-1}	60.42	0.18	39.39	0.15	0.41	**Non-Additive**
Seeds capsule^{-1}	19.17	8.52	72.30	0.003	0.038	**Non-Additive**
Test weight (gm)	7.81	0.82	91.35	0.098	4.84	**Non-Additive**
Biological yield plant^{-1}	5.90	1.77	92.32	0.34	19.14	**Non-Additive**
Harvest index (%)	36.75	4.70	58.53	0.84	5.11	**Non-Additive**
Total chlorophyll content (mg/ml)	29.9	6.14	63.95	0.056	0.38	**Non-Additive**
Relative leaf water content (%)	32.87	0.33	66.78	4.42	46.01	**Non-Additive**
Lipid Peroxidation (nmol/ml)	10.32	16.5	73.16	0.50	3.13	**Non-Additive**
Electrolyte leakage index (%)	26.00	4.87	69.12	5.00	42.96	**Non-Additive**
Proline content (mg/gm)	34.47	7.01	58.51	0.019	0.103	**Non-Additive**
Ascorbic acid content (mg)	19.62	8.97	71.4	2.42	19.53	**Non-Additive**
Pollen viability (%)	34.12	1.23	64.63	2.10	21.78	**Non-Additive**
Flower drop (%)	8.23	14.68	77.07	3.26	24.29	**Non-Additive**
Seed yield plant^{-1}	10.02	3.20	86.76	0.21	5.36	**Non-Additive**

V. DISCUSSION

Genetic improvement in any crop species is an unavoidable and ongoing process in order to face future problems. The strengths of available germplasm must be examined in order to discover possible genotypes that may be utilized for evolving acceptable varieties to fulfil future demands, which ultimately leads to the country's food and nutritional security. The success in any breeding program is heavily dependent on understanding the genetic diversity inherent in a given crop species for the traits under development. Yield is a complex property that is dependent on a number of quantitatively inherited component traits. As a result, before beginning any breeding effort, it is critical to have a complete understanding of the variability present in the available genetic material as well as the level of correlation existing between yield and yield components. The diversity of parents is critical for a successful hybridization program (Murthy and Arunachalam, 1966), because crosses between parents with the greatest genetic divergence are likely to produce favorable recombinants in the progenies. However, selecting the most suitable and genetically divergent parents is a challenging task for the plant breeder unless he is given the essential knowledge on the genetic variability existing in the available germplasm.

In order to assess genetic variability, correlation, and path analysis, as well as to examine the relationships between component characters and calculate the direct and indirect effects of those characteristics on seed yield, twenty-five chickpea germplasms from IIPR, KANPUR, and check were examined. Under the following subheadings, the main conclusions of the current study are examined in this chapter in relation to the findings of previous studies.:

5.1 Parameters of genetic variability

- 5.1.1 Genetic variability
- 5.1.2 Phenotypic and genotypic coefficient of variation
- 5.1.3 Heritability and genetic advance

5.2 Correlation coefficient analysis

5.3 Path coefficient analysis

5.4 Stability analysis by Eberhart and Russell’s (1966) model

5.5 Parameters of genetic variability

- 5.5.1 Analysis of variance

5.5.2 Per se performance of parents and their crosses

5.5 Estimation of heterosis and heterobeltiosis

5.6 Combining ability analysis

5.1 PARAMETERS OF GENETIC VARIABILITY

5.1.1 Genetic variability

For twenty-two characteristics among 25 genotypes, the estimate of genetic variability was observed. The ANOVA results showed MSS owning to genotypes recorded significant for every trait studied in all of the environmental conditions. Characters harvest index (%), Total chlorophyll content (mg/ml), electrolyte leakage index, Ascorbic acid content (mg), and Flower drop (%) were all non-significant in the pooled environment. In EN-2, the empty capsules plant^{-1} was found significant for replication.

Significant variability was discovered for all variables in all conditions, indicating that the genotypes had a sufficient level of exploitable genetic variation that could be used further for breeding pre-breeding lines, or suitable cultivars. Similar findings were reported by Rajesh *et al* 2023, Khade *et al* 2022, Shikha *et al* 2022 and Viswanath *et al* 2022.

1.1.3 Phenotypic and genotypic coefficient of variation

The phenotypic and genotypic coefficients of variation for each of the 22 characters were calculated. As a result, by estimating phenotypic and genotypic coefficients of variation (PCV and GCV), these parameters were made unit free. GCV is preferred for comparing the variability of different traits since it reveals the heritable genetic component of total variance.

In the current study, the phenotypic coefficient of variation was higher compared to the genotypic coefficient of variation for all traits in every environment. In each investigation, the trait, seed yield plant^{-1}, had a high magnitude of both coefficients. Trait proline in EN-1, EN-2, EN-3, Total chlorophyll content (mg/ml) in EN-2 and EN-3, Relative leaf water content (%), seeds capsule^{-1}, empty capsules plant^{-1} in EN-1, Electrolyte leakage index (%) in EN-2, plant height in EN-3, and biological yield in pooled analysis all had high magnitudes for both coefficients.

The moderate magnitudes for both the coefficients were expressed by Lipid Peroxidation (nmol/ml) in each analysis whereas, for Flower drop (%), full capsules plant^{-1}, test weight (gm), and harvest index (%) in EN-1, EN-2 and EN-3, for plant height in EN-1, EN-2 and pooled analysis, for biological yield and Electrolyte leakage index (%)in EN-1 and EN-3, Relative leaf water content (%) and seeds capsule^{-1} in EN-2 and EN-3, empty capsules plant^{-1} in EN-3 and pooled, for primary offshoots plant^{-1}, secondary offshoots plant^{-1}, Total chlorophyll content (mg/ml) in EN-1, Ascorbic acid content (mg) in EN-3 and capsules plant^{-1} in pooled analysis.

A large GCV shows there is enough genetic variation in the population and that environmental factors have very little impact on trait expression. For all traits, phenotypic coefficient of variation estimates was greater than that of genotypic estimations. This is because error variance occurs in the phenotypic coefficient of variance.

5.1.3 Heritability and Genetic advance

It has been shown that taking heritability and genetic advancement into account at the same time is very helpful in predicting genetic gain and successful selection for the improvement of relevant traits. It is not necessary, nevertheless, for a character with high heritability to also have significant genetic advancement.

Selection may be successful in this case if high or moderate heritability is combined with either low genetic advance or high genetic advance. Conversely, low genetic advance or high heritability combined with the other suggests non-additive gene action in the inheritance of associated characters.

To draw inferences regarding these characteristics, the estimates of heritability have been largely classed into low (0-30%), medium (30%-60%), and high (> 60%), while estimates of genetic advance have been broadly categorised into (0-10%), medium (20-30%), and high (> 30%).

Plant height, full capsules plant^{-1}, Lipid Peroxidation (nmol/ml), proline, and seed yield plant^{-1} had high coupled heritability and genetic advance in EN-1, EN-2, EN-3 and pooled analysis, wherein, for test weight (gm), harvest index (%), Total chlorophyll content (mg/ml), Relative leaf water content (%), Electrolyte leakage index (%)and Flower drop (%)in EN-1, EN-2 and EN-3, empty capsules plant^{-1} in EN-1, EN-2 and pooled, seeds capsule^{-1} in EN-1 and EN-3, biological yield plant^{-1} in EN-1 and pooled, number of primary and secondary branches plant^{-1} in EN-1, Ascorbic acid content (mg) in EN-3 and capsules plant^{-1} in pooled.

Pollen viability (%)in EN-1, EN-2, EN-3, and pooled showed high heritability with moderate genetic advancement, capsules plant^{-1} in EN-1, EN-2 and EN-3, primary offshoots plant^{-1} in EN-2, EN-3 and pooled, secondary offshoots plant-1 and seeds capsule^{-1} in EN-2 and pooled, Ascorbic acid content (mg) in EN-1, empty capsules plant^{-1} and biological yield plant^{-1} in EN-2, harvest maturity days, test weight (gm), Total chlorophyll content (mg/ml) and Relative leaf water content (%) in the pooled analysis.

Table 5.1 Characters exhibiting varying degrees of heritability and genetic advancement

Character	High heritability + high genetic advance as % to mean			
	EN-1	EN-2	EN-3	Pooled
Plant height	✓	✓	✓	✓
primary offshoots plant^{-1}	✓			
Secondary offshoots plant^{-1}	✓			
Capsules plant^{-1}				✓
Full capsules plant^{-1}	✓	✓	✓	✓
Empty capsules plant^{-1}	✓		✓	✓
Seeds capsule^{-1}	✓		✓	
Test weight (gm)	✓	✓	✓	
Biological yield plant^{-1}	✓		✓	✓
Harvest index (%)	✓	✓	✓	
Total chlorophyll content (mg/ml)	✓	✓	✓	
Relative leaf water content (%)	✓	✓	✓	
Lipid Peroxidation (nmol/ml)	✓	✓	✓	✓
Electrolyte leakage index (%)	✓	✓	✓	
Proline content (mg/gm)	✓	✓	✓	✓
Ascorbic acid content (mg)			✓	
Flower drop (%)	✓	✓	✓	
Seed yield plant^{-1}	✓	✓	✓	✓
	High heritability +moderate genetic advance as % to mean			
Harvest maturity days				✓
Primary offshoots plant^{-1}		✓	✓	✓
Secondary offshoots plant^{-1}		✓		✓
Capsules plant^{-1}	✓	✓	✓	
Empty capsules plant^{-1}		✓		
Number of seeds per pod^{-1}		✓		✓
Test weight (gm)				✓
Biological yield plant^{-1}		✓		
Total chlorophyll content (mg/ml)				✓
Relative leaf water content (%)				✓
Ascorbic acid content (mg)	✓			
Pollen viability (%)	✓	✓	✓	✓

Table 5.2: Selection of better genotype based on mean values for all traits [EN-1, EN-2, EN-3].

Sl.no.	Character	Genotype		
		EN-1	EN-2	EN-3
1.	**First blossoming days**	ICC-5335	KWR-108	KWR-108
2.	**50% blossoming days**	PBG-5	KWR-108	KWR-108
3.	**Harvest maturity days**	BG-212	KWR-108	KWR-108
4.	**Plant height**	ICC-5434	ICC-5335	IPC-06-77
5.	**Primary offshoots plant^{-1}**	ICC-5434	IPC-07-56	KWR-108, GNG 469
6.	**Secondary offshoots plant^{-1}**	IPC-06-77	IPC-07-56	GNG 469
7.	**Capsules plant^{-1}**	SADABAHAR	GNG 469	IPC-07-56
8.	**Full capsules plant^{-1}**	SADABAHAR	GNG 469	BG-212
9.	**Empty capsules plant^{-1}**	ICC-5335	ICC-5335	BG-212
10.	**Seeds capsule^{-1}**	PBG-5, KPG-59	IPC-06-77	IPC-07-56
11.	**Test weight (gm)**	GNG 469	GNG 469	PUSA 3043
12.	**Biological yield plant^{-1}**	BG-212	BG-212	ICC-5335
13.	**Harvest index (%)**	BG-212	ICC-5335	ICC-5335
14.	**Total chlorophyll content (mg/ml)**	KPG-59	IPC-06-77	GNG 469
15.	**Relative leaf water content (%)**	ICC-5434	KWR-108	ICC-5434
16.	**Lipid Peroxidation (nmol/ml)**	GNG 469	GNG 469	KPG-59
17.	**Electrolyte leakage index (%)**	KPG-59	GNG 469	GNG 469
18.	**Proline content (mg/gm)**	PDG-4	GNG 469	PDG-4
19.	**Ascorbic acid content (mg)**	ICC-3525	IPC-07-56	PDG-4
20.	**Pollen viability (%)**	ICC-5434	IPC-06-77	IPC-06-77, BG 212
21.	**Flower drop (%)**	GNG 469	GNG 469	PDG-4
22.	**Seed yield plant^{-1}**	BG-212	BG-212	ICC-5335

Table 5.3: Characteristics summary exhibiting phenotypic and genotypic coefficients of variation [EN-1]

Sl.no.	Character	PCV	GCV	Similar results were found by
1.	First blossoming days	Low	Low	Sanjeev *et al* 2023, Vikram *et al* 2022, Nikhitha *et al* 2022
2.	50% blossoming days	Low	Low	Rajesh *et al* 2023, Kishore *et al* 2023, Pravallika *et al* 2022, Harish *et al* 2022
3.	Harvest maturity days	Low	Low	Nimita *et al* 2022, Rajesh *et al* 2023, Suman *et al* 2023, Sanjeev *et al* 2023
4.	Plant height	Moderate	Moderate	Rajesh *et al* 2023, Viswanatha *et al* 2022, Shikha *et al* 2022, Kumar *et al* 2021
5.	Primary offshoots plant^{-1}	Moderate	Moderate	Rajesh *et al* 2023, Kishore *et al* 2023, Meena *et al* 2021
6.	Secondary offshoots plant^{-1}	Moderate	Moderate	Rajesh *et al* 2023, Khade *et al* 2022, Manasa *et al* 2020, Kumar et al*.,* 2019
7.	Capsules plant^{-1}	Low	Low	-
8.	Full capsules plant^{-1}	Moderate	Moderate	-
9.	Empty capsules plant^{-1}	High	High	Shivangi *et al* 2023, Dhopre *et al* 2022, Tahir and Mirghani, 2016
10.	Seeds capsule^{-1}	High	High	Pravallika et al*.,* 2022, Gautam *et al* 2021, Tsehaye *et al* 2020
11.	Test weight (gm)	Moderate	Moderate	Viswanath *et al* 2022, Hailu *et al* 2020, Anusha *et al* 2020
12.	Biological yield plant^{-1}	Moderate	Moderate	Bharathi *et al* 2022, Mukesh *et al* 2016
13.	Harvest index (%)	Moderate	Moderate	Rajesh *et al* 2023, Shikha *et al* 2022, Viswanath *et al* 2022
14.	Total chlorophyll content (mg/ml)	Moderate	Moderate	Kumar *et al* 2021
15.	Relative leaf water content (%)	High	High	-
16.	Lipid Peroxidation (nmol/ml)	Moderate	Moderate	-
17.	Electrolyte leakage index (%)	Moderate	Moderate	-
18.	Proline content (mg/gm)	High	High	Zahedi *et al* 2016, Lamara *et al* 2022, Singh *et al* 2014
19.	Ascorbic acid content (mg)	Low	Low	-
20.	Pollen viability (%)	Low	Low	Kushwah *et al* 2021, Vijayakumar *et al* 2019
21.	Flower drop (%)	Moderate	Moderate	-
22.	Seed yield plant^{-1}	High	High	Rajesh *et al* 2023, Khade *et al* 2022, Bharathi *et al* 2022, Gulwane *et al* 2022

Table 5.4: Characteristics summary exhibiting phenotypic and genotypic coefficients of variation [EN-2]

Sl.no.	Character	PCV	GCV	Similar results were found by
1.	First blossoming days	Low	Low	Sanjeev *et al* 2023, Vikram *et al* 2022, Nikhitha *et al* 2022
2.	50% blossoming days	Low	Low	Rajesh *et al* 2023, Kishore *et al* 2023, Pravallika *et al* 2022, Harish *et al* 2022
3.	Harvest maturity days	Low	Low	Nimita *et al* 2022, Rajesh *et al* 2023, Suman *et al* 2023, Sanjeev *et al* 2023
4.	Plant height	Moderate	Moderate	Rajesh *et al* 2023, Viswanatha *et al* 2022, Shikha *et al* 2022, Kumar *et al* 2021
5.	Primary offshoots plant^{-1}	Moderate	Low	Shikha *et al* 2022, Khade *et al* 2022
6.	Secondary offshoots plant^{-1}	Low	Low	-
7.	Capsules plant^{-1}	Low	Low	-
8.	Full capsules plant^{-1}	Moderate	Moderate	Shivangi *et al* 2023, Shivangi *et al* 2023
9.	Empty capsules plant^{-1}	Low	Low	-
10.	Seeds capsule^{-1}	Moderate	Moderate	Rajesh *et al* 2023, Kishore *et al* 2023, Shikha *et al* 2022
11.	Test weight (gm)	Moderate	Moderate	Viswanath *et al* 2022, Hailu *et al* 2020, Anusha *et al* 2020
12.	Biological yield plant^{-1}	Moderate	Low	Pravalik *et al* 2022
13.	Harvest index (%)	Moderate	Moderate	Rajesh *et al* 2023, Shikha *et al* 2022, Viswanath *et al* 2022
14.	Total chlorophyll content (mg/ml)	High	High	Chandrakala *et al* 2023, Semba and Rao, 2022
15.	Relative leaf water content (%)	Moderate	Moderate	Kushwah *et al* 2021, Ilakiya *et al* 2022
16.	Lipid Peroxidation (nmol/ml)	Moderate	Moderate	-
17.	Electrolyte leakage index (%)	High	High	-
18.	Proline content (mg/gm)	High	High	Zahedi *et al* 2016, Lamara *et al* 2022, Singh *et al* 2014
19.	Ascorbic acid content (mg)	Low	Low	-
20.	Pollen viability (%)	Low	Low	Kushwah *et al* 2021, Vijayakumar *et al* 2019
21.	Flower drop (%)	Moderate	Moderate	-
22.	Seed yield plant^{-1}	High	High	Rajesh *et al* 2023, Khade *et al* 2022, Bharathi *et al* 2022, Gulwane *et al* 2022

Table 5.5: Characteristics summary exhibiting phenotypic and genotypic coefficients of variation [EN-3]

Sl.no.	Character	PCV	GCV	Similar results were found by
1.	First blossoming days	Low	Low	Sanjeev *et al* 2023, Vikram *et al* 2022, Nikhitha *et al* 2022
2.	50% blossoming days	Low	Low	Rajesh *et al* 2023, Kishore *et al* 2023, Pravallika *et al* 2022, Harish *et al* 2022
3.	Harvest maturity days	Low	Low	Nimita *et al* 2022, Rajesh *et al* 2023, Suman *et al* 2023, Sanjeev *et al* 2023
4.	Plant height	High	High	Mohan *et al* 2019
5.	Primary offshoots plant^{-1}	Low	Low	Manasa *et al* 2020
6.	Secondary offshoots plant^{-1}	Low	Low	-
7.	Capsules plant^{-1}	Low	Low	-
8.	Full capsules plant^{-1}	Moderate	Moderate	Shivangi *et al* 2023, Shivangi *et al* 2023
9.	Empty capsules plant^{-1}	Moderate	Moderate	-
10.	Seeds capsule^{-1}	Moderate	Moderate	Rajesh *et al* 2023, Kishore *et al* 2023, Shikha *et al* 2022
11.	Test weight (gm)	Moderate	Moderate	Viswanath *et al* 2022, Hailu *et al* 2020, Anusha *et al* 2020
12.	Biological yield plant^{-1}	Moderate	Moderate	Bharathi *et al* 2022, Mukesh *et al* 2016
13.	Harvest index (%)	Moderate	Moderate	Rajesh *et al* 2023, Shikha *et al* 2022, Viswanath *et al* 2022
14.	Total chlorophyll content (mg/ml)	High	High	Chandrakala *et al* 2023, Semba and Rao, 2022
15.	Relative leaf water content (%)	Moderate	Moderate	Kushwah *et al* 2021, Ilakiya *et al* 2022
16.	Lipid Peroxidation (nmol/ml)	Moderate	Moderate	-
17.	Electrolyte leakage index (%)	Moderate	Moderate	-
18.	Proline content (mg/gm)	High	High	Zahedi *et al* 2016, Lamara *et al* 2022, Singh *et al* 2014
19.	Ascorbic acid content (mg)	Moderate	Moderate	Chandrakala *et al* 2023, Chacko *et al* 2023, Semba and Rao, 2022
20.	Pollen viability (%)	Low	Low	Kushwah *et al* 2021, Vijayakumar *et al* 2019
21.	Flower drop (%)	Moderate	Moderate	-
22.	Seed yield plant^{-1}	High	High	Rajesh *et al* 2023, Khade *et al* 2022, Bharathi *et al* 2022, Gulwane *et al* 2022

Table 5.6: Characteristics summary exhibiting phenotypic and genotypic coefficients of variation [Pooled]

Sl.no.	Character	PCV	GCV	Similar results were found by
1.	First blossoming days	Low	Low	Sanjeev *et al* 2023, Vikram *et al* 2022, Nikhitha *et al* 2022
2.	50% blossoming days	Low	Low	Rajesh *et al* 2023, Kishore *et al* 2023, Pravallika *et al* 2022, Harish *et al* 2022
3.	Harvest maturity days	Low	Low	Nimita *et al* 2022, Rajesh *et al* 2023, Suman *et al* 2023, Sanjeev *et al* 2023
4.	Plant height	Moderate	Moderate	Rajesh *et al* 2023, Viswanatha *et al* 2022, Shikha *et al* 2022, Kumar *et al* 2021
5.	Primary offshoots plant^{-1}	Low	Low	Manasa *et al* 2020
6.	Secondary offshoots plant^{-1}	Low	Low	-
7.	Capsules plant^{-1}	Moderate	Moderate	Kishore *et al* 2023, Meena *et al* 2021
8.	Full capsules plant^{-1}	High	High	Kathikeyan *et al* 2022, Swathi and Lal, 2021, Sanjay *et al* 2019
9.	Empty capsules plant^{-1}	Moderate	Moderate	-
10.	Seeds capsule^{-1}	Moderate	Low	Khade *et al* 2022
11.	Test weight (gm)	Low	Low	-
12.	Biological yield plant^{-1}	High	High	Viswanath *et al* 2022, Singh *et al* 2021, Kumar *et al* 2021
13.	Harvest index (%)	Low	Low	-
14.	Total chlorophyll content (mg/ml)	Moderate	Low	-
15.	Relative leaf water content (%)	Moderate	Low	-
16.	Lipid Peroxidation (nmol/ml)	Moderate	Moderate	-
17.	Electrolyte leakage index (%)	Low	Low	-
18.	Proline content (mg/gm)	High	Moderate	Singh *et al* 2014
19.	Ascorbic acid content (mg)	Low	Low	-
20.	Pollen viability (%)	Low	Low	Kushwah *et al* 2021, Vijayakumar *et al* 2019
21.	Flower drop (%)	Low	Low	-
22.	Seed yield plant^{-1}	High	High	Rajesh *et al* 2023, Khade *et al* 2022, Bharathi *et al* 2022, Gulwane *et al* 2022

Table 5.7: Characteristics summary expressing heritability and genetic advance combinations [EN-1]

Sl.no.	Character	H(bs)	GA	Similar results were found by
1.	First blossoming days	High	LOW	Sanjeev *et al* 2023, Nikhitha *et al* 2022, Vijayakumar *et al* 2019
2.	50% blossoming days	High	LOW	Rajesh *et al* 2023, Kishore *et al* 2023, Gautam *et al* 2021
3.	Harvest maturity days	High	LOW	Nikhitha *et al* 2022, Sanjay *et al* 2019
4.	Plant height	High	High	Rajesh *et al* 2023, Viswanatha *et al* 2022, Shikha *et al* 2022
5.	Primary offshoots plant^{-1}	High	High	Rajesh *et al* 2023, Kishore *et al* 2023
6.	Secondary offshoots plant^{-1}	High	High	Rajesh *et al* 2023, Khade *et al* 2022, Mohan *et al* 2019
7.	Capsules plant^{-1}	High	Moderate	Gautam *et al* 2021, Kumar *et al* 2020
8.	Full capsules plant^{-1}	High	High	Shivangi *et al* 2023, Kathikeyan *et al* 2022
9.	Empty capsules plant^{-1}	High	High	Shivangi *et al* 2023, Dhopre *et al* 2022
10.	Seeds capsule^{-1}	High	High	Kishore *et al* 2023, Pravallika *et al* 2022
11.	Test weight (gm)	High	High	Gulwane *et al* 2022, Karthikeyan *et al* 2022, Xalxo *et al* 2021
12.	Biological yield plant^{-1}	High	High	Meena *et al* 2021, Singh *et al* 2021, Kumar *et al* 2021
13.	Harvest index (%)	High	High	Rajesh *et al* 2023, Viswanath *et al* 2022, Shikha *et al* 2022
14.	Total chlorophyll content (mg/ml)	High	High	Chandrakala *et al* 2023, Semba and Rao, 2022, Kumar *et al* 2021
15.	Relative leaf water content (%)	High	High	Kushwah *et al* 2021, Ilakiya *et al* 2022
16.	Lipid Peroxidation (nmol/ml)	High	High	Ilakiya *et al* 2022
17.	Electrolyte leakage index (%)	High	High	-
18.	Proline content (mg/gm)	High	High	Ilakiya *et al* 2022, Singh *et al* 2014, Jitender *et al* 2014
19.	Ascorbic acid content (mg)	High	Moderate	-
20.	Pollen viability (%)	High	Moderate	Kushwah *et al* 2021, Vijayakumar *et al* 2019
21.	Flower drop (%)	High	High	-
22.	Seed yield plant^{-1}	High	High	Rajesh *et al* 2023, Khade *et al* 2022, Bharathi *et al* 2022, Gulwane *et al* 2022

Table 5.8: Characteristics summary expressing heritability and genetic advance combinations [EN-2]

Sl.no.	Character	H(bs)	GA	Similar results were found by
1.	First blossoming days	High	LOW	Sanjeev *et al* 2023, Nikhitha *et al* 2022, Vijayakumar *et al* 2019
2.	50% blossoming days	High	LOW	Rajesh *et al* 2023, Kishore *et al* 2023, Gautam *et al* 2021
3.	Harvest maturity days	High	LOW	Nikhitha *et al* 2022, Sanjay *et al* 2019
4.	Plant height	High	High	Rajesh *et al* 2023, Viswanatha *et al* 2022, Shikha *et al* 2022
5.	Primary offshoots plant^{-1}	High	Moderate	Khade *et al* 2022, Shikha *et al* 2022
6.	Secondary offshoots plant^{-1}	High	Moderate	-
7.	Capsules plant^{-1}	High	Moderate	Gautam *et al* 2021, Kumar *et al* 2020
8.	Full capsules plant^{-1}	High	High	Shivangi *et al* 2023, Shivangi *et al* 2023, Kathikeyan *et al* 2022
9.	Empty capsules plant^{-1}	High	Moderate	Tahir and Mirghani, 2016
10.	Seeds capsule^{-1}	High	Moderate	Kumar *et al* 2020
11.	Test weight (gm)	High	High	Gulwane *et al* 2022, Karthikeyan *et al* 2022, Xalxo *et al* 2021
12.	Biological yield plant^{-1}	High	Moderate	Meena *et al* 2021, Gautam *et al* 2021
13.	Harvest index (%)	High	High	Rajesh *et al* 2023, Viswanath *et al* 2022, Shikha *et al* 2022
14.	Total chlorophyll content (mg/ml)	High	High	Chandrakala *et al* 2023, Semba and Rao, 2022, Kumar *et al* 2021
15.	Relative leaf water content (%)	High	High	Kushwah *et al* 2021, Ilakiya *et al* 2022
16.	Lipid Peroxidation (nmol/ml)	High	High	Ilakiya *et al* 2022
17.	Electrolyte leakage index (%)	High	High	-
18.	Proline content (mg/gm)	High	High	Ilakiya *et al* 2022, Singh *et al* 2014, Jitender *et al* 2014
19.	Ascorbic acid content (mg)	High	LOW	-
20.	Pollen viability (%)	High	Moderate	Kushwah *et al* 2021, Vijayakumar *et al* 2019
21.	Flower drop (%)	High	High	-
22.	Seed yield plant^{-1}	High	High	Rajesh *et al* 2023, Khade *et al* 2022, Bharathi *et al* 2022, Gulwane *et al* 2022

Table 5.9: Characteristics summary expressing heritability and genetic advance combinations [EN-3]

