GERMPLASM EVALUATION AND NUTRIENT MANAGEMENT IN STRAWBERRY (*FRAGARIA* × *ANANASSA* DUCH.) UNDER PUNJAB CONDITIONS

A Thesis

Submitted in partial fulfillment of the requirements for the

award of the degree of

DOCTOR OF PHILOSOPHY

in

HORTICULTURE

By

WINEET CHAWLA
41500162

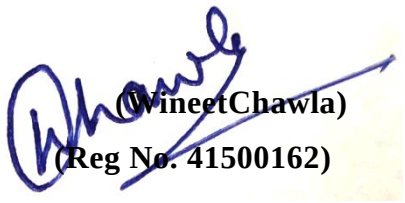
Supervised By

DR. SHAILESH KUMAR SINGH

LOVELY PROFESSIONAL UNIVERSITY
PUNJAB
2020

DECLARATION

I hereby declare that the thesis entitled **"Germplasm evaluation and nutrient management in strawberry (*Fragaria* × *ananassa*Duch.) under Punjab conditions"** submitted for **Doctor of Philosophy inHorticulture** to the School of Agriculture, Lovely Professional University is entirely original work and all ideas and references are duly acknowledged. The research work has not been formed the basis for the award of any other degree.



Place: LPU, Phagwara **(WineetChawla)**

Date: 10-10-2020 **(Reg No. 41500162)**

Dr.Shailesh Kumar Singh
Associate Professor
School of Agriculture
Lovely Professional University, Punjab

CERTIFICATE-I

This is to certify that the thesis entitled, **"Germplasm evaluation and nutrient management in strawberry (*Fragaria* × *ananassa*Duch.) under Punjab conditions"**submitted to the Faculty of Technology and Sciences**,** Lovely Professional University, Phagwara, Punjab in partial fulfillment of the requirement for the degree of**DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Horticulture**embodies the results of a piece of bonafide research carried out by**Mr.WineetChawla**under my guidance and supervision.To the best of my knowledge, the present work is the result of original investigation and study. No part of this thesis has ever been submitted for any other degree or diploma or published in any other form. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.

Place: LPU, Phagwara
Date: 10-10-2020

Supervisor
(Dr. Shailesh Kumar Singh)

LOVELY PROFESSIONAL UNIVERSITY

CERTIFICATE-II

This is to certify that the thesis entitled **"Germplasm evaluation and nutrient management in strawberry (*Fragaria* × *ananassa* Duch.) under Punjab conditions"** submitted by **Mr. Wineet Chawla (Registration No. 41500162)** to the Lovely Professional University, Phagwara in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Horticulture** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an external examiner.

SKsingh

Chairperson, Advisory Committee
(Dr. Shailesh Kumar Singh)
Associate Professor and Head
Department of Horticulture
Lovely Professional University
Phagwara-144 411

External Examiner
(Dr. W. S. Dhillon)
Ex-Assistant Director General
(ADG), Horticulture
Indian Council of Agricultural Research (ICAR), New Delhi

5/12/2020

Dean
School of Agriculture
Lovely Professional University
Phagwara-144 411

SCHOOL OF AGRICULTURE

LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA

Title	**:**	Germplasm evaluation and nutrient management in strawberry (*Fragaria* × *ananassa*Duch.) under Punjab conditions
Name of the Student	**:**	WineetChawla
Registration Number	**:**	41500162
Year of Admission	**:**	2015
Name of Research Guide and Designation	**:**	Dr Shailesh Kumar Singh Associate Professor Department of Horticulture

Lovely Professional University, Punjab

ABSTRACT

Introduction: Strawberry (*Fragaria* × *ananassa*Duch.) belongs to the family Rosaceae. It has gained the status of being one of the most important soft fruit of the world after grapes. It is also known as one of the most attractive, delicious and refreshing fruit of the world and occupies a significant place in fruit growing. Strawberry fruits are in great demand for fresh market as well as in processing industries and are used in preserve and confectioneries. The fresh, ripe fruit of strawberry is a rich source of vitamins and minerals. The added advantage with strawberry is that it gives early and high returns per unit area compared to other fruits because its crop is ready for harvesting within six months after planting.

Background of research: Strawberry cultivation is restricted to the mid hill area. Although it can be grown in different parts of country on account of selection of proper variety, location, and prevailing climatic conditions. Currently its cultivation is limited due to lack of proper package of practices in the plains of Punjab. There are cultivars/varieties available with us but merely tested for their adaptability and performance in Punjab condition before recommending for commercial cultivation. Keeping in view the maximum work has been done in leading countries but the

lesswork has been done under sub tropics of Punjab state. So, the investigation was carried out entitled "Germplasm evaluation and nutrient management schedule in Strawberry under Punjab conditions".

Methodology: The study was carried out during the time period of year 2017-2019 at Reseach farm, Baba Farid College, Bathinda. The investigation was divided into three separate experiments. In first experiment, the twelve genotypes of strawberry were evaluated under Punjab condition on the basis of growth, floral, yield and quality parameters and experiment was layout in Randomized Block Design and three Replication. The second experiment was layout in Factorial RBD and tested the thirteen different nutrient treatments along with three best genotypes of strawberry under Punjab conditions with respect to growth, floral, yield and quality parameters. The third experiment was layout in Factorial CRD and studied the effect of packaging material and storage conditions on different genotypes with regards to quality and shelf life of fruits.

Experimental findings: The genotypes Winter Dawn, Chandler and Camarosa were reported to perform better under Punjab conditions on the basis of various growth, flowering, fruiting, yield and quality related parameters.On the basis various growth, flowering, fruiting, yield, quality and Benefit cost ratio related parameters it can be confirmed that the INM practices T_{11} (100%NPK + FYM + vermicompost + Biofertilizer), T_8 (100%NPK + FYM + Biofertilizer) and T_{12} (75%NPK + FYM + vermicompost + Biofertilizer) are best for cultivation of all the three cultivars viz. Chandler, Winter Dawn and Camarosa under Punjab conditions.On the basis of various quality parameters during storage of strawberry fruits after packaging with LDPE-50micron film under refrigerated temperature was reported to be best.

Conclusion: The outcome of this investigation can be concluded that the genotype Winter Dawn, Chandler and Camarosa are suitable for cultivation under Punjab conditions. The farmers can adopt INM practices for getting higher income which may include T_{11} (100%NPK + FYM + vermicompost + Biofertilizer), T_8 (100%NPK + FYM + Biofertilizer) and T_{12} (75%NPK + FYM + vermicompost + Biofertilizer). The shelf life of fruits can be enhanced by packaging the fruits with LDPE-50micron film and storing under refrigerated temperature.

ACKNOWLEDGEMENT

All praises to almighty God, the cherisher and sustainer of the world, master of the day of judgment, who bestowed me the health and courage to undertake these studies

I am overwhelmed with rejoice to avail of this rare opportunity to evince my profound sense of reverence and gratitude to my advisor, Dr. Shailesh Kumar Singh, Associate Professor and Head, Department of Horticulture, School of Agriculture, Faculty of Technology and Sciences, LPU, Jalandhar Punjab and Chairman of my Advisory Committee for imparting his valuable and expert guidance, constructive criticism, constant encouragement, painstaking efforts, unending benevolence, vital suggestions and debonair discussions throughout this course of investigation right from the initiation of the work to the ship-shaping (preparation) of the manuscript.

My heartfelt gratitude is due to Dr. Ramesh Sadawarti, Dean, School of Agriculture, LPU for boosting my morale and inspiring me always and scholarly suggestions, constructive criticism and affection throughout my course work and research programme.

I deem it a great privilege to express my inner feelings of heart for Dr.S.S.Bal, Dean, Agriculture Baba Farid College, Bathinda, for their unflinching interest, relentless efforts, valuable advice, close supervision, constant encouragement and motivation during the entire period of research.

I am highly grateful to all the Faculty and staff members of School of Agriculture, Faculty of Technology and Science, LPU, for their constant encouragement, support and guidance during the study programme.

With profound sense of gratitude, I found myself lucky enough to reciprocate the help and sincere cooperation's offered by my colleagues and special thanks toDr. Ritu Pawn& Mr. Chhaterjeet Singh.

I shall be failing in my duties if I do not acknowledge the assistance and cooperation provided to me during the study and research work by the staff of Central library, Lovely Professional University.

Where emotions are involved words cease to mean, lexicon could not have the words to express the affection, blessings, encouragement, sacrifice and love of my beloved parents without which I would have never come to this proliferative stage and engaged myself in career building. The impetus to go high and still higher in the academic field much beyond blue yonder, however ,developed in the sweet lap of my beloved parents from where I first commenced my educational career. It would be my bounded duty to put on record a line of utmost gratitude to my beloved father Mr. V. K.Chawla motherSmtUsha Rani, Tamanna,Lakshit, Manu, Sonia, Ruchi Gaur and Deepa Gaur who as a matter of fact have been a real source to put me of the horizon of this success. I seize this opportunity to express my heartfelt feelings and deep sense of love to my dearest brothers, Dr. RajeshSingla, Dr. Arvinder,Dr.Ranjeet, Dr. Vikas, Dr. Ashwani, Dr.Harish,for their love, affection, valuable advices and for their direct or indirect help.

All those who care for me may not have got a mention, but none shall ever be forgotten.

Place: Jalandhar, Punjab **WineetChawla**
Date: 10-10-2020 **(41500162)**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

Abbreviated Form	Full Form
Ha	Hectare
ha^{-1}	Per hectare
MT	Million tonnes
et al.	et alii (and order)
ft.	Foot
Mm	Milli meter
M	Meter
%	Per cent
/	Per
C.D	Critical difference
N.S.	Non significant
DAP	Days after planting
etc	Et cetera
No.	Number
RHm	Morning relative humidity
RHe	Evening relative humidity
Tmax	Maximum temperature
Tmin	Minimum temperature
g	Gram
cm	Centi meter
cm^2	Centi meter square
Mg	Mili gram
mg/g	Milli gram per gram
cv.	Cultivar
FYM	Farm Yard Manure
N: P: K	Nitrogen:Phosphorus:Potassium
Ml	Milliliter
%	Per cent
^0C	Degree Celsius
^0B	Degree Brix
Hrs	Hours
Min.	Minute
Nm	Nano Meter
A	Absorbance at specific wavelength
V	Volume
W	Weight
q	Quintal

t	Tonnes
Rs	Rupees
sq. cm	Square centimetre
PSB	Phosphate Solubilizing Bacteria
INM	Integrated Nutrient Management
AMF	ArbuscularMycorrhizal Fungi
VAM	Vesicular AbuscularMycorrhizae
LAI	Leaf area index
TSS	Total Soluble Solids
E-W	East-West
N-S	North-South
RDF	Recommended Doses of Fertilizers
DF	Degree of Freedom
LDPE	Low density polyethylene

CHAPTER-I

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is a herbaceous fruit plant which belongs to the family Rosaceae and is octaploid in nature having chromosome number 2n=8x=56. Strawberry fruit is one of the refreshing, delicious, and attractive aggregate fruit. Strawberry cultivation was started in France during the 17th Century.

Strawberry fruits contain vitamins and minerals. Strawberry is preferably consumed for table purposes, in addition, it is being used variously viz., canning, making candy, jam, and jelly. It is also used as flavouring component in ice-creams. Thus, it is having very high market demand and industrial requirements, particularly in the processing and confectionary industries. Strawberry fruit crop gives high returns per unit area and is quick growing crop which is ready to be harvested within five months after planting as compared to other fruit crops (Sharma and Sharma, 2004). It is also grown in a kitchen garden.

The strawberry crop has wider climatic adaptability and is being grown in temperate, subtropical as well as tropical climate. The major strawberry growing countries includes USA, Spain, Turkey, Korea and Egypt. In India, it is being commercially grown in states of Maharashtra, as a leading state, including Uttrakhand, hills of Darjeeling (West Bengal), Himachal Pradesh, and Jammu and Kashmir. In recent years, its cultivation has also been extended from the temperate to the sub-tropical regions (Haryana & Punjab) where this is grown as an annual crop.

The cultivation of strawberry is highly influenced by the climatic adaptability of the region because of the specific, critical photoperiod and temperature requirement of a cultivar and is being further dependent on the cultural practices (Sharma and Sharma, 2003). Further, the extent of vegetative growth in strawberry plants, floral development, and transition between vegetative to reproductive phases depends on variety, temperature, and photoperiod interaction (Darrow, 1936).

In strawberry, although three types of photoperiodic responses have been reported, only two types of octoploid cultivars are commercially cultivated viz., short day, and day-neutral (Hancock *et al.*, 1999). The short day varieties are also known as “June-bearing” or “single cropping strawberries” or “non-ever bearing” strawberries

(Larson, 1994). Day-neutral cultivars are not influenced by photoperiodic changes and undergo reproductive transitions when the temperature goes down 28°C (Durner and Poling, 1987). Thus, the potentially harvesting period can be extended for a longer period.

There is a wide range of cultivars/varieties available with us but merely tested for their adaptability and performance in Punjab conditions before recommending for commercial cultivation. Many germplasms have been grown but their adaptability and acclimatization to subtropical climatic condition of Punjab are yet to be confirmed for better performance and exploitation towards quantitative and qualitative yield. Currently, strawberry cultivation is limited due to lack of proper package of practices in the plains of Punjab. Thus, evaluation of suitability of genotypes for commercial cultivation will not only help the farmers to grow suitable varieties but it will also help them to understand their superiority over presently grown varieties.

The consumption of chemical fertilizers in India is increasing day by day which leads to serious environmental consequences. A significant amount of nitrogenous fertilizers is also being lost as leaching to groundwater causing water body contamination and toxicity to flora and fauna. The run-off or movement of these heavy dose fertilizers containing nitrogen and phosphorus into the water body is responsible for eutrophication causing threat to marine or aquatic life. The amount of nitrogen which is escaped to the atmosphere as N_2 or N_2O is responsible for acid rain and makes the soil acidic. The intensified fruit cultivation system requires the judicious use of inorganic, organic, and biofertilizers for yield sustainability and improved soil health (Jat, 2013).

The application of excessive chemical fertilizers had bad influence on the health of soil and has reduced the productivity of crops and deteriorated product quality. The integrated application means a balanced dose of inorganic sources in combination with organic sources viz., compost, FYM, vermicomposting, green manuring; biofertilizers sources viz., PSB, N- fixing bacteria (Rhizobium, *Azospirillum*, *Azotobacter*s) and K mobilizing bacteria; and nutrient sources fortified with micronutrients (Herbert, 1998). This approach creates a balance between the application of different sources of plant nutrition to minimize a gap between nutrient uptake and loss with nutrient supply and further provides a good amount of organic

matter in the soil, which is essential for beneficial microbes to grow in the rhizosphere.

Strawberry crop is a good option in diversification for the farming community over the traditional cropping sequence of rice and wheat. Simultaneously, the availability of the produce in abundance and premium prices in the market will lead to the economic and nutritional security of the society.

Although several works have been carried out in the countries where it is well accepted as commercial crop but less work has been done under subtropics of Punjab state. So, the investigation entitled "Germplasm evaluation and nutrient management in strawberry (*Fragaria* × *ananassa* Duch.) under Punjab conditions" was worked out with the undermentioned objectives:

1. To evaluate the different genotypes of strawberry for growth, yield and fruit quality.
2. To standardize the nutrient management practices for growth, yield and fruit quality of strawberry.
3. To study the effect of different packaging material and storage condition on shelf life extension of strawberry.
4. To determine the best nutrient and cultivar combination through benefit cost ratio.

CHAPTER-II

REVIEW OF LITERATURE

The experimental findings of various researchers on the germplasm evaluation and nutrient management in strawberry (*Fragaria* × *ananassa* Duch.) under Punjab conditions for growth, flowering and fruiting of strawberry are reviewed as under:

2.1 GERMPLASM EVALUATION

2.1.1 VEGETATIVE CHARACTERS

Significant variations in various cultivars of strawberry with respect to leaf area have been reported by Tanaka and Mizuta (1974) due to the fact of individual progenies might have responded differently to temperature, amount of light, photoperiod and media status. Dhaliwal and Singh (1983) were experimented on the evaluation of twelve cultivars of strawberry under Ludhiana conditions and revealed that cultivar Pusa Early Dwarf had performed better than other cultivars with respect to vegetative characters.

Beniwal *et al*. (1989) were carried out an experiment on the performance of different cultivars of strawberry under Hisar conditions. They observed that strawberry cv. Howard 17 found the highest survival rate (77.5%) while the number of leaves (13.9) was maximum in cv. Blackmore. The strawberry cv. Elista was showed the highest plant height and number of runners/plant (4.7).

The evaluation of fifteen short-day and day-neutral varieties of strawberry in British Columbia was done by Baumann *et al.* (1993). The variety Irvine had reflected maximum counts of runner per plant as compared with other day-neutral varieties but 'Puget Beauty' (9) and 'Shuswap' (10) were showed the highest number of runners as compared to other short-day varieties. The variety Selva (58 cm^2) was having maximum leaf size in the first year and 'Fern' and 'Irvine' (48 cm^2) obtained the highest leaf size in the second year as compared to other day-neutral varieties while the highest leaf size in variety 'Shuswap' (63 cm^2) in the first year and variety Sequoia (67 cm^2) in the second year was reported in short-day varieties.

Chandel and Badiyala (1997) carried an experiment to evaluate eight different cultivars of strawberry under subtropical conditions of Himachal Pradesh and found

that cultivar Belrubi showed the maximum number of runners while cultivar Etna showed the highest plant spread.

Strawberry cultivar Missionary and Belrubi showed the highest plant spread and cultivar Belrubi, Gorella, and Selva were having the maximum number of leaves and petiole length as reported by Suman (2000). Wang and Camp (2000) investigated the impact of day and night temperature on growth and fruit quality in two strawberry cultivars viz. 'Earliglow' and 'Kent', and it was observed that the day-night temperature of 25-12^{0}C was favorable for leaf and plant growth.

Fernandez (2001) revealed that the Florida cultivar Sweet Charlie was reported with minimum plant growth in spring and was less productive than California cultivars 'Chandler' and 'Camarosa'.

Pradeepkumar *et al*. (2002) worked out to evaluate the performance of different strawberry cultivars and revealed the highest vegetative growth in cultivar Sujatha, highest runner count in 'Majesty', leaf area was highest in 'Belrubi' in 1st year and 'Missionary' in the subsequent year while plant spread and leaf count was maximum in Gorella (Asrey and Singh, 2004).

The performance of Fifty-five genotypes of strawberry in Italian mountain areas was assessed by Giongo *et al.* (2006). They noticed that cultivar 'Elsigrade' and 'Elsinore' were performed better than other varieties in relation to height and spread of plants. Das *et al.* (2007) have worked out to check the performance of 33 cultivars of strawberry after the application of various mulching materials. They observed that the variety Dilpasand showed highest leaf count per plant at commencement of flowering stage while variety Missionary showed better results in reference to plant height and leaf count per plant at the end of fruiting.

Sharma *et al*. (2009) worked on the evaluation of various cultivars of strawberry under subtropical conditions. They revealed that cultivar Katrain Sweet showed the greatest plant height (40.14cm), plant spread (24.33cm), counts of leaves (18.90) and leaf area index (0.68) in comparison to other cultivars viz. Belrubi, Blakemore, Fern and Gorella.

The performance of seventeen varieties of strawberry was evaluated by Rao and Lal (2010) in the Himalayan condition of Garhwal district. They observed that the

variety ‘Chandler’ was performed better than other varieties with respect to plant height (23.22 cm) and leaf area (1134 cm^2).

Sahu and Chandel (2014) tested thirteen genotypes of strawberry under mid-hill conditions of Himachal Pradesh. They found that cultivar ‘Festival’ and ‘Camarosa’ were better than others with respect to the plant height and leaf area.