Sl.no.	Character	H(bs)	GA	Similar results were found by
1.	First blossoming days	High	LOW	Sanjeev *et al* 2023, Nikhitha *et al* 2022, Vijayakumar *et al* 2019
2.	50% blossoming days	High	LOW	Rajesh *et al* 2023, Kishore *et al* 2023, Gautam *et al* 2021
3.	Harvest maturity days	High	LOW	Nikhitha *et al* 2022, Sanjay *et al* 2019
4.	Plant height	High	High	Rajesh *et al* 2023, Viswanatha *et al* 2022, Shikha *et al* 2022
5.	Primary offshoots plant^{-1}	High	Moderate	Khade *et al* 2022, Shikha *et al* 2022
6.	Secondary offshoots plant^{-1}	High	LOW	Gautam *et al* 2021, Tsehaye *et al* 2020, Kumar *et al* 2019
7.	Capsules plant^{-1}	High	Moderate	Gautam *et al* 2021, Kumar *et al* 2020
8.	Full capsules plant^{-1}	High	High	Shivangi *et al* 2023, Shivangi *et al* 2023, Kathikeyan *et al* 2022
9.	Empty capsules plant^{-1}	High	High	Shivangi *et al* 2023, Dhopre *et al* 2022
10.	Seeds capsule^{-1}	High	High	Kishore *et al* 2023, Pravallika et al., 2022
11.	Test weight (gm)	High	High	Gulwane *et al* 2022, Karthikeyan *et al* 2022, Xalxo *et al* 2021
12.	Biological yield plant^{-1}	High	High	Viswanath *et al* 2022, Singh *et al* 2021, Kumar *et al* 2021
13.	Harvest index (%)	High	High	Rajesh *et al* 2023, Viswanath *et al* 2022, Shikha *et al* 2022
14.	Total chlorophyll content (mg/ml)	High	High	Chandrakala *et al* 2023, Semba and Rao, 2022, Kumar *et al* 2021
15.	Relative leaf water content (%)	High	High	Kushwah *et al* 2021, Ilakiya *et al* 2022
16.	Lipid Peroxidation (nmol/ml)	High	High	Ilakiya *et al* 2022
17.	Electrolyte leakage index (%)	High	High	-
18.	Proline content (mg/gm)	High	High	Ilakiya *et al* 2022, Singh *et al* 2014, Jitender *et al* 2014
19.	Ascorbic acid content (mg)	High	High	Chandrakala *et al* 2023, Chacko *et al* 2023, Ilakiya *et al* 2022
20.	Pollen viability (%)	High	Moderate	Kushwah *et al* 2021, Vijayakumar *et al* 2019
21.	Flower drop (%)	High	High	-
22.	Seed yield plant^{-1}	High	High	Rajesh *et al* 2023, Khade *et al* 2022, Bharathi *et al* 2022, Gulwane *et al* 2022

Table 5.10: Characteristics summary expressing heritability and genetic advance combinations [Pooled]

Sl.no.	Character	H(bs)	GA	Similar results were found by
1.	First blossoming days	High	LOW	Sanjeev *et al* 2023, Nikhitha *et al* 2022, Vijayakumar *et al* 2019
2.	50% blossoming days	High	LOW	Rajesh *et al* 2023, Kishore *et al* 2023, Gautam *et al* 2021
3.	Harvest maturity days	High	Moderate	Nikhitha *et al* 2022, Sanjay *et al* 2019
4.	Plant height	High	High	Rajesh *et al* 2023, Viswanatha *et al* 2022, Shikha *et al* 2022
5.	Primary offshoots plant^{-1}	High	Moderate	Khade *et al* 2022, Shikha *et al* 2022
6.	Secondary offshoots plant^{-1}	High	Moderate	-
7.	Capsules plant^{-1}	High	High	Rajesh *et al* 2023, Kishore *et al* 2023, Shikha *et al* 2022
8.	Full capsules plant^{-1}	High	High	Shivangi *et al* 2023, Shivangi *et al* 2023, Kathikeyan *et al* 2022
9.	Empty capsules plant^{-1}	High	High	Shivangi *et al* 2023, Dhopre *et al* 2022
10.	Seeds capsule^{-1}	High	Moderate	Kumar *et al* 2020
11.	Test weight (gm)	High	Moderate	Tak & Meena, 2021, Sanjay *et al* 2019
12.	Biological yield plant^{-1}	High	High	Viswanath *et al* 2022, Singh *et al* 2021, Kumar *et al* 2021
13.	Harvest index (%)	LOW	LOW	Tsehaye *et al* 2020
14.	Total chlorophyll content (mg/ml)	Moderate	Moderate	-
15.	Relative leaf water content (%)	High	Moderate	Meena *et al* 2014
16.	Lipid Peroxidation (nmol/ml)	High	High	Ilakiya *et al* 2022
17.	Electrolyte leakage index (%)	LOW	LOW	-
18.	Proline content (mg/gm)	High	High	Ilakiya *et al* 2022, Singh *et al* 2014, Jitender *et al* 2014
19.	Ascorbic acid content (mg)	LOW	LOW	-
20.	Pollen viability (%)	High	Moderate	Kushwah *et al* 2021, Vijayakumar *et al* 2019
21.	Flower drop (%)	Low	LOW	-
22.	Seed yield plant^{-1}	High	High	Rajesh *et al* 2023, Khade *et al* 2022, Bharathi *et al* 2022, Gulwane *et al* 2022

5.2 Correlation coefficient analysis

Correlation studies are crucial in identifying an association between any two or more characters. Linkage, pleiotropy, and heterozygosity primarily causes correlation between two characters. A positive connection between desirable traits is beneficial to plant breeders since it allows for the concurrent enhancement of both traits. Negative correlation, on the contrary will impede the concurrent display of both.

The genotypic expression of the characteristics under investigation was shown to be influenced by the environment, as indicated by the scales of genotypic correlation coefficients being generally greater than the equivalent phenotypic correlation coefficients. Plant breeders benefit when two desirable traits have a positive connection because it makes it possible to improve both traits at the same time. Conversely, it will be challenging to simultaneously represent both characters with high values if there is a negative association. In this study, correlation coefficients were computed for every possible feature pair, with a focus on seed yield and its constituent genotypic and phenotypic aspects.

Significant positive genotypic correlation of seed yield plant^{-1} was expressed by characters pollen viability, harvest index (%), biological yield plant^{-1}, primary offshoots plant^{-1}, Relative leaf water content (%) and capsules plant^{-1} in all analysis, secondary offshoots plant^{-1}, test weight (gm) and Total chlorophyll content (mg/ml) in EN-1, EN-2 and pooled, plant height in EN-2, EN-3 and pooled, seeds capsule^{-1} in EN-2 and pooled, proline in EN-2 and first blossoming days, 50% blossoming days and harvest maturity days in pooled analysis respectively While negative significant correlation with empty capsules plant^{-1} in all analysis, Flower drop (%)in EN-1, EN-2 and pooled, first blossoming days, harvest maturity days in EN-2 and EN-3, Lipid Peroxidation (nmol/ml) in EN-3 and pooled, 50% blossoming days in EN-2 and proline, Electrolyte leakage index (%) and Ascorbic acid content (mg) in pooled analysis respectively in the present findings.

Phenotypic positive significant correlation with seed yield plant^{-1} was expressed by the characters harvest index (%), pollen viability, biological yield plant^{-1}, full capsules plant^{-1}, capsules plant^{-1} and Relative leaf water content (%) in all analysis, primary offshoots plant^{-1} and test weight (gm) in EN-1, EN-2 and pooled, secondary offshoots plant^{-1} and Total chlorophyll content (mg/ml) in EN-1, EN-3 and pooled, plant height in EN-2, EN-3 and pooled, secondary offshoots plant^{-1} in EN-2 and pooled, proline in EN-2, first blossoming days, 50% blossoming days and harvest maturity days in pooled analysis respectively, whereas negative significant correlation with empty capsules plant^{-1} in all analysis, harvest maturity days and first blossoming days in EN-2 and EN-3, Flower drop (%)in EN-2 and pooled, Lipid Peroxidation (nmol/ml) in EN-3 and pooled, 50% blossoming days in EN-2 and proline in pooled analysis respectively.

Table 5.11: Overview of the genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients between chickpea seed yield and its components [EN-1]

characters	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	**1.000**	+*	+*	-	-	-	-*	-	+	-	-	+	-*	-	-	+	+	-*	+	-	+*	-
C2	+*	**1.000**	+*	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-*	-	-	+	-
C3	+*	+*	**1.000**	-*	-	-	-	-	-	-	-	-	-	-	-	+	+	-*	-	-	+	-
C4	-	-	-*	**1.000**	+*	+*	+*	+*	-*	+*	+	+	+*	+	+	+	-	+	+	+*	-*	+
C5	-	-	-	+*	**1.000**	+*	+*	+*	-	+*	+	+*	+*	+	+*	+	-	-	+	+*	-	+*
C6	-	-	-	+*	+*	**1.000**	+*	+*	-	+*	+*	+*	+*	+*	+*	+	-	+	+	+*	-*	+*
C7	-	-	-	+*	+*	+*	**1.000**	+*	-	+*	+	+	+*	+*	+*	-	-*	+*	+	+*	-*	+*
C8	-	-	-	+*	+*	+*	+*	**1.000**	-*	+*	+	+	+*	+*	+*	-	-*	+*	+	+*	-*	+*
C9	+	-	+	-*	-	-	-	-*	**1.000**	-	-	-*	-*	-	-	-	+	-	+	-	+	-*
C10	-	-	-	+*	+*	+*	+*	+*	-	**1.000**	-	+*	+	+	+	+	-	+	-	+	-	+
C11	-	-	-	+	+	+*	+	+	-	-	**1.000**	+*	+*	+*	+	-	-	+*	-	+	-*	+*
C12	+	+	-	+	+*	+*	+	+	-*	+	+*	**1.000**	+	+	+	+	-	+	-	+	-	+*
C13	-	-	-	+*	+*	+*	+*	+*	-*	+	+*	+	**1.000**	+*	+*	-	-	+	-	+*	-*	+*
C14	-	-	-	+	+	+	+*	+*	-	+	+*	+	+*	**1.000**	+*	-*	-*	+*	-	+	-*	+*
C15	-	-	-	+	+*	+*	+*	+*	-	+	+	+	+*	+*	**1.000**	-	-	+*	-	+*	-*	+*
C16	+	+	+	-	+	+	-	-	-	+	-	+	-	-*	-	**1.000**	+*	-*	-	+	+	+
C17	+	+	+	-	+	-	-*	-*	+	-	-	+	-	-*	-	+*	**1.000**	-*	-	+	+*	-
C18	-*	-*	-*	+	-	+	+*	+*	-	+	+*	-	+	*	+*	-*	-*	**1.000**	+	-	-*	+
C19	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	+	**1.000**	-	-	-
C20	-	-	-	+*	+*	+*	+	+*	-	+	+	+	+*	+	+	+	+	-	-	**1.000**	-	+*
C21	+*	+	+	-*	-	-*	-*	-*	+	-	-*	-	-*	-*	-*	+	+*	-*	-	-	**1.000**	-*
C22	-	-	-	+	+*	+*	+*	+*	-*	+	+*	+*	+*	+*	+*	+	-	+	-	+*	-*	**1.000**

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17-Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

Table 5.12: Overview of the genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients between chickpea seed yield and its components [EN-2]

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	**1.000**	+*	+*	-*	-*	-*	-*	-*	+	-*	-*	-*	-*	-*	-*	+	+	-*	+	-*	+*	-*
C2	+*	**1.000**	+*	-*	-*	-*	-*	-*	+	-*	-*	-*	-*	-*	-*	+	+	-*	+	-*	+*	-*
C3	+*	+*	**1.000**	-*	-*	-*	-*	-*	+	-*	-*	-*	-*	-*	-*	+	+	-*	-	-*	+*	-*
C4	-*	-*	-*	**1.000**	+*	+*	+*	+*	-	+*	+*	+*	+*	+*	+*	-	-	+*	-	+*	-*	+*
C5	-*	-*	-*	+*	**1.000**	+*	+*	+*	-	+*	+	+	+*	+*	+*	-	-*	+*	+*	+*	-*	+*
C6	-*	-*	-*	+*	+*	**1.000**	+*	+*	-	+*	+	+*	+*	+*	+*	+	-	+*	+*	+*	-	+*
C7	-*	-*	-*	+*	+*	+*	**1.000**	+*	-	+*	+*	+*	+*	+*	+*	-	-	+*	+	+*	-*	+*
C8	-*	-*	-*	+*	+*	+*	+*	**1.000**	-*	+*	+*	+*	+*	+*	+*	-	-*	=*	+	+*	-*	+*
C9	+	+	+	-	-	-	-	-*	**1.000**	-	-*	-*	-*	-	-*	+	+*	-	-	-*	*	-*
C10	-*	-*	-*	+*	+	*	+*	+*	-	**1.000**	+*	+*	+*	+*	+*	-	-	+*	+	+	-*	+*
C11	-*	-*	-*	+*	+	+	+*	*	-*	+	**1.000**	+*	+*	+*	+*	-	-*	+*	+	+	-*	+*
C12	-*	-*	-*	+*	+	+*	+*	+*	-	+	+*	**1.000**	+*	+*	+*	+	-	+*	+	+*	-	+*
C13	-*	-*	-*	+*	+*	+*	+*	+*	-*	+*	+*	+*	**1.000**	+*	+*	-	-	+*	+	+*	-*	+*
C14	-*	-*	-*	+*	+*	+*	+*	+*	-	+*	+*	+*	+*	**1.000**	+*	-	-*	+*	+	+*	-*	+*
C15	-*	-*	-*	+*	+*	+*	+*	+*	-*	+*	+*	+*	+*	+*	**1.000**	-	-*	+*	-	+*	-*	+*
C16	+	+	+	-	-	+	-	-	+	-	-	+	-	-	-	**1.000**	*	-*	+	-	+*	-
C17	+	+	+	-	-*	-	-*	-*	+	-	-*	-	-	-*	-*	+*	**1.000**	-*	-	-	+*	-
C18	-*	-*	-*	+*	+*	+*	+*	+*	-	+*	*	+*	+*	+*	+*	-*	-*	**1.000**	+	+	-*	+*
C19	-	+	-	-	+	+	+	+	-	+	+	+	+	+	-	+	-	+	**1.000**	-	+	+
C20	-*	-*	-*	+*	+	+*	+*	+*	-*	+	+	+*	+*	+*	+*	-	-	+	-	**1.000**	-	+*
C21	+*	*	+*	-*	-*	-	-*	-*	+*	-*	-*	-	-*	-*	-*	+*	+*	-*	+	-	**1.000**	-*
C22	-*	-*	-*	+*	+*	+*	+*	+*	-*	+*	+*	+*	+*	+*	+*	-	-	+*	+	+*	-*	**1.000**

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17- Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

Table 5.13: Overview of the genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients between chickpea seed yield and its components [EN-3]

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	**1.000**	+*	+*	-*	-	-	-*	-*	+	+	-	-	-*	-*	-*	+*	+*	-*	-	-*	+*	-*
C2	+*	**1.000**	+*	-	-	-	-*	-*	+	+	-*	-	-	-	-*	+*	+*	-*	-	-	+*	-
C3	+*	+*	**1.000**	-	-*	-*	-*	-*	+	+	-*	-	-*	-*	-*	+*	+*	-	-	-*	+*	-*
C4	-*	-	-	**1.000**	+	+	+*	+*	-*	+	+	+*	+*	+	+*	-*	-	+	+	+*	-	+*
C5	-	-	-*	+	**1.000**	+*	+*	+*	-	+	+	+	+*	+*	+*	-	-*	+*	+*	+*	-*	+*
C6	-	-	-*	+	+*	**1.000**	+*	+*	-	+	+	+	+	+	+*	-	-*	+*	+*	+*	-*	+
C7	-*	-*	-*	+*	+*	+*	**1.000**	+*	-	+*	+	+*	+*	-	+*	-	-	-	+	+*	-	+*
C8	-*	-*	-*	+*	+*	+*	+*	**1.000**	-*	+	+	+*	+*	+	+*	-*	-	+	+	+*	-	+*
C9	+	+	+	-*	-	-	-	-*	**1.000**	+	-	-*	-*	-*	-*	+*	+	-	-	-*	+	-*
C10	-	+	+	+	+	+	+	+	-	**1.000**	-	+*	+	-	+	+	+	-	-	+	+	+
C11	-	-*	-	+	+	+	+	+	-	-	**1.000**	+	+	+	+	-	-	+	+*	+	-	+
C12	-	-	-	+*	+	+	+*	+*	-*	+	+	**1.000**	+*	+	+	-	-	+	+	+*	+	+*
C13	-*	-	-*	+*	+*	+	+*	+*	-*	+	+	+*	**1.000**	+	+*	-*	-	+	+	+*	-	+*
C14	-	-	-	+	+	+	-	+	-*	-	+	+	+	**1.000**	+*	-*	-*	+*	+*	+	-*	+
C15	-*	-*	-*	+*	+*	+*	+*	+*	-*	+	+	+	+*	+*	**1.000**	-*	-*	+*	+*	+*	-*	+*
C16	+*	+*	+*	-*	-	-	-	-*	+*	+	-	-	-*	-*	-*	**1.000**	+*	-*	-*	-	+*	-*
C17	+*	+*	+	-	-	-*	-	-	+	+	-	-	-	-*	-*	+*	**1.000**	-*	-*	-	+*	-
C18	-*	-*	-	+	+	+	+	+	-	-	+	+	+	+*	+*	-*	-*	**1.000**	+*	+	-*	+
C19	-	-	-	+	+*	+*	+	+	-	-	+	+	+	+*	+*	-*	-*	+*	**1.000**	+	-*	+
C20	-+*	-*	-*	+*	+*	+*	+*	+*	-*	+	+	+*	+*	+	+*	-	-	+	+	**1.000**	-	+*
C21	+*	+*	+*	-	-*	-*	-	-	+	+	-	+	-	-*	-*	+*	+*	-*	-*	-	**1.000**	-
C22	-*	-	-*	+*	+	+	+*	+*	-*	+	+	+*	+*	+	+*	-*	-	+	+	+*	-	**1.000**

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17-Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

Table 5.13: Overview of the genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients between chickpea seed yield and its components [Pooled]

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	**1.000**	+*	+*	+*	+*	+*	+*	+*	-*	+*	+*	+*	+*	+	+*	-*	-*	-*	+	+*	-*	+*
C2	+*	**1.000**	+*	+*	+*	+*	+*	+*	-*	+*	+*	+*	+	+*	+*	-*	-*	-*	+	+*	-*	+*
C3	+*	+*	**1.000**	+*	+*	+*	+*	+*	-*	+*	+*	+*	+	+*	+*	-*	-*	-*	-	+*	-*	+*
C4	+*	+*	+*	**1.000**	+*	+*	+*	+*	-*	+*	+*	+*	-	+*	+*	-*	-*	-*	+	+*	-*	+*
C5	+*	+*	+*	+*	**1.000**	+*	+*	+*	-*	+*	+*	+*	+*	+*	+*	-*	-*	-*	-*	+*	-*	+*
C6	+*	+*	+*	+*	+*	**1.000**	+*	+*	-*	+*	+*	+*	+*	+*	+*	-*	-*	-*	-	+*	-*	+*
C7	+*	+*	+*	+*	+*	+*	**1.000**	+*	-*	+*	+*	+*	+	+	+*	-*	-*	-*	-	+*	-*	+*
C8	+*	+*	+*	+*	+*	+*	+*	**1.000**	-*	+*	+*	+*	+	+	+*	-*	-*	-*	-	+*	-*	+*
C9	-*	-*	-*	-*	-*	-*	-*	-*	**1.000**	-*	-*	-*	+	-*	-*	*	+*	+*	+	-*	+*	-*
C10	+*	+*	+*	+*	+*	+*	+*	+*	-*	**1.000**	+	+*	+*	+*	+*	-*	+	-	-	+*	-*	+*
C11	+*	+*	+*	+*	+*	+*	+*	*	-*	+	**1.000**	+*	-	+*	+*	-*	-*	-	-*	+*	-*	+*
C12	+*	+*	+*	+*	+*	+*	+*	+*	-*	+*	+*	**1.000**	+*	+*	+*	-*	-*	-*	-	+*	-*	+*
C13	-	-	-	+	+*	+*	+	+	-	+*	+	+	**1.000**	+	-*	+*	+*	-*	-*	+	+*	+*
C14	+	+	+	+*	+*	+*	+	+*	-*	+*	+*	+*	+*	**1.000**	+*	-	+*	-	-*	+	-	+*
C15	+*	+*	+*	+*	+*	+*	+*	+*	-*	+*	+*	+*	+*	+*	**1.000**	-*	+	-*	-*	+*	-*	+*
C16	-*	-*	-*	-*	-*	-*	-*	-*	+*	-*	-*	-*	+	-*	-*	**1.000**	+*	+*	-*	-*	+*	-*
C17	-*	-*	-*	-*	-*	-*	-*	-*	+	-	-*	-*	+*	-*	-*	*	**1.000**	+*	-*	-*	-*	-*
C18	-*	-*	-*	-*	-*	-*	-*	-*	+*	-	+	-*	+	+*	-	+*	+	**1.000**	+	-*	+*	-*
C19	-	+	-	+	-	-	-	-	+	-	+	-	-*	+	-	-	-*	+	**1.000**	-*	+*	-*
C20	+*	+*	+*	+*	+*	+*	+*	+*	-*	+*	+*	+*	+*	+	+*	-*	-	-*	-*	**1.000**	-*	+*
C21	-*	-*	-*	-*	-*	-*	-*	-*	+*	-*	-*	-*	-	-*	-*	+*	+*	+	+	-*	**1.000**	-*
C22	+*	+*	+*	+*	+*	+*	+*	+*	-*	+*	+*	+*	+*	+*	+*	-*	-	-*	-	+*	-*	**1.000**

C1-Days to fist flowering, C2-50% blossoming days, C3- Harvest maturity days, C4-Plant height, C5-Primary offshoots , C6-Secondary offshoots , C7- Capsules plant^{-1}, C8- Full capsules , C9- empty capsules, C10- seeds capsule^{-1}, C11- Test weight (gm), C12- Biological yield, C13- Harvest index (%), C14-Total chlorophyll content (mg/ml), C15- Relative leaf water content (%), C16-Lipid Peroxidation (nmol/ml), C17-Electrolyte leakage index, C18- Proline content (mg/gm), C19-Ascorbic acid content (mg), C20-Pollen viability, C21-Flower drop (%), C22- Seed yield plant^{-1}

Table 5.15: An overview of traits with genotypic and phenotypic correlations to seed yield [EN-1]

Sl.no	Characters	Correlation with grain yield		Similar kind of results were found by
		Genotypic	Phenotypic	
1.	First blossoming days	-	-	(Tutlani *et al* 2023), (Nikhitha & Walia, 2022), (Kushwah *et al* 2021)
2.	50% blossoming days	-	-	(Reddy *et al* 2023), (Tutlani *et al* 2023), (Nikhitha & Walia, 2022), (Xalxo *et al* 2021)
3.	Harvest maturity days	-	-	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Nawaz, 2018), (Sohail, 2018)
4.	Plant height	+	+	(Tutlani *et al* 2023), (Ningwal *et al..,* 2023), (Nikhitha & Walia, 2022), (Tak & Meena, 2021)
5.	Primary offshoots plant^{-1}	+*	+*	(Reddy et al., 2023), (Vikram et al., 2022), (Nikhitha & Walia, 2022), (Ningwal et al.., 2023)
6.	Secondary offshoots plant^{-1}	+*	+*	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022)
7.	Capsules plant^{-1}	+*	+*	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022)
8.	Full capsules plant^{-1}	+*	+*	(Singh *et al* 2018), (Atieno *et al* 2017)
9.	Empty capsules plant^{-1}	-*	-*	(Sabaghnia & Janmohammadi, 2019), (Chegini *et al* 2017)
10.	Seeds capsule^{-1}	+	+	(Ningwal et al.., 2023), (Hailu, 2020)
11.	Test weight (gm)	+*	+*	(Vikram *et al* 2022), (Xalxo *et al* 2021), (Sohail, 2018)
12.	Biological yield plant^{-1}	+*	+*	(Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Tak & Meena, 2021)
13.	Harvest index (%)	+*	+*	(Ningwal *et al..,* 2023), (Nikhitha & Walia, 2022), (Devi *et al* 2022)
14.	Total chlorophyll content (mg/ml)	+*	+*	(Reddy *et al* 2023), (Devi *et al* 2022), (Kumar *et al* 2021)
15.	Relative leaf water content (%)	+*	+*	(Kushwah *et al* 2021), (Kumar *et al* 2021)
16.	Lipid Peroxidation (nmol/ml)	+	+	-
17.	Electrolyte leakage index (%)	-	-	(Moghimi *et al* 2023), (Awasthi *et al* 2017)
18.	Proline content (mg/gm)	+	+	(Tutlani *et al* 2023)
19.	Ascorbic acid content (mg)	-	-	-
20.	Pollen viability (%)	+*	+*	(Devi *et al* 2022)
21.	Flower drop (%)	-*	-*	-

Table 5.16: An overview of traits with genotypic and phenotypic correlations to seed yield [EN-2]

Sl.no	Characters	Correlation with grain yield		Similar kind of results were found by
		Genotypic	Phenotypic	
1.	First blossoming days	-*	-*	(Tutlani *et al* 2023), (Nikhitha & Walia, 2022), (Kushwah *et al* 2021)
2.	50% blossoming days	-*	-*	(Reddy *et al* 2023), (Tutlani *et al* 2023), (Nikhitha & Walia, 2022), (Xalxo *et al* 2021)
3.	Harvest maturity days	-*	-*	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Nawaz, 2018), (Sohail, 2018)
4.	Plant height	+*	+*	(Tutlani *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022), (Tak & Meena, 2021)
5.	Primary offshoots plant^{-1}	+*	+*	(Reddy et al., 2023), (Vikram et al., 2022), (Nikhitha & Walia, 2022), (Ningwal et al.., 2023)
6.	Secondary offshoots plant^{-1}	+*	+*	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022)
7.	Capsules plant^{-1}	+*	+*	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022)
8.	Full capsules plant^{-1}	+*	+*	(Singh *et al* 2018), (Atieno *et al* 2017)
9.	Empty capsules plant^{-1}	-*	-*	(Sabaghnia & Janmohammadi, 2019), (Chegini *et al* 2017)
10.	Seeds capsule^{-1}	+*	+*	(Reddy *et al* 2023), (Vikram *et al* 2022)
11.	Test weight (gm)	+*	+*	(Vikram *et al* 2022), (Xalxo *et al* 2021), (Sohail, 2018)
12.	Biological yield plant^{-1}	+*	+*	(Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Tak & Meena, 2021)
13.	Harvest index (%)	+*	+*	(Ningwal *et al..,* 2023), (Nikhitha & Walia, 2022), (Devi *et al* 2022)
14.	Total chlorophyll content (mg/ml)	+*	+*	(Reddy *et al* 2023), (Devi *et al* 2022), (Kumar *et al* 2021)
15.	Relative leaf water content (%)	+*	+*	(Kushwah *et al* 2021), (Kumar *et al* 2021)
16.	Lipid Peroxidation (nmol/ml)	-	-	(Tutlani *et al* 2023)
17.	Electrolyte leakage index (%)	-	-	(Moghimi *et al* 2023), (Awasthi *et al* 2017)
18.	Proline content (mg/gm)	+*	+*	(Hussain *et al* 2022)
19.	Ascorbic acid content (mg)	+	+	(Awasthi *et al* 2017)
20.	Pollen viability (%)	+*	+*	(Devi *et al* 2022)
21.	Flower drop (%)	-*	-*	-

Table 5.17: An overview of traits with genotypic and phenotypic correlations to seed yield [EN-3]

Sl.no	Characters	Correlation with grain yield		Similar kind of results were found by
		Genotypic	Phenotypic	
1.	First blossoming days	-*	-*	(Tutlani *et al* 2023), (Nikhitha & Walia, 2022), (Kushwah *et al* 2021)
2.	50% blossoming days	-	-	(Reddy *et al* 2023), (Tutlani *et al* 2023), (Nikhitha & Walia, 2022), (Xalxo *et al* 2021)
3.	Harvest maturity days	-*	-*	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Nawaz, 2018), (Sohail, 2018)
4.	Plant height	+*	+*	(Tutlani *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022), (Tak & Meena, 2021)
5.	Primary offshoots plant^{-1}	+*	+	(Reddy *et al* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022), (Ningwal *et al..,* 2023)
6.	Secondary offshoots plant^{-1}	+	+	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022)
7.	Capsules plant^{-1}	+*	+*	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022)
8.	Full capsules plant^{-1}	+*	+*	(Singh *et al* 2018), (Atieno *et al* 2017)
9.	Empty capsules plant^{-1}	-*	-*	(Sabaghnia & Janmohammadi, 2019), (Chegini *et al* 2017)
10.	Seeds capsule^{-1}	+	+	(Ningwal et al.., 2023), (Hailu, 2020)
11.	Test weight (gm)	+	+	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Nikhitha & Walia, 2022)
12.	Biological yield plant^{-1}	+*	+*	(Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Tak & Meena, 2021)
13.	Harvest index (%)	+*	+*	(Ningwal *et al..,* 2023), (Nikhitha & Walia, 2022), (Devi *et al* 2022)
14.	Total chlorophyll content (mg/ml)	+	+	(Tutlani *et al* 2023), (Awasthi *et al* 2017)
15.	Relative leaf water content (%)	+*	+*	(Kushwah *et al* 2021), (Kumar *et al* 2021)
16.	Lipid Peroxidation (nmol/ml)	-*	-*	(Tutlani *et al* 2023)
17.	Electrolyte leakage index (%)	-	-	(Moghimi *et al* 2023), (Awasthi *et al* 2017)
18.	Proline content (mg/gm)	+	+	(Tutlani *et al* 2023)
19.	Ascorbic acid content (mg)	+	+	(Awasthi *et al* 2017)
20.	Pollen viability (%)	+*	+*	(Devi *et al* 2022)
21.	Flower drop (%)	-	-	-

Table 5.18: An overview of traits with genotypic and phenotypic correlations to seed yield [Pooled]

Sl.no	Characters	Correlation with grain yield		Similar kind of results were found by
		Genotypic	Phenotypic	
1.	First blossoming days	+*	+*	(Vikram *et al* 2022), (Jagadish and vijayalakshmi, 2015)
2.	50% blossoming days	+*	+*	(Vikram *et al* 2022), (Jagadish and vijayalakshmi, 2015)
3.	Harvest maturity days	+*	+*	(Vikram *et al* 2022), (Jagadish and vijayalakshmi, 2015)
4.	Plant height	+*	+*	(Tutlani *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022), (Tak & Meena, 2021)
5.	Primary offshoots plant^{-1}	+*	+*	(Reddy et al., 2023), (Vikram et al., 2022), (Nikhitha & Walia, 2022), (Ningwal et al.., 2023)
6.	Secondary offshoots plant^{-1}	+*	+*	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022)
7.	Capsules plant^{-1}	+*	+*	(Reddy *et al* 2023), (Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Nikhitha & Walia, 2022)
8.	Full capsules plant^{-1}	+*	+*	(Singh *et al* 2018), (Atieno *et al* 2017)
9.	Empty capsules plant^{-1}	-*	-*	(Sabaghnia & Janmohammadi, 2019), (Chegini *et al* 2017)
10.	Seeds capsule^{-1}	+*	+*	(Reddy *et al* 2023), (Vikram *et al* 2022)
11.	Test weight (gm)	+*	+*	(Vikram *et al* 2022), (Xalxo *et al* 2021), (Sohail, 2018)
12.	Biological yield plant^{-1}	+*	+*	(Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Tak & Meena, 2021)
13.	Harvest index (%)	+*	+*	(Ningwal *et al..,* 2023), (Nikhitha & Walia, 2022), (Devi *et al* 2022)
14.	Total chlorophyll content (mg/ml)	+*	+*	(Reddy *et al* 2023), (Devi *et al* 2022), (Kumar *et al* 2021)
15.	Relative leaf water content (%)	+*	+*	(Kushwah *et al* 2021), (Kumar *et al* 2021)
16.	Lipid Peroxidation (nmol/ml)	-*	-*	(Tutlani *et al* 2023)
17.	Electrolyte leakage index (%)	-*	-	(Moghimi *et al* 2023), (Awasthi *et al* 2017)
18.	Proline content (mg/gm)	-*	-*	(Hussain *et al* 2022)
19.	Ascorbic acid content (mg)	-*	-	-
20.	Pollen viability (%)	+*	+*	(Devi *et al* 2022)
21.	Flower drop (%)	-*	-*	-

5.3 Path coefficient analysis

In order to observe the causal element, path coefficient analysis was carried out using genotypic correlation coefficient and seed yield plant^{-1} as the dependent variable. Coefficient analysis allows for the separation of total correlation components into direct and indirect effects caused by other characters, which contributes to a better understanding of the causal system. Standard partial regression coefficients are another name for path coefficients. They lack units, are directional, and can be greater or less than unity, allowing for straightforward interpretation. Diagram of path uses a full representation of the causative element involving the deciding the outcome, *i.e.,* seed yield plant^{-1}, which is the core assumption of path analysis. The path analysis results from the experiment are detailed in the next sections.