Sharma *et al.* (2014) reported that cultivar Chandler showed the highest plant spread (44.8 cm), and 'Selva' was found with maximum leaf count per plant and leaf area while cultivar Dana was characterised with the highest plant height (26.03 cm).

The performance of four cultivars of strawberry viz. Camarosa, Winter Dawn, Nabila and Seascape under Mahabaleshwar conditions were evaluated by Gaikwad *et al.* (2018) and revealed that cv. Nabila was having highest plant height (30.80 cm) while the lowest (22.9 cm) was observed in cv. Seascape. They also observed that plant spread in cv. Winter Dawn was statistically at par with ‘Camarosa’ and ‘Nabila’.

2.1.2 FLORAL CHARACTERS

Joolka and Badiyala (1983) reported that different varieties showed different periods of flowering because of different chilling hours requirement. Grewal and Dhaliwal (1984) evaluated fourteen strawberry varieties and found that flowering in ‘Florida-90’ and ‘Climax’ was at initiation in the month of mid-January. They observed that cultivar Blackmore produced the highest flower numbers (31.15) per plant while the least flower numbers were recorded in cultivar Fairdfox while cultivar Pusa Early Dwarf showed minimum (96 days) flower duration. The flower formation ceases due to low temperature and the embryo sac differentiation takes place within 2 days before flowering (Wahdan and Waister, 1984).

The significant difference in different cultivars of strawberry with respect to flowering time has been recorded by Nicoll and Galletta (1987), who had reported that the difference in time of flowering may be due to different chilling requirements of these strawberry cultivars. The characteristics of flower and flowering behaviour are major attribute used for the identification of species and cultivars. Stanisavljevic and Gavrilovic (1998) studied phenological and pomological properties of 19 strawberry cultivars and observed significant differences among them regarding flowering time and fruit ripening.

Manakasem and Goodwin (1998) revealed that the temperature of 12.5 to 13.8°C is critical for flower formation. The cultivar summer berry started flowering at 15°C, 20°C and 25°C but stopped flower bud formation and constant development of flowers at the higher temperature (Taimatsu *et al.*, 1991).

Suman (2000) observed that strawberry cultivar Shasta showed flower duration of 77.33 days and cultivar Belrubi showed the highest flower count per plant. Sharma *et al.* (2002) worked out on an investigation to test eight different cultivars of strawberry in Jammu plains and found that cultivar Belrubi had maximum flower numbers (16.40) per plant as compared to other cultivars.

Gunduz and Ozdemir (2003) revealed that early flowering was found in cultivar Sweet Charlie as compared to cultivars 'Camarosa' and 'Selva'. Asrey and Singh (2004) evaluated the six varieties of strawberry and identified that cultivar 'Fern' and 'Gorella' were good in early planting whereas Chandler performed well as late cultivars.

The performance of some cultivars of strawberry in Lucknow was evaluated by Deepa *et al.* (2012). They observed that cultivar Seascap (4.736) was having maximum flower numbers per plant while minimum (1.880) was found in 'Gorella' whereas cultivars Seascap and Addie had maximum fruit set.

Neocleous and Vasilakakis (2012) experimented on three cultivars viz. Camarosa, Fern, and Selva grown on two different soilless substrates and observed early flowering in cultivar Camarosa. Morishita *et al.* (2012) and Morishita (2014) reported that everbearing attributes in some strawberry cultivars due to the nodal position of the first inflorescence.

Sahu and Chandel (2014) studied the response of various strawberry cultivars under mid-hill conditions of Himachal and found that early flowering was in cv. 'Sweet Charlie' and 'Ofra' and the maximum span of flowering were observed in 'Camarosa' and 'Sweet Charlies'.

Sharma *et al.* (2014) evaluated fifteen strawberry cultivars and observed that cultivar Pajaro had produced early flowering which took 115.50 days whereas Selva produced late flowering (134.50 days). They studied that duration of flowering was maximum in early blooming cultivars while in late-blooming cultivars was having lesser duration of flowering.

The performance of ten different cultivars of strawberry was evaluated by Jami *et al.* (2015) and observed that the highest flower counts (35.07), and fruit set (33.73) was in cultivars Sweet Charlie while 'Chandler' also performed better than other cultivars with respect to flower characters.

Das *et al.* (2015) tested various strawberry varieties in Supaul region of Bihar and observed that cultivar Festival performed better than others in respect of highest growth, plant height (21.34 cm), flowering span (60.09 days) and fruiting span (55.62 days).

Ahmed *et al.* (2019) investigated different genotypes of strawberry in Narsingdi and observed that flowering was early in 'BARI Strawberry-1' as compared to other genotypes.

2.1.3 FRUITING CHARACTERS

Moore *et al.* (1970) reported that the number of achenes influenced the berry weight which may be due to differential achene activity in the production of growth-promoting hormones and differential sensitivity of receptacle tissues.

Simanek and Skulcova (1977) evaluated the different cultivars of strawberry and observed that cv. 'Vigerla' and 'Humme Grande' had resulted in good production but small and poor-quality fruits. The maximum productivity was found in cv. 'Sengana' and 'Surprise deHalles'.

Cordrey *et al.* (1980) conducted an experiment on ten cultivars of strawberry comprising with two standard cultivars at two locations. They recorded that the highest yield (23829 lb/acre) was found in cv. Cardinal than standard cultivar at West Tennessee Experiment Station while cv. Atlas gave highest yield (13783 lb/acre) than standard cultivar Tennessee Beauty at Plateau Experiment Station.

Avidov and Shaul (1986) reported variation in yield due to environmental factors like temperature, light intensity and photoperiods. The cultivar Hiku, Kent and Viking gave maximum yield as recorded by Nes (1993) and lowest was found in cultivars Elvira, Headly, Rapella, Elsanta and Karola. Germain *et al.* (1996) noticed that variety Chandler' was observed for better yield in Paris.

Haffner and Vestrheim (1997) conducted an experiment on fifteen cultivars of strawberry for quality parameters. They reported that cv. Elvira, and Rapella had greater ascorbic acid (68 mg/100 g fresh weight) in fruits which was followed by cv.

Glooscap (55mg) and cv. Elsanta (53mg). Gupta (1998) found that cv. Chandler had maximum fruit weight under mid-hill conditions of Himachal Pradesh.

Funaro *et al.* (2000) tested thirteen strawberry varieties in Calabria and reported that cv. Camarosa, Clea, Tudla and Carlsbad produced good yield (700-800 g/plant) per plant. They also observed that cv. Camarosa and Tudla were better than other cultivars with respect to production and quality.

Chandler *et al.* (2000) recorded that the cultivar Festival of strawberry was sweetest than Camarosa. The impact of day and night temperature on plant growth and fruit quality in two different cultivars (Earliglow and Kent) of strawberry was investigated by Wang and Camp (2000) who had concluded that when the day and night temperature raised then fruit surface and flesh color was darker (decrease in L* value).

The effect of polythene on the performance of 35 strawberry cultivars was investigated at Shimla (India) by Pramanick *et al.* (2002) tested thirty five cultivars of strawberry in Shimla and noticed that greatest fruit yield per plant in cv. Etna (243.80 q/ha) and cv. Belrubi (213.20 q/ha) whereas maximum fruit count per plant (30) was found in cv. Shimla Delicious. Sharma and Sharma (2002) studied various fruit characters of fifteen strawberry cultivars and observed maximum yield per plot in cv. Etna.

Nagre *et al.* (2005) worked out research of various varieties of strawberry and recorded the greatest fruit yield (15.55 t/ha) in 'Chandler' while the lowest was found in varieties Fairfax and Australia. The performance of fourteen strawberry cultivars in the Krasnodar region of Russia was tested by Prichko *et al.*, (2005) and observed that cv. Marmolada had maximum productivity.

Das *et al.* (2007) had evaluated the influence of mulches on various cultivars of strawberry and recorded the highest yield in cv. Etna. Sharma and Thakur (2008) reported that maximum yield was recorded in cultivars 'Chandler' and 'Selva' under mid-hill conditions of Himachal.

Singh *et al.* (2008) tested 25 strawberry genotypes under sub-tropics and observed that highest fruits count was noticed per plant in variety Dana while maximum fruit size and fruit yield per plant were found in cv. Camarosa. They also

reported that cv. Ofra produced good fruit quality with respect to anthocyanin content, TSS, total sugars and ascorbic acid.

Moncada *et al.* (2009) studied different cultivars of strawberry with two experiments in Sicily. They observed in the first experiment cv. Carisma' (65.4 t/ha) showed maximum yield while cv. Rubea showed less yield. They found in the second experiment maximum yield was with 'MT 99.20.1' selection (48.1 t/ha). An evaluation of six strawberry cultivars viz. 'Camarosa', 'Galexia', 'Festival', 'Earlibrite', 'Sabrosa' and 'Plarionfre' in southern Brazil was studied by Ristow *et al.* (2009) and recorded highest productivity (43.0 t/ha) in cv. Camarosa.

Santos *et al.* (2009) tested different cultivars of strawberry in two seasons and revealed that maximum fruit count was found in Strawberry cv. 'Festival' in two seasons as compared to other cultivars. Strawberry cultivars viz. 'Induka', 'Jonsok', 'Dukat' and 'Korona' performed better than other cultivars which were investigated by Laugale and Bite (2009). Miserendino *et al.* (2009) studied the eight cultivars of strawberry with respect to yield and quality of fruits. They found that cv. Colima showed maximum productivity.

Voca *et al.* (2009) worked on variation in fruit quality aspects of strawberry cultivar Diamante (day-neutral) when cultivated offseason. They recorded that the quality of strawberry fruits and colour of fruits varied as per the extent of variation in the season thus confirmed the significant effect of climatic factors over quality in photo-insensitive cultivars of strawberry.

The genotypes 'Chandler' (190.70 g) and 'Senga Sengana' (165.80 g) were found superior for yield per plant as compared to other genotypes reported by Rao and Lal **(**2010**).** The performance of six cultivars viz. 'INIA Yvahe', 'INIA Guenoa', 'Yuri', 'Earlibrite', 'SGK 50.4' and 'SGJ 37.2' of strawberry were investigated by Lado *et al.* (2012) and the highest firmness of fruit and more consumers like were recorded in cultivars 'Yuri'.

Kruger *et al.* (2012) observed that fruit colour as fruit surface becomes darker (decreased *L** value), redder (reduces *h*)* due to the rise of day/night temperatures. The effect of two different substrates (cocopeat and rockwool) on the different three strawberry cultivars (Camarosa, Selva and Fern) was tested by Neocleous and Vasilakakis (2012) and reported that cv. Camarosa (442 g plant) and Fern (447 g

plant) gave the highest yield than 'Selva'. The highest total yield was found in cocopeat substrates. Early production was found in cv. Camarosa. The performance of ten day-neutral strawberry varieties was evaluated for organic farming by Hoashi-Erhardt *et al.* (2012) and highest yield was found in cv. Aromas and cv. Seascape both the years.

Ruan *et al*. (2013) worked out on eleven strawberry varieties (6 day-neutral and 5 everbearing) under hydroponic system and revealed that maximum summer yield was found in ever-bearing cultivars than day neutral cultivars due to early summer flowering in everbearing cultivars but maximum autumn yield was found in day-neutral cultivars as compared to everbearing cultivars. They recorded that low malformed fruits; maximum fruit size and better firmness were obtained in (San Andreas) day neutral cultivars than those of ever bearing cultivars.

The evaluation of fourteen strawberry genotypes with respect to different yield parameters was studied by Garg *et al.* (2014) and recorded that significant positive correlation for yield (0.953 and 0.937) and also found in the number of fruits and fruit lengths (0.868 and 0.743).

The performance of seven strawberry varieties was evaluated by Kamangar *et al*. (2014) and revealed that the maximum production was obtained in cultivar Queen Elisa while the lowest was in cultivar Selva. Sahu and Chandel (2014) checked the thirteen varieties of strawberry and recorded that cultivars Festival, Chandler, Camarosa and Sweet Charlie were performed well in terms of yield and size of the fruit. They also showed that the maximum size of berry, weight and firmness was obtained in cultivar Festival.

Jami *et al.* (2015) worked out on ten different strawberry genotypes in the foothills of Nagaland and reported that cultivar Sweet Charlie was performed better than others cultivars in terms of maximum flowers count (35.07), highest fruit counts (33.73 per plant), highest fruit weight (7.77g) and yield (262.00 g/plant). They also observed that cultivars Sweet Charlie, Chandler, and Ofra were estimated with maximum TSS (13.70 Brix) content.

Belakud *et al*. (2015) evaluated fifteen genotypes of strawberry with regards to yield and quality traits. They concluded that highest yield and size of fruit were obtained in cv. Chandler while cv. Sweet Charlie showed the minimum acidity

(0.09%) and the highest juice pH (5.92). They also recorded that maximum sugar (7.23%) was found in cv. Belruby.

Neetu and Sharma (2018) evaluated the different cultivars of strawberry with regards to growth and yield in Chattisgarh. They concluded that cv. Nabila, Camarosa and Flaminia were found with the highest count of flowers and fruits per plant. They also recorded that cv. Nabila produced the heaviest fruits, maximum fruit yield per plant (655.06g/plant) and lower spoilage percent.

Ahmed *et al.* (2019) studied various varieties of strawberry for vegetative growth, flowering and fruiting at Narsingdi and observed that maximum fruit count was found in 'RABI 3' while 'Festival' was recorded with maximum fruit weight (21.45g). They also found that genotype Festival was performed better than other genotypes with respect to fruit size, fruit weight and yield.

2.1.4 GENETIC VARIABILITY AND INHERITANCE

The genome of *Fragaria vesca* was sequenced in 2010 (Shulaev *et al.*, 2010). The genome structure study of octaploid species estimated the genome size of 1C = 708–720 Mb (Akiyama *et al.*, 2001; Davis, 2007), polyploidy and allogamous behavior. Of the various genome composition models, AAA′A′BBB′B′ was the most recent and accepted model (Kunihisa, 2011; Isobe *et al.*, 2013; Debnath, 2016). *Fragaria vesca* or similar species may be the contributor of A-type genomes, while the B-type genomes might be descendent of a close relative of *Fragaria iinumae* (Davis, 2007). *Fragaria chiloensis* has been reported to be the source of winter hardiness (Staudt, 1999), root disease resistance (Lawrence *et al*., 1990). *Fragaria virginiana* bears a range of important horticultural traits including day-neutral, frost tolerance, winter hardy, wider climatic adaptability and red stele resistance (Hancock *et al.*, 2002).

The possible reasons for the tetraploidy in *Fragaria* may be the formation of unreduced gametes during interspecific hybridization of diploids; hybridization followed by induction of tetraploidy either by viruses or by industrial pollutants; hexaploid (*F. moschata*) × diploid hybridization; tetraploid derivative from an octoploid (*F.* × *ananassa*) × diploid hybridization (Ahokas, 1999) or autotetraploidy due to chromosome doubling (Dermen and Darrow, 1938). The phylogenetic study has confirmed multiple polyploidizations in *Fragaria* which has resulted in

allopolyploid origin of hexaploids and octaploids, but the origin of allotetraploid and autotetraploid has not been differentiated (Rousseau-Gueutin *et al*., 2008).

June bearing (short-day plants); typically showing an obligate photoperiodic response and flower induction occurs with shorter photoperiod in comparison to the critical level. Short day strawberry varieties show continuous flowering with suppressed growth when transferred in conditions which support vegetative growth, in case the chilling requirement has not been provided (Guttridge, 1958; Jahn and Dana, 1966). However, if the chilling requirement was fulfilled then the vegetative growth was strongly promoted with suppression of flowering (Porlingis and Boynton, 1961; Piringer and Scott, 1964; Bailey and Rossi, 1965; Paroussi *et al*., 2002). Nestby (1989) and Tehranifar *et al*. (1998) have recommended 28 days of chilling treatment as the optimum requirement for fruit set in June bearing varieties while excessive treatment can enhance vegetative growth with poor flowering (Lieten *et al*., 1995).

Camarosa is an early short-day cultivar and bears fruit having good appearance and flavor. This strawberry plant is a self-pollinating cultivar with great productivity and is highly adapted to produce fruits for a longer period at lower latitudes. Winter Dawn is an early short-day variety that produces numerous runners during summer but few runners with open canopy when transplanted during the fruiting period. Fruits are irregular in shape and size but heavy bearer. The other June bearing strawberry cultivars include Chandler, Camino Real, Gaviota, Lassen, Tioga, Torrey, Tufts, Ventana, Honeoye, Sweet Sunrise, Hood, Puget Relaince, Valley Red, Shuksan, Charm, Sweet Bliss, Tillamook, Totem, Rainier, Puget Crimson, Cavendish, Allstar, Jewel, Earliglow, Lateglow and Annapolis (Finn *et al.*, 2013).

Ever-bearing (long-day plants), these varieties show facultative long day photoperiodic response and flowering is accelerated with the length of photoperiod. They have two crops in a year where the spring crop was relatively longer. The common cultivars were Quinault, Ft. Laramie, Gem, Ogallala, Ozark Beauty and Rockhill (Finn *et al.*, 2013).

Day-neutral varieties are remontant strawberry where the flowering response was independent of photoperiod (Durner *et al.*, 1984). They flower throughout the growing season as long as temperature remains below 90^0F. Hotness of weather results in temporary suspension of fruiting. Day-neutral cultivars are generally ever

bearing in nature and have poor runner producing habit. The common cultivars were Albion, Monterey, San Andreas, Tristar, Tribute, Seascape and Mara des Bois (Finn *et al.*, 2013).

The everbearing and day-neutral varieties group can produce more than two crops in a year and show continuous growth and flowering (Nicoll 1987). Although variable thoughts have been proposed for the inheritance of day neutrality, the most recent study by Shaw and Famula (2005) had provided evidence for a single dominant gene while Serce and Hancock (2005) had confirmed the role of numerous other loci. The everbearing varieties have been reported to carry the homozygous recessive genes for day neutrality (Brown and Wareing, 1965; Hancock *et al.*, 2008).

Genetic and environmental parameters of 5,100 genotypes of strawberry were estimated by Hansche *et al.* (1967). The traits with high heritability were fruit firmness (h^2 = 0.46) and yield (h^2 = 0.48), with moderate heritability was fruit size (0.20) and with 0 heritability was fruit appearance. There were no strong phenotypic correlations among traits measured. The estimate of the genotypic correlation between yield and size was quite large (0.65). On the other hand, estimates of the genotypic correlation between firmness and yield, firmness and size were not significantly different from zero. Low heritability estimates for total berry yield and quality traits like firmness, easy capping, pH value, soluble solids, external and internal appearances but high for yield-related traits like average berry weight, berries per flower stalk, yield per flower stalk and flower stalk number was reported by Spangelo *et al.* (1971).

Morishita (1994) studied on inheritance and genetic variation of yield and quality characters for advanced breeding of strawberry**.** High heritability was observed for average fruit weight, sugar/acid ratio, color of fruit, glossiness, titratable acidity and seed position which suggest that in a breeding program while selecting the parents these characters need to be evaluated.

Verma *et al.* (2002) studied the extent of genetic variability, heritability and genetic advance as percent of mean in respect of 19 quantitative characters in 30 germplasm of strawberry. There was high phenotypic (46.01 %) and genotypic coefficient of variation (45.98 %) for the number of fruits per plant followed by the number of runners per plant, fruit weight and length of leaf petiole indicating the

extent of variability based on these characters. High heritability and GAPM were estimated for the number of fruits per plant and fruit weight which ranged from 3.20 to 18.76 and 1.46 to 8.83 g respectively, showing high heritability (99.90 %) coupled with high genetic advance as percent of the mean.