The path coefficient study of multiple traits found that the character with the greatest direct positive effect on seed yield plant^{-1} was harvest index (%), biological yield plant^{-1}, pollen viability, proline and Flower drop (%)in all analysis, empty capsules plant^{-1} and full capsules plant^{-1} in EN-1, EN-2 and EN-3, secondary offshoots plant^{-1} and Total chlorophyll content (mg/ml) in EN-2, EN-3 and pooled, 50% blossoming days in EN-1 and EN-2, seeds capsule^{-1} in EN-1 and EN-3, 50% blossoming days in EN-1 and pooled, harvest maturity days, Lipid Peroxidation (nmol/ml) and plant height in EN-3 and pooled, Electrolyte leakage index (%)in EN-1, Ascorbic acid content (mg) in EN-2, Relative leaf water content (%) in EN-3 and capsules plant^{-1} in pooled analysis respectively while negative direct effects were shown by primary offshoots plant^{-1} in all analysis, capsules plant^{-1} in EN-1, EN-2 and EN-3, Relative leaf water content (%) EN-1, EN-2 and pooled, Ascorbic acid content (mg) in EN-1, EN-3 and pooled, Electrolyte leakage index (%)and test weight (gm) in EN-2, EN-3 and pooled, harvest maturity days, plant height and Lipid Peroxidation (nmol/ml) in EN-1 and EN-2, first blossoming days in EN-2 and EN-3, Total chlorophyll content (mg/ml) in EN-1 and pooled, seeds capsule^{-1} in EN-2 and pooled, test weight (gm) and 50% blossoming days in EN-3 and pooled, secondary offshoots plant^{-1} in EN-1, full capsules plant^{-1} and empty capsules plant^{-1} in pooled analysis respectively.

Table 5.19: An overview of characters exhibiting positive direct effect on seed yield plant^{-1}

sl.no	Characters	Positive direct effect on seed yield			
		EN-1	EN-2	EN-3	Pooled
1.	First blossoming days				✓
2.	50% blossoming days				
3.	Harvest maturity days				✓
4.	Plant height	✓	✓	✓	✓
5.	Primary offshoots plant^{-1}	✓	✓	✓	
6.	Secondary offshoots plant^{-1}	✓	✓	✓	✓
7.	Capsules plant^{-1}	✓	✓	✓	✓
8.	Full capsules plant^{-1}	✓	✓	✓	
9.	Empty capsules plant^{-1}				
10.	Seeds capsule^{-1}	✓	✓	✓	
11.	Test weight (gm)	✓	✓	✓	
12.	Biological yield plant^{-1}	✓	✓	✓	✓
13.	Harvest index (%)	✓	✓	✓	✓
14.	Total chlorophyll content (mg/ml)	✓	✓	✓	
15.	Relative leaf water content (%)	✓	✓	✓	
16.	Lipid Peroxidation (nmol/ml)	✓			✓
17.	Electrolyte leakage index (%)				
18.	Proline content (mg/gm)	✓	✓	✓	✓
19.	Ascorbic acid content (mg)		✓	✓	
20.	Pollen viability (%)	✓	✓	✓	✓
21.	Flower drop (%)				✓

Table 5.20: An overview of characters exhibiting positive direct effect on seed yield plant^{-1} [EN-1]

Sl.no	Characters	Direct effect on seed yield	Similar kind of results were found by
1.	First blossoming days	-ve	(Nikhitha & Walia, 2022), (Jagadish and vijayalakshmi, 2015)
2.	50% blossoming days	-ve	(Vikram *et al* 2022), (Tutlani *et al* 2023), (Nawaz, 2018)
3.	Harvest maturity days	-ve	(Reddy *et al* 2023), (Vikram *et al* 2022), (Tak & Meena, 2021)
4.	Plant height	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
5.	Primary offshoots plant^{-1}	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
6.	Secondary offshoots plant^{-1}	+ve	(Vikram *et al* 2022), (Xalxo *et al* 2021), (Hailu, 2020)
7.	Capsules plant^{-1}	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
8.	Full capsules plant^{-1}	+ve	(Singh *et al* 2018), (Atieno *et al* 2017)
9.	Empty capsules plant^{-1}	-ve	(Sabaghnia & Janmohammadi, 2019)
10.	Seeds capsule^{-1}	+ve	(Reddy *et al* 2023), (Vikram *et al* 2022), (Xalxo *et al* 2021)
11.	Test weight (gm)	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Xalxo *et al* 2021)
12.	Biological yield plant^{-1}	+ve	(Nikhitha & Walia, 2022), (Vikram *et al* 2022), (Xalxo *et al* 2021)
13.	Harvest index (%)	+ve	(Nikhitha & Walia, 2022), (Vikram *et al* 2022), (Sohail, 2018)
14.	Total chlorophyll content (mg/ml)	+ve	(Reddy *et al* 2023), (Kumar *et al* 2021), (Madhuri *et al* 2020)
15.	Relative leaf water content (%)	+ve	(Tutlani *et al* 2023), (Jagadish and vijayalakshmi, 2015), (Madhuri *et al* 2020)
16.	Lipid Peroxidation (nmol/ml)	+ve	(Tutlani *et al* 2023)
17.	Electrolyte leakage index (%)	-ve	(Moghimi *et al* 2023), (Devi *et al* 2022)
18.	Proline content (mg/gm)	+ve	(Tutlani *et al* 2023), (Madhuri *et al* 2020)
19.	Ascorbic acid content (mg)	-ve	-
20.	Pollen viability (%)	+ve	(Kushwah *et al* 2021)
21.	Flower drop (%)	-ve	-

Table 5.21: An overview of characters exhibiting positive direct effects on seed yield plant^{-1} [EN-2]

Sl.no	Characters	Direct effect on seed yield	Similar kind of results were found by
1.	First blossoming days	-ve	(Nikhitha & Walia, 2022), (Jagadish and vijayalakshmi, 2015)
2.	50% blossoming days	-ve	(Vikram *et al* 2022), (Tutlani *et al* 2023), (Nawaz, 2018)
3.	Harvest maturity days	-ve	(Reddy *et al* 2023), (Vikram *et al* 2022), (Tak & Meena, 2021)
4.	Plant height	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
5.	Primary offshoots plant^{-1}	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
6.	Secondary offshoots plant^{-1}	+ve	(Vikram *et al* 2022), (Xalxo *et al* 2021), (Hailu, 2020)
7.	Capsules plant^{-1}	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
8.	Full capsules plant^{-1}	+ve	(Singh *et al* 2018), (Atieno *et al* 2017)
9.	Empty capsules plant^{-1}	-ve	(Sabaghnia & Janmohammadi, 2019)
10.	Seeds capsule^{-1}	+ve	(Reddy *et al* 2023), (Vikram *et al* 2022), (Xalxo *et al* 2021)
11.	Test weight (gm)	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Xalxo *et al* 2021)
12.	Biological yield plant^{-1}	+ve	(Nikhitha & Walia, 2022), (Vikram *et al* 2022), (Xalxo *et al* 2021)
13.	Harvest index (%)	+ve	(Nikhitha & Walia, 2022), (Vikram *et al* 2022), (Sohail, 2018)
14.	Total chlorophyll content (mg/ml)	+ve	(Reddy *et al* 2023), (Kumar *et al* 2021), (Madhuri *et al* 2020)
15.	Relative leaf water content (%)	+ve	(Tutlani *et al* 2023), (Jagadish and vijayalakshmi, 2015), (Madhuri *et al* 2020)
16.	Lipid Peroxidation (nmol/ml)	-ve	(Tutlani *et al* 2023)
17.	Electrolyte leakage index (%)	-ve	(Moghimi *et al* 2023), (Devi *et al* 2022)
18.	Proline content (mg/gm)	+ve	(Tutlani *et al* 2023), (Madhuri *et al* 2020)
19.	Ascorbic acid content (mg)	+ve	(Chandrakala *et al* 2023)
20.	Pollen viability (%)	+ve	(Kushwah *et al* 2021)
21.	Flower drop (%)	-ve	-

Table 5.22: An overview of characters exhibiting positive direct effect on seed yield plant^{-1} [EN-3]

Sl.no	Characters	Direct effect on seed yield	Similar kind of results were found by
1.	First blossoming days	-ve	(Nikhitha & Walia, 2022), (Jagadish and vijayalakshmi, 2015)
2.	50% blossoming days	-ve	(Vikram *et al* 2022), (Tutlani *et al* 2023), (Nawaz, 2018)
3.	Harvest maturity days	-ve	(Reddy *et al* 2023), (Vikram *et al* 2022), (Tak & Meena, 2021)
4.	Plant height	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
5.	Primary offshoots plant^{-1}	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
6.	Secondary offshoots plant^{-1}	+ve	(Vikram *et al* 2022), (Xalxo *et al* 2021), (Hailu, 2020)
7.	Capsules plant^{-1}	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
8.	Full capsules plant^{-1}	+ve	(Singh *et al* 2018), (Atieno *et al* 2017)
9.	Empty capsules plant^{-1}	-ve	(Sabaghnia & Janmohammadi, 2019)
10.	Seeds capsule^{-1}	+ve	(Reddy *et al* 2023), (Vikram *et al* 2022), (Xalxo *et al* 2021)
11.	Test weight (gm)	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Xalxo *et al* 2021)
12.	Biological yield plant^{-1}	+ve	(Nikhitha & Walia, 2022), (Vikram *et al* 2022), (Xalxo *et al* 2021)
13.	Harvest index (%)	+ve	(Nikhitha & Walia, 2022), (Vikram *et al* 2022), (Sohail, 2018)
14.	Total chlorophyll content (mg/ml)	+ve	(Reddy *et al* 2023), (Kumar *et al* 2021), (Madhuri *et al* 2020)
15.	Relative leaf water content (%)	+ve	(Tutlani *et al* 2023), (Jagadish and vijayalakshmi, 2015), (Madhuri *et al* 2020)
16.	Lipid Peroxidation (nmol/ml)	-ve	(Tutlani *et al* 2023)
17.	Electrolyte leakage index (%)	-ve	(Moghimi *et al* 2023), (Devi *et al* 2022)
18.	Proline content (mg/gm)	+ve	(Tutlani *et al* 2023), (Madhuri *et al* 2020)
19.	Ascorbic acid content (mg)	+ve	(Chandrakala *et al* 2023)
20.	Pollen viability (%)	+ve	(Kushwah *et al* 2021)
21.	Flower drop (%)	-ve	-

Table 5.23: An overview of characters exhibiting positive direct effect seed yield plant^{-1} [pooled]

Sl.no	Characters	Direct effect on seed yield	Similar kind of results were found by
1.	First blossoming days	+ve	(Vikram *et al* 2022), (Jagadish and vijayalakshmi, 2015)
2.	50% blossoming days	+ve	(Ningwal *et al..,* 2023), (Vikram *et al* 2022), (Jagadish and vijayalakshmi, 2015)
3.	Harvest maturity days	+ve	(Tutlani *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
4.	Plant height	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
5.	Primary offshoots plant^{-1}	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
6.	Secondary offshoots plant^{-1}	+ve	(Vikram *et al* 2022), (Xalxo *et al* 2021), (Hailu, 2020)
7.	Capsules plant^{-1}	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Vikram *et al* 2022)
8.	Full capsules plant^{-1}	+ve	(Singh *et al* 2018), (Atieno *et al* 2017)
9.	Empty capsules plant^{-1}	-ve	(Sabaghnia & Janmohammadi, 2019)
10.	Seeds capsule^{-1}	+ve	(Reddy *et al* 2023), (Vikram *et al* 2022), (Xalxo *et al* 2021)
11.	Test weight (gm)	+ve	(Reddy *et al* 2023), (Nikhitha & Walia, 2022), (Xalxo *et al* 2021)
12.	Biological yield plant^{-1}	+ve	(Nikhitha & Walia, 2022), (Vikram *et al* 2022), (Xalxo *et al* 2021)
13.	Harvest index (%)	+ve	(Nikhitha & Walia, 2022), (Vikram *et al* 2022), (Sohail, 2018)
14.	Total chlorophyll content (mg/ml)	+ve	(Reddy *et al* 2023), (Kumar *et al* 2021), (Madhuri *et al* 2020)
15.	Relative leaf water content (%)	+ve	(Tutlani *et al* 2023), (Jagadish and vijayalakshmi, 2015), (Madhuri *et al* 2020)
16.	Lipid Peroxidation (nmol/ml)	-ve	(Tutlani *et al* 2023)
17.	Electrolyte leakage index (%)	-ve	(Moghimi *et al* 2023), (Devi *et al* 2022)
18.	Proline content (mg/gm)	-ve	(Moghimi *et al* 2023), (Rajput *et al* 2023)
19.	Ascorbic acid content (mg)	-ve	-
20.	Pollen viability (%)	+ve	(Kushwah *et al* 2021)
21.	Flower drop (%)	-ve	-

5.4 STABILITY ANALYSIS BY EBERHART AND RUSSELL’S MODEL

In rapidly shifting environmental conditions, crop yield stability across a range of environments is more significant, particularly for the chickpea crop, which is cultivated in an array of eco-adaphic scenarios. In such cases, breeding stable genotypes should be an intrinsic part of a chickpea breeding effortsIt is found that the G X E interplay is common and plays a major role in the selection's inability to provide the expected gain (Comstock and Moll, 1960). "Well buffered" refers to a population that can adapt its genotypic or phenotypic state in response to environmental differences in a way that yields a high and stable economic return (Allard and Bradshaw, 1964).

The current study looked into how the environment affected chickpea genotype performance and how stable genotypes were identified. The findings are described below:

5.4.1 Analysis of variance for stability

Stability's ANOVA revealed genotypic variations amongst every trait was significant (Table 4.18). The individual environment impact was significant for all attributes, per the pooled analysis of variance. The genotype x environment interaction showed significant variations among the variables under consideration when measured against pooled error. The genotype x environment (linear) and pooled deviation components of the genotype x environment interaction are separated. Pooled deviations and the genotype x environment (linear) interaction were shown to be significant for all characteristics. When examined against pooled error, environment (linear) revealed a significant difference in all traits highlighting the significance of both linear and non-linear components for each attribute.

Similar reportings have been made by Qaisi and Bayati (2023), Shimray *et al* (2022), Pathy *et al* (2022), Dhopre *et al* (2022), Das *et al* (2022) and Mahmood *et al* (2021).

An ideal genotype, according to Eberhart and Russell, has a high mean (x= μ) performance alongside a unit regression coefficient *i.e.,* (bi=1) & a minimal deviation from regression *i.e.,* (S^2di=0). As a result, the mean (x) & deviation from regression (S^2di=0) are regarded as markers of stability, whereas linear regression (bi) is used to assess genotype responsiveness.

5.4.2 Stability for individual traits

Yield is a complicated entity that is influenced by several connected traits. As a result, yield stability is unquestionably dependent on the stability of contributing features. The following traits are discussed in relation to the stability analysis results:

5.4.2.1 First blossoming days

K 850, IPC-97-67, ICC 244-263, BPM and RSG 945 genotypes had a higher mean, R.C *i.e.,* (bi=1), minimal D.F.R *i.e.,* (S^2di~0), suggesting that they were stable, not perfect.

ICC-5434, ICC-5439 and SADABAHAR on the other hand, had a lower mean value coupled with R.C lesser to unity (bi<1) and a minimal D.F.R (S2di~0), depicting their above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments. KWR-108, PBG-7 and IPC-06-77 on contrary, exhibited low mean against grand mean paired with higher R.C (bi>1) with insignificant D.F.R (S^2di~0), demonstrating below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and a high S^2di value are unstable.

5.4.2.2 50% blossoming days

IPC-06-77, IPC-97-67, BG-212, and GNG 469 genotypes with a minimal D.F.R (S^2di~0) and a lower mean suggesting ideal and fair stability, whereas, PUSA 3043 recorded higher mean value, R.C *i.e.,* (bi=1), and minimal D.F.R *i.e.,* (S^2di~0) revealed stable but not ideal stability.

Genotypes ICC-5434 and SADABAHAR, on contrary, had a low mean, R.C smaller than unity (bi<1) and the minute D.F.R (S^2di~0), depicting above-average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments. On the contrary, PBG-7 and ICC-5335 genotypes had low mean paired with higher R.C *i.e.,* (bi>1) with little D.F.R (S^2di~0) indicating below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and a high S^2di value are unstable.

5.4.2.3 Harvest maturity days

Genotypes IPC-97-67, ICC-5434, and ICC-5439 had a minimal D.F.R S2di~0) and a lower mean, depicting ideal and fair stability, whereas, K-850, ICC-3525, and IPC 05-28 had higher mean, R.C *i.e.,* (bi=1), and a small D.F.R (S^2di~0), demonstrating stable but not ideal stability.

Any other genotypes with a high S2di value and any bi value are unstable.

5.4.2.4 Plant height

Genotype SADABAHAR had a high mean value and a tiny D.F.R (S2di~0), suggesting fair and ideal stability, while genotype K-850 had a lower mean value coupled with R.C *i.e.,* (bi=1), a minor D.F.R *i.e.,* (S^2di~0), suggesting stable but not ideal stability.

Genotypes KWR 108 and IPC 07-56 on the other hand, had a higher mean with a R.C lower to unity (bi<1), a minimal D.F.R (S^2di~0), showing above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments. On the contrary, genotype JG 14 exhibited a higher mean value, higher R.C *i.e.,* (bi>1) couple with minimal D.F.R (S2di~0), revealing below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and a high S^2di value are unstable.

1.4.2.5. Primary offshoots plant^{-1}

Genotype RSG 931 demonstrated stability with a lower mean, R.C (bi~1), and a minute D.F.R (S^2di~0).

Genotypes KWR-108, ICC 244-263, ICC-5439 and GNG 469 demonstrated above average stability with a higher mean, R.C lower than unity (bi<1), and a minute D.F.R (S^2di~0) suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments. IPC-06-77, K-850, BG-212, ICC-5434, IPC-07-56, SADABAHAR, PBG-5, JG-14 on the other hand recorded higher mean paired with higher R.C *i.e.,* (bi>1), a minimal D.F.R *i.e.,* (S^2di~0), suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and higher of S^2di value are unstable.

1.4.2.6. Secondary offshoots plant^{-1}

ICC 244-263 and ICC-5439 had higher mean, a R.C below unity (bi<1) with a minimal D.F.R (S^2di~0), showing above average stability.

KWR-108, PBG-7, ICC-3020, IPC-06-77, K-850, BG-212, ICC-5434, IPC-07-56, GNG 469, SADABAHAR, PBG-5, JG 14 all on the other hand, have higher mean paired with higher coefficient of regression (bi>1) with small D.F.R (S2di~0), owning below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and a high S2di value are unstable.

1.4.2.7. Capsules plant^{-1}

PBG-7, IPC-06-77, ICC-5335 and ICC-5439 with small D.F.R (S^2di~0) with higher mean expressed ideal and fair stability, whereas ICC-3525 and RSG 945 having low mean couple with R.C (b=1) and minimal D.F.R (S^2di~0) recorded stable but not ideal stability.

On the contrary, genotypes GNG 469, SADABAHAR, PBG-5, JG 14 had a higher mean and coefficient of regression (bi>1) coupled with a minimal D.F.R (S^2di~0), showing below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and a high S2di value are unstable.

1.4.2.8. Full capsules plant^{-1}

The higher mean, R.C unit (b=1) and minimal D.F.R (S^2di~0) of genotype ICC-5439 indicate that this genotype was ideal and stable.

Genotype PBG-7 exhibited higher mean and R.C (bi<1) with minimal D.F.R (S^2di~0), depicted above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, while, ICC-5434, SADABAHAR and JG 14 showed higher mean coupled with higher R.C *i.e.,* (bi>1), insignificant D.F.R *i.e.,* (S^2di~0), showing below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and a high S^2di value are unstable.

1.4.2.9. Empty capsules plant^{-1}

Genotypes IPC 05-28 and SADABAHAR with minute D.F.R (S^2di~0) and lower mean values depicted fair and ideal stability, while genotype BPM higher mean and R.C (bi=1), and a minimal regression from deviation (S^2di~0) recorded stable but not a perfect stability.

On the other hand, genotypes KWR-108, IPC-06-77, IPC-07-56, GNG 469, and RSG 945 exhibited lower mean and R.C *i.e.,* (bi<1), minimal D.F.R *i.e.,* (S^2di~0), depicting above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments whereas, ICC-5335, IPC-97-67, ICC-5434, PDG-4, and RSG-888 recorded lower mean accompanied by higher R.C (bi>1) with minor D.F.R (S^2di~0) depicted below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any other bi value and a high S2di value were unstable.

1.4.2.10. Seeds capsule^{-1}

KWR-108 had a greater mean, R.C *i.e.,* (bi=1), minimal D.F.R *i.e.,* (S^2di~0), showing ideal stability while genotype K-850 lower mean and R.C (bi=1), and a minimal regression from deviation (S^2di~0) recorded stable but not a perfect stability.

On the other hand, genotypes ICC-3020, ICC-3525 and IPC-07-56 exhibited higher mean values with lower R.C *i.e.,* (bi<1), a minute D.F.R *i.e.,* (S^2di~0), suggesting above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, whereas, IPC-06-77, KPG-59, BG-212, ICC-5434, RSG-888, SADABAHAR, PBG-5 and JG-14 had higher mean accompanied by a higher R.C (bi>1) with minimal D.F.R (S^2di~0) recording below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and a high S^2di value are unstable.

1.4.2.11. Test weight (gm)

Genotypes ICC-3020, K-850, IPC-97-67, ICC-5439 and IPC-07-56 had minimal D.F.R (S2di~0), R.C (bi=1) with a higher mean, suggesting ideal and fair stability, whereas, KPG-59, ICC 244-263, ICC-5434 and IPC 05-28 had lower mean, R.C (bi=1), along with small D.F.R (S^2di~0), suggesting stable but not ideal stability.

In contrary, genotypes KWR-108, IPC-06-77, ICC-5335, PDG-4 and GNG 469 had higher mean, R.C *i.e.,* (bi>1), minute D.F.R *i.e.,* (S^2di~0) recorded below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotype any bi value and higher S^2di value are unstable.

1.4.2.12. Biological yield plant^{-1}

Genotype PBG-7 exhibiting a higher mean value and minor D.F.R (S^2di~0) suggested fair and ideal stability, while genotype ICC 244-263, BPM, RSG 931, IPC 05-28 and GNG 469 with a lower mean, R.C *i.e.,* (bi=1), a tiny D.F.R *i.e.,* (S^2di~0) suggested stable but not ideal stability.

In contrast, genotypes KWR-108, IPC-06-77 and IPC-07-56 displayed high mean alongside R.C lower than unity (bi<1) and a small D.F.R (S^2di~0) suggesting above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, while IPC-97-67 and BG-212 carried higher mean in combination with a higher R.C (bi>1) with insignificant D.F.R (S^2di~0) demonstrated below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and high S^2di are unstable.

1.4.2.13. Harvest index (%)

Genotypes KWR-108, IPC-06-77, ICC-5335, ICC-5434 and IPC-07-56 carried high mean alongside lower R.C *i.e.,* (bi<1), minimal D.F.R *i.e.,* (S^2di~0), suggesting above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, whereas, PDG-4 possessed high mean, greater regression coefficients (bi>1) and insignificant

D.F.R (S^2di~0), showing below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any other bi and S^2di value are unstable.

1.4.2.14. Total chlorophyll content (mg/ml)

Genotypes IPC-06-77, KPG-59, BG-212, ICC-5439, IPC-07-56, PDG-4 and GNG 469 displayed high mean, alongside R.C *i.e.,* (bi<1), a small D.F.R *i.e.,* (S^2di~0) demonstrating above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, while KWR-108, ICC-5335, ICC-5434, SADABAHAR and JG 14 possessed higher mean together with a high R.C (bi>1) with insignificant D.F.R (S^2di~0) depicted below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any other bi and S^2di value are unstable.

1.4.2.15. Relative leaf water content (%)

Genotypes PDG-4 carried high mean, lower R.C *i.e.,* (bi<1), minimal D.F.R *i.e.,* (S^2di~0), suggesting above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, while, KWR-108, ICC-5335, BG-212, IPC-07-56 and SADABAHAR possessed higher mean paired with higher regression coefficients (bi>1) and insignificant D.F.R (S^2di0), demonstrating below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi value and S^2di value are unstable.

1.4.2.16. Lipid Peroxidation (nmol/ml)

The higher mean value and R.C *i.e.,* (bi=1), minimal D.F.R *i.e.,* (S^2di~0) of genotype ICC 244-263 indicated stable, not ideal stability.

On the contrary, KWR-108, IPC-06-77, KPG-59, ICC-5335, BG-212, IPC-07-56, PDG-4, and SADABAHAR demonstrated lower mean alongside R.C *i.e.,* (bi<1), a small D.F.R *i.e.,* (S^2di~0), suggesting above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, while, RSG 931, IPC 05-28, and GNG 469 experienced lower mean paired with higher R.C *i.e.,* (bi>1) and insignificant D.F.R *i.e.,* (S^2di~0) revealed below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi or S^2di values are unstable.

1.4.2.17. Electrolyte leakage index (%)

With a minimal D.F.R (S^2di~0) and lower mean, genotype GNG 469 demonstrated fair to perfect stability.

On the other hand, genotypes IPC-06-77 and BG-212 possessed a lower mean value alongside lower R.C *i.e.,* (bi<1), a minimal D.F.R *i.e.,* (S^2di~0), demonstrating above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, while genotypes KWR-108 and SADABAHAR experienced a lower mean value to grand mean accompanied by a higher R.C *i.e.,* (bi>1), insignificant D.F.R *i.e.,* (S^2di~0), suggesting below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi and S^2di value are unstable.

1.4.2.18. Proline content (mg/gm)

Genotypes ICC-5335, IPC-07-56, PDG-4 and SADABAHAR exhibiting a high mean values and minimal D.F.R (S^2di~0) suggested fair and ideal stability, while genotypes IPC 05-28, PUSA 3043 and RSG 945 that had lower mean, R.C *i.e.,* (bi=1), tiny D.F.R *i.e.,* (S^2di~0) suggested stable but not ideal stability.

Conversely, genotypes BG-212 and ICC-5434 displayed higher mean alongside lower R.C *i.e.,* (bi<1), a small D.F.R *i.e.,* (S^2di~0), suggesting above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, while KWR-108, IPC-06-77, KPG-59 and GNG 469 displayed higher mean in combination with higher R.C *i.e.,* (bi>1), insignificant D.F.R *i.e.,* (S^2di~0) revealed below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi and S2di value are unstable.

1.4.2.19. Ascorbic acid content (mg)

Genotype IPC-06-77, K-850 and ICC-5439 with a higher mean value and lower R.C *i.e.,* (bi<1), a minimal D.F.R *i.e.,* (S^2di~0), displayed above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments whereas, PBG-7 and ICC-3020 displayed higher mean in combination with higher R.C *i.e.,* (bi>1), insignificant D.F.R *i.e.,* (S^2di~0) revealed below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any other bi and S^2di values are unstable.

1.4.2.20. Pollen viability

Genotypes KWR-108, SADABAHAR and JG-14 with a slight D.F.R (S^2di~0) coupled with higher mean suggested ideal and fair stability, while, IPC-97-67, RSG 931 and RSG 945 displaying lower mean with R.C (bi=1), with a minimal D.F.R (S^2di~0) demonstrated stable but not ideal stability.

Any other genotypes with any bi value and S^2di value ae unstable.

1.4.2.21. Flower drop (%)

RSG 931, PBG-5, and JG-14 genotypes showed higher mean, R.C *i.e.*, (bi=1), a small D.F.R *i.e.*, (S^2di~0), suggesting stable, not ideal.

Conversely, genotype PBG-7 and PDG-4 had a lower mean value alongside a lower R.C *i.e.*, (bi<1), a minimal D.F.R *i.e.*, (S^2di~0), suggesting above average stability suggesting increased resilience to alterations in the surroundings, which in turn enhances the specificity of adaptation to low yielding environments, while KWR-108, IPC-06-77 and IPC-07-56 were having a low mean value to grand mean accompanied by a higher R.C *i.e.,* (bi>1), an insignificant D.F.R *i.e.*, (S^2di~0) revealed below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi and S2di value are unstable.

1.4.2.22. Seed yield plant^{-1}

Genotypes KWR-108, PBG-7, IPC-06-77, ICC-5434, IPC-07-56, SADABAHAR and JG-14 alongside little D.F.R (S^2di~0) together with a higher mean stated ideal and fair stability, while, K-850, BPM and IPC 05-28 through a small D.F.R (S^2di~0) suggested stable but not ideal stability.

On the contrary, genotypes ICC-5335 and BG-212 displayed high mean alongside higher R.C *i.e.,* (bi>1), a minimal D.F.R *i.e.,* (S^2di~0), suggesting below average stability suggesting below average stability suggesting that they typically react well in favorable conditions but produce poorly in unfavorable ones.

Any other genotypes with any bi and S^2di value are unstable.

Table 5.24: Chickpea genotypes designated based on adaptability and stability

Character	Ideal and stable (bi~1, S^2di~0, M>GM)	Stable (bi~1, S^2di~0, M<GM)	Below average stability (bi>1, S^2di~0, M>GM)	Above average stability (bi <1, S^2di~0, M>GM)
First blossoming days		K 850, IPC-97-67, ICC 244-263, BPM, RSG 945	KWR-108, PBG-7, IPC-06-77	ICC-5434, ICC-5439, SADABAHAR
50% blossoming days	IPC-06-77, IPC-97-67, BG-212, GNG 469	PUSA 3043	PBG-7, ICC-5335	ICC-5434, SADABAHAR
Harvest maturity days	IPC-97-67, ICC-5434, ICC-5439	K-850, ICC-3525, IPC 05-28	-	-
Plant height	SADABAHAR	K-850	JG-14	KWR 108, IPC 07-56
Primary offshoots plant^{-1}	-	RSG 931	IPC-06-77, K-850, BG-212, ICC-5434, IPC-07-56, SADABAHAR, PBG-5, JG-14	KWR-108, ICC 244-263, ICC-5439, GNG 469
Secondary offshoots plant^{-1}	-	-	KWR-108, PBG-7, ICC-3020, IPC-06-77, K-850, BG-212, ICC-5434, IPC-07-56, GNG 469, SADABAHAR, PBG-5, JG-14	ICC 244-263, ICC-5439

Table 5.24: Chickpea genotypes designated based on adaptability and stability

Character	Ideal and stable (bi~1, S^2di~0, M>GM)	Stable (bi~1, S^2di~0, M<GM)	Below average stability (bi>1, S^2di~0, M>GM)	Above average stability (bi <1, S^2di~0, M>GM)
Capsules plant^{-1}	PBG-7, IPC-06-77, ICC-5335, ICC-5439	ICC-3525, RSG 945	GNG 469, SADABAHAR, PBG-5, JG-14	-
Full capsules plant^{-1}	ICC-5439	-	ICC-5434, SADABAHAR and JG 14	PBG-7
Empty capsules plant^{-1}	IPC 05-28, SADABAHAR	BPM	ICC-5335, IPC-97-67, ICC-5434, PDG-4, RSG-888	KWR-108, IPC-06-77, IPC-07-56, GNG 469, RSG 945
Seeds capsule^{-1}	KWR-108	K-850	IPC-06-77, KPG-59, BG-212, ICC-5434, RSG-888, SADABAHAR, PBG-5, JG-14	ICC-3020, ICC-3525, IPC-07-56
Test weight (gm)	ICC-3020, K-850, IPC-97-67, ICC-5439, IPC-07-56	KPG-59, ICC 244-263, ICC-5434, IPC 05-28	KWR-108, IPC-06-77, ICC-5335, PDG-4, GNG 469	-

Table 5.24: Chickpea genotypes designated based on adaptability and stability

Character	Ideal and stable ($bi\sim1$, $S^2di\sim0$, M>GM)	Stable ($bi\sim1$, $S^2di\sim0$, M<GM)	Below average stability ($bi>1$, $S^2di\sim0$, M>GM)	Above average stability ($bi<1$, $S^2di\sim0$, M>GM)
Biological yield plant^{-1}	PBG-7	ICC 244-263, BPM, RSG 931, IPC 05-28, GNG 469	IPC-97-67, BG-212	KWR-108, IPC-06-77, IPC-07-56
Harvest index (%)	-	-	PDG-4	KWR-108, IPC-06-77, ICC-5335, ICC-5434, IPC-07-56
Total chlorophyll content (mg/ml)	-	-	KWR-108, ICC-5335, ICC-5434, SADABAHAR, JG-14	IPC-06-77, KPG-59, BG-212, ICC-5439, IPC-07-56, PDG-4, GNG 469
Relative leaf water content (%)	-	-	KWR-108, ICC-5335, BG-212, IPC-07-56, SADABAHAR	PDG-4
Lipid Peroxidation (nmol/ml)	-	ICC 244-263	RSG 931, IPC 05-28, GNG 469	KWR-108, IPC-06-77, KPG-59, ICC-5335, BG-212, IPC-07-56, PDG-4, SADABAHAR
Electrolyte leakage index	GNG 469	-	KWR-108, SADABAHAR	IPC-06-77 and BG-212

Table 5.24: Chickpea genotypes designated based on adaptability and stability

Character	Ideal and stable (bi~1, S^2di~0, M>GM)	Stable (bi~1, S^2di~0, M<GM)	Below average stability (bi>1, S^2di~0, M>GM)	Above average stability (bi <1, S^2di~0, M>GM)
Proline	ICC-5335, IPC-07-56, PDG-4, SADABAHAR	IPC 05-28, PUSA 3043, RSG 945	KWR-108, IPC-06-77, KPG-59, GNG 469	BG-212, ICC-5434
Ascorbic acid content (mg)	-	-	PBG-7, ICC-3020	IPC-06-77, K-850, ICC-5439
Pollen viability	KWR-108, SADABAHAR, JG-14	IPC-97-67, RSG 931, RSG 945	-	-
Flower drop (%)	-	RSG 931, PBG-5, JG-14	KWR-108, IPC-06-77, IPC-07-56	PBG-7, PDG-4
Seed yield plant^{-1}	KWR-108, PBG-7, IPC-06-77, ICC-5434, IPC-07-56, SADABAHAR, JG-14	K-850, BPM, IPC 05-28	ICC-5335, BG-212	-

5.5 PARAMETERS OF VARIABILITY (Hybrids and Parents)

The commercialization of heterosis in chickpea would aid in the identification of the parents that produce the finest cross combinations with the most heterosis. Depending on the breeding goals, both +ve & -ve heterosis is advantageous. Negative heterosis is sought for first blossoming days, 50% flowering, & maturity, empty capsules plant^{-1}, Lipid Peroxidation (nmol/ml), electrolyte leakage index (%), and flower drop (%). In chickpea research around the world, additive & non-additive effects on seed yield & associated components have been observed.

The primary goal of combining ability is to find parents with a higher potential to pass on desired features to their offspring and pinpointing finest specific crosses for seed yield and their individual traits. An equally significant goal has been to gather knowledge about the nature and degree of gene action, which has a direct influence on the selection of the most appropriate and efficient breeding protocols. Furthermore, the efficacy of genetic improvement is dependent on an understanding of the mechanisms of inheritance of yield and component characteristics, as well as the recognition of parents displaying genetic repetency for yield. This demonstrates the importance of assessing the parents for their combining ability, as highly productive parents may not pair well enough to generate improved hybrids and sergeants when managing segregating generations in order to accomplish enhanced varieties.

5.5.1. ANALYSIS OF VARIANCE

The ANOVA for the setup implicated significant genotype variations for all twenty-two characters, indicating presence of significant variability in every involved trait. Further differentiation of genotypic variance to hybrids & parents demonstrated that MSS owing to these showed significance for every variable save secondary offshoots plant^{-1} among parents. Similarly, MSS owing to parent v/s hybrids exhibited significance for practically all characteristics excepting seeds capsule^{-1}, harvest index (%) and Ascorbic acid content (mg) (%). This revealed that the disparity between parents and hybrids was large, with average heterosis. (Table 4.30, 4.31).

5.5.2 PER SE PERFORMANCE OF PARENTS AND CROSSES

The averages of all hybrids, parents, & standard check for all the twenty-two traits are given in appendix- II. Wide variation range was observed for all traits in the study based on mean performance of entire traits. Tables 5.25 and 5.26 show the top five prospective hybrids & parents basing per se performance on yield and contributing characteristics. Among all parents and hybrids, better genotypes selection basing performance is underlined in Table 5.27.

Table 5.25: Top five potential parents based on yield performance and contributing traits

Parents	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108		**V**	**III**	**III**	**IV**	**V**	**V**	**V**	**III**	**III**	**III**
ICC 5335	**I**	**I**	**IV**						**IV**	**V**	**II**
ICC 5434				**V**	**V**		**IV**	**IV**	**III**	**I**	
BG 212	**IV**	**IV**	**II**	**I**	**I**	**I**	**I**	**II**		**III**	**I**
IPC 07-56				**IV**	**II**	**II**	**II**	**I**	**I**	**II**	**IV**
IPC 06-77	**IV**	**IV**							**V**	**I**	
SADABAHAR	**II**	**II**	**I**		**III**	**III**	**III**	**III**	**II**	**III**	
GNG 469	**V**	**III**	**V**		**V**					**III**	
KPG 59					**II**	**IV**				**IV**	
PDG 4	**III**	**III**	**IV**	**II**	**III**	**IV**			**IV**	**I**	**V**

Parents	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index	Proline	Ascorbic acid content (mg)	Pollen viability	Flower drop (%)	Seed yield plant^{-1}
KWR 108	**IV**	**I**			**I**		**IV**	**I**	**IV**	**IV**	**II**
ICC 5335	**III**	**III**	**II**	**III**					**III**		**III**
ICC 5434			**V**	**II**		**IV**		**III**		**V**	
BG 212	**I**	**IV**		**IV**	**V**			**II**	**I**		**I**
IPC 07-56	**V**	**II**	**IV**	**V**					**V**		**IV**
IPC 06-77		**V**	**III**		**IV**	**III**	**III**	**IV**		**I**	**V**
SADABAHAR										**III**	
GNG 469				**I**	**II**	**II**	**II**		**II**		
KPG 59					**III**	**V**	**I**	**III**		**II**	
PDG 4	**II**		**I**			**I**	**V**	**V**			

Table 5.26: Top five potential hybrids on yield basis per se performance & contributing characteristics

Crosses	First blossomin g days	50% blossomin g days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108 X GNG 469							**V**	**IV**	**III**	**IV**	
KWR 108 X KPG 59									**IV**	**IV**	**IV**
KWR 108 X PDG 4										**IV**	
ICC 5335 X GNG 469				**III**					**V**	**IV**	**V**
ICC 5335 X KPG 59					**II**	**IV**			**I**		
ICC 5335 X PDG 4	**II**	**II**	**I**	**II**			**I**	**I**		**I**	
ICC 5434 X GNG 469	**V**	**V**	**II**		**I**	**II**				**V**	
ICC 5434 X KPG 59										**V**	
ICC 5434 X PDG 4									**II**	**III**	**II**
BG 212 X GNG 469	**III**	**III**	**II**		**III**					**III**	
BG 212 X KPG 59		**IV**	**III**		**IV**						**I**
BG 212 X PDG 4										**IV**	
IPC 07-56 X GNG 469					**V**	**III**					
IPC 07-56 X KPG 59						**V**					
IPC 07-56 X PDG 4				**V**						**III**	
IPC 06-77 X GNG 469										**IV**	**III**
IPC 06-77 X KPG 59					**III**	**I**				**I**	
IPC 06-77 X PDG 4	**IV**	**III**	**V**	**IV**			**III**	**II**		**III**	
SADABAHAR X GNG 469	**I**	**I**		**I**			**IV**	**V**		**II**	
SADABAHAR X KPG 59							**II**	**III**		**III**	
SADABAHAR X PDG 4	**V**	**V**	**IV**								

Table 5.26: Top five potential hybrids on yield basis per se performance & contributing characteristics

Crosses	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index	Proline	Ascorbic acid content (mg)	Pollen viability	Flower drop (%)	Seed yield plant^{-1}
KWR 108 X GNG 469		II				V				IV	
KWR 108 X KPG 59		V		II		IV					
KWR 108 X PDG 4											
ICC 5335 X GNG 469							I				
ICC 5335 X KPG 59			V		V						
ICC 5335 X PDG 4		I		I	IV	III					II
ICC 5434 X GNG 469			II	IV					II		
ICC 5434 X KPG 59				III				II	I		
ICC 5434 X PDG 4		I			III	I					
BG 212 X GNG 469					II						
BG 212 X KPG 59	V								V		
BG 212 X PDG 4							II			V	
IPC 07-56 X GNG 469			IV			II			III		
IPC 07-56 X KPG 59								IV			
IPC 07-56 X PDG 4	III									II	
IPC 06-77 X GNG 469		IV					III				III
IPC 06-77 X KPG 59			I								
IPC 06-77 X PDG 4	IV	III					V	V		I	I
SADABAHAR X GNG 469	I		III		I			I			IV
SADABAHAR X KPG 59	II			V				III		III	V
SADABAHAR X PDG 4						V	IV		IV		

Table 5.27: Choosing a superior genotype on the basis of mean values

sl.no.	Character	Parents	Crosses
1.	**First blossoming days**	ICC 5335	SADABAHAR X GNG 469
2.	**50% blossoming days**	ICC 5335	SADABAHAR X GNG 469
3.	**Harvest maturity days**	SADABAHAR	ICC 5335 X PDG 4
4.	**Plant height**	BG 212	SADABAHAR X GNG 469
5.	**Primary offshoots plant^{-1}**	BG 212	ICC 5434 X GNG 469
6.	**Secondary offshoots plant^{-1}**	BG 212	IPC 06-77 X KPG 59
7.	**Capsules plant^{-1}**	BG 212	ICC 5335 X PDG 4
8.	**Full capsules plant^{-1}**	IPC 07-56	ICC 5335 X PDG 4
9.	**Empty capsules plant^{-1}**	IPC 07-56	ICC 5335 X KPG 59
10.	**Seeds capsule^{-1}**	ICC 5434, IPC 06-77, PDG 4	ICC 5335 X PDG 4, IPC 06-77 X KPG 59
11.	**Test weight (gm)**	BG 212	BG 212 X KPG 59
12.	**Biological yield plant^{-1}**	BG 212	SADABAHAR X GNG 469
13.	**Harvest index (%)**	KWR 108	ICC 5335 X PDG 4, ICC 5434 X PDG 4
14.	**Total chlorophyll content (mg/ml)**	PDG 4	IPC 06-77 X KPG 59
15.	**Relative leaf water content (%)**	GNG 469	ICC 5335 X PDG 4
16.	**Lipid Peroxidation (nmol/ml)**	KWR 108	SADABAHAR X GNG 469
17.	**Electrolyte leakage index (%)**	PDG 4	ICC 5434 X PDG 4
18.	**Proline content (mg/gm)**	KPG 59	ICC 5335 X GNG 469
19.	**Ascorbic acid content (mg)**	KWR 108	SADABAHAR X GNG 469
20.	**Pollen viability (%)**	BG 212	ICC 5434 X KPG 59
21.	**Flower drop (%)**	IPC 06-77	IPC 06-77 X PDG 4
22.	**Seed yield plant^{-1}**	BG 212	IPC 06-77 X PDG 4

5.6 HETEROSIS, HETEROBILTOSIS & STANDARD HETEROSIS

Heterosis degree offers insight into genetic variability level in a cross's parents which assists in the selection of superior F1's parents to harness hybrid vigor. The expression of a combined effect of advantageous genes, interaction amongst alleles, mitochondrial genes and non-allelic interaction, inherited from both parents are all included in modern definitions of heterosis. Hybrid vigor mining is limited in self-pollinated crops such as chickpea, because the lack of an appropriate method for producing hybrid seed makes commercial hybrid production impractical. As a result, heterosis may not be economically valuable in this crop at this time. Though it does show the genetic potential of the parental combination, there may be a possible way to preserve heterosis among pure lines by fixing the interacting alleles if it is a product of epistatic gene effects. (Arunachalam *et al* 1984). Transgressive segregation is feasible.

Three different forms of heterosis were estimated in this study: average heterosis, heterobeltiosis, and relative heterosis. Although heterosis over mid-parental value has little practical significance, it has attracted scholarly interest. Another helpful concept is heterobeltiosis, or heterosis over better parent, which provides information about over dominance. These might be directly for commercial purposes in cross-pollinated crops, but amongst self-pollinated, they could be for transgressive segregant selection provided their genetic makeup supports it.

In the current study, considerable relative heterosis was noted in every characteristic in almost of crosses. For seed yield plant^{-1} relative heterosis ranged at -29.52 (BG 212 X GNG 469) to 45.07 per cent (SADABAHAR X KPG 59). Among the crosses 12 crosses were exhibited positively significant and 4 crosses showed negatively significant. Among the 21 crosses, the top three crosses were SADABAHAR X KPG 59 (45.07%), SADABAHAR X GNG 469 (44.46 %) and ICC 5434 X PDG 4 (37.32%). Table 5.28 shows the hybrids with desirable significant relative heterosis alongside two or more quantitative characteristics.

Mather (1949) defines heterotic crosses as those that go beyond boundary of their parents. Fonesca & Patterson (1968) developed 'heterobeltiosis' to describe Fl's supremacy over the better parent. The degree of heterobeltiosis in seed yield plant^{-1} ranged from -41.95 (BG 212 X GNG 469) to 43.55 per cent (SADABAHAR X GNG 469). 8 crosses were positively significant & 7 negatively significant; the top three significant crosses were SADABAHAR X GNG 469 (43.55%), SADABAHAR X KPG 59 (42.72 %) and IPC 06-77 X PDG 4 (28.32 %). Table 5.29 shows hybrids with desirable significant heterobeltiosis alongside two or more quantitative characteristics.

Since yield is the outcome of the multiplicative interplay of its multiple constituents, Whitehouse *et al* (1958) argued there might not be a distinct gene system concerning yield. Because of this, yield heterosis can be determined either by multiplying the impacts of partial dominance of component characteristics or by calculating the influence of heterosis on each of the yield components.

Table 5.28: Hybrids possessing desirable relative heterosis with two or more quantitative traits

Hybrids	First blossomin g days	50% blossomin g days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108 X GNG 469	✓	✓		✓			✓	✓	✓		
KWR 108 X KPG 59	✓	✓									✓
KWR 108 X PDG 4	✓	✓									
ICC 5335 X GNG 469	✓	✓		✓							✓
ICC 5335 X KPG 59	✓	✓			✓	✓			✓		
ICC 5335 X PDG 4	✓	✓		✓			✓	✓		✓	
ICC 5434 X GNG 469	✓	✓		✓	✓	✓					
ICC 5434 X KPG 59	✓	✓									✓
ICC 5434 X PDG 4	✓	✓									✓
BG 212 X GNG 469	✓	✓		✓							
BG 212 X KPG 59	✓	✓									✓
BG 212 X PDG 4	✓	✓									
IPC 07-56 X GNG 469	✓	✓				✓					
IPC 07-56 X KPG 59	✓	✓		✓							
IPC 07-56 X PDG 4	✓	✓		✓							✓
IPC 06-77 X GNG 469	✓	✓									✓
IPC 06-77 X KPG 59	✓	✓				✓	✓			✓	
IPC 06-77 X PDG 4	✓	✓		✓			✓	✓			✓
SADABAHAR X GNG 469	✓	✓		✓			✓	✓		✓	✓
SADABAHAR X KPG 59	✓	✓		✓			✓	✓		✓	✓
SADABAHAR X PDG 4	✓	✓									

Table 5.28: Hybrids possessing desirable relative heterosis with two or more quantitative traits

Hybrids	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index	Proline	Ascorbic acid content (mg)	Pollen viability	Flower drop (%)	Seed yield plant^{-1}
KWR 108 X GNG 469	✓			✓		✓	✓			✓	✓
KWR 108 X KPG 59	✓	✓		✓		✓					✓
KWR 108 X PDG 4				✓		✓	✓				
ICC 5335 X GNG 469	✓			✓	✓	✓	✓				✓
ICC 5335 X KPG 59					✓	✓	✓			✓	
ICC 5335 X PDG 4	✓	✓		✓	✓	✓	✓			✓	✓
ICC 5434 X GNG 469	✓		✓	✓	✓	✓			✓		
ICC 5434 X KPG 59	✓			✓		✓		✓	✓		✓
ICC 5434 X PDG 4	✓	✓			✓	✓				✓	✓
BG 212 X GNG 469					✓	✓	✓			✓	
BG 212 X KPG 59	✓					✓					✓
BG 212 X PDG 4							✓			✓	
IPC 07-56 X GNG 469	✓		✓		✓	✓			✓		
IPC 07-56 X KPG 59					✓	✓	✓	✓			
IPC 07-56 X PDG 4	✓			✓				✓		✓	✓
IPC 06-77 X GNG 469	✓			✓		✓	✓			✓	✓
IPC 06-77 X KPG 59		✓	✓	✓	✓						
IPC 06-77 X PDG 4	✓	✓		✓	✓		✓	✓		✓	✓
SADABAHAR X GNG 469	✓		✓		✓			✓			✓
SADABAHAR X KPG 59	✓			✓	✓			✓		✓	✓
SADABAHAR X PDG 4				✓		✓	✓		✓		

Table 5.29: Hybrids possessing desirable heterobeltiosis with two or more quantitative traits

Hybrids	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108 X GNG 469	✓	✓					✓	✓	✓		
KWR 108 X KPG 59	✓	✓							✓		✓
KWR 108 X PDG 4	✓	✓									
ICC 5335 X GNG 469	✓	✓		✓							
ICC 5335 X KPG 59	✓	✓							✓		
ICC 5335 X PDG 4	✓	✓	✓	✓			✓	✓			
ICC 5434 X GNG 469	✓	✓	✓		✓	✓					
ICC 5434 X KPG 59	✓	✓									✓
ICC 5434 X PDG 4	✓	✓									✓
BG 212 X GNG 469	✓	✓	✓								
BG 212 X KPG 59	✓	✓									
BG 212 X PDG 4	✓	✓									
IPC 07-56 X GNG 469	✓	✓									
IPC 07-56 X KPG 59	✓	✓									
IPC 07-56 X PDG 4	✓	✓									✓
IPC 06-77 X GNG 469	✓	✓									✓
IPC 06-77 X KPG 59	✓	✓				✓					
IPC 06-77 X PDG 4	✓	✓	✓	✓			✓	✓			✓
SADABAHAR X GNG 469	✓	✓		✓							✓
SADABAHAR X KPG 59	✓	✓					✓				✓
SADABAHAR X PDG 4	✓	✓									

Table 5.29: Hybrids possessing desirable heterobeltiosis with two or more quantitative traits

Hybrids	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
KWR 108 X GNG 469						✓				✓	
KWR 108 X KPG 59				✓		✓					
KWR 108 X PDG 4				✓		✓	✓				
ICC 5335 X GNG 469					✓	✓	✓				
ICC 5335 X KPG 59					✓	✓				✓	
ICC 5335 X PDG 4				✓	✓	✓	✓			✓	✓
ICC 5434 X GNG 469			✓	✓	✓	✓					
ICC 5434 X KPG 59				✓		✓		✓	✓		✓
ICC 5434 X PDG 4					✓	✓				✓	✓
BG 212 X GNG 469					✓	✓	✓			✓	
BG 212 X KPG 59						✓					
BG 212 X PDG 4						✓	✓			✓	
IPC 07-56 X GNG 469			✓		✓	✓					
IPC 07-56 X KPG 59					✓	✓					
IPC 07-56 X PDG 4	✓			✓	✓	✓		✓		✓	✓
IPC 06-77 X GNG 469	✓					✓	✓			✓	✓
IPC 06-77 X KPG 59			✓	✓	✓	✓					
IPC 06-77 X PDG 4	✓						✓			✓	✓
SADABAHAR X GNG 469	✓		✓		✓	✓		✓			✓
SADABAHAR X KPG 59	✓			✓	✓	✓		✓		✓	✓
SADABAHAR X PDG 4				✓	✓	✓	✓		✓	✓	

Table 5.30: Hybrids possessing desirable standard heterosis with two or more quantitative traits

Hybrids	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108 X GNG 469	✓	✓	✓		✓		✓	✓	✓		
KWR 108 X KPG 59	✓	✓			✓						✓
KWR 108 X PDG 4	✓	✓	✓								✓
ICC 5335 X GNG 469	✓	✓	✓	✓							
ICC 5335 X KPG 59	✓	✓	✓								✓
ICC 5335 X PDG 4	✓	✓	✓	✓			✓	✓	✓		✓
ICC 5434 X GNG 469	✓	✓	✓		✓	✓					
ICC 5434 X KPG 59	✓	✓	✓		✓						✓
ICC 5434 X PDG 4	✓	✓			✓						✓
BG 212 X GNG 469	✓	✓	✓								✓
BG 212 X KPG 59	✓	✓									
BG 212 X PDG 4	✓	✓			✓	✓					✓
IPC 07-56 X GNG 469	✓	✓	✓								
IPC 07-56 X KPG 59	✓	✓					✓	✓	✓	✓	✓
IPC 07-56 X PDG 4	✓	✓			✓						✓
IPC 06-77 X GNG 469	✓	✓	✓								✓
IPC 06-77 X KPG 59	✓	✓				✓					✓
IPC 06-77 X PDG 4	✓	✓	✓		✓		✓	✓	✓		✓
SADABAHAR X GNG 469	✓	✓		✓	✓						✓
SADABAHAR X KPG 59	✓	✓	✓	✓	✓		✓				✓
SADABAHAR X PDG 4	✓	✓			✓					✓	✓

Table 5.30: Hybrids possessing desirable standard heterosis with two or more quantitative traits

Hybrids	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
KWR 108 X GNG 469						✓	✓	✓		✓	
KWR 108 X KPG 59				✓		✓	✓	✓		✓	
KWR 108 X PDG 4		✓	✓	✓		✓	✓	✓			✓
ICC 5335 X GNG 469					✓	✓	✓				✓
ICC 5335 X KPG 59		✓			✓	✓	✓			✓	✓
ICC 5335 X PDG 4			✓	✓	✓	✓				✓	✓
ICC 5434 X GNG 469		✓	✓	✓	✓	✓	✓				
ICC 5434 X KPG 59				✓		✓	✓	✓	✓		✓
ICC 5434 X PDG 4			✓	✓	✓	✓	✓	✓		✓	✓
BG 212 X GNG 469	✓	✓	✓		✓	✓		✓	✓	✓	✓
BG 212 X KPG 59					✓	✓	✓	✓			
BG 212 X PDG 4	✓		✓			✓	✓	✓		✓	✓
IPC 07-56 X GNG 469			✓		✓	✓	✓				
IPC 07-56 X KPG 59	✓	✓			✓	✓	✓				✓
IPC 07-56 X PDG 4	✓	✓	✓	✓	✓	✓		✓		✓	✓
IPC 06-77 X GNG 469	✓					✓	✓	✓		✓	✓
IPC 06-77 X KPG 59			✓	✓	✓	✓	✓	✓			✓
IPC 06-77 X PDG 4	✓		✓		✓		✓			✓	✓
SADABAHAR X GNG 469	✓	✓	✓	✓	✓	✓	✓	✓			✓
SADABAHAR X KPG 59	✓	✓		✓	✓	✓	✓	✓		✓	✓
SADABAHAR X PDG 4	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓

5.7 COMBINIG ABILITY ANALYSIS

Recombination breeding has been widely employed in self-pollinated crops such as chickpea to generate variability repositories for exploitation in breeding programs. Plant breeders typically employ combining ability when assessing potential of genes and examine their influences involved in specific traits. Because chickpeas are self-pollinated, gca impacts are of greater significance since they associated with additive, add x add interaction. Specific combining ability effects, on the contrary, serve a purpose particularly when basing add x add impacts, *i.e.,* crosses that exhibit SCA effects experiencing performance & involving a minimum of one general good combiner parent, such might generate desirable transgressive segregants.