Kumar *et al.* (2012) conducted field studies for variability in sixteen strawberry genotypes and reported that MSS due to treatment was highly significant for all vegetative, yields and quality-related traits of parental lines and PCV was relatively higher than GCV which confirms the significance of environmental effect on the traits up to a certain extent. Mishra *et al.* (2015) had also similar findings who had estimated the highest heritability (98.44) and a high degree of genetic advance (76.84) for fruit yield per plant confirming the existence of additive gene action for this trait which enables the selection based on fruit yield as a mean of crop improvement. The fruit yield was having a positive and significant association with all other traits under study except leaf count, titratable acidity and ascorbic acid at both genotypic and phenotypic levels.

Singh *et al.* (2015) studied the inheritance, variability & interrelationships of inorganic macro-nutrients and micro-nutrients in the plants of strawberry (*Fragaria ananassa* Duch.) information about the variability in the genetics & inheritance of elements of minerals in a strawberry was very less, as it was necessary for the selection of the genotypes which were better and were suitable for the approaches in breeding to improve the quality of fruits. The results of the study indicated that the effect of genotype on the mineral content of fruit was stronger than that of the environment. Six genotypes, viz. 'Sweet Charlie', 'Ofra', 'Festival', 'Elista', 'Douglas' and 'Camarosa' were found to have higher contents of mineral as well as the better yield of fruits & thus could be valuable in more programs of breeding. The contents of N, K, Ca, Mg, Fe, Mn, Zn, & Cu, together with the yield of fruit, could be upgraded by following the methods of selection & hybridization as these characters presented a high percentage of heritability by more than 80% & high advances in the genetics as a percentage of the mean by more than 40% through the recurrent selection was appropriate for increasing the contents of P, that indicated more than 79.81% of moderate heritability & low genetic advance as a percentage of the mean (> 33.86%). Furthermore, the contents of Mg & N can be utilized as consistent tools

with which to classify the utmost prolific & the genotypes which were rich in minerals, as designated by the analysis of correlation & path.

2.1.5 CORRELATION AND PATH ANALYSIS

Genetic study of strawberry fruit size involving five varieties was conducted by Sherman (1966). The within cross-analysis showed that the fruit weight was highly associated with total fruit weight per plant. In contrast to the within cross-correlations there was no relationship between crown weight and fruit size between crosses. The average harvest date was significantly correlated with fruit weight. Lacey (1973) studied phenotypic associations between vegetative and yield-related traits in strawberry and reported that plant height and leaf count were correlated to fruit count and size and so the yield. It was concluded that these vegetative traits were suitable traits for the early selection of high yielding types. Correlations with respect to generative and vegetative characters in the strawberry were studied by Hortynski *et al.* (1976). It was observed that plant vigour, height, leaf weight, leaf number and leaf area were strongly associated with fruit yield, number of fruits and single fruit weight in the clonal progeny of the F1. Plant vigour was the most stable character in the clones. Some characters assessed at the pre-flowering stage, such as plant height, vigour and leaf number were altered by environment and yield. Leaf number at the onset of winter in the second year of growth was substantially associated with yield of the following summer (Hortynski, 1979).

Phenotypic and genotypic correlations as well as selection indices were obtained for yield, fruit size, freezing quality and total soluble solids (TSS) content in each of five experiments including 18 strawberry types and five replications by Wenzel (1980). There was a negative correlation between average fruit yield-related traits like yield and size with TSS. All the cultivars showed strong relationships between fruit yield and initial crown count, final plant count and fruit count. These strong correlations of various traits with yield were varieties dependent as well (Hancock *et al.*, 1983).

La1 and Seth (1981) a negative correlation of fruit yield with runner counts while a positive correlation was reported with inflorescence count, fruit count, and fruit size. Similarly, fruit count was having a positive correlation with leaf count, inflorescence growth, inflorescence count and TSS whereas a negative correlation

was reported with flower size. Nicoll (1987) evaluated different cultivars of strawberry in the United States, Canada, Europe, and Asia. They found that fruit yield was significant and positive associations with the count of fruit, inflorescence, leaf and crown while negatively correlated with shoot growth, runner count, and root growth related traits. Similarly, a strong correlation between vegetative traits and yield was reported by Strik and Proctor (1988).

Yield and its components were studied during 1983-84 in 20 varieties in Russia by Burmistrov (1988). The cultivars 'Marysa', 'Libuse', 'Maria' and 'Redgauntlet' were selected for use in breeding for yield and were used in correlation studies to determine the components mainly responsible for high yield. The closest correlation between yield per plant and yield per ha ($r = 0.91$) was reported. Hanson (1989) observed that flower removal reduced the number of fruits distinctly but probably to less than half the value of control when only flowers of rank 3-4 were retained. No significant correlation was found between flower removal and fruit growth.

Correlations and path analysis in strawberry were studied by Hortynski (1989) who had reported that fruit yield was strongly correlated to fruit counts per plant while insignificantly to single fruit weight. High phenotypic and genotypic correlations were found between the toughness of skin and firmness of flesh. The correlation between the fruit firmness and weight was near zero and indicated no genetic relationship among these characters. The analysis of path coefficients showed a higher direct influence of the fruit weight on fruit yield. Number of fruits showed a higher direct negative influence on the fruit weight.

Correlation and path analysis study was undertaken by Das *et al.* (2006) and they had reported a positive correlation of fruit yield with the characters like canopy volume, berry counts, berry size, harvest duration and sugar content of fruits. The characters like canopy spread, petiole length and berry weight were in general positively and a significantly correlated with each other both at genotypic and phenotypic levels. Number of berries per plant had a significant positive correlation with canopy spread, duration of harvest and yields both at genotypic and phenotypic levels. Berry diameter was significantly correlated with canopy spread, petiole length, berry weight and negatively correlated with numbers of runners per plant. Petiole

length was not directly associated with yield. Total soluble solids had significant positive association with berry weight, TSS/acid ratio and sugar content. The path coefficient analysis revealed that the maximum direct effect on yield was by fruit yield per plant (0.61) followed by harvest duration (0.33). Berry length, canopy spread and the number of leaves per plant had a negative direct effect on yield.

Sharma and Sharma (2006) studied the correlation and path analysis in strawberry. Phenotypic correlation coefficient was highest (0.66) between yield and fruit number per plant. At the genotypic level, significantly higher values of correlation coefficient were observed between yield per plant, and leaf number per plant (0.96) and between yield per plant and fruit breadth (0.96). In general, genotypic correlation coefficients were higher than the phenotypic correlation coefficient. Through path coefficient estimation, a strong positive and direct contribution of fruit count was reported toward fruit yield and fruit size in order.

Rao *et al.* (2010) studied and reported a significantly high degree of positive correlation of yield with berry size, achenes count, and flower count per plant of strawberry. Among the various contributing traits, the fruit diameter followed by flower counts was the highest and positive (direct) contributor towards the fruit yield. So, these traits can be taken into consideration while performing the selection for crop improvement. Similar findings were also reported by Singh *et al.* (2010).

Bartczak *et al.* (2010) worked on three different types of Frigo strawberry plants and two strawberry cultivars (Honeoye and Elsanta) for analysis of regression and reported a strong and positive correlation of biomass of the strawberry plants, crown count and root length with the fruit yield, in the order.

Haque *et al.* (2015) studied 18 tissue culture variants of strawberry, and observed a significant level of variation in traits. Further, a positive correlation was noticed for petiole length, first flower opening, fruit count, TSS, and individual fruit weight with average fruit yield per plant. These traits were also having the direct and positive effect over fruit yield per plant.

2.2 NUTRIENT MANAGEMENT

2.2.1 VEGETATIVE CHARACTERS

An experiment consisting of vermicompost made from food and paper wastes under a high plastic hoop tunnel was tested on strawberry by Arancon *et al.* (2004)

and observed that the treatment of vermicompost had improved leaf area by 37% and plant runners by 36% in comparison to other treatment.

The impact of various nutrient sources on growth and yield of strawberry cultivar Senga Sengana have been investigated by Nazir *et al.* (2006) and reported that highest (13.03) number of runner per plant, plant height (23.39 cm) and plant spread (24.21 cm) due to the application of Poultry manure in combination with *Azotobacter*, wood ash, PSB and oil cake.

Khokhar *et al.* (2008) conducted an experiment on optimum nutrient supply influence over yield and quality parameters of strawberry fruits. *Azotobacter* inoculation in combination with 50% of nitrogen from vermicompost and 50% through chemical fertilizers as split doses at planting and at prior to flowering reported to give the better result for various plant growth attributes viz. crown count, runners count and runner length whereas application of nitrogen through chemical fertilizers only had resulted in better plant height, plant spread and leaf area.

The influence of the different application of inorganic fertilizer and organic manure over various parameters in strawberry cultivar Chandler have been investigated by Iqbal *et al.* (2008) and that highest plant spread (27.65 cm), plant height (20.29 cm) and leaf area (69.05 cm^2) was obtained in the treatment of 50% nitrogen by urea and 50%by application of poultry manure with *Azotobacter*.

An investigation was worked out on the influence of integrated organic farm yard manure through urea and *Azotobacter* over various parameters in strawberry cultivar Chandler by Iqbal *et al.* (2009) which confirmed that the treatment of 25% nitrogen through FYM in combination with *Azotobacter* showed the highest value of (21.24cm) plant height, plant spread (28.16cm) and leaf area (79.45cm^2) which was statistically better than 100 percent nitrogen through urea with *Azotobacter*.

The influence of INM on various parameters of strawberry has been tested by Umar *et al.* (2009) and found that 100 percent nitrogen through urea in combination with *Azotobacter* showed the highest value of (28.67 cm) plant spread, (21.50 cm) plant height and (75.31 cm^2) leaf area/plant.

Singh and Singh (2009) recorded the highest chlorophyll level (2.63 mg/100g) due to the application of *Azotobacter* and *Azospirillium* (each 2 kg/ha) in combination with nitrogen spray (50%) and GA3@100pm in strawberry variety Sweet Charlie.

Kirad *et al.* (2010) worked out over the influence of INM on various parameters of strawberry and revealed that treatment consisting of 75% fertilizer recommendation in combination with 25% vermicompost and microbial culture in rhizosphere showed the highest (32.37 cm) plant spread and fair plant height.

However, Dar *et al.* (2010) had noticed greater leaf count, plant growth parameters including spread and height, petiole length, flower count, fruit size, specific gravity, fruit yield and ascorbic acid concentration in Sweet Charlie cultivar of strawberry after application of organic nutrient sources.

Singh *et al.* (2012) experimented on the impact of biofertilizers and micronutrients on strawberry cultivar Chandler and resulted that the treatment Arbuscular Mycorrhiza (AM) @ 12 kg/ha in the combination of *Azotobacter*@ 10 Kg/ha showed the greatest value of plant height, plant spread and leaves number /plant.

Gupta and Tripathi (2012) revealed that the highest value of (17.65 cm and 19.45 cm) plant height, (59.60 and 63.60) leaves count and (4.32 and 5.34) number of runners (4.32 and 5.34) were obtained in treatment consisting 7 kg/ha *Azotobacter* + 30 t/ha vermicompost 30 t/ha. Singh *et al.* (2012) obtained the highest runners count due to application of FYM @ 10 t/ha in amalgamation with *Azotobacter*, PSB and AMF.

The effects of two different levels of each *Azotobacter* and PSB on strawberry cv. Chandler with respect to growth, flowering, yield and quality has been investigated by Mishra and Tripathi (2012) and reported that the maximum (5.26) runners per plant, (7.17) crown count per plant and (19.29 cm) height of plant were obtained in combined treatment of *Azotobacter* and PSB.

Lata *et al*. (2013) researched the influence of INM practices on various growth parameters in strawberry cultivar Chandler. They found that the application of *Azotobacter* (50%) in combination with *Azospirillum* (50%), NPK (50%) and FYM resulted in greatest plant growth including plant height, leaf count per plant and leaf size over other treatments.

The effect of six diverse organic amendments on various parameters in cultivar Chandler have been investigated by Khalid *et al.* (2013) and founded that the maximum (20.37 cm) canopy spread, (15.21 cm) plant height and fresh weight of

plant was obtained in treatment (soil + silt + FYM) as compared to other treatments. They also found that highest (6.67) leaves count, (43.07 cm^2) leaf area and (0.92 g)fresh weight were observed in treatment consisting of soil + silt + 200 g $kg^{-1}$of vermicompost. Thus, the application of FYM and vermicompost were reported to improve growth, yield and fruit quality in strawberry. Similarly, Verma and Rao (2013) observed greater plant height, spread and leaf area due to the application of *Azotobacter* and PSB in combination with vermicompost and 50% NPK recommendations. Singh *et al.* (2015) studied and observed similar findings for growth-related traits in strawberry.

Wani *et al.* (2015) evaluated the influence of the treatment mixture of organic and inorganic fertilizer on various characters of strawberry cv. Sweet Charley. They revealed that the application of 25 % inorganic fertilizer + 75 % manures recorded maximum (15.25) mean leave/plants and (21.50 cm) mean plant spread. However, in contradiction Singh (2016) had reported greater vegetative growth due to application of NPK as 100% of fertilizer recommendation in comparison to INM practices in strawberry cultivar Chandler.

Experimentation was worked out to evaluate the impact of INM on strawberry with regards to yield and quality under naturally ventilated polyhouse condition by Subraya *et al.* (2017) and confirmed the greater yield per plant due to application of 100% RDF in combination with *Azospirillum* and PSB.

Beer *et al.* (2017) worked out on the influence of nutrient sources as organic, inorganic and bio-fertilizer on strawberry with regards to vegetative characters, flowering and yield and reported that highest value of (23.91 cm) plant height, (65.37) leave numbers per plant, (7.87) number of runners and (8.25) crown count per plant due to the application of vermicompost (30 ton/ha) + *Azotobacter* (7 kg/Ha) + NPK (80:100:100).

Kushwah *et al.* (2018) worked out on the influence of INM on various parameters of strawberry varieties Chandler and reported the highest (19.53cm) height of plant and (17.93) leave count per plant and (10.07cm) length of petiole were obtained in 75% RDF + 25% Vermicompost + *Azotobacter* @ 5kg/ha + PSB@ 5kg/ha which was at par with 75% RDF + 25% Poultry manure + *Azotobacter* @5kg/ha + PSB@ 5kg/ha.

Other fruits

Singh *et al.* (2008) noticed the greatest plant height and length of internodes due to the application of NPK 120:60:60 + *Azotobacter* + vermicompost @ 2.5 t/ha + PSB in okra. Baksh *et al.* (2008) noticed the highest plant height, spread and trunk girth in Sardar guava due to the application of NPK (100%) in combination with 250g of PSB and *Azotobacter* each.

The impact of inorganic and organic nutrient sources on tomato with respect to growth and yield have been investigated by Mudasir *et al.* (2009) and the highest (130.06 cm) plant height and (11.46) branch count per plant were obtained in the treatment with 95 N + 75 P + 55 K kg/ha + Poultry Manure (3.5 t/ha) while minimum plant height and number of branches were found in control.

The influence of INM on tomato was evaluated by Chumyani *et al.* (2010) who had reported maximum (69.37 cm) plant height and (50.87) leaf count per plant due to application of treatment having 50 % NPK + 50 % FYM + bio-fertilizers in contrast to rest of the treatments.

Yeptho *et al.* (2010) investigated the various nutrient management under protected cultivation of tomato and observed the greatest height and count of branches and leaf count by treatment of 50% NPK + 50% poultry manure + bio-fertilizer as compared to other treatments.

Singh and Ram (2018) worked out over the influence of organic, chemical fertilizers and bio-fertilizers on okra and reported that the application of 50% of fertilizer recommendation + vermicompost showed highest (88.75) plant height and (26.56) number of leaves while minimum was found in control.

Verma *et al.* (2019) experimented to estimate the influence of organic, inorganic and bio-fertilizers on vegetative growth of Dragan fruit *(Hylocereus undatus* L.*)* and resulted that the treatment having FYM + NPK (75%) +*Azotobacter* +PSB showed the highest (7.61) branch counts per plant and (58.41) count of the thorn in comparison to control.

Kamatyanatti *et al.* (2019) experimented to determine the impact of INM practices on plum and they found that the treatment containing 75% of N through Urea, 12.5 % of N through vermicompost + 12.5 % of N through FYM in

combination with biofertilizer showed the highest (70.63 cm) annual shoot growth and leaf area (13.13 cm^2).

2.2.2 FLORAL CHARACTERS

The influence of the various combination of N, P and FYM on strawberry cultivar Tuft was investigated by Yusuf *et al.* (2003) and recorded that maximum (14.63) flowers number per plant was obtained in treatment containing N (150kg/ha), P (100kg/ha) and FYM (20t/ha).

A research work was worked out on different combinations of organic sources of nutrients on strawberry cultivar Senga Sengana by Nowsheen *et al.* (2006) and recorded the earliest flowering (10.33 days) due to combined use of poultry manure, *Azotobacter*, wood ash and PSB.

Yavari *et al.* (2008) investigated the check interaction of organic substrates and chemical sources of nutrients on strawberry cv. Selva and reported that treatment (50%) liquorice processing wastes + (50%) mineral soil showed maximum floral bud, yield and shoot weight.

Zargar *et al.* (2008) reported that treatment of PSB + N 225 kg per ha and P 150 kg per ha showed significant results with respect to primary flowers (8.0) and secondary flowers (10.0) per plant and total flowers count per plant (7.0) in strawberry.

Standardization of INM on strawberry cultivar Chandler cultivation was carried out by Yadav *et al.* (2010) and resulted that the use of half N through vermicompost and remaining half nitrogen through inorganic source was applied at planting and prior to flowering as the equal split dose which recorded maximum (29.60) flowers number, (142.33 days) duration of flowering and (71.33 days) duration of harvesting with respect to other treatments.

A study was conducted by Gupta and Tripathi (2012) to check the impact of vermicompost alone and *Azotobacter* alone or in their combination over the growth, flower and fruiting characters of strawberry cv. Chandler and noticed that the treatment combination of *Azotobacter* (6 kg/ha) and vermicompost (30t/ha) showed the highest value of (67.48 and 64.51, respectively) flowers number, (39.21 and 36.19, respectively) fruits/plants and maximum harvest span (71.04 and 69.02 days, respectively). They also observed that this treatment was recorded with lesser (56.15

and 54.15 days, respectively) days to produce 1st flower and (6.44and 5.94 days, respectively) days to fruit set.

The effect of biofertilizer on strawberry cv. Chandler was evaluated by Mishra and Tripathi (2012) resulted that the treatment containing six kg of each *Azotobacter* and PSB in one hectare showed the highest value of (67.27) number of flowers.

Singh *et al.* (2012) investigated over the impact of bio-fertilizers and micronutrients in combination with the application of *Azotobacter* (10kg) + Vesicular arbuscular mycorrhizae (VAM) (12kg) per hectare recorded maximum flower count (38.80) and fruit count (29.13). Similarly, the maximum flower count, early flowering, fruiting and largest flowering span was recorded due to the application of combination of 50% NPK as fertilizer recommendation and *Azotobacter* in combination with PSB and vermicompost as reported by Verma and Rao (2014).

Singh *et al.* (2015) worked on the use of vermicompost and biofertilizers in strawberry and the earliest flowering (50.39 days) was reported in vermicompost + AM treatment. The number of flowers (64.23) was noticed to be highest in vermi-compost + *Azotobacter* + PSB + AM treatments.

Tripathi *et al.* (2015) worked out the consequence of *Azotobacter* and vermicompost on strawberry cv. Chandler in relation to growth, flowering, yield and quality and reported that the treatment *Azotobacter 6* kg/ha + vermicompost 30 t/ha showed highest flower count (65.99) while the lowest flower number was noticed in control.

Wani *et al.* (2017) tested the influence of various combinations of fertilizer and manures in strawberry and they found that the application of 25% of fertilizer recommendation from inorganic sources and 75% from organic manures showed 2.5 more flower buds/plant than control.

Singh *et al.* (2017) worked out the influence of INM on strawberry variety Chandler with respect of quality parameters and revealed that the use of 75% of NPK recommendation in combination with Vermicompost, *Azotobacter* and PSB showed the highest values of fruit length (33.50 mm), width of fruit (25.14 mm), weight of fruit (25.14 mm) and (10.46cc) fruit volume which was statistically at par with 75% of NPK recommendation in combination with FYM, *Azotobacter* and PSB while minimum values had obtained in control (untreated). They also reported that

maximum TSS (12.23^0B), total Sugar (9.16%) and (4.95) pH were recorded by 50% NPK + Vermicompost + *Azotobacter* + PSB.

Beer *et al*. (2017) reported that the treatment consisting of vermicompost (25 ton/ha) + *Azotobacter* (6 kg/Ha) + NPK (70:80:80) resulted the lowest (49.41 days) days taken to 1st flower and highest flowers numbers per plant which may be due to availability of the substantial amount of nutrients and growth-regulating hormones throughout the crop span.

Changotra *et al.* (2017) evaluated the influence of chemical fertilizers and bio-fertilizers used in the cultivation of strawberry cv Chandler under Punjab conditions and concluded that maximum plant height (21.43 cm), leaf count per plants (27.18) and leaf area (119.10 cm^2) while the minimum was recorded in control (no fertilizer).

The influence of INM on strawberry (*Fragaria* × *ananassa* Duch.) cultivar Sweet Charlie have been tested by Jain *et al.* (2017) and earliest flowering (40.68 days) was reported due to application of vermicompost in combination with Poultry manure and bio-fertilizers comprising *Azotobacter* and PSB while, maximum numbers of flower (13.42) per plant had been noticed with the application of vermicompost in combination with FYM, *Azotobacter* and PSB.

Kushwah *et al.* (2018) worked out an investigation over INM practices in strawberry *cv*. Chandler where 75% RDF + 25% Vermicompost + *Azotobacter* @ 5kg/ha + PSB@ 5kg/ha showed the lowest days taken to first flower appearance (58.43) and highest flower count per plant (28.13) which was at par over 50% RDF + 50% Vermicompost + *Azotobacter* @5kg/ha + PSB@5kg/ha

Soni *et al.* (2018) had done an investigation overuse of organic manures and biofertilizers on strawberry cv. Sweet Charlie and recorded that treatment consisting 50%Vermicompost +50% Poultry Manure + *Azotobacter* showed the highest number of flowers (30.41) followed by treatment consisting 50% Vermicompost +50% FYM + *Azotobacter* (25.73). This may be attributed with ease of nutrient uptake by plants and translocation of phytohormones like cytokinin towards the auxiliary tissues for inducing bud break through loss of apical dominance. Further, the development of new and active sink towards auxiliary buds resulted in mobilization of photosynthates and early shift of vegetative buds into reproductive buds.

Other Fruit Crops

Shilpi *et al.* (2014) noticed that the treatment containing 75% of RDF and 25% vermicompost in brinjal cultivar Pant Rituraj showed the highest flower count (16.77). Singh and Ram (2018) conducted an experiment on okra and reported that the treatment (50% RDF + Vermicompost) recorded the highest days to first flowering (46.40) and 50% flowering (51.00). They also found that the highest days to first picking (62.59) was in (50% RDF + Vermicompost) while the lowest was found in control.

Kamatyanatti *et al.* (2019) worked out on the influence of INM on plum and they confirmed the highest flower count per unit of the shoot (87.19) in treatment which consists of 75% of N from inorganic source, 12.5% of N through vermicompost and 12.5% of N through FYM in combination with biofertilizers.

2.2.3 FRUIT CHARACTERS

Wang and Lin (2002) worked out on research on strawberry and revealed that the highest TSS (8.3 ^{0}Brix, 6.3 ^{0}Brix), total sugar (4.38%, 5.87 %) and titratable acidity (0.54%, 0.51%) in cv. Honeoye and Allstar were obtained due to the application of 50% soil + 50% compost. Rana and Chandel (2003) advocated that the maximum length (37.32 mm), width (23.65 mm) and weight of fruit (10.02 g) were noticed due to the use of treatment consisting of 60 kg N/ha + *Azotobacter* in strawberry cv. Chandler.

Khokhar *et al.* (2008) worked out on the influence of optimum nutrient supply in strawberry fruits. It was reported that use of vermicompost and inorganic sources of nitrogen as 50% from each in combination with *Azotobacter* inoculation in two split doses, half at the time of planting and a half prior to flowering, resulted in good fruiting in terms of flower count, berries count, fruit yield and net benefit.

The influence of organic and chemical fertilization on strawberry under plastic-house has been tested by Mahadeen (2009) and reported that there was an increase in fruit yield in treatment consisting NPK fertilizer with organic fertilizer. They observed that maximum (27.62 ton/ha) yield was recorded in the treatment of 40 tons of organic fertilizer with 60 kg NPK-fertilizer/ha whereas the untreated plot showed minimum yield (21.76 ton/ha) in strawberry.

Umar *et al.* (2009) observed that the highest yield (372.89 g/plant) and acidity (0.77%) were obtained in treatment consisting of 100 percent N through urea in combination with *Azotobacter* while, the treatment consisting 25 percent N by FYM and 75% N through urea in combination with *Azotobacter* showed maximum fruit size (38.4 x 28.9 mm), TSS (6.8 ^{0}Brix), anthocyanin contents, total sugar (4.85%) and ascorbic acid in strawberry fruit.

The impact of biofertilizers and bioregulator on strawberry has been studied by Singh and Singh (2009) and revealed that the treatment consisting of *Azotobacter* + *Azosprillium* + 50% N of the standard dose + GA_3 @ 100ppm showed the highest value of ascorbic acid contents, TSS and total sugars.

Iqbal *et al.* (2009) worked out the influence of INM consisting of FYM, urea and *Azotobacter* on strawberry cultivar Chandler. Application of FYM (25%) and urea (75%) as source of nitrogen in combination with *Azotobacter* had resulted in highest TSS, sugar content, ascorbic acid level and anthocyanin concentration while 100% nitrogen through urea in combination with *Azotobacter* resulted in maximum yield (372.89 g per plant) at par with the application of FYM (25%) and urea (75%) as the source of nitrogen in combination with *Azotobacter* (358.43 g per plant). The influence of different organic fertilizer combinations in strawberry cultivar Sweet Charlie have been observed by Dar *et al.* (2010) and reported an increased leaf count, plant growth (spread and height), flowers count, fruit size, specific gravity, fruit pH, fruit yield and ascorbic acid content of fruits.

Singh *et al.* (2012) recorded that the treatment consisting of vermicompost + *Azotobacter* + *Azospirillum* + PSB recorded maximum TSS and sugar content with lower acidity in strawberry fruits. Dadashpour and Jouki (2012) worked out over the impact of combined application of organic nutrient sources on strawberry in Iran and resulted in highest fruit size (3.95cm x 3.11cm), weight (11.11g), TSS (9.01^{o}B), total sugar (7.95 %) and yield (238.95g per plant) due to the placement of manure + *Azotobacter* + wood ash + PSB + oil cake.

Mishra and Tripathi (2012) conducted an experiment on the influence of bio-fertilizers on strawberry cultivar Chandler and recognized that the highest fruits set per plant (37.88) and harvesting span (70.90 days) due to the application of a combination of *Azotobacter* and PSB (6 kg per ha of each).

Verma and Rao (2014) observed that the application of treatment consisting of 50%RDF in association with vermicompost, PSB and *Azotobacter* induced early flowering with the highest flower count, large flowering span, fruit count and weight, fruit yield per plant and per hectare. This treatment had further reduced EC and pH of soil and improved organic carbon, available nitrogen, phosphorus and potassium in the soil. Further, the replacement of vermicompost in combination treatment by FYM had also given better results on various aspects. Wani *et al.* (2015) had also advocated in favour of INM treatments for better yield and related attributes in strawberry.

Singh *et al.* (2015) worked out on the influence of organic sources on strawberry and noticed the highest plant growth (height and spread), leaf count, flower and fruit count, fruit set and fruit yield per plant due to the application of combination vermicompost, *Azotobacter*, PSB and AM as the nutrient source while early flowering and runners count were highest due to the application of vermicompost in combination with PSB and AM. The lowest value was reported in control.

Singh (2016) worked out on the impact of INM approach on strawberry and concluded that the treatment containing 100 % of NPK as chemical fertilizers substantially raised the plant height, plant spread, leaf count, leaf length, width, leaf area, fresh and dry weight of leaf, harvesting span and days taken to 1st flower while 75% NPK + Vermicompost + *Azotobacter* + PSB application resulted in highest flower count, number of fruits, fruit setting percentage and maximum fruit yield. The fruit quality attributes including TSS, reducing and non-reducing sugar, TSS/Acid ratio, pH and lowest acid content were noticed due to the application of 50% NPK + Vermicompost + *Azotobacter* + PSB.

Ahmadi *et al*. (2017) studied to evaluate the impact of INM in strawberry cultivar Sabrina under polyhouse at College of Horticulture, UHS Campus, Bengaluru and found that the highest number of fruits/plant (19.07), fruit weight (16.23 g), fruit length (4.28 cm), fruit diameter (2.56 cm), fruit volume (18.83 mL), yield/plant (309.70 g), yield/ha (17.20 tons), Benefit: Cost ratio (2.37), TSS (10.13°Brix), total sugars (6.01%), reducing sugars (5.17%), TSS: Acid ratio (16.78) and lowest titratable acidity (0.61%) were observed in the plants treated with 100% RDF + VAM

@10 kg/ha + 0.4% Boron + 0.5% $ZnSO_4$ spray than the control, while the treatment 100% NPK through FYM only showed lowest results.

The effect of INM approach on strawberry cv. Sweet Charlie has been tested by Jain *et al.* (2017) and reported that the use of vermicompost + Poultry manure + *Azotobacter* + PSB showed the highest fruits per plant (11.78), fruit weight (12.86 g) and yield (112.63 g per plant) and shelf life (5.69 days). They also recorded that significant total soluble solid (7.05°B), vitamin C (53.44 mg/100g of pulp) and pH (2.66) were obtained due to the application of vermicompost + Poultry manure + *Azotobacter* + PSB which was substantially at par with treatments consisting poultry manure+ compost +*Azotobacter*+ PSB and FYM + vermicompost + *Azotobator* + PSB) respectively.

The effect of INM on strawberry have been investigated by Kushwah *et al.* (2018) and observed that the highest (276.36 g) yield per plant, (9.62^0B) TSS in fruit, (8.13%) total sugar, (1.69) specific gravity and (84.99 %) juice content were obtained in treatment 75% RDF + 25% Vermicompost + *Azotobacter* @ 5kg/ha + PSB@ 5kg/ha followed by treatment 50% RDF + 50% Vermicompost + *Azotobacter* @5kg/ha + PSB@5kg/ha.

Other fruits

The influence of organic and inorganic sources of nutrients on the yield of tomato has been investigated by Patil *et al.* (2004). They revealed that use of 50% fertilizer recommendation (NPK 100:50:50 kg/ha) + 50% FYM showed the highest yield (2.34 kg/plant).

Marathe and Bharambe (2005) worked out on tomato and observed that the highest length of fruit (74.0 mm) and width (76.7 mm) were recorded in the treatment 50%RDF +25% N through FYM + *Azotobacter* + PSB but the weight of fruit was observed the highest in treatment consisting 50% RDF fertilizer + 50% N through FYM. The treatment consisting of 75% of NPK recommendation + 10 kg/plant of vermicompost showed highest fruit weight and fruit diameter which was observed by Athani *et al.* (2007) in guava.

Sudhakar and Purushotham (2008) discovered the influence of biofertilizer on tomato and recorded that maximum number of fruits (25.75) and yield (75.10 t ha^{-1})

were obtained in the treatment 75 % RDF (150:60:80 NPK kg/ha) + bio-fertilizer + PSB (15 kg/ha).

Premsekhar and Rajashree (2009) worked out on the influence of fertilizers on tomato and reported maximum plant height (72.60 cm), fruits number per plant (33.70) and yield (43.85 t/ha) in treatment consisting of 75 percent Nitrogen + 100 percent P and K + *Azospirillum* (2 kg/ha).

The influence of INM on okra cv. Arka Anamika have been investigated by Bairwa *et al.* (2009) and reported that the treatment consisting of 60% recommended dose of NPK through inorganic fertilize + vermicompost @ 10q/ha +*Azotobacter*+ neem-cake@6q/ha + PSB showed the maximum number of fruits/plants (18.36), height of plant at 90DAS (77.80cm), stem base diameter (2.25cm), count of fruiting nodes per plant (19.18), fruits count per plant (18.36), fruit weight (17.65 g) and length (12.26 cm).

The impact of INM on the yield of guava have been investigated by Singh *et al.* (2011) who advocated that application of 50% of fertilizer recommendation +25 kg of FYM +50 kg of vermicompost showed the maximum number of fruits (194.30). The impact of INM practices on sapota have been investigated by Baviskar *et al.* (2011) who recorded that the treatment consisting of 1125g N, 750g P and 375g of K in combination with 15 kg of vermicompost, 250 g of *Azotobacter* and 250 g of PSB showed the highest number of fruits per plant and fruit yield (kg/plant). The various organic and biofertilizers sources were tested on guava by Devi *et al.* (2012) and revealed that the highest (230.5 g) fruit weight was noticed in the application of vermicompost (19 kg) + Neem-cake (9 kg) + *Azotobacter* (100g) + phosphorous solubilizes (100g) + potash mobilizers (100g) per plant per year while the maximum fruit count per plant (626.3) was recorded in the application of FYM (26 kg) + *Azotobacter* (100g) + phosphorous solubilizes (100g) + potash mobilizers (100g) per plant per year.

Singh and Varu (2013) concluded that the application of fertilizer recommendation (100N:100P:125K in g per plant) along with *Azotobacter* @50 g per plant+ PSB @ 2.5 g per m^2 was recorded better result in papaya with respect to fruit numbers (45.33), length of fruit (30cm) and weight of fruit (1.7 kg). Sharma *et al.* (2013) worked out on research on INM strategies on guava and reported that the

maximum fruit yield (41.14 kg per plant), fruit length (8.39 cm), breadth (7.94 cm), weight (244.24 g) and pectin (0.81%) were obtained in the treatment consisting of 75% of N through inorganic source + 25% of N through FYM per plant whereas maximum (12.95ºB) TSS, (8.61%) total sugars were recorded in 50% of N through FYM + 50% of N through inorganic source per plant + *Azotobacter*.

The effect of INM on guava have been tested by Akash *et al.* (2013) and observed that the use of 25% of N through FYM + 75% of N through inorganic sources resulted in better fruit quality with respect to the length of fruit (8.39 cm), breadth (7.94 cm) and weight of fruit (244.24 g). Kumar *et al.* (2013) observed in pear fruit crop that the highest length of fruit (7.05 cm), breadth of fruit (7.08 cm) and weight of fruit (187.00g) were obtained in treatment 20 kg FYM + 30 g *Azotobacter*.

The effect of INM on acid lime cv. Kagzi have been investigated by Nurbhanej *et al.* (2014) and reported that the treatment 75% of fertilizer recommendation + vermicompost 9 kg/tree + AAU PGPR consortium 3.5 ml/tree showed the highest yield per tree (46.92 kg), fruit weight (53.20 g) and fruit diameter (4.52 cm). They also resulted that maximum ascorbic acid content (29.63 mg/100g juice) and total soluble solids (8.85 °B) in the same treatment.

Jamwal *et al.* (2018) worked out INM on guava cv. Allahabad Safeda under meadow orcharding and they reported that the highest fruit count per tree (21), fruit length (7.10cm), average fruit weight (190.10gm), fruit diameter (7.15 cm), fruit volume (192.13) and fruit yield per ha (199.58 q) were recorded due to application of 75% Nitrogen through urea + 25 % Vermicompost + *Azotobacter*.

Prabhu *et al.* (2018) worked out over the impact of INM on acid lime cv. PKM1 and reported that maximum fruit set (65.28), number of fruits/tree (1045.9), fruit weight (39.94 g), yield/tree (48.98 kg) and juice (27.98 ml) were noticed in treatment consisting 100% of recommended dose of chemical fertilizers@ 600:200:300 g NPK/ plant/ year + *Azospirillum*@100g/plant + Phosphorus Solubilizing Bacteria @100 g/plant + Arbuscular Mycorrhizal fungi @500g/plant + *Trichoderma harzianum*@ 100 g/plant.

The impact of INM on the yield of Okra was investigated by Singh and Ram (2018). They revealed that the use of 50%RDF + Vermicompost showed the maximum fruit count per plant (28.50), yield per hectare (320.74q), length (22.85)

and diameter (26.45) of fruit while, all the yield and quality parameters showed minimum value in control. The influence of INM on yield of plum have been investigated by Kamatyanatti *et al.* (2019) and they reported that the treatment consisting of three nitrogen sources viz. 75% as inorganic source, 12.5% as vermicompost and 12.5% as FYM in combination with biofertilizers showed highest fruits count per feet of shoot (32.58) and (4.01 kg/cm^2) fruit firmness (4.01 kg/cm^2), fruit weight (12.35 gm), and fruit yield per tree (53.43 kg/tree) as compared to other treatments.

2.3 BENEFIT COST RATIO

Selvi *et al.* (2000) worked out on the economics of okra (Parbhani Kranti) cultivation through INM and reported that the treatment consisting of strain micro-food + composted corn pith (25 tonnes per hectare)+ *Azospirillium* (2 kg per hectare) showed maximum income per hectare (Rs.20912) and B:C ratio (11.3) and was statistically at par to the treatment consisting of CCP + *Azospirillium*.

Prabhu *et al.* (2002) observed that the highest marketable yield per hectare (14.17 t/ha), gross income (Rs.141700/ha), net income (Rs.43900.50) when estimated at the variable cost and net additional income when compared with the control (Rs.43900.50/ha) were observed in treatment consisting of two-third of fertilizer recommendation + FYM (10 tonnes per hectare) Azospirillium +VAM. They also reported that maximum benefit: cost ratio in treatment consisting of 1/3 RDF +Azospirillium + PSB.

Dass *et al.* (2008) worked out on the influence of INM on tomato in Orissa and confirmed that 50% of fertilizer recommendation + Bio-fertilizer + Vermi-compost showed maximum yield (20.75 t/ha) and benefit: cost ratio (3.0) as compared with other treatments. Bairwa *et al.* (2009) had worked out the influence of INM on okra cv. Arka Anamika and reported that the treatment consisting of 60% recommended dose of NPK through inorganic fertilizers + vermicompost @ 10q/ha +*Azotobacter*+ neem-cake @ 6q/ha + PSB showed the maximum benefit: cost ratio (3.19). Neerja *et al.* (2010) had worked out the influence of INM on tomato and reported that the combined application of seedling dip with 75% N + 100% PK + FYM (25 t/ha) + *Azotobacter* (2 kg/ha) showed maximum (1:2.51) cost: benefit ratio and highest (Rs.1,48,089/-) net return.

Jain *et al.* (2017) studied the impact of INM on strawberry cv. Sweet Charlie and reported that the treatment Vermicompost+ FYM+ *Azotobacter*+ PSB was highest cost: benefit ratio (1:3.69). Kushwah *et al.* (2018) reported in strawberry cv. Chandler that highest yield (24.87 t/ha), net return (19.86 lakh/ha) and benefit-cost ratio (1:4.97) were recorded by 75% RDF + 25% Vermicompost + *Azotobacter* @ 5 kg perha + PSB @ 5 kg per ha.