Both GCA & SCA was significant for every trait, (Table 5.31) shows that the parents IPC 06-77, ICC 5335, and PDG 4 were goof general combiners for seed yield plant^{-1}. As previously mentioned, additive or additive x additive interactions that is, genetic components of variation that can be fixed are the main cause of major GCA impacts. This result was found in Malge *et al*., (2021), Sasane *et al* (2021) and Kumar *et al*., (2019).

Crosses KWR 108 X KPG 59, ICC 5335 X PDG 4, ICC 5434 X PDG 4, BG 212 X KPG 59, IPC 07-56 X PDG 4, IPC 06-77 X PDG 4, SADABAHAR X GNG 469, and SADABAHAR X KPG 59 had significant and beneficial combining ability effects concerning seed yield plant^{-1}. Every single one of them had significant SCA impacts for one/more component traits, and they all had heterobeltiosis for yield & component attributes except for the harvest index (%), which was presented in table 5.32.

When it is possible to produce commercial hybrid seed, significant SCA impacts can be induced by intra- or interallelic interaction and applied to both self & cross-pollinated species. The high SCA, however, might be the result dominant allele accumulation inherited parents if its parents are skilled general combiners. In such a scenario, selecting transgressive segregants in segregating generations can readily take advantage of the trait in self-pollinated crops. These hybrids should be used for heterosis breeding. Parents with strong GCA effects (presence of additive gene action) and hybrids with non-significant SCA effects (lack of dominance) are effective in identifying superior segregants. Pedigree technique for selecting in recombination breeding is advised for hybrids with non-substantial SCA effects and parents with significant GCA effects. This was confirmed by the findings of Halladakeri *et al* (2022) and Kumar *et al* (2019).

Table 5.31: Differentiation of parents respective to general combining ability (GCA) on multiple characteristics in chickpea

Parents	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108	P	P	P	A	P	P	A	A	G	P	A
ICC 5335	A	P	A	A	G	A	P	P	G	A	G
ICC 5434	P	A	P	P	A	P	P	P	A	P	A
BG 212	G	G	G	A	G	A	A	P	P	P	P
IPC 07-56	P	P	P	P	A	G	P	P	P	P	P
IPC 06-77	A	A	A	P	A	A	A	A	P	G	G
SADABAHAR	A	G	A	G	P	P	G	G	P	A	P
GNG 469	P	P	P	P	A	A	A	A	A	P	P
KPG 59	P	P	P	P	A	A	P	P	P	P	P
PDG 4	G	G	G	A	P	P	G	A	A	G	G

Parents	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
KWR 108	A	A	P	G	P	G	G	A	P	P	A
ICC 5335	A	A	A	G	G	G	G	P	P	A	G
ICC 5434	P	P	G	A	A	G	P	A	G	P	P
BG 212	P	P	P	P	P	P	G	P	P	P	P
IPC 07-56	P	P	A	P	A	P	P	A	A	P	P
IPC 06-77	A	G	G	P	P	P	G	P	P	G	G
SADABAHAR	G	P	G	A	A	P	P	G	A	A	P
GNG 469	A	P	A	P	G	G	G	P	A	P	A
KPG 59	P	P	G	A	P	P	P	G	A	P	P
PDG 4	A	A	P	P	P	A	G	P	P	G	G

Table 5.32: Hybrids having desirable significant heterobeltosis along with the SCA and GCA performance

Hybrids	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108 X GNG 469											
KWR 108 X KPG 59	✓(G)	✓(G)	✓(G)								✓(G)
KWR 108 X PDG 4					✓(G)						
ICC 5335 X GNG 469											✓(G)
ICC 5335 X KPG 59					✓(G)				✓(G)		
ICC 5335 X PDG 4	✓(G)	✓(G)	✓(G)				✓(G)	✓(G)		✓(G)	
ICC 5434 X GNG 469	✓(G)	✓(G)	✓(G)	✓(G)	✓(G)	✓(G)					
ICC 5434 X KPG 59											
ICC 5434 X PDG 4									✓(G)		✓(G)
BG 212 X GNG 469	✓(G)	✓(G)	✓(G)								
BG 212 X KPG 59	✓(G)	✓(G)									✓(G)
BG 212 X PDG 4											
IPC 07-56 X GNG 469											
IPC 07-56 X KPG 59				✓(G)							
IPC 07-56 X PDG 4											✓(G)
IPC 06-77 X GNG 469											✓(G)
IPC 06-77 X KPG 59			✓(G)		✓(G)					✓(G)	
IPC 06-77 X PDG 4	✓(G)	✓(G)		✓(G)							✓(G)
SADABAHAR X GNG 469	✓(G)	✓(G)	✓(G)								✓(G)
SADABAHAR X KPG 59							✓(G)				✓(G)
SADABAHAR X PDG 4											

Table 5.32: Hybrids having desirable significant heterobeltosis along with the SCA and GCA performance

Hybrids	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
KWR 108 X GNG 469										✓(G)	
KWR 108 X KPG 59	✓(G)			✓(G)		✓(G)					✓(G)
KWR 108 X PDG 4							✓(G)				
ICC 5335 X GNG 469							✓(G)				
ICC 5335 X KPG 59					✓(G)	✓(G)	✓(G)			✓(G)	
ICC 5335 X PDG 4				✓(G)	✓(G)	✓(G)					✓(G)
ICC 5434 X GNG 469			✓(G)	✓(G)							
ICC 5434 X KPG 59				✓(G)			✓(G)	✓(G)	✓(G)		
ICC 5434 X PDG 4					✓(G)	✓(G)				✓(G)	✓(G)
BG 212 X GNG 469					✓(G)						
BG 212 X KPG 59	✓(G)					✓(G)			✓(G)		✓(G)
BG 212 X PDG 4			✓(G)				✓(G)			(G)	
IPC 07-56 X GNG 469			✓(G)			✓(G)					
IPC 07-56 X KPG 59							✓(G)				
IPC 07-56 X PDG 4	✓(G)			✓(G)						✓(G)	✓(G)
IPC 06-77 X GNG 469				✓(G)		✓(G)					
IPC 06-77 X KPG 59			✓(G)		✓(G)						
IPC 06-77 X PDG 4	✓(G)						✓(G)	✓(G)		✓(G)	✓(G)
SADABAHAR X GNG 469	✓(G)		✓(G)		✓(G)			✓(G)			✓(G)
SADABAHAR X KPG 59	✓(G)									✓(G)	✓(G)
SADABAHAR X PDG 4						✓(G)	✓(G)				

5.8 Estimation of Gene Action

The variance resulting from GCA is smaller compared to that of SCA, as demonstrated by the following table, therefore the GCA-SCA variance ratio is expected to be below one. As a result, each trait within study proved non-additive form of gene action.

Many genes regulate the yield trait, which manifests itself in a complicated way. Breeders need to comprehend how genes function in order to choose the best breeding strategies and eventually increase the productivity of the crop and traits that contribute to yield. There are three kinds of gene actions that influence trait expression: additive, dominance, and epistasis. Improvement of crops and selection techniques are advised when additive gene action is controlling. Conversely, allelic & non-allelic interactions between genes are linked to dominance & epistasis gene effects. Creating composite varieties or taking advantage of heterosis can be helpful in certain circumstances. Therefore, while choosing suitable breeding techniques, breeders can benefit much from the understanding of gene action.

5.33: Contributions of lines, testers, & Line x Tester for gene action

No.	Trait	Gene action	Reference
1.	**First blossoming days**	**Non-Additive**	Jha *et al* (2019)
2.	**50% blossoming days**	**Non-Additive**	Gaur *et al* (2020), Kumar *et al* (2019)
3.	**Harvest maturity days**	**Non-Additive**	Kumar *et al* (2019)
4.	**Plant height**	**Non-Additive**	Halladakeri *et al* (2022)
5.	**Primary offshoots plant^{-1}**	**Non-Additive**	Halladakeri *et al* (2022)
6.	**Secondary offshoots plant^{-1}**	**Non-Additive**	Halladakeri *et al* (2022)
7.	**Capsules plant^{-1}**	**Non-Additive**	-
8.	**Full capsules plant^{-1}**	**Non-Additive**	-
9.	**Empty capsules plant^{-1}**	**Non-Additive**	-
10.	**Seeds capsule^{-1}**	**Non-Additive**	Kumar *et al* (2019)
11.	**Test weight (gm)**	**Non-Additive**	-
12.	**Biological yield**	**Non-Additive**	Kumar *et al* (2019)
13.	**Harvest index (%)**	**Non-Additive**	Kumar *et al* (2019)
14.	**Total chlorophyll content (mg/ml)**	**Non-Additive**	Jagadish and Jayalakshmi (2014)
15.	**Relative leaf water content (%)**	**Non-Additive**	Jagadish and Jayalakshmi (2014)
16.	**Lipid Peroxidation (nmol/ml)**	**Non-Additive**	-
17.	**Electrolyte leakage index (%)**	**Non-Additive**	-
18.	**Proline content (mg/gm)**	**Non-Additive**	-
19.	**Ascorbic acid content (mg)**	**Non-Additive**	-
20.	**Pollen viability (%)**	**Non-Additive**	-
21.	**Flower drop (%)**	**Non-Additive**	-
22.	**Seed yield plant^{-1}**	**Non-Additive**	Kumar *et al* (2019)

VI. SUMMARY, CONCLUSION AND FUTURE THRUST

The current study titled "Heterosis and stability studies in *Cicer arietinum* [L.] against chilling and heat stress: a morphological, phenological and biochemical assessment" was carried out during the Rabi 2020-21 in three dates of sowing. 25 genotypes in randomized block design were sown in two replicates. Out of which 10 were selected basing seed yield and stress related characters and crossed in L x T fashion during rabi 2021-22 and were assessed with the parents and check in rabi 2022-23.

Observations were recorded on first blossoming days, 50% blossoming days, harvest maturity days, plant height, primary offshoots plant^{-1}, secondary offshoots plant^{-1}, capsules plant^{-1}, full capsules plant^{-1}, empty capsules plant^{-1}, seeds capsule^{-1}, test weight (gm), biological yield plant^{-1}, harvest index (%), Total chlorophyll content (mg/ml), Relative leaf water content (%), Lipid Peroxidation (nmol/ml), electrolyte leakage index, Proline content (mg/gm), Ascorbic acid content (mg), pollen viability, Flower drop (%), seed yield plant^{-1} in every environment. To evaluate, genetic variability, correlation, path, stability, heterosis, and combining ability analyses were performed on the collected data.

6.1 SUMMARY

The genetic variability estimates were observed for twenty-two traits among 25 genotypes. ANOVA illustrated genotyped MSS recorded significance for all the studied characters in every environment. Pooled environment recorded non-significant values for characters harvest index (%), Total chlorophyll content (mg/ml), electrolyte leakage index, Ascorbic acid content (mg) and Flower drop (%). Empty capsules plant^{-1} showed significance for replication in EN-2.

For every character across every scenario, the phenotypic coefficient of variability estimates was greater compared to genotypic estimates. Across all habitats, the highest estimations of them both were found for the characteristic's proline and seed yield plant^{-1}.

For plant height, full capsules plant^{-1}, Lipid Peroxidation (nmol/ml), proline, and seed yield plant-1 in EN-1, EN-2, EN-3, and pooled analysis, combo of high heritability & genetic advance was recorded, whereas, EN-1, EN-2 and EN-3 for test weight (gm), harvest index (%), total chlorophyll content (mg/ml), relative leaf water content (%), electrolyte leakage index (%) and flower drop (%). Empty capsules plant^{-1} in EN-1, EN-2 and pooled, seeds capsule^{-1} in EN-1 and EN-3, biological yield plant^{-1} among EN-1 and pooled, number of primary and secondary branches plant^{-1} in EN-1, ascorbic acid content (mg) in EN-3 and capsules plant^{-1} in pooled.

Pollen viability (%) in EN-1, EN-2, EN-3 & pooled had high heritability alongside moderate GA, as did the capsules plant^{-1} in EN-1, EN-2 and EN-3, the primary offshoots plant^{-1} in EN-2, EN-3 and pooled, the secondary offshoots plant^{-1} and seeds capsule^{-1} in EN-2 and pooled, the ascorbic acid content (mg) in EN-1, the empty capsules plant^{-1}, biological yield plant^{-1} in EN-2, harvest maturity days, test weight (gm), total chlorophyll and relative leaf water content (%)in pooled analysis. This could be linked to additive gene activity, this determines how they manifest, making phenotypic selection for their amenability feasible.

The key traits contributing towards yield noted among chickpea entries based on correlation and path studies are pollen viability, harvest index (%), biological yield plant^{-1}, primary offshoots plant^{-1}, relative leaf water content (%), capsules plant^{-1}, proline content (mg/gm), flower drop (%), secondary offshoots plant^{-1}, test weight (gm), Total chlorophyll content (mg/ml), empty capsules plant^{-1} and filled pods plant^{-1}. As a result, directional selection based on these qualities will be particularly efficient for increasing seed yields.

The phenotypic stability ANOVA expressed MSS attributable to genotypes remained significant for every trait. Genotype x environment (linear) interaction and pooled deviation proved to have been significant among all variables, indicating how genotypes respond differently in different environments.

The genotypes KWR-108, PBG-7, IPC-06-77, ICC-5434, IPC-07-56, SADABAHAR and JG-14 are stable exhibiting steady performance for seed yield and related characters. Genotypes K-850, BPM and IPC 05-28 demonstrated stability, but not ideal for yield contributing variables whereas, Genotypes ICC-5335 and BG-212 displayed below average stability suggesting that thy were adapted to input rich environment.

Significant variations in genotypes for each of the twenty-two characters were found by the experimental design ANOVA, portraying variability amongst every trait in question. The position of genotypic variance in parents and hybrids was further investigated, and it was shown that all features with secondary offshoots plant-1 among parents had considerable MSS. Likewise, MSS concerning parent v/s hybrids remained significant for every character save seeds capsule^{-1}, harvest index (%) & ascorbic acid content (mg).

Basing per se performance of seed yield plant^{-1}, top five promising parents were BG 212, KWR 108, ICC 5335, IPC 07-56, IPC 06-77, and top five promising hybrids based on the same were IPC 06-77 X PDG 4, ICC 5335 X PDG 4, IPC 06-77 X GNG 469, SADABAHAR X GNG 469, SADABAHAR X KPG 59. Based on overall mean values, IPC 06-77 X PDG 4 cross showed best performance for seed yield plant^{-1}.

In current investigation, significant relative heterosis was visible in all the traits save harvest maturity days for most crosses. The significant negative heterosis was for 4 crosses & positive heterosis was significant for 12 crosses among the 21 crosses. Among the 21 crosses, the top three crosses which are desirable for these particular trait, SADABAHAR X KPG 59, SADABAHAR X GNG 469 and ICC 5434 X PDG 4. 12 hybrids having desirable significant relative heterosis along with two and more than two quantitative traits.

Significant heterobeltiosis was expressed every trait save seeds capsule^{-1} & harvest index (%) for almost of crosses. For seed yield plant^{-1}, 8 crosses recorded positive significance and 7 for negative significance. Among 21 cross combinations, top three significant crosses were SADABAHAR X GNG 469, SADABAHAR X KPG 59 and IPC 06-77 X PDG 4. For multiple characters, significant Heterobeltiosis was expressed for 8 hybrids.

Significant standard heterosis was recorded for every trait for almost of crosses. For seed yield plant^{-1}, 7 crosses recorded positive significance and 8 for negative significance. Among 21 cross combinations, top three significant crosses were IPC 06-77 X PDG 4, ICC 5335 X PDG 4 and SADABAHAR X GNG 469. For multiple characters, significant standard heterosis was expressed for 7 hybrids.

GCA alongside SCA was significant for every studied. IPC 06-77, ICC 5335 and PDG 4 for seed yield plant^{-1} were proved good combiners (general). Pertaining yield component traits, those parents also proved to be the same.

SCA impacts concerning seed yield plant^{-1} recorded positive significance for 8 crosses *viz.,* BG 212 X KPG 59, IPC 07-56 X PDG 4, SADABAHAR X KPG 59, KWR 108 X KPG 59, ICC 5335 X GNG 469, ICC 5434 X PDG 4, IPC 06-77 X PDG 4, SADABAHAR X GNG 469 depicted high heterobeltiosis along with one general good combiner parent at least and higher effects of SCA for seed yield plant^{-1}. All the characters in the study recorded non-additive gene action in the study

CONCLUSIONS

1. All attributes exhibited sufficient variability in all analyses, suggesting that using diverse parents in the process of hybridization can increase the degree of variance.
2. Most important attributes *i.e.,* plant height, no. of filled pods plant^{-1}, lipid peroxidation (nmol/ml), proline content, seed yield plant^{-1}, test weight (gm), harvest index (%), total chlorophyll content (mg/ml), relative leaf water content (%), electrolyte leakage index (%) and flower drop (%) may be governed by additive gene action in all environments as these traits expressed high or moderate heritability and genetic advance.
3. Pollen viability, harvest index (%), biological yield plant^{-1}, no. of primary branches plant^{-1}, Relative leaf water content (%) and no. of pods plant^{-1}, proline content, flower drop (%), no. of secondary branches plant^{-1}, test weight (gm) and total chlorophyll content (mg/ml), no. of empty pods plant^{-1} and no. of filled pods plant^{-1} will be very effective for improvement of seed yield.
4. Stability analysis revealed that genotypes KWR-108, PBG-7, IPC-06-77, ICC-5434, IPC-07-56, SADABAHAR and JG-14 proved to be stable exhibiting steady performance in yield context.
5. Based on screening against both the stress conditions and stability, the characters plant height, no. of filled pods plant^{-1}, Lipid Peroxidation (nmol/ml), proline content, Harvest index (%), Pollen viability, biological yield per plant, No. of filled pods per plant were contributing to seed yield plant^{-1} based on the analysis and the genotypes KWR-108, PBG-7, IPC-06-77, ICC-5434, IPC-07-56, SADABAHAR and JG-14 were stable yielders amongst the twenty-five under study under all the environments. Selection for crossing programme was based on these characters that contributed to yield during the stress conditions.

6. Parent IPC 06-77, ICC 5335 and PDG 4 were general good combiners for yield and component traits could be employed in the crossing plan to gather desired features in a limited number of lines or genotypes, which might prove extremely valuable for heterosis breeding in addition to the creation of inbred & composites.

7. Basing average and heterosis (average heterosis, heterobeltoisis & economic heterosis) combinations IPC 06-77 X PDG 4, ICC 5335 X PDG 4, IPC 06-77 X GNG 469, SADABAHAR X GNG 469, IPC 07-56 X PDG 4, SADABAHAR X KPG 59 and ICC 5434 X PDG 4 resulted high seed yield per plant plus other related characters. Hence, these hybrid combinations could be commercially exploited.

8. Based on the findings of the entire study, the cross between IPC 06-77 X PDG 4, ICC 5335 X PDG 4 & IPC 07-56 X PDG 4 were found to have higher mean performance, combining ability estimates better, and have a higher percentage of standard heterosis for yield related characters. As a result, these hybrids can be used for commercial purposes.

9. Moreover, the evidence of non-additive gene action detected in this research supports the use of breeding approaches like recurrent selection, diallel selective mating, and biparental mating instead of pedigree or backcross traditional techniques, that might disregard unfixable aspects of genetic variances for yield & their constituents.

SUGGESSIONS FOR FUTURE WORK

1. High genetic variability traits may be enhanced directly by selecting or by incorporating these traits into hybridization systems which compensate for variance, according to studies on variability.

2. Characters that have a positive significant relationship with seed yield were identified by the correlation studies. These characters should be prioritized in selection programs aiming at yield enhancement.

3. The current study has yielded important insights into the amount of heterosis, the impacts of genes and combining ability, & the efficacy of parents & F_1 in relation to seed yield plant^{-1} & its constituents. Without going into detail about the study's findings, some recommendations for an additional effort to improve chickpeas

might be made based on the resources used.

4. The complex characteristic of seed yield plant^{-1} is reliant either on direct or indirect contributions of an extensive number of constituent traits. Character development by selecting in segregating generations would be supported in populations where the bulk of genetic diversity is additive.

5. The hybridization would prove increasingly successful and breeding techniques such as Line x Tester mating & selective breeding might be recommended if the non-additive impact factor were significant.

6. Breeders may employ hybrids that performed well in terms of quantitative traits as advanced lines of breeding in their breeding initiatives to create new varieties. These hybrids can also be used for studies aimed at further segregating generations.

7. The overabundance of non-additive genetic variations was noticed responsible for inheritance of every trait in the combining ability study, both for significant and degree of genetic variance components. By heterosis breeding, the benefit of the dominating gene effect for the majority of characters may be obtained.

8. In the future, single cross hybrid should be quickly screened via confirmation of hybrid purity tests. The desirable hybrids BG 212 X KPG 59, IPC 07-56 X PDG 4, SADABAHAR X KPG 59, KWR 108 X KPG 59, ICC 5335 X GNG 469, ICC 5434 X PDG 4, IPC 06-77 X PDG 4, SADABAHAR X GNG 469 must be considered for specific trait associated varietal development.

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APPENDICES I

Mean values for various traits

MEAN EN-1	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR-108	87.00	95.00	164.00	43.56	4.10	7.20	63.60	54.80	8.80	1.90	11.44
JG 14	88.50	94.50	167.00	33.02	3.80	6.50	59.90	49.80	10.10	1.50	10.65
ICC-3020	93.50	100.00	172.50	33.34	3.70	7.20	57.40	48.90	8.50	1.70	11.40
IPC-06-77	88.00	95.00	169.50	41.50	4.30	7.40	63.50	54.90	8.60	2.00	11.92
KPG-59	88.00	95.50	170.00	33.98	3.30	6.10	63.80	52.50	11.30	2.70	10.17
K-850	88.50	94.50	168.50	35.34	4.30	6.40	49.10	37.20	11.90	1.70	11.25
ICC-5335	83.00	95.00	163.00	39.39	4.10	6.50	62.80	57.60	5.20	1.40	14.10
IPC-97-67	89.50	95.00	167.50	36.79	3.40	5.90	56.30	49.60	6.70	1.60	11.89
ICC 244-263	89.50	97.50	168.00	35.31	3.90	5.90	54.50	42.40	12.10	1.80	9.70
BG-212	88.00	95.00	159.50	37.37	4.60	7.10	58.70	52.40	6.30	2.30	14.00
ICC-3525	93.00	99.50	171.50	43.10	3.90	6.50	56.80	50.30	6.50	1.90	9.52
ICC-5434	87.00	95.00	162.00	46.54	4.70	7.20	64.60	56.90	7.70	2.60	9.00
ICC-5439	88.50	97.50	166.00	40.33	3.70	6.40	59.80	52.90	6.90	1.40	11.10
BPM	89.50	95.00	165.00	34.39	3.30	5.80	49.60	40.00	9.60	1.50	10.72
IPC-07-56	92.50	99.50	173.00	42.69	4.50	7.10	66.40	57.50	8.90	2.10	12.02
RSG 931	87.50	94.50	164.50	35.45	3.90	6.20	54.20	41.10	13.10	1.50	10.20
PDG-4	86.50	93.50	161.00	44.19	3.30	6.20	62.90	55.30	7.60	1.90	11.50
IPC 05-28	90.00	98.50	171.00	31.03	3.10	5.10	50.80	42.20	8.60	1.30	9.05
PUSA 3043	90.50	97.50	171.50	31.35	3.30	5.40	52.00	40.90	11.10	1.30	9.20
RSG-888	88.50	96.00	163.00	45.78	4.30	6.70	61.80	53.30	8.50	2.30	8.00
GNG 469	86.50	93.50	163.50	40.85	3.60	7.10	66.80	55.90	10.90	1.40	14.60
RSG 945	91.00	97.50	170.50	31.88	3.30	5.30	51.70	40.30	11.40	1.30	8.90
SADABAHAR	87.00	94.50	167.00	41.60	4.50	7.30	67.10	59.20	7.90	2.00	9.50
PBG-5	84.50	92.50	164.50	40.80	4.10	7.10	61.30	50.70	10.60	2.70	11.00
PBG-7	90.50	97.00	169.50	43.32	3.90	6.90	61.90	53.60	8.30	2.10	11.10
Mean	**88.66**	**95.94**	**166.92**	**38.52**	**3.88**	**6.50**	**59.09**	**50.01**	**9.08**	**1.84**	**10.88**

MEAN EN-1	Biological yield plant-1	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant-1
KWR-108	18.73	51.35	2.04	58.46	19.93	40.95	1.20	30.00	82.40	25.26	9.61
JG 14	20.25	42.76	1.52	49.00	24.69	48.51	1.08	35.00	74.40	27.39	8.65
ICC-3020	21.65	41.58	1.60	47.65	21.61	61.26	0.85	31.94	73.00	30.70	9.00
IPC-06-77	18.58	52.70	1.94	53.28	21.22	43.39	1.09	31.15	79.20	25.06	9.74
KPG-59	20.10	41.84	2.52	48.99	13.79	25.90	2.18	28.85	70.20	23.13	8.41
K-850	20.61	39.46	1.71	49.68	19.60	61.02	1.11	31.94	78.20	36.28	8.12
ICC-5335	20.69	53.95	1.99	50.65	20.58	46.65	1.30	29.24	81.00	22.89	11.15
IPC-97-67	20.65	40.47	1.76	33.36	23.64	48.61	1.11	30.00	75.20	26.94	8.34
ICC 244-263	18.83	36.03	1.76	50.12	24.31	54.50	1.03	28.46	72.20	31.68	6.77
BG-212	25.33	55.41	1.84	51.50	19.18	45.84	1.71	30.00	83.30	30.49	14.00
ICC-3525	22.60	36.29	1.60	34.43	18.12	51.23	1.06	37.69	71.30	31.74	8.20
ICC-5434	19.45	50.55	1.98	58.52	20.32	46.54	1.51	29.61	83.70	26.48	9.83
ICC-5439	20.88	43.12	1.79	36.64	22.89	46.58	1.16	29.23	73.50	28.29	8.99
BPM	19.54	42.18	1.64	31.32	24.74	54.84	1.08	30.39	71.30	36.34	8.24
IPC-07-56	20.61	50.99	1.84	50.61	21.35	42.39	1.22	31.94	82.60	23.87	10.51
RSG 931	17.66	38.67	1.59	38.53	17.94	54.67	0.78	34.23	76.00	32.66	6.83
PDG-4	17.33	45.40	2.09	49.78	14.40	27.37	2.61	33.47	72.20	22.53	7.87
IPC 05-28	17.67	35.04	1.43	32.48	18.36	48.50	1.11	28.47	68.90	34.66	6.19
PUSA 3043	16.89	34.84	1.20	35.71	20.06	46.77	0.94	32.48	74.20	34.22	5.88
RSG-888	20.37	31.97	1.18	32.59	23.21	48.33	0.93	34.79	74.10	28.89	6.52
GNG 469	18.82	41.53	2.23	49.61	13.28	28.87	2.46	36.54	69.70	21.72	7.79
RSG 945	15.40	37.52	1.28	35.65	18.01	45.25	0.99	31.15	72.90	34.08	5.81
SADABAHAR	17.45	55.29	1.99	51.44	22.22	42.49	1.26	33.46	82.20	23.67	9.57
PBG-5	20.93	39.67	1.35	35.91	24.90	55.42	0.98	27.70	72.80	29.56	8.31
PBG-7	19.81	43.27	1.83	32.10	21.70	57.54	1.10	28.86	75.00	29.34	8.61
Mean	**19.63**	**43.27**	**1.75**	**43.92**	**20.40**	**46.93**	**1.27**	**31.46**	**75.58**	**28.71**	**8.52**