2.4 PACKAGING MATERIAL AND STORAGE

The polythene bags packaging material showed the minimum fruit weight loss as compared to unpacked fruit that has been observed by Thompson (2001). Yamashita *et al.* (2002) studied the post-harvest quality of atemoya fruit when packed in different packaging material at different storage temperatures and reported that minimum loss of weight was found in packed atemoya as compared to control. Fruit did not ripen in the LDPE packaging material which may be due to the adverse atmosphere inside the packaging. They also reported that PD-955 film showed 30 percent increase in the shelf life of fruits which were stored at 15°C temperature.

Babarinde and Fabunmi (2009) conducted an experiment on the effect of different packaging materials and storage temperature (room and refrigerating condition) on okra with respect to quality parameters viz. weight loss, colour, moisture, ascorbic acid, pH, titratable acidity, etc. and reported that the packaging material LDPE showed better results with respect to weight loss, pH, ascorbic acid and firmness in both storage temperature. The ascorbic acid content and (6.7 to 5.5) pH values were going to decline but raised titratable acidity in both stored temperatures. The minimum weight loss in marketable okra was found in LDPE at room (9 days) and (more than 9 days) refrigerated temperature.

An experiment was conducted on the impact of different packaging material (7, 15 and 21 µm thick polyethylene bags) and storage temperatures (7, 14 and 21°C) on the two hot peppers cv. 'Wonder King' and 'P-6' by Amjad *et al.* (2009) and reported that the hot pepper cv. P-6 packed in polyethylene bags 7 µm stored at temperature 7 °C showed the least weight loss. They also reported that the highest (53mg/100g) ascorbic acid content and extend (20 days) shelf life were obtained in hot pepper cv. P-6 packed in 15 µm stored at temperature 14°C while hot pepper cv.

Wonder king packed in polyethylene bags 7 µm stored at temperature 7 °C showed the highest (107mg/100g) vitamin C level.

Peano *et al.* (2014) studied the influence of different packaging material viz., biobased and polypropylene perforated films on quality and nutraceutical characteristics of strawberries cv. Envie-2 stored under cool room at ±2°C and at room temperature ±20°C and reported that fruits with bio-based films packaging and storage at ±2°C maintained better fruit quality when compared to the stored at room temperature.

Giuggioli *et al.* (2015) studied the raspberries that variation in temperature changed the aroma and quality of raspberry fruit and the increase in the shelf life of fruit was found in modified atmosphere packaging. Bhatia *et al*. (2015) worked out on the impact of packing (PP, LDPE and KPA) material on pomegranate cv. Mridula and observed the maximum antioxidant, ascorbic acid and anthocyanin were preserved in PP bags in comparison to LDPE and KPA when aril was stored at a cold temperature for 15 days.

The different packaging material viz. LDPE, PP, MP and HDPE) and storage condition (cold and room temperature) impact on shelf life arils of pomegranate have been investigated by Safari *et al*. (2016) and recorded the highest shelf life, TSS (14.5 ^{o}B) and total sugar (8.54) through HDPE (40% microns) packaging material.

Sualeh *et al.* (2016) had performed an experiment on the impact of different packing material and different storage condition on tomato and reported that the minimum weight loss was observed by tomato packed in HDPE stored in the refrigerator while maximum was found in control stored at room temperature

Panda *et al.* (2016) conducted an experiment on the impact of different packaging materials on the shelf life of strawberry variety Sweet Charlie stored under ambient condition (18-25^{0}C & 80-90% relative humidity) and observed that LDPE along with PP and cling film showed significant results with respect to reduction in decay loss. They also reported that among the different packaging materials LDPE 50-micron was performed better as compared to other packaging material with respect to (5.49%) weight loss and best organoleptic rating of strawberry and reported that LDPE 50 and LDPE 75 micron showed good amount of ascorbic acid (31.56 mg/ 100g, 29.86 mg/ 100g respectively). They recorded that the effect of packaging

material on TSS and titratable acidity was not significant and a decreasing trend was noted during storage for the TSS (6.35% - 5.78%) and titratable acidity (0.91% - 0.70%).

Watharkar *et al.* (2017) studied the effect of different packaging material viz. LDPE 100-gauges, Polypropylene (PP) 90-gauges and laminated Aluminum Foil (LAF) on grapes with respect to quality parameters and revealed that the LDPE packaging material in grapes showed the least loss in (22.00N) hardness and thickness (44.84 cm) as compared to the rest of the treatments. They also concluded that maximum (4 weeks) shelf life of grape and better quality retention was recorded due to LDPE packaging of grapes stored in refrigeration conditions.

Rinaldi *et al.* (2017) investigated to understand the impact of different (PVC 12µm PVC 30µm, LDPE 100µm , LDPE 200µm and control) packaging material at different storage condition (ambient & low temperature) on passion fruits and reported that the lowest weight loss was found in the treatment passion fruit packed in PVC 12µm at refrigeration condition.

The impact of package material (HDPE & LDPE) on guava cv. Khaja have been tested by Nagaraju and Banik (2019) and observed that all the treatments of LDPE and HDPE showed significant result on the basis of marketable fruit quality and increase shelf life of guava fruits.

CHAPTER-III

MATERIALS AND METHODS

The current research work "Germplasm evaluation and nutrient management in strawberry (*Fragaria* × *ananassa* Duch.) under Punjab conditions" was performed in the experimental orchard of the Baba Farid College, Bathinda during 2017-19.

3.1. AREA

Research Farm of Baba Farid College, Baba Farid Group of Institutons, Bathinda (Punjab) is located in the northwestern region of India and between 30.2518°N latitude 74.8417°E longitude at an average 201-meter elevation above from mean sea level.

3.2. CLIMATE

The climate is the semi-arid type with May and June are the hottest months while December and January are mild months at Research farm of Baba Farid College, Baba Farid Group of Institutions, Bathinda. The average (39.7^{o}C) maximum temperature was recorded in May whereas the average (4.4^{o}C) minimum temperature was found in January and 384.1 mm total rainfall was recorded from October, 2017 to September, 2018. The month of June was the hottest month with an average (41.2^{o}C) maximum temperature, while the minimum temperature was recorded in December month from October 2018 to September 2019. The monthly data of temperature, relative humidity and rainfall has been mentioned during the cultivation year 2017-18 and 2018-19 in Fig-3.1.

3.3. SOIL

The soil sample was collected before starting the experiment. The experiment field soil was analyzed for physic-chemical with the following methods:

3.4. FIELD PREPARATION

The field was prepared in the research farm by tillage and planking the soil for this study. The unwanted material and weeds were removed from the field and prepared 15cm raised beds with 2 x1 m length and width of the bed.

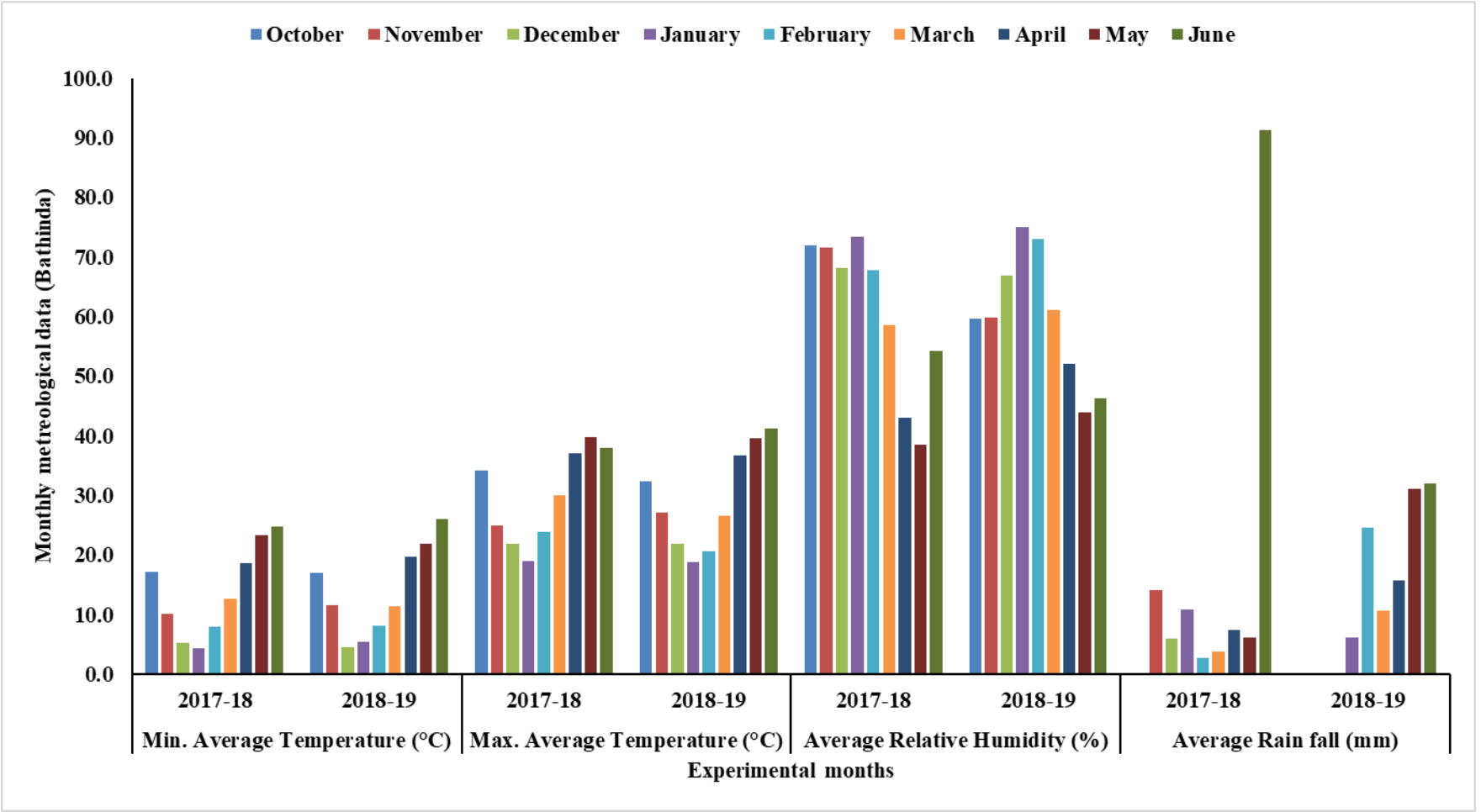


Figure-3.1: Monthly metrological data during 2017-18 and 2018-19

S.No.	Particulars	Contents	Method used	Reference
1	Soil pH	8.26	A soil water (1:2.5) was used to estimate pH by digital pH meter	Jackson (1973)
2	Electrical conductivity (dSm^{-1})	0.18	A soil water (1:2.5) was used to estimate pH by digital pH meter	Jackson (1973)
3	Organic carbon (%)	0.70	Rapid titration method as described by Walkeley and Black	Piper (1966)
4	Available N ($kg\ ha^{-1}$)	176.60	Alkaline $KMnO_4$ method	Subbiah and Asija (1956)
5	Available P ($kg\ ha^{-1}$)	18.94	Olsen's method using $NaHCO_3$ extractant at pH 8.5	Olsen *et al.* (1954)
6	Available K ($Kg\ ha^{-1}$)	408.68	Flame Photometer	Merwin and Peech 1951)

3.4.1. CULTURAL PRACTICES

The runners were treated with (0.2%) Bavistin by dipping the roots of plants for 5 minutes then these treated runners were transplanted on the raised beds. The estimated amount of FYM (50 ton per hectare) was utilized on the raised beds at the time of field preparation. The calculated amount of fertilizer urea, di-ammonium phosphate (DAP), and murate of potash (MOP) were applied on the raised beds to complete the recommended dose of fertilizers (150:100:120 Kg NPK per hectare). The half nitrogen dose and full phosphorus and potash dose were applied at the time of planting and half nitrogen dose through urea was utilized after one-month planting. The uniform runners were planted on the 15 cm raised beds with the use of kurpi on 24th October, 2017 and 10th November, 2018. The plant roots were covered with soil but only crown naked. Watering operation was done immediately after planting.

The light irrigation was continuously applied up to 14 days after planting for maintaining the soil moisture with help of a watering can. The continuous water was applied at regular intervals.

Black polythene mulch was used on the raised beds to control the weed growth, maintain soil moisture, temperature and protect from fruit rotting. The

process of hoeing and weeding were done after 35 days of planting with use of kurpi and second weeding after 60 days of planting. Chlorpyriphos 20% EC and Carboryl at 0.15 % were applied on the raised bed to check the attack of pest.

3.5. EXPERIMENTAL DETAIL

Strawberry cultivars were collected from Dr. YS Parmar University of Horticulture and Forestry, Solan, HP and KF Bioplants Pvt. for the studies. The study was divided into three separate experiments, and the methodologies used in these experiments have been discussed below:

3.5.1. EXPERIMENT-I: GERMPLASM EVALUATION OF STRAWBERRY UNDER PUNJAB CONDITIONS

The runners were planted on (15cm) raised bed on 24th October 2017. Twenty-one plants of each twelve genotypes with thrice replication were planted on the thirty-six raised beds at row x plant spacing of 30 cm x 30 cm. The dimension of the raised bed was 2 m x 1 m. The genotypes which were used as treatments: V_1(Chandler), V_2(Winter Dawn), V_3(Camarosa), V_4(FL-09-127), V_5(E1-13#32), V_6(Sweet Charlie), V_7(Hadar), V_8(E1-13#33), V_9(E1-13#31), V_{10}(Yamini), V_{11}(E-22), V_{12}(Shani). The genotype/variety Chandler (V_1) was used as check genotype as it is most common commercial cultivar of strawberry in this region

TECHNICAL PROGRAM OF WORK DONE

- **Treatments** : 12 strawberry cultivars
- **Replications** : 3
- **Spacing** : 30 x 30 cm
- **Plot size** : 2x 1 m
- **Total number of plants/ plot** : 21
- **Experimental design** : Randomized Complete Block Design (RCBD)

Total 756 well-rooted runners have been planted on the raised bed. Plant material was procured from Dr. YS Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh and KF Bioplants Pvt. Twenty-one plantlets of strawberry

were planted in each plot and each treatment was replicated thrice. During this experiment recommended culture practices of UHF, Nauni was followed for germplasm evaluation of strawberry as mentioned above.

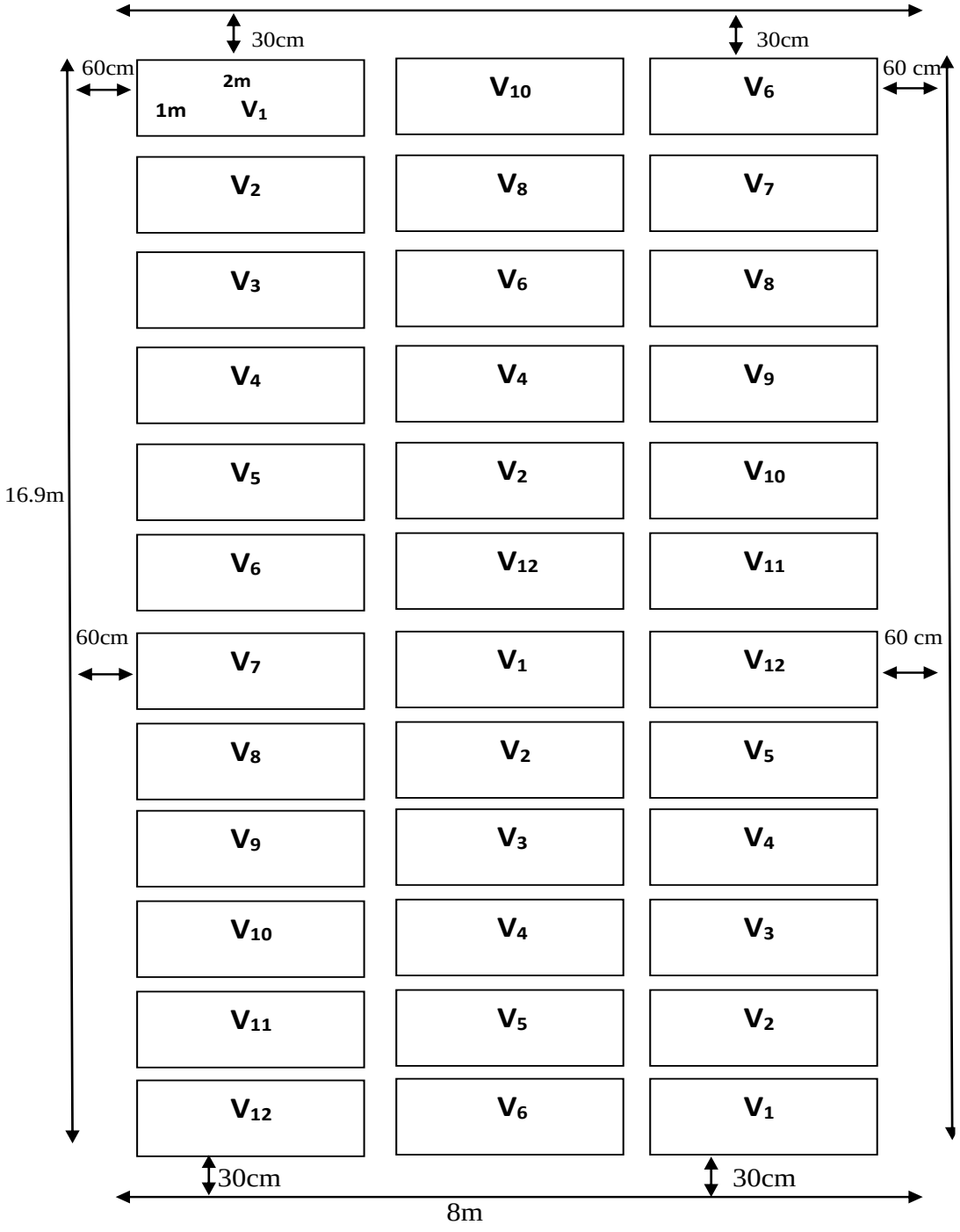


Fig.3.2LAYOUT OF FIELD EXPERIMENT-I

OBSERVATION RECORDED

The data of following parameters like vegetative, flower and fruit &quality characters was recorded in the study of germplasm evaluation.

VEGETATIVE CHARACTERS	FLOWERING CHARACTERS
Plant height (cm)	Flower size (cm)
Plant spread (cm)	Petal size (cm)
Number of leaves (count)	Number of petals (count)
Leaf area (cm^2)	Number of stamens (count)
Number of runners per plant (count)	Days to flowering (Days)
Days to runner formation after planting (Days)	Duration of flowering (Days)
Petiole length (cm)	Number of Flower per plant (count)
FRUIT AND QUALITY CHARACTERS	
Fruit length (cm)	Tititable Acidity (%)
Fruit breadth (cm)	Total sugars (%)
Number of calyx per fruit (count)	Reducing sugars (%)
Number of achenes per fruit (count)	Non-reducing sugars (%)
Days to maturity (Days)	TSS/Acid Ratio
Number of fruits per plant (count)	Total Sugar / acid Ratio
Average berry weight (g)	pH of fruit juice
Yield per plant (g/plant)	Specific gravity
Yield per hectare (tonnes/hec.)	Vitamin C (mg/100g)
Total soluble solids (^oB)	Anthocyanin (mg/100g)
QUALITATIVE CHARACTERS	
Leaf shape	Petal colour
Leaf base	Anther attachment
Leaf apex	Fruit shape
Leaf surface	Calyx removal / Ease of capping
Nature of leaf	Core
Leaf margins	Flesh colour
Flower type	Achene colour
Petal shape	Achene placement

3.5.2. EXPERIMENT-II: STANDARDIZATION OF NUTRIENT MANAGEMENT SCHEDULE OF STRAWBERRY UNDER PUNJAB CONDITIONS

TECHNICAL PROGRAM OF WORK DONE

Notation	Treatment
T_1:	Control
T_2:	(100%) NPK (150:100:120)
T_3:	(75%) NPK (112.5:75:90)
T_4:	(50%) NPK (75:50:60)
T_5:	(100%) NPK (150:100:120) + FYM
T_6:	(75%) NPK (112.5:75:90) + FYM
T_7:	(50%) NPK (75:50:60) + FYM
T_8:	(100%) NPK (150:100:120) + FYM + *Azotobacter*
T_9:	(75%) NPK (112.5:75:90) + FYM + *Azotobacter*
T_{10}:	(50%) NPK (75:50:60) + FYM + *Azotobacter*
T_{11}:	(100%) NPK (150:100:120) + FYM + vermicompost + *Azotobacter*
T_{12}:	(75%) NPK (112.5:75:90) + FYM + vermicompost + *Azotobacter*
T_{13}:	(50%) NPK (75:50:60) +FYM + vermicompost + *Azotobacter*

Component	**Quantity**
100 % NPK	150 kg Nitrogen, 100 kg & 120 kg per hectare
75 % NPK	112.5 kg Nitrogen, 75 kg & 90 kg per hectare
50 % NPK	75 kg Nitrogen, 50 kg & 60 kg per hectare
Farm Yard Manure (FYM)	50 ton/hectare
Vermicompost	5 ton/hectare
Azotobacter	10 kg/hectare

The calculated amount of fertilizer urea, di-ammonium phosphate (DAP), and murate of potash (MOP) were applied on the raised beds to complete the 100 % NPK, 75% NPK and 50% NPK doses through fertilizer.

Selected best performing three cultivars/genotypes from Experiment-I (V_1- Chandler, V_2- Winter Dawn and V_3- Camarosa) were subjected to the application of above mentioned 13 treatments and layout was designed as per Fig-3.3.

- **Treatments** : 13
- **Cultivars** : 3
- **Replications** : 3
- **Spacing** : 30 cm x 30 cm
- **Plot size** : 2 m x 1 m
- **Experimental design** : Factorial Randomized BlockDesign (RBD)
- **Total numbers of plants/plot**: 21

The 2457 well rooted runners were planted on the raised bed. Plant material was procured from KF bioplants Private Company. During this experiment recommended culture practices were followed as mentioned above.

OBSERVATION RECORDED

The data of following parameters like vegetative, flower and fruit &quality characters was recorded in the study of nutrient management schedule.

VEGETATIVE CHARACTERS	
Mortality rate (%)	Leaf area (cm^2)
Plant height (cm)	Number of runners per plant (count)
Plant spread (cm)	Days to runner formation after planting (days)
Number of leaves (count)	
FLOWERING CHARACTERS	
Flower size (cm)	Duration of flowering (days)
Days to flowering (days)	Number of Flower per plant (count)
FRUIT AND QUALITY CHARACTERS	
Fruit length (cm)	Total soluble solids (^oB)
Fruit breadth (cm)	Tititable Acidity (%)
Days to maturity(days)	Reducing sugars (%)
Number of fruits per plant (count)	Non-reducing sugars (%)
Average berry weight (g)	Total sugars (%)
Yield per plant (g/plant)	TSS/Acid Ratio
Yield per hectare (tonnes)	Total Sugar: acid Ratio
Shelf-life (days)	pH of fruit (mg/100g)
Benefit Cost ratio	Specific gravity
	Anthocyanin (mg/100g)

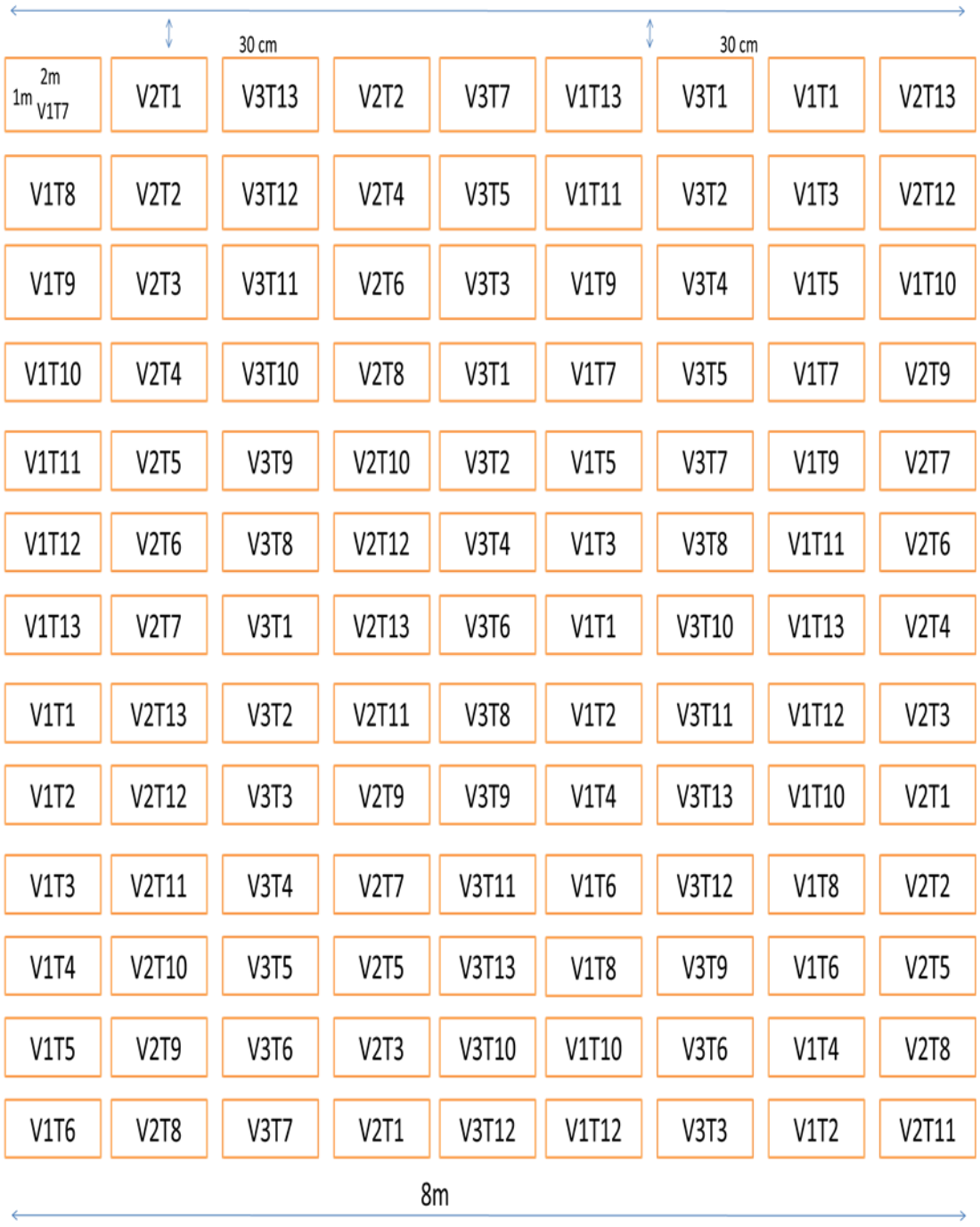


Fig. 3.3. LAYOUT OF FIELD EXPERIMENT-II

3.5.3. EXPERIMENT-III: EFFECT OF DIFFERENT PACKAGING MATERIALS AND STORAGE CONDITIONS ON SHELF-LIFE EXTENSION IN STRAWBERRY FRUITS

Treatment detail:

P1- Control (No pack)

P2- LDPE 50 micron

P3- LDPE 75 micron

2 storage conditions (Ambient and Refrigerate) with 3 best cultivars/genotypes selected from first experiment

- **Treatments** : 6
- **Cultivars** : 3
- **Replications** : 3
- **Number of fruits per treatment** : 10
- **Experiment design** : Factorial CRD (Complete Randomized Design)

OBSERVATION RECORDED

The data of fruit quality parameters was recorded at 2 days interval (2, 4, 6 days) from the ten stored fruits.

FRUIT QUALITY PARAMETERS

Weight loss (%)

Total soluble solids (^{o}B)

Titratable Acidity (%)

Reducing sugars (%)

Total sugars (%)

TSS/Acid Ratio

Vitamin C (mg/100g)

Shelf-life (days)

Polyphenol (mg/100g)

3.6. DETAILS OF OBSERVATIONS RECORDED

The various observations viz. vegetative, floral and fruit characters were recorded from ten plants per bed using the methodology as mentioned below. The fruit samples were collected at weekly intervals from different treatments after fruit formation. The fruit samples were estimated for different physico-chemical parameters at Horticulture laboratory.

3.6.1. VEGETATIVE CHARACTERS

3.6.1.1. Mortality of plants (%)

The dead plants/runners were counted after nine days of transplanting of each treatment. Mortality percentage of plants was estimated by using the following formula:

$$\text{Mortality percentage}(\%) = \frac{\text{Total number of plant died}}{\text{Total number of transplanted plant}} \times 100$$

3.6.1.2. Plant height (cm)

The observation was taken from the selected 10 plants per replication. The height of the plant was calculated in centimeters (cm) by using a measuring scale from the ground surface to apex of plant. The average plant height was calculated from the 10 plants each treatment per replication at 45 and 90 days after planting.

3.6.1.3. Plant spread (cm)

The spread of plant was calculated on the basis average of 10 plants of each treatment per replication. The spread was expressed in centimeter (cm) by using measuring scale from both sides of East-to-West and North-to-South direction.

3.6.1.4. Number of leaves (Count)

The leaves were counted on the basis average leave count of 10 plants of each treatment per replication.

3.6.1.5. Leaf area (cm^2)

The four leaves for each treatment per replication were collected randomly. The data of average leaf area was expressed in square centimeters by using leaf area meter at the end of harvesting. The total leaf area of plant was calculated by multiplication of the mean leaf area into the number of leaves per plant.

3.6.1.6. Number of runners per plant (count)

The runners were counted on each plant per replication at the end of season. The average value of the runner count was calculated.

3.6.1.7. Days to runner formation (days)

The date of planting and formation of first runner were noted and the days taken for formation of first runner after planting were calculated in days.

3.6.1.8. Petiole length (cm)

The petiole size was calculated on the basis average of 4 leaf each treatment per replication. It was determined with help of scale from the crown base to leaf blade base and was expressed in centimeter.

3.6.2. FLOWERING CHARACTERS

3.6.4.1. Flower size (cm)

The flower size was expressed in centimeters (cm) with help of Vernier's caliper from one petal to opposite petal. The mean flower size was calculated from selected 10 flowers per replication.

3.6.4.2. Petal Size (cm)

The petal length was recorded in centimeters (cm) by using the scale from a distal end to the petal base. Petal breadth was observed in centimeters with the use of the scale from the broadest point. The selected 10 flowers per replication from each treatment was determined the mean petal length and petal breadth which was shown in the results.

3.6.4.3. Number of petals (count)

The petals were counted on the flower from marked treatment per replication at the end of the season. The average value of number of petals per flower was estimated.

3.6.4.4. Number of stamens (count)

The stamens were counted on the flower by visual observation. The average number of stamens was calculated from selected 10 flowers of each treatment per replication.

3.6.4.5. Days to flowering (days)

The number of days for flowering was estimated on the basis of days counted from planting date to the opening of 1stflower as described by Kidmose *et al.* (1996).

3.6.4.6. Duration of flowering (days)

The date of opening of the first flower and last flower was noted in each treatment per

replication which was calculated in days to express flowering duration.

3.6.4.7. Number of flowers per plant (count)

The flowers were counted at weekly intervals on the same plant in each treatment per replication from the 10 marked plants and indicated as the total average number of flowers per plant.

3.6.3. FRUIT CHARACTERS

3.6.3.1. Fruit length (cm)

The fruit size measured from calyx plug to apex of the fruit with help of vernier calipers and mean observation was expressed as fruit length in cm.

3.6.3.2. Fruit breadth (cm)

The fruit size measured at the shoulder of the berry with the use of vernier caliper and the mean value was expressed as fruit breadth in cm.

3.6.3.3. Number of calyx per fruit (count)

The count of calyx was recorded from the 10 fruits of each treatment per replication and the average was estimated.

3.6.3.4. Number of achenes (count)

The count of achenes in fruits was taken from the fully ripened fruits.

3.6.3.5. Days to fruit maturity (days)

The date of flower opening and date of fruit mature were recorded in each treatment per replication and the duration period between the flowers opening to fruit maturity was calculated in days.

3.6.3.6. Number of fruits per plant (count)

The fruits were counted at each harvesting on the same plant in each treatment per replication from the 10 marked plants and the average was estimated.

3.6.3.7. Average berry weight (g)

The ripened fruit weight was estimated by using top pan weight balance. The average was estimated in gram (g) from the selected 10 fruits in each treatment per replication.

3.6.3.8. Yield per plant (g)

The total harvested fruits weight was measured in each treatment per replication with the help of top pan weight balance from 5 selected plants and the average was estimated in gram per plant.

3.6.3.9. Yield per hectare (tonnes)

The yield per plot was estimated by the weight of fruits which was harvested in the plot with help of weight balance. The yield per hectare was calculated in tonnes per hectare according to the yield per plot and number of plants per plot.

3.6.3.10. Benefit:Cost ratio

The cost of all inputs as a fixed cost and the variable cost was estimated on the basis of available market-rate and gross output was estimated on the basis of the prevailing market price of strawberry fruits and the yield per hectare. The net return was estimated by excluding cost of cultivation from gross return or output and the benefit:cost ratio was estimated as the net return on the unit cost of cultivation by using the given formula:

$$\text{Benefit:Cost Ratio} = \frac{\text{Net Gross Return}}{\text{Total cost of cultivation}}$$

3.6.3.11. Weight loss (%)

The fruit weight was measured with help of pan weight balance. The loss in weight during storage was calculated in per cent (%) by subtracting the final weight of fruit from the initial weight of the fruits.

3.6.3.12. Total soluble solids (°B)

After each replication juice of ten tagged fruits was extracted which was further filtered through a muslin cloth. Hand refractometer was used to determine the total soluble solid content of juice which was measured in the terms of ^{0}Brix. The obtained values of TSS were amended at temperature 20°C by using a temperature correction chart (AOAC, 1990).

3.6.3.13. Titratable acidity (%)

Two ml of strained juice was diluted to 20ml by adding distilled water. 0.1N NaOH solution was used for titration against diluted strained juice in which phenolphthalein was used as the indicator. The colorless solution changed to light pink which reflected the endpoint. Anhydrous malic acid acidity was determined through the use of formula as follows:

$$\text{Acidity (\%)} = \frac{0.0067 \times \text{Vol. of NaOH utilized}}{\text{Volume of juice taken}} \times 100$$

3.6.3.14. TSS: Acid ratio

Total soluble solids values were divided with corresponding total titratable acidity to obtain the TSS/Acid ratio.

3.6.3.15. Total sugar (%)

Total and reducing sugar were estimated through method described by Lane and Eynon (AOAC, 1990).

After taking 10 ml of fresh juice in a beaker and adding lead acetate to obtain a precipitate. The excess of lead acetate was neutralized and removed by adding potassium oxalate. The precipitate was filtered out with Whatman filter paper. Filtrated solution was diluted up to 100ml with the help of distilled water. Total and reducing sugars were estimated from this. aliquot use. 5ml of 60% conc. HCl was added in 25ml aliquot after that for acid hydrolysis solution was left over for 24 hours at room temperature. With the help of water bath solution was heated for 10 minutes at 68^{o}C temperature. Solution was titrated against 40% NaOH and after some time to neutralize the excessive HCl, 10% NaOH was used for titration. At the end of neutralization point 0.1N NaOH was used. 5 ml of each Fehling solution A and B was used to titrate with neutralized solution produced in above process with the help of indicator methylene blue. Endpoint was obtained with the appearance of a brick red color. Total sugar percentage was calculated through given formula:

$$\text{Total sugars (\%)} = \frac{\text{Fehling solution factor (0.05)}}{\text{Volume of filtrate used}} x \frac{\text{Dilution made}}{\text{Volume of juice taken}} x \frac{\text{Final volume made}}{\text{Volume of aliquot taken}} x100$$

3.6.3.16. Reducing sugar (%)

Ten ml of boiling Fehling solution (5 ml each of Fehling solution A and B) was titrated against the aliquot solution in which methylene blue was used as an indicator to obtain the total reducing sugar percentage. End point was indicated with the appearance of brick red color. Reducing sugar percentage was calculated with the help of formula:

$$\text{Reducing sugars (\%)} = \frac{\text{Fehling solution factor (0.05)}}{\text{Volume of filtrate used}} x \frac{\text{Dilution made}}{\text{Volume of juice taken}} x100$$

3.6.3.17. Non-reducing sugars (%)

Reducing sugars were subtracted from total sugars to obtain non reducing sugars and the obtained value was multiplied with 0.95 correction factor (AOAC, 1990).

Non-reducing sugars = (Total sugars – Reducing sugars) x 0.95

3.6.3.18. Total Sugar: Acid ratio

Total Sugar values were divided with corresponding total titratable acidity to obtain the Total Sugar :Acid ratio

3.6.3.19. Specific gravity

Specific gravity was measured by water displacement method

$$\text{Specific gravity of fruit} = \frac{\text{weight of fruit (g)}}{\text{Volume of displaced water by fruit (ml)}}$$

3.6.3.20. pH of fruit

pH of the fruit was determined with the help of a digital pH meter. The pH meter was standardized against the standard buffer solution before use. Each sample was taken in clean beaker and its pH was recorded at room temperature.

3.6.3.21. Vitamin C (mg per 100gm)

Stabilizing reagent (metaphosphoric acid) was added to the fresh juice to obtain ascorbic acid concentration. 2, 6-dichlorophenol was used at titrant and indophenol dye was used as an indicator to obtain light pink color which remains for 15 sec was endpoint (AOAC 2000). Result was expressed in mg/100ml of juice.

$$\text{Ascorbic acid (mg/100ml of fruit juice)} =$$

$$\text{Dye factor } x \frac{\text{Volume of dye used for titration of the juice}}{\text{Volume of extract taken}} x \frac{\text{Final volume made}}{\text{Volume of juice taken}} x100$$

3.6.3.22. Anthocyanin content (mg per 100gm)

Five ml of sample was taken in beaker and volume was made up to 100 ml with the help of ethanolic HCl (made by 85 parts 95 % ethanol and 15 parts of 1.5 N HCL) and kept overnight at 4^{o}C.Whatman's No.1 filter paper was used to filter the solution and left out residue on filter paper was washed with the help of ethanolic HCl and diluted

with the same solvent up to 100 ml. solution was further filtered through fine Millipore and out of this solution 10 ml aliquot was taken which was made up to volume 20 ml with ethanolic HCl. Absorbance was measured at 535 nm wavelength with the help of a spectrophotometer after keeping the solution in dark for 2 hours. The total anthocyanin content was calculated as follows:

$$\text{Total absorbance per 100ml} = \frac{\text{Specific OD value at 535nm wavelength x volume made up of extract x total volume}}{\text{Volume of extract taken x volume of the sample}} x100$$

1 mg/ml of solution is equivalent to the absorbance of 98.2. Therefore,

$$\text{Anthocyanin content (mg/100ml)} = \frac{\text{Total absorbance for the sample}}{98.2} x100$$

3.6.3.23. Shelf-life

The shelf life of fruit was measured in each treatment on the basis of visual observation and quality of fruit like size or weight. The fully ripened 10 fruits were stored at room temperature and refrigerator temperature after weight in the laboratory.

3.6.3.24. Polyphenol (mg/100g)

Total soluble phenolic compounds were determined by using Folin-Ciocalteau's Phenol Reagent as oxidizing reagent as described by Nunes *et al.* (2005). Absorbance was recorded at 765 nm wavelength which was proportional to the concentration of phenolic compounds. Standard curve was plotted by taking absorbance at 765nm.