MEAN EN-2	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR-108	85.00	91.00	164.00	43.48	3.90	6.40	66.50	56.80	9.70	1.90	11.55
JG 14	88.50	93.50	168.00	39.40	3.90	6.60	58.40	46.60	11.80	1.50	9.20
ICC-3020	86.00	93.50	169.50	37.52	3.70	6.30	51.10	40.30	10.80	2.10	11.45
IPC-06-77	87.50	94.50	170.00	43.19	4.30	6.80	65.00	55.70	9.30	2.10	11.30
KPG-59	85.50	92.50	169.00	40.77	3.80	6.40	62.00	49.90	12.10	1.90	10.15
K-850	88.50	96.00	172.00	34.48	3.90	6.90	51.60	40.40	11.20	1.70	11.35
ICC-5335	86.00	94.00	169.50	45.55	3.50	5.90	62.80	53.80	9.00	1.70	14.10
IPC-97-67	88.50	94.00	170.00	38.37	3.40	5.70	63.30	53.00	10.30	1.90	11.90
ICC 244-263	90.00	97.00	174.00	35.35	4.10	6.60	51.20	39.90	11.30	1.60	9.70
BG-212	85.50	93.50	168.00	44.61	3.80	6.70	66.00	54.80	11.20	1.70	10.50
ICC-3525	89.50	96.50	175.50	31.26	3.10	5.20	57.60	47.80	9.80	1.60	9.30
ICC-5434	86.50	92.50	167.00	42.67	3.90	6.70	67.40	57.30	10.10	2.10	9.30
ICC-5439	86.50	93.50	169.50	35.33	3.80	6.50	62.10	49.70	12.40	1.70	11.10
BPM	89.00	96.00	172.00	39.67	3.30	5.60	59.60	47.50	12.10	1.80	10.60
IPC-07-56	87.50	93.50	168.00	40.64	4.40	7.10	62.30	52.50	9.80	1.90	11.90
RSG 931	88.50	95.50	171.50	31.16	3.50	5.70	54.70	42.90	11.80	1.90	9.90
PDG-4	88.50	95.00	172.00	34.38	3.90	6.30	55.20	44.40	10.80	1.70	11.30
IPC 05-28	90.50	97.50	175.00	31.35	3.70	6.00	54.30	44.80	9.50	1.30	9.05
PUSA 3043	91.00	96.50	176.00	30.49	3.10	5.10	52.20	40.60	11.60	1.50	9.15
RSG-888	90.50	98.00	176.50	31.06	3.30	5.40	53.60	42.50	11.10	1.60	8.30
GNG 469	87.50	93.50	169.50	40.09	4.30	6.50	69.40	59.20	10.20	1.70	14.20
RSG 945	90.00	97.50	172.00	30.42	3.30	5.40	52.50	40.50	12.00	1.30	8.90
SADABAHAR	86.50	93.00	167.00	42.25	4.30	6.60	66.90	56.20	10.70	1.90	9.50
PBG-5	89.00	95.50	172.50	32.97	3.60	5.80	60.50	48.00	12.50	1.70	8.20
PBG-7	86.00	93.50	169.50	43.06	4.10	6.40	61.80	50.00	11.80	1.70	10.55
Mean	**87.92**	**94.68**	**170.70**	**37.58**	**3.76**	**6.18**	**59.52**	**48.60**	**10.92**	**1.74**	**10.50**

MEAN EN-2	Biological yield $plant^{-1}$	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield $plant^{-1}$
KWR-108	19.69	52.19	2.08	58.66	21.36	40.70	1.80	31.17	82.70	22.87	10.27
JG 14	18.95	41.91	1.59	49.75	26.37	61.77	1.28	26.16	76.10	29.70	7.95
ICC-3020	18.93	35.94	1.60	50.76	24.26	56.85	1.15	29.62	76.90	31.39	6.80
IPC-06-77	19.42	52.21	2.40	56.52	20.50	43.47	1.70	32.31	85.40	26.18	10.14
KPG-59	19.20	40.71	2.30	53.55	15.23	30.06	2.15	28.46	74.30	20.14	7.82
K-850	18.25	40.39	1.31	45.61	28.75	48.66	1.42	31.93	75.20	34.30	7.36
ICC-5335	22.58	52.92	2.07	50.83	21.23	41.02	1.70	28.47	85.00	25.54	11.95
IPC-97-67	19.92	39.91	1.86	34.78	21.49	55.59	1.39	30.77	73.70	22.93	7.95
ICC 244-263	18.20	36.54	1.70	33.54	24.39	48.66	1.43	34.23	73.70	32.44	6.64
BG-212	25.97	52.38	2.08	50.82	20.74	45.38	1.85	31.16	80.80	27.73	13.60
ICC-3525	19.69	36.23	0.89	38.42	25.34	51.38	0.88	31.16	72.10	31.34	7.14
ICC-5434	21.47	51.01	2.08	51.57	22.54	40.50	1.85	30.39	81.60	25.29	10.95
ICC-5439	19.87	44.18	1.90	36.98	28.94	60.36	1.43	35.77	72.20	35.49	8.79
BPM	18.92	42.83	1.13	31.67	24.13	55.03	1.47	29.61	72.60	32.94	8.12
IPC-07-56	19.69	52.20	1.91	49.58	22.21	40.72	1.83	36.31	75.50	24.87	10.28
RSG 931	18.09	38.19	1.22	36.70	19.67	58.07	1.36	29.40	74.80	31.65	6.93
PDG-4	18.55	41.78	2.00	49.46	15.27	29.97	2.07	31.54	72.50	21.06	7.73
IPC 05-28	17.88	38.51	1.14	33.40	21.51	54.99	0.71	28.85	81.80	31.50	6.90
PUSA 3043	17.04	35.91	1.06	32.55	21.44	48.89	0.72	30.00	71.80	33.66	6.14
RSG-888	17.11	33.53	1.09	35.75	24.43	40.85	0.81	30.77	71.90	32.82	5.74
GNG 469	18.90	41.73	2.23	47.66	14.38	28.72	2.30	31.33	71.10	19.01	7.87
RSG 945	16.07	35.86	1.10	35.63	18.72	57.66	0.83	33.08	71.80	32.90	5.78
SADABAHAR	19.64	50.61	2.15	51.51	21.69	42.69	1.89	34.23	81.40	25.25	9.94
PBG-5	17.17	36.67	1.22	35.40	20.39	55.77	0.91	28.07	72.90	28.11	6.29
PBG-7	19.55	40.68	1.87	48.72	21.39	49.07	1.59	29.23	77.00	29.01	7.95
Mean	**19.23**	**42.60**	**1.68**	**43.99**	**21.85**	**47.47**	**1.46**	**30.96**	**76.19**	**28.32**	**8.28**

MEAN EN-3	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR-108	76.50	82.50	139.50	35.92	3.70	5.50	43.80	32.50	10.40	1.70	10.30
JG 14	79.50	85.00	141.50	27.35	3.20	5.20	40.60	29.70	11.80	1.60	9.90
ICC-3020	81.00	86.50	143.50	23.31	3.30	5.30	38.10	21.70	16.40	1.70	10.50
IPC-06-77	78.00	86.50	142.50	37.36	3.40	5.50	44.10	33.00	11.10	1.50	10.40
KPG-59	80.50	86.50	144.50	27.93	3.30	5.30	34.00	22.90	11.10	1.70	9.20
K-850	82.00	87.50	145.00	22.74	3.00	5.20	38.50	23.80	14.70	1.50	10.35
ICC-5335	78.50	85.50	146.50	30.69	3.10	5.10	43.70	32.90	10.80	1.90	13.05
IPC-97-67	82.50	87.50	143.50	27.13	3.50	5.50	40.70	27.60	13.10	1.50	11.10
ICC 244-263	83.50	88.50	147.50	21.98	3.50	5.50	40.90	26.40	14.50	1.60	8.85
BG-212	81.50	87.50	143.50	31.59	3.50	5.50	44.50	34.80	9.70	1.60	11.05
ICC-3525	83.00	89.50	147.50	24.80	3.30	5.40	38.60	24.10	14.50	1.90	8.50
ICC-5434	83.50	87.50	142.50	29.89	3.50	5.50	43.80	32.30	11.50	1.80	8.20
ICC-5439	82.00	86.50	142.50	22.87	3.50	5.50	40.40	28.00	12.40	1.30	10.15
BPM	82.00	88.50	145.50	16.44	3.30	5.30	38.70	26.30	12.40	1.60	9.65
IPC-07-56	81.00	87.50	141.50	32.99	3.50	5.50	44.90	34.10	10.80	2.50	11.05
RSG 931	83.50	89.50	146.50	16.00	3.20	5.10	37.20	24.50	12.70	1.80	9.20
PDG-4	79.50	86.50	145.50	28.65	3.30	5.30	38.20	26.90	11.30	1.30	10.45
IPC 05-28	81.50	87.50	147.00	33.90	2.70	4.70	33.90	22.50	11.40	1.70	8.25
PUSA 3043	85.50	90.00	147.00	31.61	3.30	5.30	35.50	24.40	11.10	1.70	15.20
RSG-888	83.50	89.50	146.00	17.34	3.10	5.10	32.10	19.90	12.20	1.50	9.35
GNG 469	80.50	85.50	141.00	24.83	3.70	5.70	35.80	25.60	10.20	1.40	13.55
RSG 945	84.00	91.50	146.50	26.88	2.90	4.90	33.60	22.70	10.90	1.30	8.30
SADABAHAR	82.50	89.50	147.50	30.29	3.50	5.50	40.80	30.10	10.70	1.70	8.40
PBG-5	83.50	91.50	149.00	22.61	3.30	5.30	37.60	24.50	13.10	1.80	6.90
PBG-7	83.00	92.00	148.50	26.85	3.30	5.10	36.20	23.70	12.50	1.70	7.05
Mean	**81.68**	**87.84**	**144.86**	**26.88**	**3.32**	**5.31**	**39.05**	**27.00**	**12.05**	**1.65**	**9.96**

MEAN EN-3	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
KWR-108	11.86	51.01	1.76	43.64	21.95	47.09	2.15	29.61	73.60	27.05	6.05
JG 14	10.47	44.16	1.42	33.84	23.17	56.03	1.98	34.61	67.40	25.96	4.63
ICC-3020	9.45	36.98	1.70	32.90	25.21	48.87	1.76	33.23	64.00	36.98	3.50
IPC-06-77	11.72	51.34	1.76	46.67	22.54	45.03	1.90	32.70	74.00	29.27	6.01
KPG-59	8.47	38.04	2.49	48.60	17.20	34.24	3.03	32.69	61.60	22.20	3.22
K-850	9.04	39.83	1.21	34.56	26.27	54.35	1.54	30.40	65.00	32.07	3.60
ICC-5335	12.32	52.49	1.39	44.49	22.40	47.07	1.99	28.97	73.00	34.29	6.48
IPC-97-67	9.38	49.08	1.29	39.24	26.13	61.48	1.87	29.62	65.10	27.22	4.61
ICC 244-263	9.59	38.94	1.30	31.55	28.39	56.64	1.91	26.92	64.50	31.53	3.73
BG-212	11.67	51.06	1.81	45.63	23.19	47.01	1.68	30.46	74.00	35.23	5.96
ICC-3525	9.37	32.79	0.88	36.60	30.65	44.42	1.68	26.40	61.80	31.39	3.07
ICC-5434	11.75	50.55	1.65	49.54	22.47	43.62	1.97	31.15	72.90	31.24	5.94
ICC-5439	6.99	36.64	1.66	42.47	26.64	53.30	1.31	32.69	64.80	26.80	2.55
BPM	9.03	44.02	1.69	33.74	30.77	58.13	1.64	29.40	64.20	29.92	3.98
IPC-07-56	12.13	51.44	1.75	43.78	23.56	48.26	1.99	32.69	73.40	31.00	6.24
RSG 931	8.62	40.59	1.48	36.85	27.47	59.76	1.71	27.31	65.60	34.81	3.50
PDG-4	9.33	46.56	2.43	46.97	18.06	33.31	3.09	44.61	63.30	22.00	4.35
IPC 05-28	8.02	34.69	1.40	33.75	26.36	61.30	1.57	24.23	58.40	38.08	2.78
PUSA 3043	11.29	30.97	1.57	33.87	31.33	53.35	1.42	35.77	63.50	35.12	3.49
RSG-888	8.76	32.33	1.45	31.68	30.80	55.78	1.54	26.92	59.90	38.52	2.84
GNG 469	9.10	47.27	2.51	48.48	18.49	32.17	3.09	40.78	62.90	22.79	4.30
RSG 945	10.55	45.29	1.61	35.44	26.67	53.03	1.48	25.78	63.60	38.43	4.77
SADABAHAR	11.16	51.28	1.71	42.44	23.39	46.91	1.94	38.63	72.30	33.62	5.70
PBG-5	8.07	32.65	1.45	31.75	29.69	59.34	1.61	31.53	63.30	31.44	2.63
PBG-7	9.03	51.07	1.53	40.87	25.88	60.71	1.53	26.94	66.50	31.66	4.61
Mean	**9.88**	**43.24**	**1.63**	**39.57**	**25.14**	**50.45**	**1.89**	**31.36**	**66.34**	**31.14**	**4.34**

MEAN Pooled	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant-1	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR-108	89.67	96.50	167.83	36.64	3.87	6.97	60.30	51.17	9.13	1.70	11.16
JG 14	88.17	95.00	169.33	36.94	3.97	6.63	58.80	48.20	10.60	2.13	11.11
ICC-3020	87.33	95.83	166.17	37.16	3.80	6.10	57.87	49.87	8.00	1.60	11.90
IPC-06-77	89.33	96.50	164.33	42.34	4.40	6.93	60.03	53.20	6.83	2.27	10.84
KPG-59	90.17	97.33	168.00	39.14	3.83	6.43	58.60	50.13	8.47	1.67	11.28
K-850	88.00	95.50	165.50	36.89	3.43	5.83	55.97	46.20	9.77	1.57	10.25
ICC-5335	88.50	95.67	166.00	39.33	3.73	6.40	60.20	50.03	10.17	1.67	10.60
IPC-97-67	87.50	94.83	167.33	38.09	3.97	6.57	60.03	50.07	9.97	2.00	9.80
ICC 244-263	88.00	93.83	167.17	42.07	3.90	6.63	62.27	52.33	9.93	1.83	10.62
BG-212	86.33	93.50	169.50	40.49	3.93	6.50	59.37	48.63	10.73	2.03	10.97
ICC-3525	87.67	94.67	170.50	39.47	3.60	6.17	59.23	49.07	10.17	1.77	12.45
ICC-5434	88.33	95.67	172.50	37.07	3.67	6.17	58.27	47.50	10.77	1.63	9.83
ICC-5439	87.33	94.00	169.50	39.22	3.67	6.27	63.03	51.50	11.53	1.87	10.33
BPM	88.17	94.67	170.50	35.39	3.93	6.37	57.40	46.60	10.80	1.83	11.03
IPC-07-56	90.67	97.33	175.83	30.97	3.37	5.50	53.37	42.63	10.73	1.47	8.83
RSG 931	88.00	94.67	169.50	37.59	3.97	6.17	62.93	51.97	10.97	1.63	10.87
PDG-4	83.83	90.50	160.50	37.32	3.80	5.90	55.37	43.50	11.57	1.70	9.68
IPC 05-28	79.50	86.00	142.50	29.34	3.30	5.33	40.93	28.13	13.10	1.60	10.27
PUSA 3043	80.33	86.50	145.33	27.12	3.13	5.20	38.73	26.53	12.20	1.70	10.87
RSG-888	82.50	87.83	144.83	26.90	3.50	5.50	42.03	29.60	12.43	1.57	10.33
GNG 469	82.83	87.83	144.17	25.85	3.43	5.47	40.93	28.13	12.80	1.67	8.95
RSG 945	82.17	88.50	144.50	21.81	3.33	5.30	40.27	28.30	11.97	1.97	9.97
SADABAHAR	82.17	88.00	146.50	31.39	3.10	5.10	35.87	24.60	11.27	1.57	11.30
PBG-5	82.67	88.83	144.50	23.02	3.23	5.23	33.83	22.73	11.10	1.40	10.40
PBG-7	83.00	91.00	148.33	26.58	3.37	5.30	38.20	26.10	12.10	1.73	7.45
Mean	**86.09**	**92.82**	**160.83**	**34.32**	**3.65**	**6.00**	**52.55**	**41.87**	**10.68**	**1.74**	**10.44**

MEAN Pooled	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
KWR-108	20.21	45.23	1.72	51.70	22.08	50.24	1.04	32.31	76.60	27.78	9.08
JG 14	19.76	44.67	2.05	50.65	18.20	43.43	1.46	30.64	75.87	28.16	8.76
ICC-3020	20.06	43.48	1.83	44.71	22.84	49.92	1.14	29.23	76.13	27.17	8.75
IPC-06-77	22.46	47.41	1.80	48.15	19.20	47.87	1.43	32.43	79.43	29.57	10.68
KPG-59	20.34	45.43	1.75	39.52	22.99	47.93	1.15	30.52	75.80	29.50	9.25
K-850	17.55	39.70	1.70	40.26	16.90	43.51	1.50	32.05	72.37	29.95	6.96
ICC-5335	18.69	36.11	1.54	39.30	18.85	41.32	1.44	34.60	72.67	28.27	6.73
IPC-97-67	17.93	44.16	1.54	41.00	21.71	47.72	1.08	30.77	75.97	29.10	7.89
ICC 244-263	19.48	45.79	1.83	46.83	23.14	53.33	1.39	28.73	77.93	27.30	8.94
BG-212	19.18	42.95	2.10	53.61	19.99	43.46	1.66	30.13	78.87	25.90	8.25
ICC-3525	20.25	44.41	1.75	43.74	23.82	48.42	1.50	30.39	77.97	27.59	9.09
ICC-5434	21.29	41.72	1.55	40.92	23.49	48.47	1.39	32.18	75.53	30.50	9.12
ICC-5439	20.08	46.01	1.70	40.07	25.20	51.96	1.58	31.92	75.47	31.24	9.29
BPM	18.78	44.06	1.71	45.24	19.05	42.92	1.75	32.41	74.27	25.86	8.31
IPC-07-56	17.34	35.98	1.10	33.90	22.46	48.24	0.74	29.87	75.17	32.66	6.26
RSG 931	18.20	42.73	1.82	44.93	18.26	43.02	1.67	32.88	74.77	25.72	7.86
PDG-4	16.19	42.79	1.61	42.58	21.24	50.64	1.55	28.97	74.50	28.05	6.76
IPC 05-28	10.54	44.16	1.63	37.80	23.64	49.97	1.88	33.51	68.47	30.73	4.71
PUSA 3043	9.94	43.45	1.69	42.55	21.96	45.22	2.18	30.69	66.53	29.52	4.43
RSG-888	10.21	46.36	1.46	38.80	25.90	55.04	1.82	29.00	67.87	31.32	4.76
GNG 469	9.37	39.99	1.40	42.87	26.59	47.11	1.65	30.08	66.50	29.81	3.85
RSG 945	9.93	45.35	1.64	38.12	27.27	55.38	1.78	29.80	67.73	31.91	4.57
SADABAHAR	9.55	37.41	1.80	38.20	25.25	49.32	2.03	34.87	61.73	31.73	3.54
PBG-5	9.47	41.63	1.86	38.53	25.32	46.99	2.04	31.16	62.13	33.24	3.97
PBG-7	9.42	45.00	1.56	38.35	26.32	55.65	1.69	32.37	67.37	32.24	4.31
Mean	**16.25**	**43.04**	**1.69**	**42.49**	**22.47**	**48.28**	**1.54**	**31.26**	**72.71**	**29.39**	**7.04**

APPENDICES II

Parents + Crosses	First blossoming days	50% blossoming days	Harvest maturity days	Plant height	Primary offshoots plant^{-1}	Secondary offshoots plant^{-1}	Capsules plant^{-1}	Full capsules plant^{-1}	Empty capsules plant^{-1}	Seeds capsule^{-1}	Test weight (gm)
KWR 108	89.50	96.00	150.00	43.98	4.10	6.20	67.30	57.60	9.70	1.70	12.65
ICC 5335	84.50	91.50	152.50	43.35	3.50	5.60	62.20	52.30	9.90	1.30	14.10
ICC 5434	91.00	97.50	159.00	43.58	3.70	5.90	68.70	59.00	9.70	1.90	9.00
BG 212	88.00	95.50	149.50	45.72	4.60	6.80	71.80	60.90	10.90	1.70	14.95
IPC 07-56	92.50	100.00	158.50	43.65	4.40	6.60	70.20	61.10	9.10	1.80	12.02
IPC 06-77	88.00	95.50	156.50	42.65	3.60	5.90	67.00	57.00	10.00	1.90	11.92
SADABAHAR	86.00	94.00	149.00	42.99	4.30	6.40	69.50	60.20	9.30	1.70	9.50
GNG 469	88.50	94.50	154.00	38.47	3.70	5.70	65.60	54.70	10.90	1.70	11.15
KPG 59	89.50	97.50	154.50	43.37	4.40	6.30	65.70	54.40	11.30	1.50	10.80
PDG 4	87.00	94.50	152.50	44.27	4.30	6.30	65.50	55.60	9.90	1.90	11.95
KWR 108 X GNG 469	102.50	109.00	162.00	46.76	3.50	6.10	73.00	63.90	9.10	1.70	12.05
KWR 108 X KPG 59	98.00	105.50	156.00	45.36	3.40	6.30	69.60	59.90	9.70	1.70	14.00
KWR 108 X PDG 4	96.50	103.00	156.00	45.04	4.00	6.80	69.80	59.40	10.40	1.70	10.50
ICC 5335 X GNG 469	102.50	110.00	161.00	48.08	3.80	6.30	65.50	55.60	9.90	1.70	13.90
ICC 5335 X KPG 59	97.00	106.50	160.00	41.70	4.50	7.10	61.70	53.20	8.50	1.50	12.10
ICC 5335 X PDG 4	91.50	99.00	146.50	48.48	3.90	6.10	76.20	65.40	10.80	2.10	12.65
ICC 5434 X GNG 469	94.00	101.50	150.00	46.19	4.60	7.30	69.30	58.20	11.10	1.60	10.60
ICC 5434 X KPG 59	101.50	108.50	165.50	41.01	3.30	5.40	67.40	56.90	10.50	1.60	11.70
ICC 5434 X PDG 4	96.50	102.50	159.00	41.37	3.70	6.10	64.80	55.80	9.00	1.90	14.30
BG 212 X GNG 469	93.00	100.00	150.00	45.49	4.30	7.00	72.50	61.80	10.70	1.90	8.65
BG 212 X KPG 59	95.00	101.00	152.50	44.40	4.20	6.90	68.00	56.50	11.50	1.50	14.70
BG 212 X PDG 4	99.00	105.50	155.00	46.37	3.70	5.60	71.40	60.10	11.30	1.70	11.55
IPC 07-56 X GNG 469	101.50	109.00	162.00	40.36	4.10	7.20	71.40	59.30	12.10	1.50	11.55
IPC 07-56 X KPG 59	99.00	108.00	160.50	47.27	3.90	7.00	64.40	52.40	12.00	1.40	9.10
IPC 07-56 X PDG 4	98.00	105.50	157.00	47.70	3.60	6.90	72.30	61.00	11.30	1.90	13.50

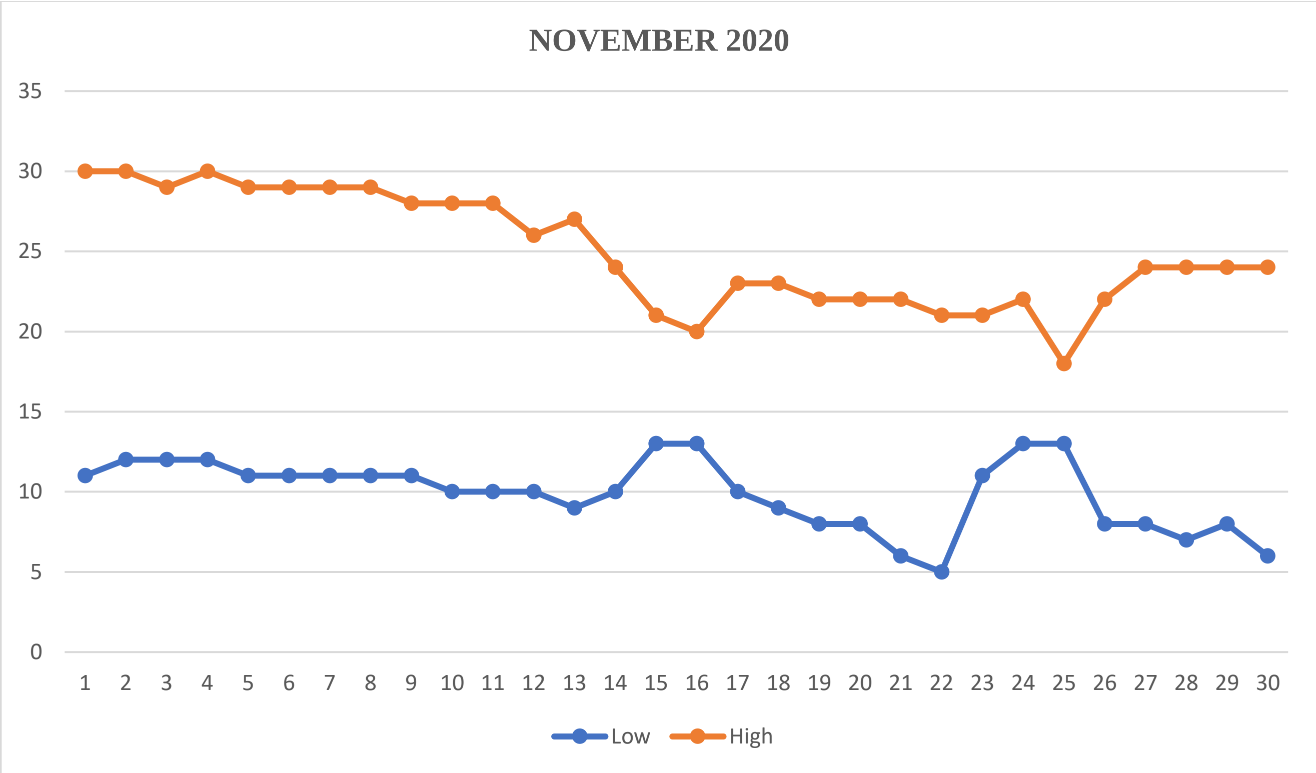
IPC 06-77 X GNG 469	99.50	106.00	160.00	39.85	3.70	5.80	69.90	58.90	11.00	1.70	14.15
IPC 06-77 X KPG 59	98.00	105.50	154.00	45.07	4.30	7.40	71.40	60.30	11.10	2.10	9.95
IPC 06-77 X PDG 4	93.50	100.00	153.50	47.97	3.70	6.80	75.70	65.00	10.70	1.90	13.80
SADABAHAR X GNG 469	91.00	97.50	154.00	49.03	3.60	5.90	73.60	63.00	10.60	2.00	13.30
SADABAHAR X KPG 59	100.00	108.00	160.50	46.68	3.40	5.50	75.90	64.10	11.80	1.90	12.35
SADABAHAR X PDG 4	94.00	101.50	153.00	44.58	3.40	5.50	70.40	59.40	11.00	1.50	10.10
CHECK	89.50	99.50	147.00	45.22	3.50	6.70	71.10	60.00	11.40	1.60	11.10
Parental mean	**88.45**	**95.65**	**153.60**	**43.20**	**4.06**	**6.17**	**67.35**	**57.28**	**10.07**	**1.71**	**11.80**
Hybrid mean	**97.21**	**104.43**	**156.57**	**45.18**	**3.84**	**6.43**	**70.20**	**59.53**	**10.67**	**1.74**	**12.12**
General mean	**94.39**	**101.60**	**155.61**	**44.54**	**3.91**	**6.35**	**69.28**	**58.80**	**10.48**	**1.73**	**12.02**

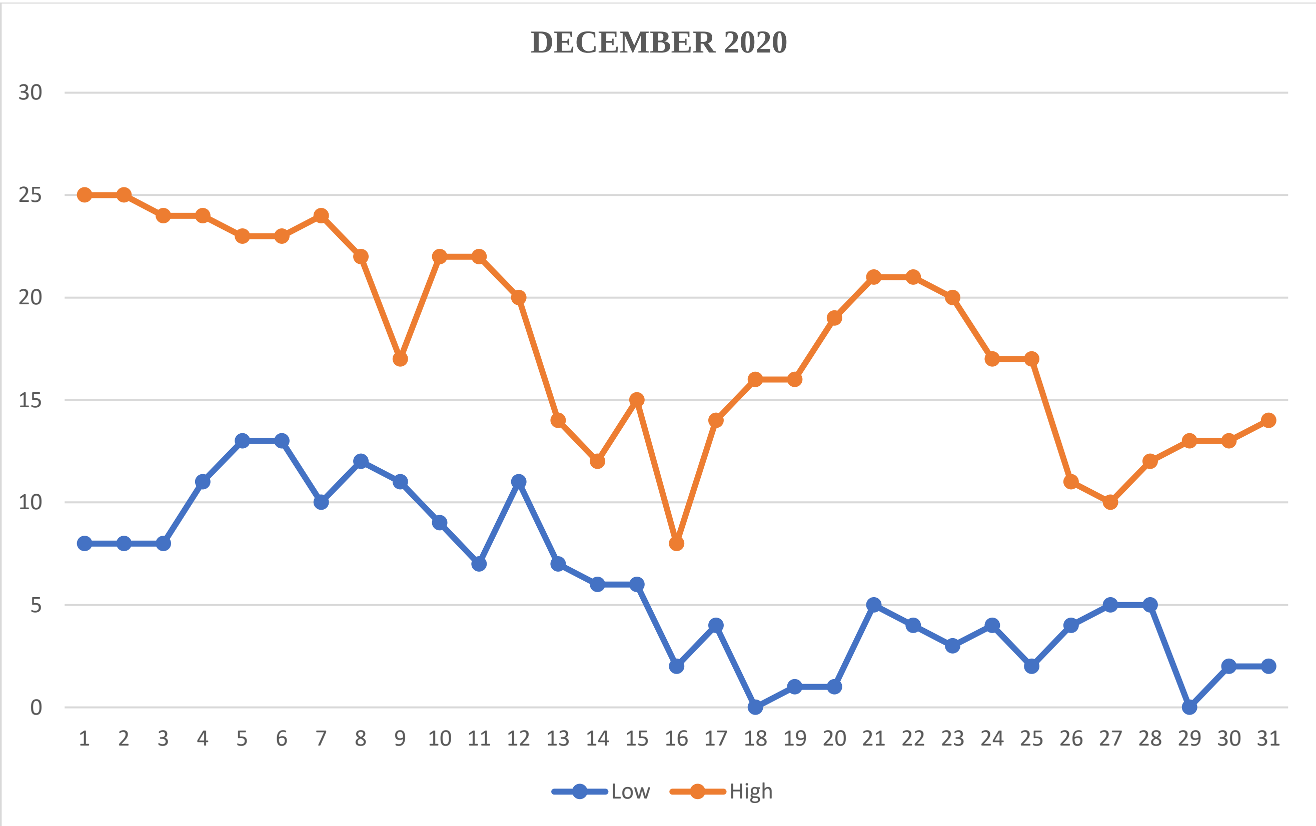
Parents + Crosses	Biological yield plant^{-1}	Harvest index (%)	Total chlorophyll content (mg/ml)	Relative leaf water content (%)	Lipid Peroxidation (nmol/ml)	Electrolyte leakage index (%)	Proline content (mg/gm)	Ascorbic acid content (mg)	Pollen viability (%)	Flower drop (%)	Seed yield plant^{-1}
KWR 108	22.59	50.46	1.74	33.62	9.07	48.22	1.56	35.22	73.50	24.61	11.41
ICC 5335	22.69	50.18	2.61	45.59	14.87	50.77	1.52	25.22	75.00	29.44	11.38
ICC 5434	16.11	47.90	2.39	48.24	12.41	44.78	1.44	28.27	70.50	25.67	7.72
BG 212	26.97	49.96	2.10	44.20	12.07	53.85	1.52	32.61	77.40	26.23	13.48
IPC 07-56	20.77	50.36	2.51	42.19	14.48	48.43	1.49	23.05	71.70	26.38	10.46
IPC 06-77	20.76	49.94	2.56	32.70	10.90	41.02	1.57	27.83	69.00	19.54	10.37
SADABAHAR	17.40	49.49	1.98	33.31	14.69	50.53	1.52	21.31	68.60	23.19	8.62
GNG 469	18.76	46.47	2.08	48.74	10.31	35.96	2.03	24.79	76.10	27.27	8.73
KPG 59	20.31	41.01	2.24	38.41	10.48	45.30	2.19	28.27	70.20	22.27	8.34
PDG 4	23.09	42.18	3.51	40.88	10.39	30.83	1.52	25.66	67.60	28.98	9.75
KWR 108 X GNG 469	23.30	50.38	1.71	48.03	10.37	32.22	2.17	26.96	71.60	17.07	11.75
KWR 108 X KPG 59	24.70	50.14	2.19	56.88	11.02	31.37	1.85	27.83	68.60	27.49	12.39
KWR 108 X PDG 4	20.75	45.05	2.21	52.19	10.49	36.46	2.18	28.27	76.00	27.82	9.35
ICC 5335 X GNG 469	24.17	48.90	2.43	53.09	11.13	41.30	2.42	25.66	71.50	28.04	11.85
ICC 5335 X KPG 59	21.25	44.17	2.82	44.88	8.95	34.29	2.23	27.83	69.30	18.22	9.39

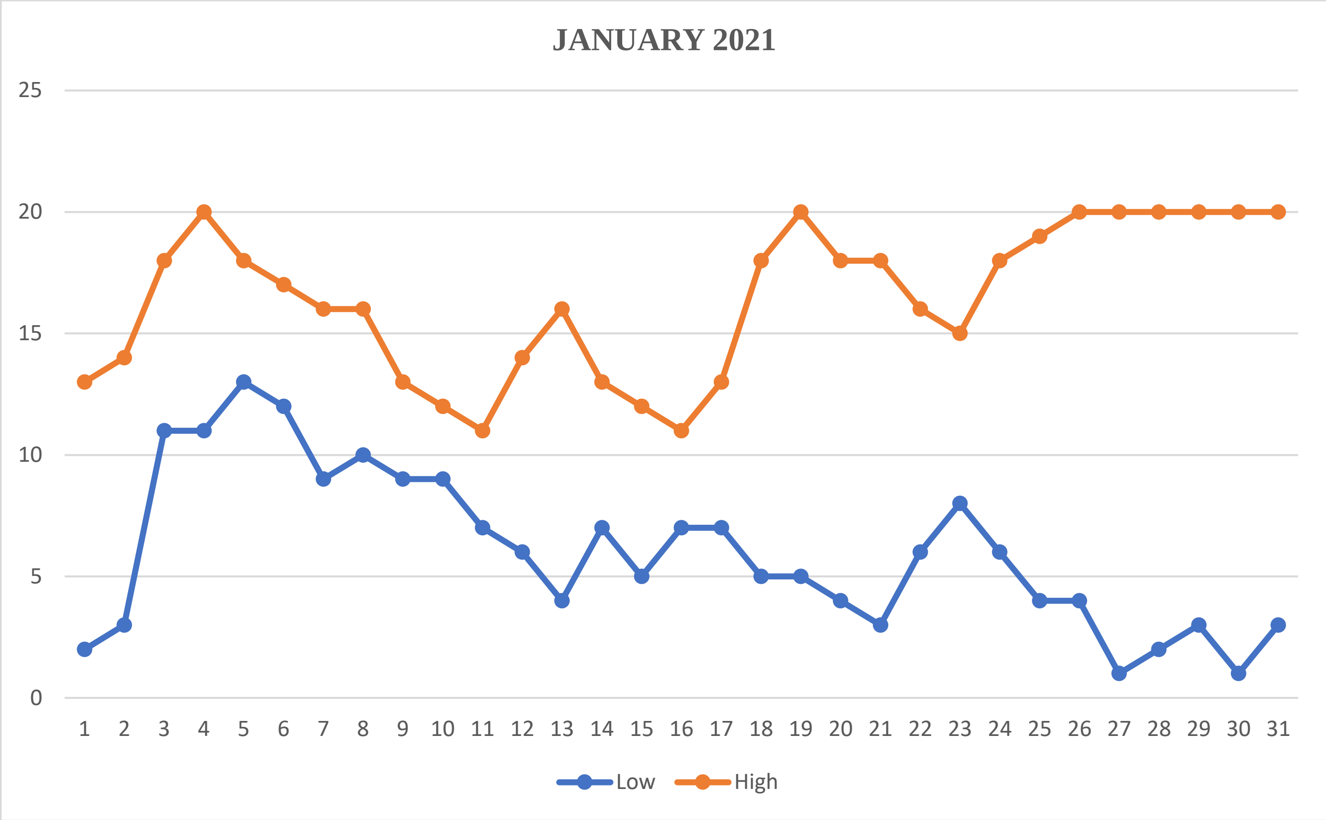
ICC 5335 X PDG 4	25.47	50.59	2.62	63.91	8.88	30.41	1.77	28.70	75.90	21.17	12.87
ICC 5434 X GNG 469	20.55	43.54	3.51	55.19	9.37	34.02	1.76	27.83	81.30	25.93	8.95
ICC 5434 X KPG 59	20.78	47.43	2.70	56.75	11.62	41.61	1.69	33.48	86.70	26.56	9.82
ICC 5434 X PDG 4	23.71	50.59	2.30	36.55	8.29	28.41	1.57	23.92	69.60	18.66	12.00
BG 212 X GNG 469	18.20	43.08	1.53	44.70	8.08	42.24	2.22	23.92	67.60	22.13	7.83
BG 212 X KPG 59	26.14	46.96	2.46	42.22	13.46	35.46	1.71	27.83	78.90	28.40	12.28
BG 212 X PDG 4	21.97	48.42	2.49	43.00	11.54	48.32	2.30	22.18	72.40	17.43	10.64
IPC 07-56 X GNG 469	21.92	47.50	3.10	44.72	9.00	29.88	1.84	22.18	80.50	25.44	10.39
IPC 07-56 X KPG 59	15.75	43.86	2.34	43.83	9.78	43.72	2.16	32.17	76.60	25.86	6.92
IPC 07-56 X PDG 4	27.18	45.22	2.40	49.49	11.96	44.37	1.43	30.00	71.80	16.91	12.30
IPC 06-77 X GNG 469	24.96	50.23	2.43	47.92	10.36	33.28	2.28	21.74	71.30	20.28	12.54
IPC 06-77 X KPG 59	18.30	49.04	4.41	45.21	9.31	42.30	1.82	22.61	71.20	24.27	8.98
IPC 06-77 X PDG 4	26.50	50.28	2.13	41.06	12.84	41.83	2.27	31.74	69.30	15.42	13.30
SADABAHAR X GNG 469	27.61	45.37	3.42	43.45	7.37	41.61	1.54	36.52	76.60	25.16	12.53
SADABAHAR X KPG 59	27.55	44.74	2.49	53.58	9.48	48.11	1.36	32.61	72.90	16.98	12.30
SADABAHAR X PDG 4	16.34	45.51	2.66	52.99	12.56	32.22	2.28	22.61	79.90	24.30	7.40
CHECK	23.48	48.99	1.63	51.35	10.80	35.98	1.88	28.26	74.80	19.81	10.91
Parental mean	**20.94**	**47.79**	**2.37**	**40.79**	**11.96**	**44.97**	**1.63**	**27.22**	**71.96**	**25.36**	**10.02**
Hybrid mean	**22.72**	**47.19**	**2.58**	**48.55**	**10.28**	**37.78**	**1.94**	**27.45**	**74.26**	**22.55**	**10.75**
General mean	**22.14**	**47.38**	**2.52**	**46.05**	**10.82**	**40.10**	**1.84**	**27.38**	**73.52**	**23.45**	**10.51**

APPENDICES III

Temperature scale of 2020-21 & 2022-23 *rabi* seasons



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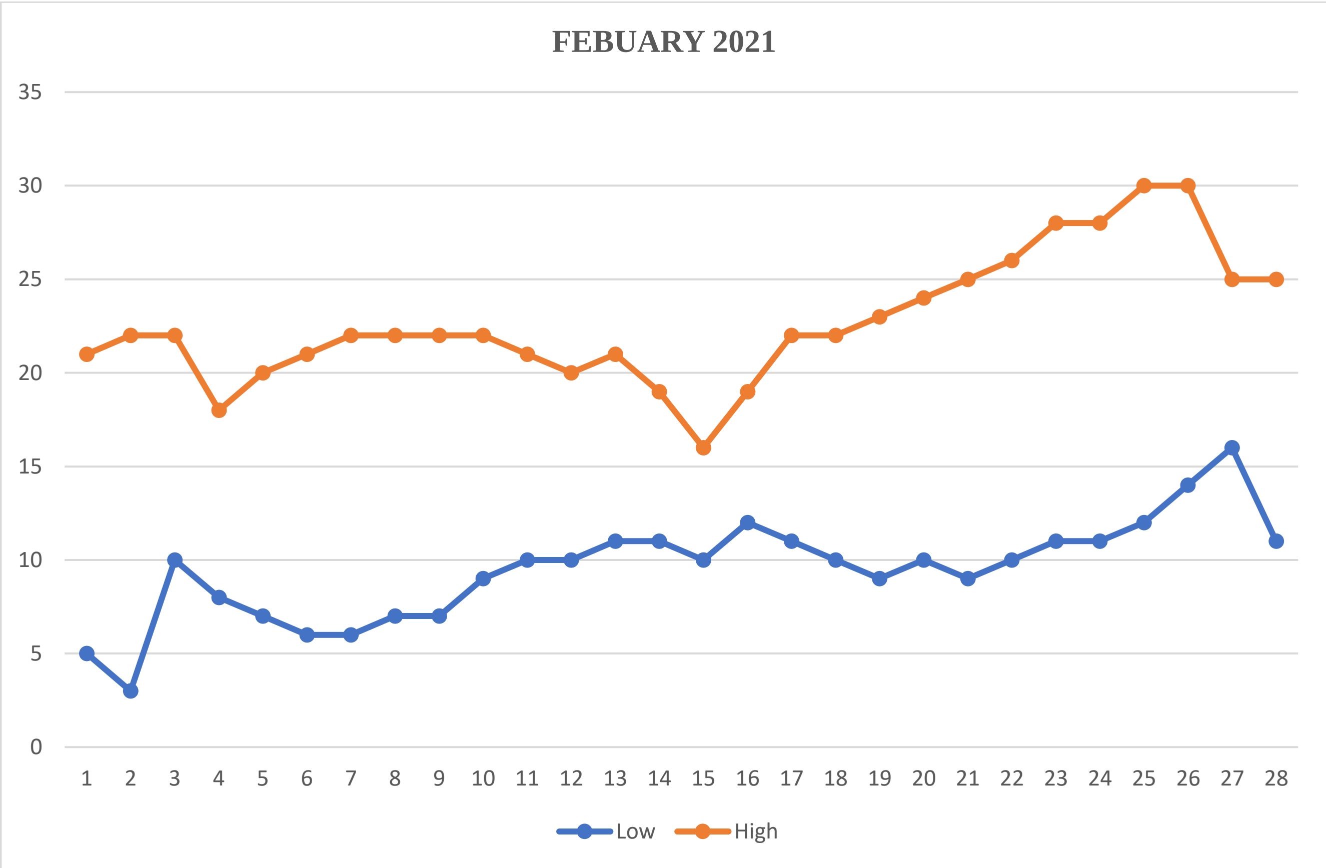
Low
High


FEBUARY 2021
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30
25
20
15
10
5
0
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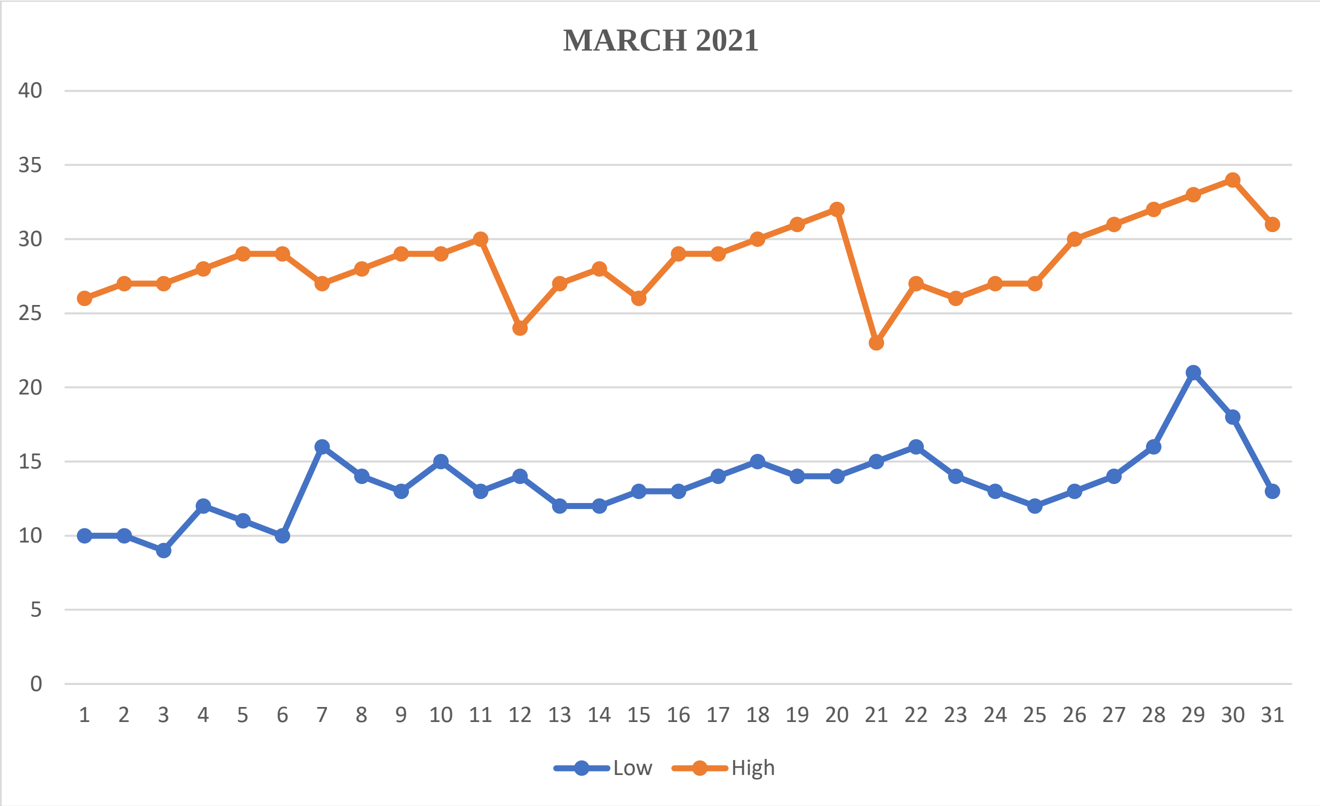
Low
High


MARCH 2021
40
35
30
25
20
15
10
5
0
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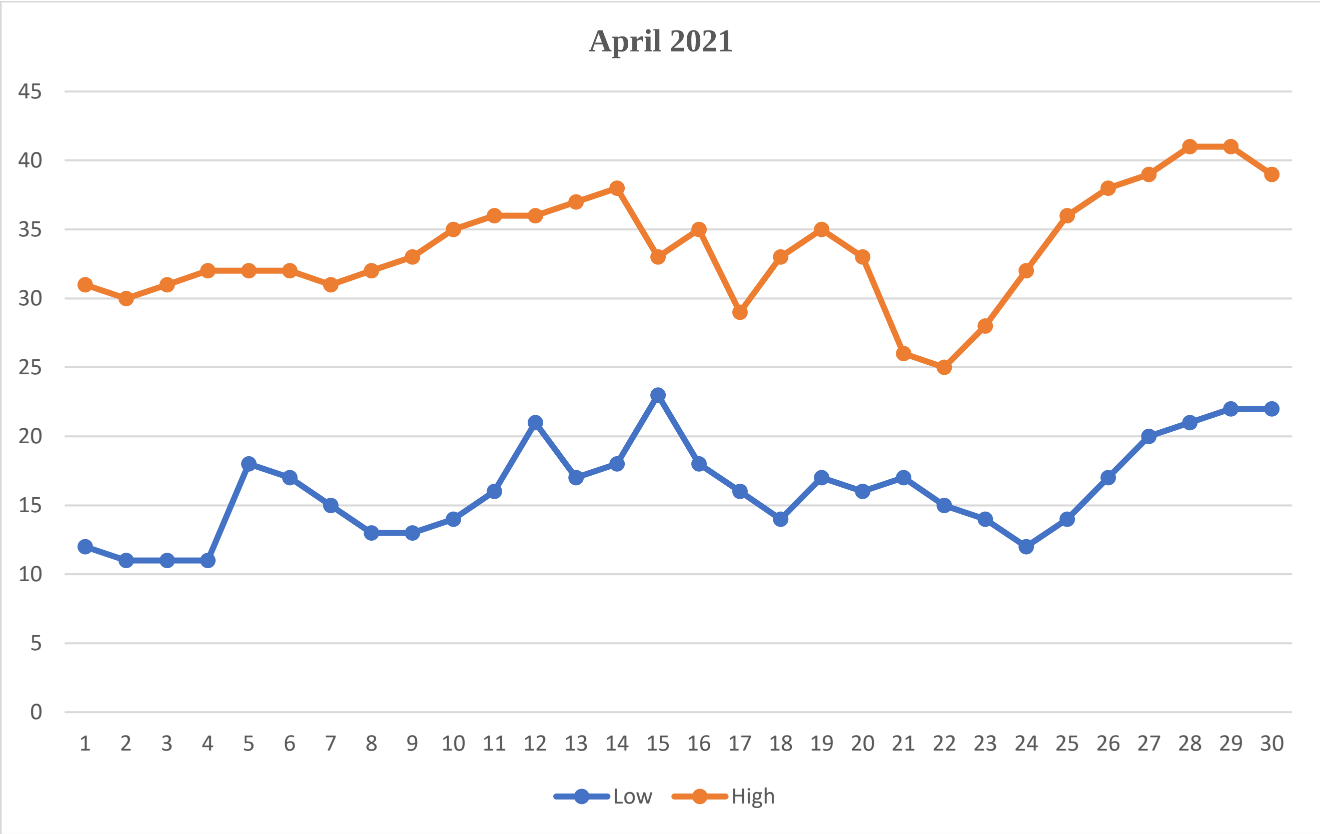
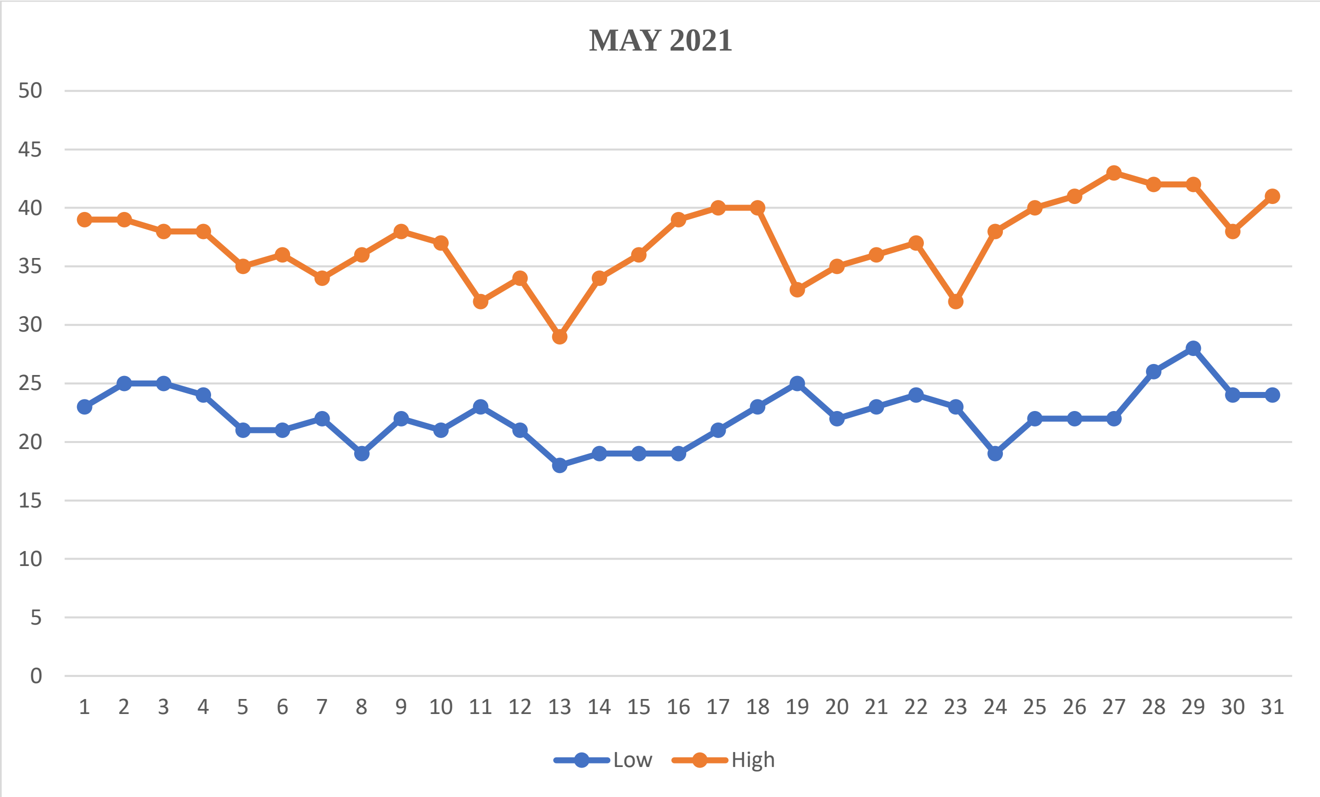
Low
High


April 2021
45
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Low
High


MAY 2021
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40
35
30
25
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10
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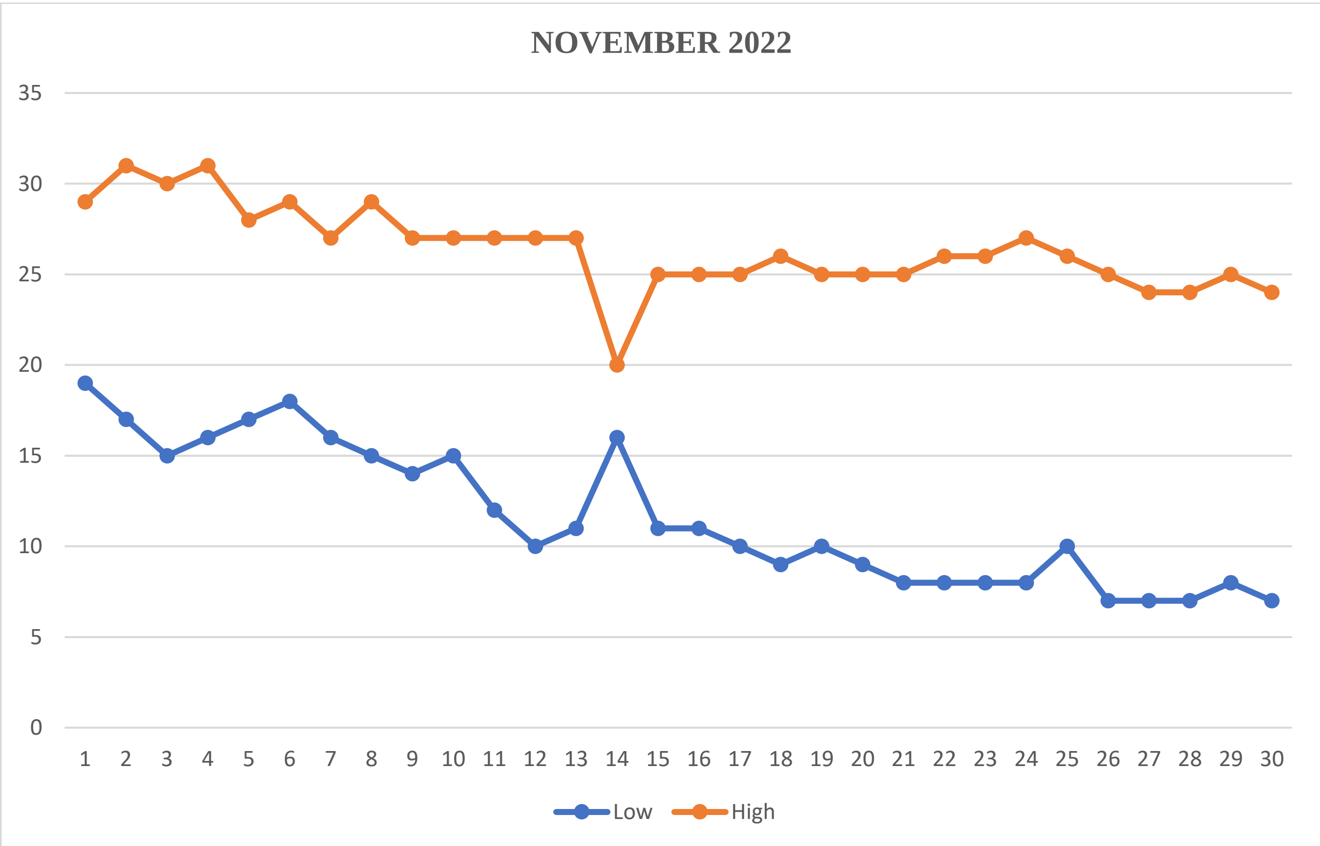
Low
High