3.6.4. QUALITATIVE CHARACTERS

3.6.4.1. Leaf shape

The shapes of leaves are generally obovate, elliptical and ovate. So, leaf shape was observed by visual evaluation.

3.6.4.2. Leaf base

Leaf base was recorded by visual observation which was classified as Acute and Obtuse.

3.6.4.3. Leaf apex

Leaf apex was recorded by visually observation which was classified as Obtuse and Acute.

3.6.4.4. Leaf surface colour

The leaf colour of upper and lower surface was recorded with help of (Royal Horticultural Society, U.K.) colour charts.

3.6.4.5. Nature of leaf

The nature of leaf is generally thin, smooth, thick and rough in nature on the basis of observation. The nature of leaf was recorded by feel the leaf put in hand and fingers.

3.6.4.6. Leaf margins

Leaf margin was recorded by visual observation of boundary area along with leaf edge which was represented as a serrated or entire type of margin.

3.6.4.7. Flower type

Flower type was checked by visual observation which was classified as staminate, pistillate and hermaphrodite.

3.6.4.8. Anther attachment

The anther attachment was recorded in each treatment from the attachment of anther with filament which was classified as versatile, dorsifixed, adnate or basifixed.

3.6.4.9. Petal shape

The petal shape was evaluated by visual observation which was classified as obovate, orbicular and ovate.

3.6.4.10. Petal colour

The colour of petal was noted from flowers in each treatment by visual observation.

3.6.4.11. Fruit shape

The fruit shape was recorded through visual observations which was classified as a globose, oblate, globose-conic, flat-conic, conic, long-conic, short-wedged, long-wedged and necked (Anonymous, 2000).

3.6.4.12. Calyx removal / Ease of capping

The calyx removal was recorded on the basis of calyx attachment to fruit which was categorized as tight or loose.

3.6.4.13. Core

The core of fruit was recorded by visually from fruit cut into two equal half peace which was core classified as hollow or compact.

3.6.4.14. Flesh colour

The flesh colour was recorded by visual observation from core colour to peripheral region of ripened fruits which was categorized as creamish white, light red and deep red.

3.6.4.15. Achene colour

The colour of achene was categorized as per visual observation.

3.6.4.16. Achene placement

The achene placement was recorded by visual observation from the placement of achene on the surface of fruit which was categorized into raised, along the fruit and sunken.

3.7. STATISTICAL ANALYSIS

3.7.1. Randomized Complete Block Design (RCBD) used in Experiment-I

The recorded data were analyzed in the OPSTAT by analysis of variance, using Randomized Block Design (RBD) (Gomez & Gomez, 1984) in the experiment of germplasm evaluation. The analysis was done for following parameters:

3.7.1.1 Genetic variability (GCV and PCV)

3.7.1.2 Heritability study

3.7.1.3 Genetic advance (GA) and genetic advances as percentage mean

3.7.1.4 Correlation coefficients

3.7.1.5 Path coefficient analysis

3.7.1.1. Genetic variability: The genetic variability was estimated at the genotypic and phenotypic level as per the statistical method designed and developed by Burton and Devane (1953). The phenotypic and genotypic variances were estimated and were applied to estimate the phenotypic and genotypic coefficient of variability (PCV and GCV).

$$\text{Genotypic variance } (\sigma^2 g) = \frac{\text{Genotypic MSS} - \text{Error MSS}}{r}$$

Environmental variance ($\sigma^2 e$) = Error MSS

Phenotypic variance ($\sigma^2 p$) = Genotypic variance ($\sigma^2 g$) + Environmental variance ($\sigma^2 e$)

$$\text{(a) GCV (\%)} = \frac{\sqrt{\text{Genotypic variance}(\sigma^2 g)}}{\text{General mean of population } (\bar{X})} \text{ X 100}$$

$$\text{(b) PCV (\%)} = \frac{\sqrt{\text{Phenotypic variance}(\sigma^2 p)}}{\text{General mean of population}(\bar{X})} \text{ X 100}$$

$$\text{(c) ECV (\%)} = \frac{\sqrt{\text{Environmental variance}(\sigma^2 e)}}{\text{General mean of population}(\bar{X})} \text{ X 100}$$

Categorization of PCV and GCV values was done as stated by Sivasubranian and Menon (1973).

Low (0-10%);Moderate (10-20%); and High (>20%)

3.7.1.2. Heritability (in broad sense): Burton (1952) stated that GCV together with heritability estimates would give the estimate heritable portion of variability and so will be helpful in selection. Heritability in a broad sense was calculated by the formula as suggested by Allard (1960).

$$\text{Heritability } (H^2)\% = \frac{\sigma^2 gi}{\sigma^2 pi} X \text{ 100}$$

Where,

$\sigma^2 gi$ = Genotypic variance for character 'i'

$\sigma^2 pi$ = Phenotypic variance for character 'i'

Heritability was classified as suggested by Robinson *et al.* (1949) and Johanson *et al.* (1955) into low (0-30%), moderate (30.1-60%) and high (>60%).

3.7.1.3. Genetic advance (GA): The possible genetic advance (GA) was estimated as proposed by Johanson *et al.* (1955) and recommended by Allard (1960).

$$\text{Genetic advance} = H^2 \sigma pi\ K$$

Where,

K = 2.06 (the constant for which the value is given as 2.06, is standard selection differential at 5% selection index as given by Lush, 1949)

σpi = Phenotypic standard deviation for character 'i'

h^2 = Heritability in broad sense

Genetic advance was classified as high (>20), moderate (10-20) and low (<10).

Genetic advance as percent of the mean (genetic gain)was calculated as % ratio of genetic advance to the population mean $(\bar{X})$(Johansonet *al.*, 1955).

$$\text{Genetic gain (\%)} = \frac{\text{Genetic advance}}{(\bar{X})} X100$$

The Genetic advance as percent mean was classified as high (>20), moderate (10.1-20) and low (≤10) (Johnson *et al.*,1955).

3.7.1.4. Correlations Coefficient: Estimation of correlations coefficient (r) between various traits understudy was essential to understand the association between traits at the genotypic and phenotypic levels. It was estimated by the method described below (Johnson *et al*., 1955; Al. Jibouri *et.al.*, 1958).

a) Genotypic correlation coefficient between X and Y

$$r(g) = \frac{\sigma g\, XY}{\sqrt{\sigma^2 gX \times \sigma^2 gY}}$$

Where,

σg XY = Genotypic covariance between X and Y

$\sigma^2 g$ X = Genotypic variance of X

$\sigma^2 g$ Y = Genotypic variance of Y

b) Phenotypic correlation coefficient between X and Y

$$r(p) = \frac{\sigma p\, XY}{\sqrt{\sigma^2 pX \times \sigma^2 pY}}$$

Where,

σp XY = Phenotypic covariance between X and Y

$\sigma^2 p$ X = Phenotypic variance of X

$\sigma^2 p$ Y = Phenotypic variance of Y

The test of significance for association between characters was done by comparing the estimated values with table 't' values at n-2 error degrees of freedom (Snedecor and Cochran, 1967).

If $t_{cal} \geq t_{tab}$, then r is significant

Where,

$$t_{cal} = \text{calculated value of } t = r\sqrt{\frac{n-2}{1-r^2}}$$

t_{tab} = tabulated value of t at n-2 degree of freedom

3.7.1.5. Path coefficient analysis

Path co-efficient analysis was carried out by the methodology advised by Wright (1921) and demonstrated by Dewey and Lu (1959) to find out the direct or indirect contribution of various traits towards the yield of the plant.

Residual effect: The residual effect is the measure of the possible effects caused by the variables which have not been included in an investigation to evaluate the possible contribution of independent variables to the dependent variable. The degree of contribution of such variable (s) may be estimated as:

$1 = P^2x_4 + P_{14}^2 + P_{24}^2 + P_{34}^2 + 2P_{14}\, r_{12}\, P_{24} + 2P_{14}r_{13}\, P_{34} + 2P_{24}\, r_{23}\, P_{34}$

The direct and indirect effects are rated as follows by Lenka and Mishra (1973).

0.00 – 0.09	Negligible
0.10 – 0.19	Low
0.20 – 0.29	Moderate
0.30 – 1.00	High
> 1.00	Very high

3.7.2. FactorialRandomized Block Design (RBD) used in Experiment-II

The data recorded was analyzed by Factorial Randomized Block Design (RBD) using statistical analysis software OPSTAT.

3.7.3. Factorial Completely Randomized Design (CRD) used in Experiment-III

The data recorded was analyzed by Factorial Completely Randomized Design (CRD) using statistical analysis software OPSTAT.

CHAPTER-IV

RESULTS & DISCUSSION

The study entitled "Germplasm evaluation and nutrient management in strawberry (*Fragaria* × *ananassa* Duch.) under Punjab conditions" was performed at Research Farm, Baba Farid College, Bathinda (Punjab) India from 2017 to 2019. The experimental findings of different experiments are being discussed below to provide relevant explanation of the experimental outcomes in light of available literatures:

4.1. EXPERIMENT-I: GERMPLASM EVALUATION OF STRAWBERRY UNDER PUNJAB CONDITIONS

The twelve-genotypes evaluated with respect to vegetative, floral, fruit characters and qualitative characters during 2017-18 and the results with discussion have been given below after statistical analysis.

4.1.1 VEGETATIVE CHARACTERS

4.1.1.1. Mortality Rate (%)

The results about the mortality rate of various genotypes of strawberry under Punjab conditions were evaluated and shown in Table 4.1. The mortality rate in strawberry genotypes shown significant difference and ranged from 11.11 percent to 52.38 percent. The lowest mortality rate of plant (11.11 percent) was observed in 'Camarosa' (V_3) which was statistically at par with 'Chandler' (V_1) whereas the highest mortality rate (52.38 percent) was found in 'Sweet Charlie' (V_6) as compared to other genotypes like V_2, V_4, V_5, V_7, V_8, V_9, V_{10}, $V_{11,}$ and V_{12}. The mortality and survival of various genotypes of strawberry might be associated with the adaptability of these genotypes in the agro-climatic conditions of the experimental area which is governed by the ability of genes to express themselves under existing climatic conditions. The current findings can be confirmed by Beniwal *et al*. (1989).

4.1.1.2. Plant height (cm)

Data pertaining to plant height of different strawberry genotypes measured under Punjab conditions has been presented in Table 4.1. The highest plant height (12.07 cm) was observed in Chandler (V_1) which was statistically followed by 'Camarosa' (V_3) (11.90 cm) and 'Winter Dawn' (V_2) (11.37 cm) whereas, minimum

height of plant (8.83 cm) was obtained in Hadar (V_7) which was followed by E1-13#31 (V_9) (9.30 cm), E1-13#32 (V_5) (9.37 cm) and 'Sweet Charlie' (V_6) (9.47 cm). These results are similar to Rao and Lal (2010) who tested different varieties of strawberry and recorded the highest plant height in Chandler. The same has been observed by Garg (2013) under mid-hill conditions of Himachal Pradesh. Grewal and Dhaliwal (1984) suggested the lower plant height in germplasm may be related to genetic structure. This is in the agreement with the studies of Sahu and Chandel (2014) who found that the cultivars 'Camarosa' and 'Festival' were the best in terms of plant height. Since plant growth is accounted for various environmental factors; this may be the main reason for differences among plant height.

4.1.1.3. Plant spread (cm)

The observations related to plant spread were statistically analyzed and represented in Table 4.1. All genotypes reflected variation in plant spreads which ranged from 10.67 cm to 13.83 cm. It is evident from observations that 'Winter Dawn' (V_2) showed the highest plant spread followed by 'Camarosa' (V_3), 'Chandler' (V_1) and 'Yamni' (V_{10}) among all genotypes while least plant spread (10.67 cm) was found in 'Hadar' which was similarly found in 'Sweet Charlie' (V_6) (10.75 cm), 'E1-13#31' (V_9) (10.83 cm), 'E1-13#32' (V_5) (11.42 cm) and 'E-22'(V_{11}) (11.83 cm). The result was closely related to findings of Gaikwad *et al.* (2018) who recorded the highest (35.52 cm) east-west plant spread in 'Winter Dawn' followed by 'Camarosa' (32.92 cm). The plant growth or spread of various genotypes of strawberry might be associated with varying degrees of adaptability of these genotypes in the existing agro-climatic conditions which is governed by the ability of genes to express themselves under existing climatic conditions. The current findings can be confirmed by work done by Beniwal *et al*. (1989). Garg (2013) had also recorded the highest plant spread in 'Chandler' under mid hill conditions of Himachal Pradesh.

4.1.1.4. Number of leaves (count)

It is evident from the observations that the number of leaves per plant of strawberry genotypes ranged from 9.50 to 14.17 (Table 4.1). The data of the number of leaves was analyzed and all the genotypes reflected statistical difference from each other. The highest leaves count (14.17) was found in the 'Chandler' (V_1) followed by 'WinterDawn' (V_2) (13.58) and 'Camarosa' (V_3) (13.33) while minimum (9.50) was

obtained in 'E-22' which was followed by 'E1-13#31' (V_9) (9.67) and 'Yamni' (V_{10}) (10.00). The present results are in agreement with Garg (2013) who recorded the maximum leaves (38.00) count in 'Chandler'. This variation in leaves number per plant could be genetic variation in the germplasms, cultivation site, cultural practices and climatic conditions (moderate or hot conditions) (Li *et al.*, 1993). The present outcome is in similarity to the experimental findings of Singh *et al*. (2008), who showed the highest leaves number (33.3) per plant in 'Chandler'.

Table 4.1 Evaluation of different strawberry genotypes on the basis of mortality and vegetative characters

Genotypes		Mortality rate (%)	Plant height (cm)	Plant spread (cm)	Number of leaves (count)	Leaf area (cm^2)
V_1	Chandler	14.29^{ef}	12.07^{a}	12.70^{ab}	13.58^{ab}	73.29^{a}
V_2	Winter Dawn	17.46^{e}	11.37^{ab}	13.83^{a}	14.17^{a}	72.08^{ab}
V_3	Camarosa	11.11^{f}	11.90^{a}	13.43^{ab}	13.33^{ab}	74.03^{a}
V_4	FL-09-127	25.40^{d}	9.67^{c}	12.60^{b}	12.50^{bc}	60.48^{bc}
V_5	E1-13#32	34.92^{cd}	9.37^{cd}	11.42^{c}	13.10^{b}	67.71^{ab}
V_6	Sweet Charlie	52.38^{a}	9.47^{cd}	10.75^{c}	10.83^{d}	61.23^{bc}
V_7	Hadar	36.51^{c}	8.83^{d}	10.67^{c}	11.67^{cd}	66.03^{b}
V_8	E1-13#33	41.27^{bc}	10.13^{bc}	12.50^{bc}	12.90^{bc}	68.38^{ab}
V_9	E1-13#31	31.75^{cd}	9.30^{cd}	10.83^{c}	9.67^{e}	54.87^{c}
V_{10}	Yamini	33.33^{cd}	10.70^{b}	12.73^{ab}	10.00^{de}	59.93^{b}
V_{11}	E-22	42.86^{b}	10.70^{b}	11.83^{b}	9.50^{e}	54.47^{c}
V_{12}	Shani	30.16^{d}	10.23^{bc}	12.45^{bc}	12.00^{c}	69.80^{ab}
Mean		**30.95**	**10.31**	**12.15**	**11.94**	**65.19**
P≤0.05						
C.D.		**5.093**	**0.735**	**1.164**	**0.963**	**6.462**
SE(m)		**1.725**	**0.249**	**0.394**	**0.326**	**2.189**
SE(d)		**2.44**	**0.352**	**0.558**	**0.461**	**3.096**
C.V.		**9.656**	**4.18**	**5.626**	**4.733**	**5.816**

4.1.1.5. Leaf Area (cm^2)

The different genotypes of strawberry under Punjab conditions were evaluated with respect to leaf area and data was presented in Table 4.1. It is confirmed from observation that leaf area was significantly varying between all genotypes and ranged

from 54.47 cm^2 to 74.03 cm^2 percent. The greatest total leaf area (74.03 cm^2) was observed in 'Camarosa' (V_3), which was statistically similar with 'Chandler' (V_1), 'WinterDawn' (V_2), whereas the lowest (54.47 cm^2) was found in 'E-22', which was statistically at par to 'E1-13#31' (V_9) (54.87 cm^2), 'Yamni' (V_{10}) (59.93 cm^2) and 'FL-09-127' (60.48 cm^2). The results were according to findings of Rao and Lal (2010), who observed maximum leaf numbers in 'Chandler' and 'Camarosa'. The difference in leaf area of genotypes may be due to different genotype which behaved differently to light, photoperiod, temperature, soil nutrition, free metabolites and their translocation to the above ground plant parts (Tanaka and Mizuta, 1974; Strik, 1988). The altitude of experiment sites also affected the leaf areas per plant and fruit yield have been reported by Crespo *et al.* (2010).

4.1.1.6. Number of runners per plant (count)

The results of twelve genotype under Punjab conditions in relation to number of runners per plant were statistically different from each other (Table 4.2). The maximum runners per plant (10.33) were count in 'Chandler' (V_1), which was at par with 'Camarosa' (V_3). 'Hadar' (V_7) showed the minimum (3.67) number of runners, which was lower than another genotype, followed by 'E1-13#31' (V_9) (4.33), 'E1-13#32' (V_5), and 'E-22' (V_{11}) (5.33). The results showed that 'Chandler' had 2.8 more runners per plant than 'Hadar' (V_7). The present investigation results are closely related to the findings of Das *et al.* (2007) and Garg (2013) who recorded the maximum count of runner per plant in 'Chandler' (4.4 & 51.50). Grewal and Dhaliwal (1984) observed runner formation in the range from 1.30 to 7.55, which was almost similar in the present investigation. The difference in runner formation of different genotypes of strawberry grown under Punjab conditions have been studied by Hancock and Bringhurst (1978). The variation in runner count per plant might be associated with cultivars potential to produce runners, difference in agro-climatic conditions and management practices used for strawberry cultivation.

4.1.1.7. Days to runner formation after planting (days)

The number of days taken to runner formation after planting was statistically analysed for all the genotypes and presented in Table-4.2. The genotype 'Chandler' (V_1) was taken minimum days for runner formation (162.77), which was closely related by 'Camarosa' (V_3) (165.83). The maximum days took to runner formation

after planting (187.7) were counted in genotype 'E-22' (V_{11}), which was similar to 'Hadar' (V_7) (185.93) and showed 25 days taken extra in comparison to 'Chandler'. The results are similar to the findings of Gupta (1998) and Garg (2013), who observed that Chandler cultivar produced runners earlier than other cultivars. Some genotypes like 'E-22', 'Hadar' showing poor runners may be due to short of day length usually in Northern India in summer as some germplasms formed runners early in 16 hours day length (Rao & Lal, 2010).