NOVEMBER 2022
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30
25
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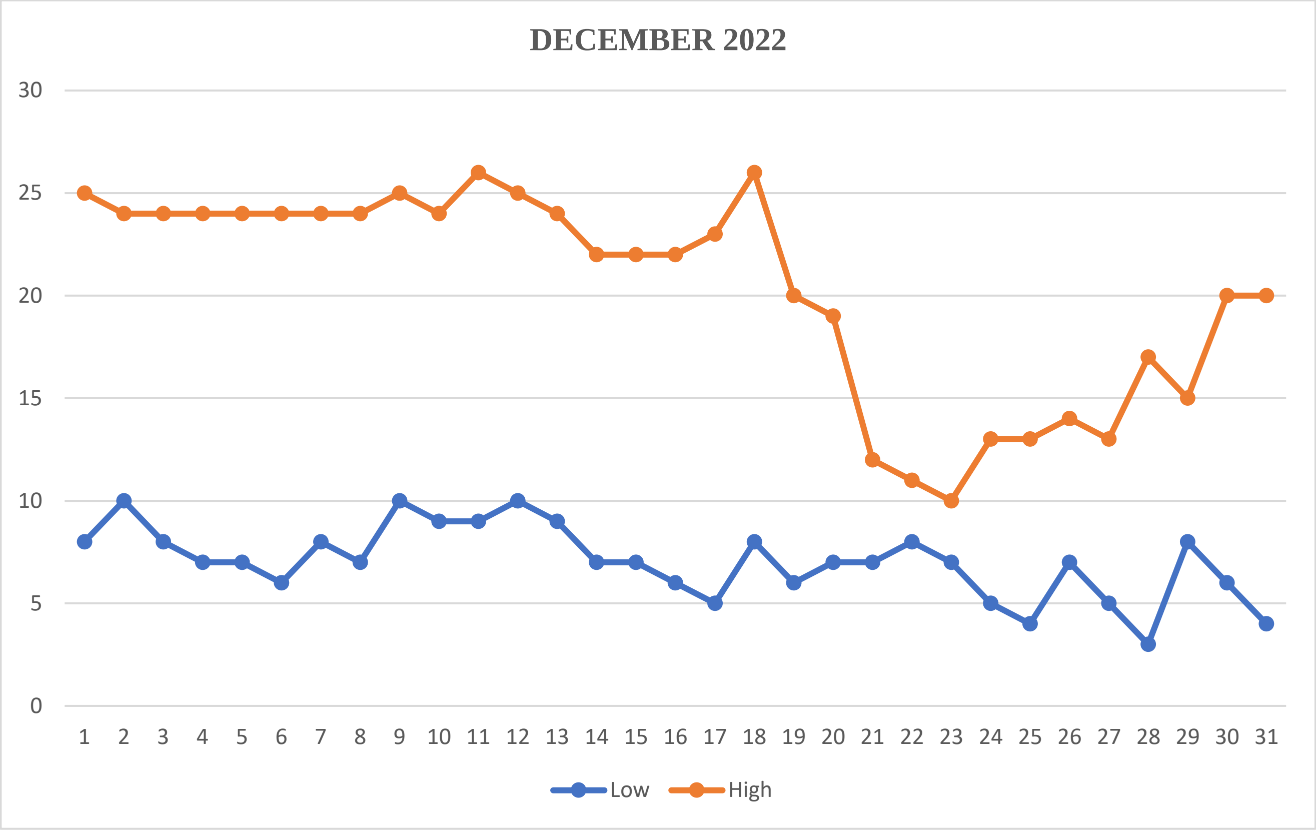
Low
High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20
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10
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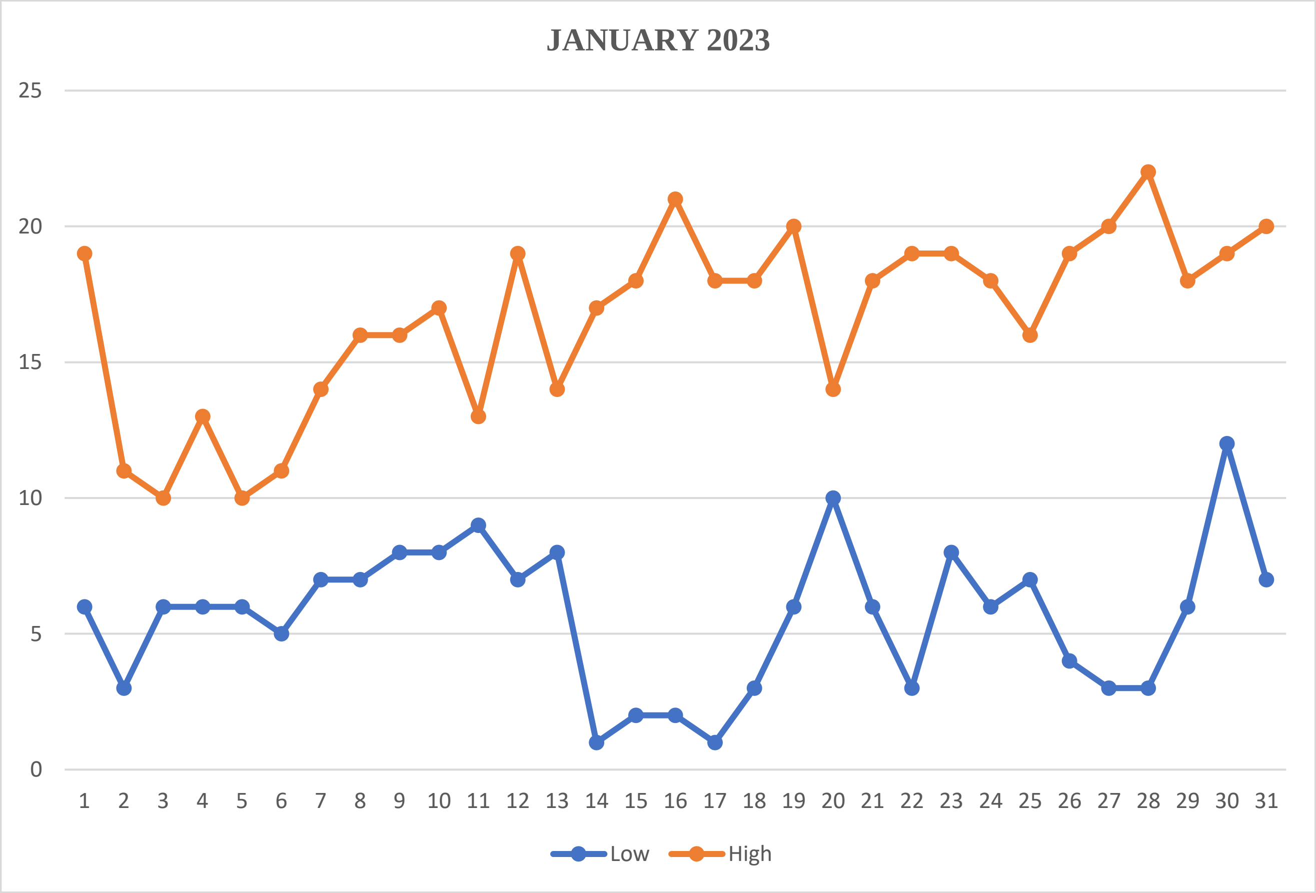
Low
High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20
15
10
5
0
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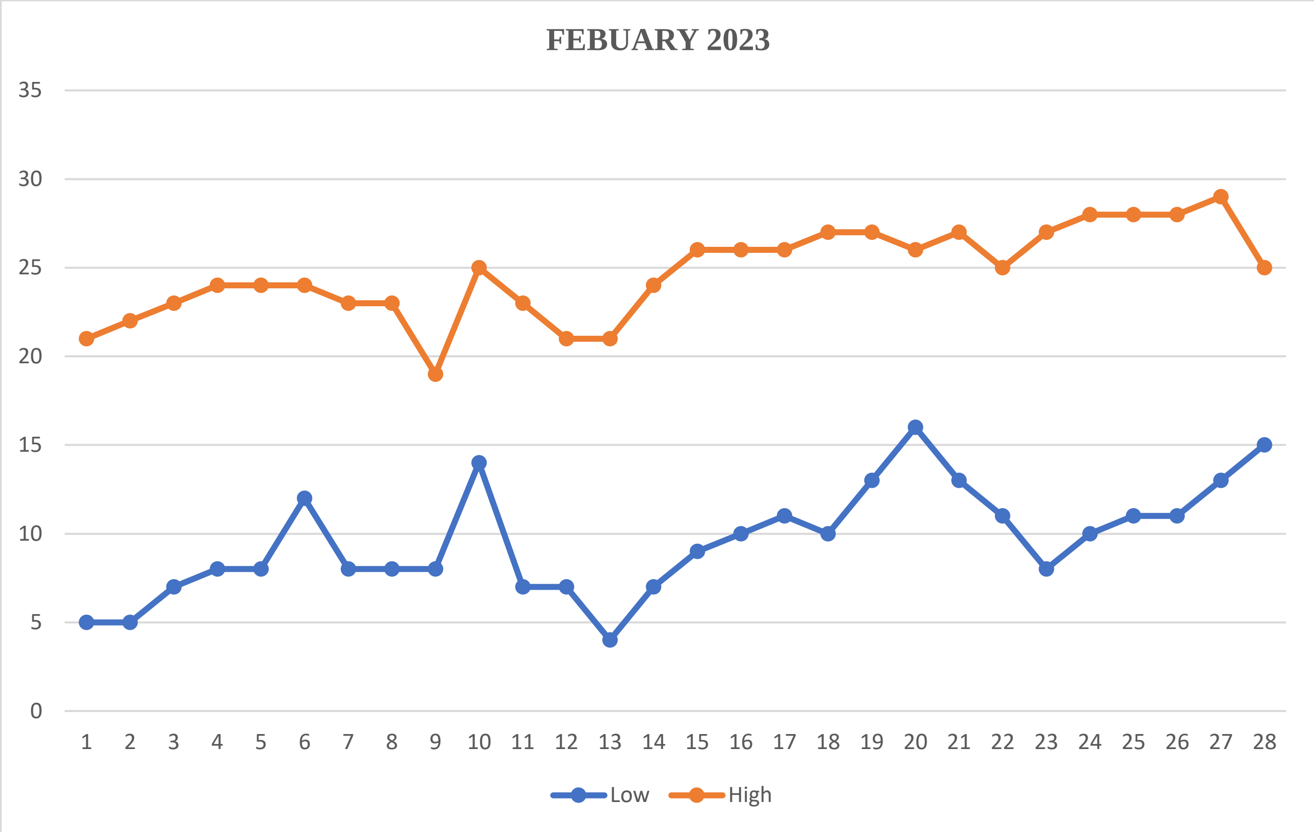
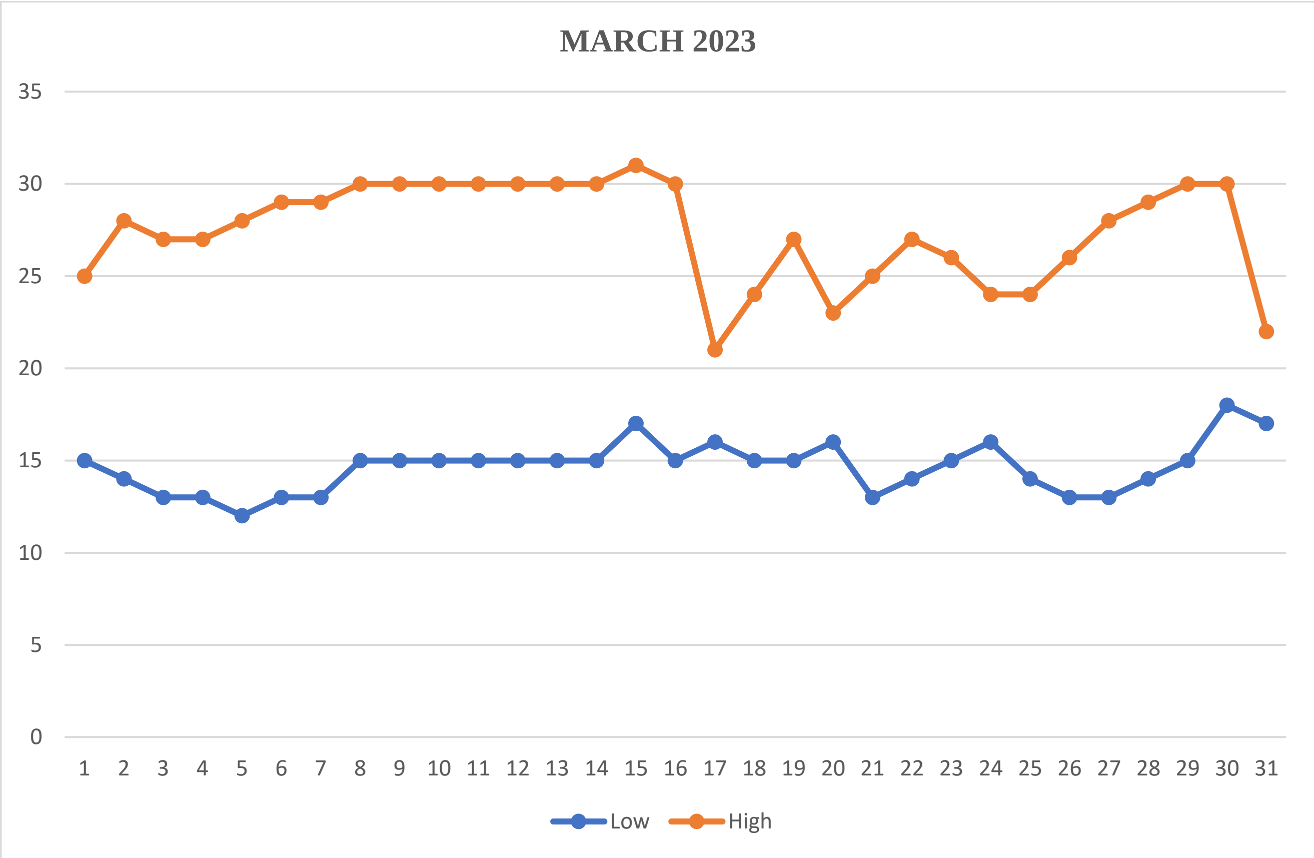
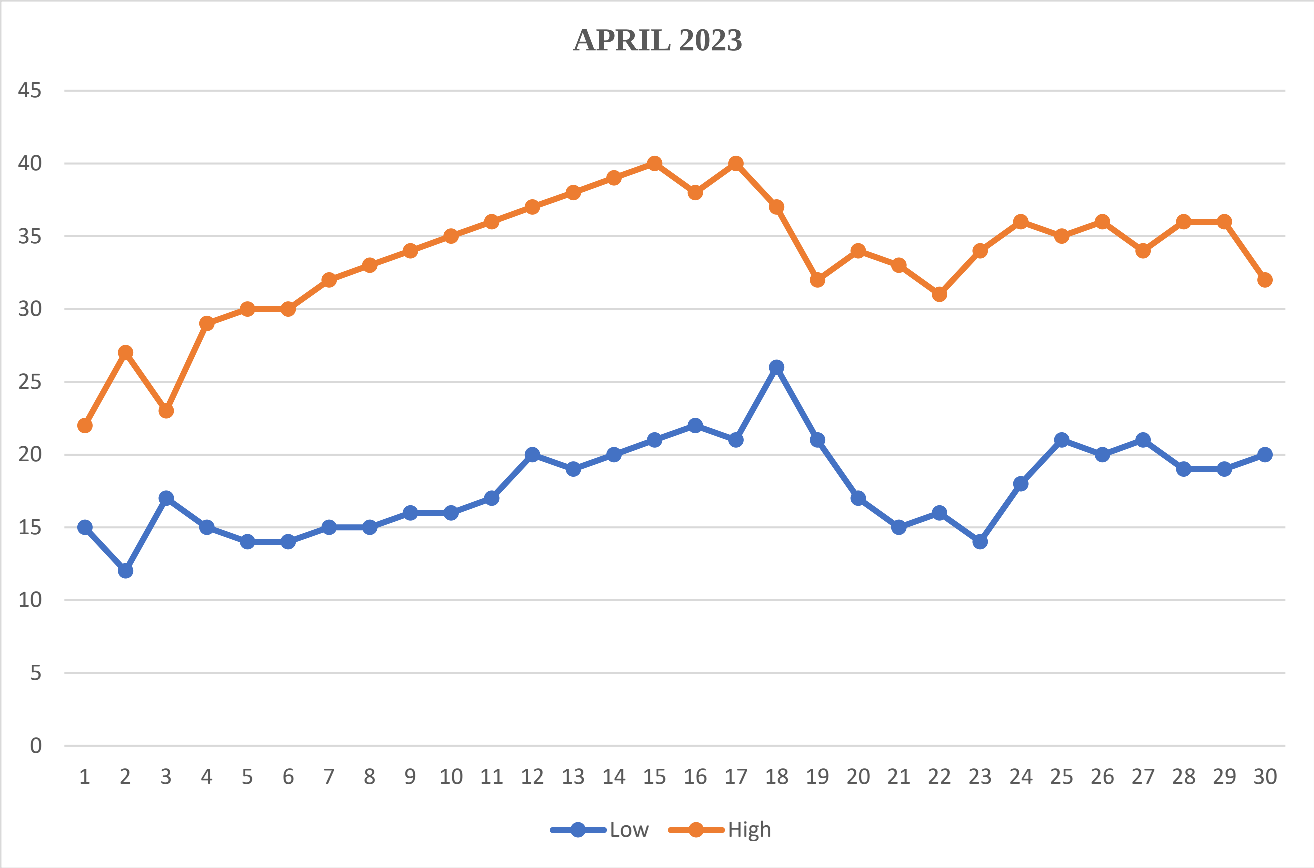
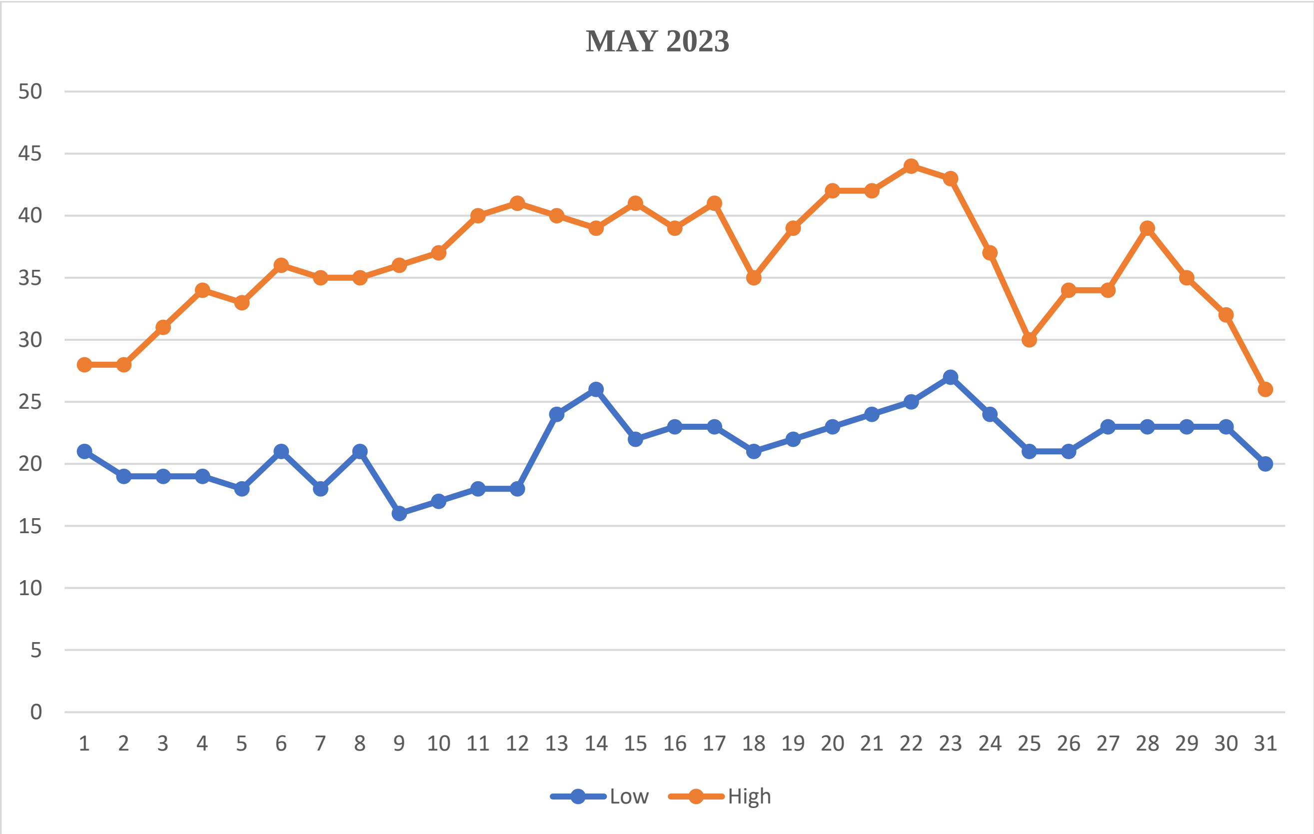
Low
High

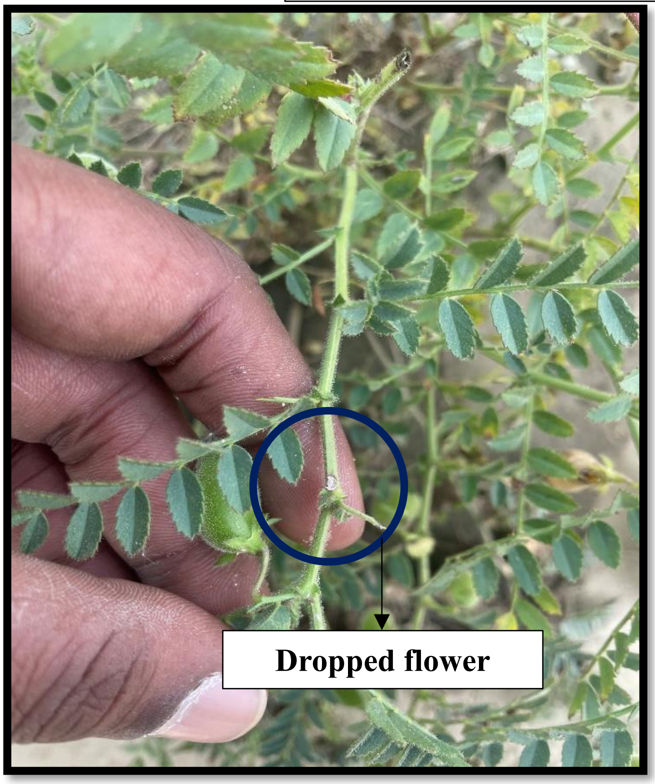

FEBUARY 2023
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Low
High


MARCH 2023
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Low
High


APRIL 2023
45
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Low
High


MAY 2023
50
45
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Low
High

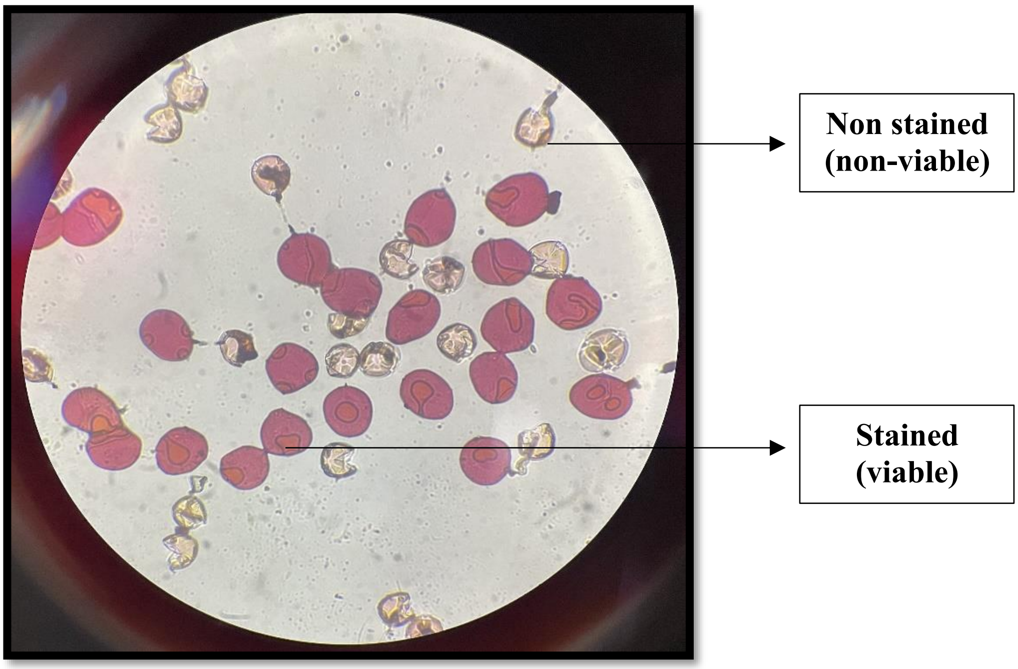
PLATES



IMG 1: Field observation and recording data for Aborted and dropped flowers

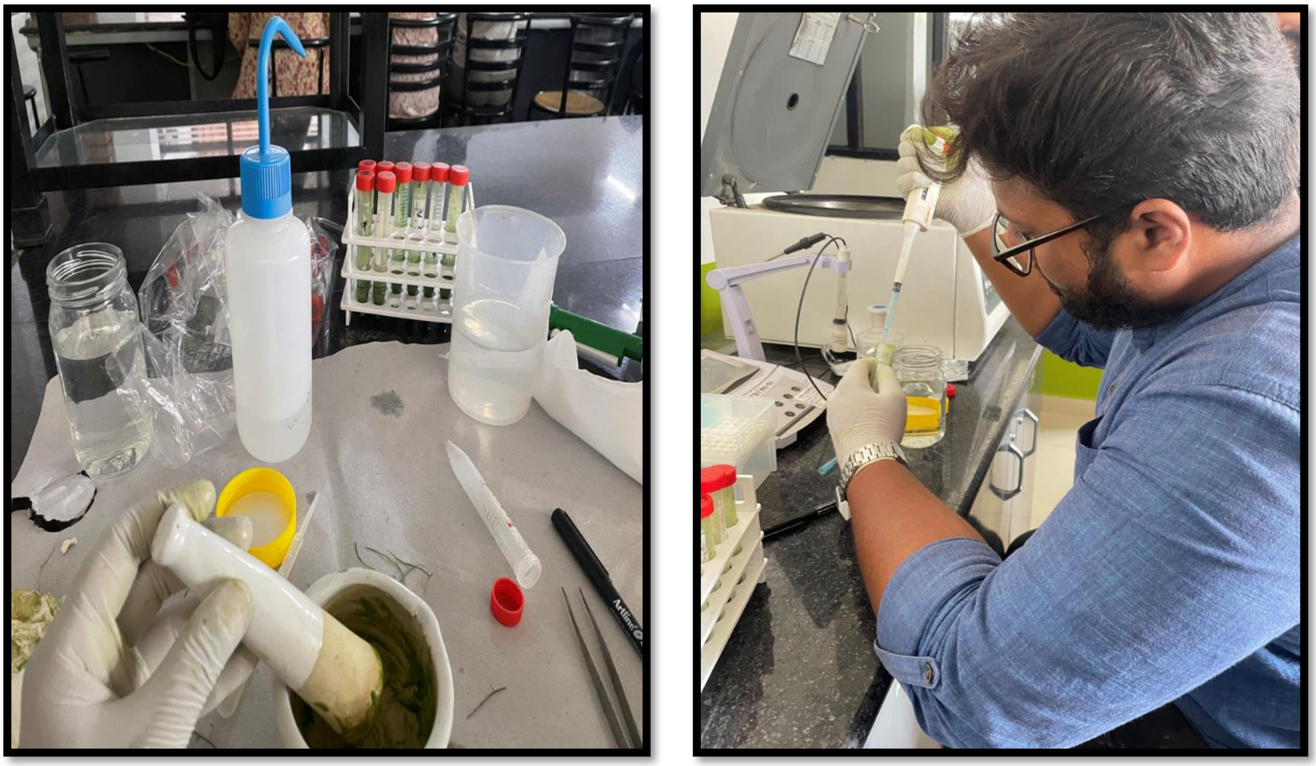
IMG 2: Extracting & estimating chlorophyll in spectrophotometer

IMG 3: Estimating Relative leaf water content using hot air oven dryer



IMG 4: Estimating pollen viability (Acetocaramine method)

IMG 5: Estimating electrolyte leakage index (using a shaker & EC meter)



IMG 6: Estimation of Proline