Table 4.2 Evaluation of different strawberry genotypes on the basis of runners and petiole characters

Genotypes		Number of runners	Days to runner formation after planting	Petiole Length (cm)
V_1	Chandler	10.33^{a}	162.77^{f}	9.43^{a}
V_2	Winter Dawn	8.33^{b}	169.60^{de}	8.53^{b}
V_3	Camarosa	9.67^{ab}	165.83^{ef}	9.63^{a}
V_4	FL-09-127	7.00^{bc}	176.10^{c}	6.80^{d}
V_5	E1-13#32	5.00^{cd}	175.47^{c}	7.87^{c}
V_6	Sweet Charlie	5.33^{cd}	177.90^{bc}	6.17^{e}
V_7	Hadar	3.67^{d}	185.93^{a}	7.80^{c}
V_8	E1-13#33	7.67^{b}	171.93^{d}	7.73^{c}
V_9	E1-13#31	4.33^{d}	180.00^{b}	8.43^{b}
V_{10}	Yamini	8.33^{b}	169.17^{de}	9.17^{a}
V_{11}	E-22	5.33^{cd}	187.70^{a}	9.13^{a}
V_{12}	Shani	6.00^{c}	167.83^{e}	8.10^{bc}
Mean		**6.75**	**174.19**	**8.23**
P≤0.05				
C.D.		**1.658**	**3.338**	**0.524**
SE(m)		**0.562**	**1.131**	**0.177**
SE(d)		**0.795**	**1.599**	**0.251**
C.V.		**14.417**	**1.124**	**3.733**

4.1.1.8. Petiole Length (cm)

The data related length of petiole in different genotypes under Punjab conditions was reported significantly different from each other (Table-4.2). The length of petiole was highest recorded in genotype 'Chandler' (V_1) (9.63cm) which was closely followed by 'Camarosa' (V_3) (9.43 cm), 'Yamini' (V_{10}) (9.17 cm), and

'E-22' (V_{11}) (9.13 cm) whereas, lowest length of petiole was obtained in 'Sweet Charlie' (V_6) (6.17 cm). The results were in line with outcomes of work done by Singh (2016) who recorded the maximum length of petiole in cultivar 'Camarosa' and 'Chandler'. The length of petiole in different genotypes is showing variation due to variation in genotype and their response to photoperiod and light intensity (Darrow, 1966).

4.1.2. FLORAL CHARACTERS

The variations in flower characters of genotypes are showing below under different parameters:

4.1.2.1. Flower size (cm)

The results were found significantly different for all genotypes under Punjab conditions in terms of flower size and varied from 1.76 cm to 1.97 cm (Table-4.3).

The genotype 'Camarosa' (V_3) was recorded (1.97 cm) with maximum flower size and was followed by 'Shani' (V_{12}) (1.94 cm), 'E1-13#32' (V_5) (1.92 cm) and 'E1-13#31' (V_9) (1.91 cm) while, lowest flower size was found in 'E-22' (V_{11}) (1.76 cm) followed by 'Yamini' (V_{10}), and 'FL-09-127' (V_4) (1.81 cm). These results may be due to germplasm variation, according to the findings of Gupta (1998).

4.1.2.2. Petal length and breadth (cm)

The results of petal length and breadth were significantly different in various strawberry genotype under Punjab conditions as presented in Table-4.3.

The highest petal length in genotypes was recorded in 'E1-13#32' (V_5) (0.88 cm) which was statistically at par with 'Camarosa' (V_3) (0.87 cm), 'E1-13#31' (V_9) (0.87 cm), and 'Shani' (V_{12}) (0.86 cm) while lowest was observed in 'E-22' (V_{11}) (0.74 cm) closely related by 'Yamini' (V_{10}) (0.76 cm).

The maximum breadth of petal was found in 'E1-13#32' (V_5) (0.88 cm), which was statistically at par with 'Camarosa' (V_3) (0.87 cm), 'E1-13#31' (0.87 cm), and 'Shani' (V_{12}) (0.86 cm) while lowest was observed in 'E-22' (V_{11}) (0.74 cm) closely related to 'Yamini' (V_{10}) (0.76 cm). A similar variation in petal size was also reported by Garg (2013) and Lata (2016).

4.1.2.3. Number of petals (count)

The data pertaining to the number of petals in different genotype under Punjab conditions ranged from 5 to 6. There was no significant difference in terms of number

of petals in different gernotypes (Table-4.3). The highest number of petal (6) was counted in genotype 'FL-09-127' (V_4), while lowest (5) was found in 'E1-13#32' (V_5), 'E1-13#33' (V_8), 'Sweet Charlie' (V_6), and 'Yamini' (V_{10}). Similarly, Singh (2016) reported that the value of petals number per fruit ranged from 5 to 6.

Table 4.3 Evaluation of different strawberry genotypes on the basis of quantitative traits of flower

Genotypes		Flower size (cm)	Petal length (cm)	Petal breadth (cm)	Number of stamens	Number of petals
V_1	Chandler	1.85^{bc}	0.83^{bc}	0.85^{b}	21.67^{b}	5.33
V_2	Winter Dawn	1.85^{bc}	0.80^{c}	0.79^{cd}	22.67^{a}	5.67
V_3	Camarosa	1.97^{a}	0.87^{ab}	0.89^{a}	22.00^{ab}	5.33
V_4	FL-09-127	1.81^{c}	0.79^{cd}	0.81^{c}	20.33^{c}	6.00
V_5	E1-13#32	1.92^{ab}	0.88^{a}	0.83^{bc}	20.00^{c}	5.00
V_6	Sweet Charlie	1.89^{b}	0.81^{bc}	0.78^{cd}	20.00^{c}	5.00
V_7	Hadar	1.87^{bc}	0.84^{b}	0.89^{a}	20.67^{c}	5.67
V_8	E1-13#33	1.84^{bc}	0.81^{bc}	0.77^{d}	20.67^{c}	5.00
V_9	E1-13#31	1.91^{ab}	0.87^{ab}	0.83^{b}	20.33^{c}	5.67
V_{10}	Yamini	1.79^{c}	0.76^{d}	0.79^{cd}	22.00^{ab}	5.00
V_{11}	E-22	1.76^{c}	0.74^{d}	0.73^{e}	20.33^{c}	5.67
V_{12}	Shani	1.94^{ab}	0.86^{ab}	0.84^{b}	22.00^{ab}	5.33
Mean		**1.87**	**0.82**	**0.82**	**21.06**	**5.39**
P≤0.05						
C.D.		**0.065**	**0.029**	**0.027**	**0.861**	**N/A**
SE(m)		**0.022**	**0.01**	**0.009**	**0.292**	**0.259**
SE(d)		**0.031**	**0.014**	**0.013**	**0.412**	**0.367**
C.V.		**2.032**	**2.095**	**1.947**	**2.399**	**8.341**

4.1.2.4. Number of stamens (count)

The data of the number of stamens per flower in different genotypes ranged from 20 to 22.67 (Table-4.3). The genotype of strawberry under this study did not differ substantially for this attribute. The genotype 'E1-13#32', 'Sweet Charlie' showed the minimum stamens count (20) followed by 'FL-09-127', E1-13#31', 'E-22', 'Hadar' (V_7), and 'E1-13#33' (V_8). The maximum (22.67) found in 'Winter Dawn' (V_2), followed by 'Shani' (V_{12}) (22), 'Yamini' (V_{10}) and 'Camarosa' (V_3). Garg (2013) had also confirmed a certain degree of variation in stamens count in strawberry varieties, which ranged between 19.33 and 24.33.

4.1.2.5. Duration of flowering (days)

The results of duration of flowering were statistically different in genotypes and ranged from 75.7 days to 88 days (Table-4.4). The largest period of flowering (88 days) had obtained in 'Camarosa' (V_3), which was statistically at par with genotype 'Chandler' (V_1) (87.3 days), whereas smallest period of flowering (75.3 days) recorded in genotype 'E-22' (V_{11}). The present results are in close conformity with the research outcome of Dhaliwal and Singh (1983) showed that maximum flowering duration in strawberry, notified as 61 to 91 days depending on genotypes. The duration of flowering varied in different genotype of strawberry recorded by Sharma and Suman (2006) and Sharma *et al*. (2014).

Table-4.4. Evaluation of different strawberry genotypes on the basis of flowering behaviors

Genotypes		Days to flowering	Duration of flowering	Number of flowers
V_1	Chandler	78.67^{f}	87.33^{ab}	19.67^{ab}
V_2	Winter Dawn	82.00^{d}	86.67^{b}	20.67^{ab}
V_3	Camarosa	79.67^{ef}	88.00^{a}	21.67^{a}
V_4	FL-09-127	82.33^{d}	84.67^{c}	17.00^{bc}
V_5	E1-13#32	79.00^{ef}	82.00^{d}	18.33^{bc}
V_6	Sweet Charlie	72.33^{g}	78.67^{f}	15.33^{c}
V_7	Hadar	73.00^{g}	78.00^{f}	13.00^{cd}
V_8	E1-13#33	80.00^{e}	80.33^{e}	15.00^{c}
V_9	E1-13#31	84.00^{c}	83.00^{d}	16.67^{bc}
V_{10}	Yamini	86.33^{b}	85.67^{bc}	17.00^{bc}
V_{11}	E-22	88.00^{a}	75.67^{g}	10.83^{d}
V_{12}	Shani	86.00^{b}	83.67^{cd}	18.50^{b}
Mean		**80.94**	**82.81**	**16.97**
P≤0.05				
C.D.		**1.13**	**1.09**	**3.09**
SE(m)		**0.38**	**0.37**	**1.05**
SE(d)		**0.54**	**0.52**	**1.48**
C.V.		**0.82**	**0.77**	**10.69**

4.1.2.6. Days to flowering after planting

The data of days to flowering in different genotypes, presented in Table-4.4, shows significant variation from 72.3 days to 88 days. The earliest flowering was

produced in genotype 'Sweet Charlie' (V6) after planting, while genotype 'E-22' (V11) took the highest days (88 days) to produce flowering after planting. The genotypes 'Chandler' (V1), 'Camarosa' (V3), and 'Winter Dawn' (V2) took 78.67 days, 79.67 days, and 82 days respectively, to produce flower after planting. The variation in days to flowering after planting in different genotype may be probably due to variability in chilling requirement of genotype under investigation where some of the genotypes reflected early flowering with little chilling period (Craig and Brown, 1977; Nicoll and Galletta, 1987).

4.1.2.7. Number of flowers per plant (count)

The significant difference in the results of the number of flowers per plant was obtained from different genotype under Punjab conditions and shown in Table-4.4.

The maximum (21.67) flowers count per plant was registered in genotype 'Camarosa' (V3), which was at par with 'Winter Dawn' (V2) (20.66) and 'Chandler' (V1) (19.67) while genotype 'E-22' (V11) had produced the minimum flower per plant. The genotype 'Shani' (V12), 'E1-13#32' (V5), 'FL-09-127' (V4), 'Yamini' (V10), and 'E1-13#31' (V9) produced 18.5, 18.3, 17, 17, and 16.67 flowers per plant, respectively. The results of flowers count in the present investigation were in similarity to the observations recorded by Deepa *et al.* (2012) who reported that 'Chandler' and 'Gorella' produced the highest flowers per plant. Similar results have been observed by Neetu and Sharma (2018), who the highest flowers count per plant was recorded in Nabila (27.42) and Camarosa (26.18).

4.1.3 FRUIT CHARACTERS

4.1.3.1. Fruit length (cm)

The results of fruit length in different genotypes of strawberry under Punjab conditions were significantly different and shown in Table-4.5.

The maximum fruit length was registered in genotype 'Camarosa' (V3) (3.87 cm), which was significant at par with 'Chandler' (V1) (3.77 cm), while the least (2.33 cm) fruit length recorded in genotype 'E-22' (V11). The present findings are closely similar to Mishra *et al.* (2015), who noticed maximum fruit length in 'Winter Dawn' (5.35 cm) and 'Camarosa' (5.32 cm). The present findings are closely related to Garg (2013), who observed the larger (34.48mm) length of fruit in cultivar 'Chandler'. Rana and Sharma (2002) also reported the maximum (3.44) strawberry

fruit length in Chandler. The results of fruit length in the present investigation were in similarity to the observations reported by Negi and Upadhyay (2016), who recorded that the berry length was highest in 'Camarosa' (45.38 mm)

Table-4.5. Evaluation of different strawberry genotypes on the basis of fruit characters like fruit size (cm), number of calyx and achene

Genotypes		Fruit length (cm)	Fruit breadth (cm)	Number of calyx	Number of achene
V_1	Chandler	3.77^{a}	3.17^{a}	12.00^{a}	178.67^{b}
V_2	Winter Dawn	3.65^{b}	3.02^{b}	10.33^{bc}	183.33^{ab}
V_3	Camarosa	3.87^{a}	3.22^{a}	11.33^{ab}	188.67^{a}
V_4	FL-09-127	2.69^{f}	2.59^{cd}	9.67^{c}	152.00^{e}
V_5	E1-13#32	3.38^{c}	3.28^{a}	11.00^{b}	168.33^{c}
V_6	Sweet Charlie	2.87^{e}	2.51^{d}	11.00^{b}	158.00^{de}
V_7	Hadar	3.05^{d}	2.68^{c}	10.67^{bc}	161.33^{d}
V_8	E1-13#33	2.41^{g}	2.14^{f}	10.33^{bc}	142.67^{f}
V_9	E1-13#31	2.63^{f}	2.53^{d}	11.33^{ab}	147.00^{ef}
V_{10}	Yamini	2.76^{ef}	2.47^{d}	9.67^{c}	155.33^{de}
V_{11}	E-22	2.33^{g}	2.26^{ef}	10.00^{c}	136.67^{f}
V_{12}	Shani	2.73^{f}	2.34^{e}	10.00^{c}	150.33^{e}
Mean		**3.01**	**2.68**	**10.61**	**160.19**
P≤0.05					
C.D.		**0.11**	**0.12**	**0.77**	**6.04**
SE(m)		**0.04**	**0.04**	**0.26**	**2.05**
SE(d)		**0.05**	**0.06**	**0.37**	**2.89**
C.V.		**2.20**	**2.56**	**4.24**	**2.21**

4.1.3.2. Fruit breadth (cm)

The data pertaining to the breadth of fruit in different strawberry genotypes showed significant variation with each other and ranged from 2.14 to 3.28 cm (Table-4.5). The maximum breadth of fruit was obtained in genotype 'E1-13#32' (3.28 cm) (V_5) which was significantly at par with 'Camarosa' (3.22 cm) (V_3) and 'Chandler' (3.17 cm) (V_1), while minimum (2.17 cm) fruit breadth was registered in genotype 'E1-13#33'. According to the finding of Rana and Sharma (2002), the highest (2.35 cm) width of fruit was found in 'Chandler'. Mishra *et al.* (2015) observed the greatest fruit breadth in 'Camarosa' (4.09 cm) and 'Winter Dawn' (4.08 cm), which was closely

similar to the present study. Sharma and Thakur (2008) reported that fruit size variations in genotypes were mainly due to vigour of the plant, fruits competition, nutrient of plants, and agro-climatic conditions.

4.1.3.3. Number of calyx per fruit (count)

The data related to the count of calyx per fruit in different genotypes under Punjab conditions ranged from 9.67 to 12. The genotype was showing negligible differences for this character (Table-4.5).

The highest (12) calyx number per fruit counted in genotype Chandler, which was followed by 'E1-13#31' (11.33) and 'Camarosa' (11.33), while minimum (9.67) calyx number per fruit was a count in genotype 'FL-09-127' and 'Yamini' which was statistically at par with 'E-22' (10), 'Shani' (10), 'Winter Dawn' (10.33) and 'E1-13#33' (10.33). Similarly, Lata (2016) reported that the value of calyx number per fruit ranged from 10 to 12.

4.1.3.4. Number of Achene (count)

The data related to the count of achenes per fruit in different genotypes under Punjab conditions varied from 136.67 to 188.67 (Table-4.5). The maximum (188.67) achene number per fruit counted in genotype 'Camarosa' (V_3), which was followed by 'Winter Dawn' (V_2) (183.33), while the minimum (136.67) achene number per fruit was counted in 'E-22' (V_{11}). The variation of achene counts per fruit (128-160) was also observed by Khanizadeh *et al.* (1992), who reported a quadratic relation between average fruit weight and count of achenes in fruit.

4.1.3.5. Number of fruits per plant (count)

The significant variation was recorded in different genotypes in terms of fruit count per plant, which varied from 6.67 to 15.33 under Punjab conditions (Table-4.6). The highest fruit count was noticed in genotype Camarosa (V_3), which was followed by 'Chandler' (V_1) (14.67) and 'Winter Dawn' (V_2) (14.5) while genotypes 'E1-13#32'(V_5), 'Shani' (V_{12}), 'FL-09-127' (V_4), 'Yamini' (V_{10}), 'E1-13#31' (V_9), and 'Sweet Charlie' (V_6) were statistically at par with each other. The minimum fruit count was reported in genotype 'E-22' (V_{11}), followed by 'Hadar' (V_7). The present outcome is in the same trend with the findings of Singh (2016), who registered maximum fruit count in cultivar 'Chandler' (13.8) and 'Camarosa' (12.3) under Ludhiana conditions. The significant variation in fruit count might be associated with

variation in adaptability of genotypes under investigation in the prevailing agro-climatic conditions and the management practices adopted for an experiment (Beniwal *et al*., 1989).

4.1.3.6. Days to fruit maturity (days)

The data in Table-4.6 show days to maturity after flowering observed in different strawberry genotype, which was significantly different from each other. The maximum number of days taken for fruit maturity i.e. 23.67, was registered in genotype 'E1-13#32' (V_5) followed by 'Camarosa' (V_3) (23 days); however, 'Chandler' (V_1) took 22.33 days, which was at par with 'WinterDawn' (V_2) (22 days) and 'Hadar' (V_7) (21.67 days). The least number of days taken for fruit maturity after flowering was observed in genotypes 'E-22' (V_{11}) (19.33 days), 'E1-13#31' (19.67 days), 'Shani' (19,67 days) and 'Sweet Charlie' (20 days). The results with a similar trend of variation in genotypes have also been marked for fruit maturity (Sharma and Suman, 2006; Sharma and Sharma, 2006; Sharma and Thakur, 2008). An evaluation of strawberry cultivars has been tested by Gupta (1998) under the mid-hill conditions of Himachal Pradesh and observed that different cultivars had taken different number of days to attain fruit maturity.

4.1.3.7. Average berry weight (g)

The data pertaining to average berry weight in different strawberry genotype showed significant variation with each other (Table-4.6), which ranged from 9.17 g to 12.77g. The average berry weight (12.77g) in genotype 'Winter Dawn' (V_2) was significantly heavier than other genotypes, which was at par with 'Camarosa' (12.63g) and 'Chandler' (12.4g) whereas the average berry weight in genotype 'E-22' (V_{11}) was followed by 'E1-13#33' and 'E1-13#31'. The average berry weight in 'Shani' (10.8), 'FL-09-127' (10.8), 'Sweet Charlie' (11.13), 'Yamini' (11.23) were statistically at par with each other.

The present outcomes are in similar findings with Raman (2016), who observed that the maximum weight of fruit was found in 'Camarosa' and 'Chandler' among the cultivars. Jami *et al.* (2015) also noticed the 'Chandler' cultivar showed the highest fruit weight. These findings are also in according to the outcomes of work done by Gaikwad *et al.* (2018), who had confirmed that cultivars 'Seascape' (24.4g) and 'Winter Dawn' (21 g) had shown maximum weight of fruit under Mahabaleshwar

conditions. Morgan (2006) suggested that berry shape and size depending upon the number of achenes formed which is affected by pollination and fertilization during blooming.

Table-4.6. Evaluation of different strawberry genotypes on the basis of yield and related traits

Genotypes		Number of fruits per plant	Days to maturity after flowering	Average berry weight (g)	Yield (g) per plant	Yield tonnes per hectare
V_1	Chandler	14.67^{ab}	22.33^{b}	12.40^{ab}	181.93^{a}	17.32^{a}
V_2	Winter Dawn	14.50^{ab}	22.00^{bc}	12.77^{a}	184.90^{a}	16.99^{a}
V_3	Camarosa	15.33^{a}	23.00^{ab}	12.63^{a}	193.87^{a}	19.17^{a}
V_4	FL-09-127	11.17^{bc}	21.33^{c}	10.80^{c}	120.47^{c}	9.97^{bc}
V_5	E1-13#32	12.83^{b}	23.67^{a}	11.97^{b}	153.57^{b}	11.10^{b}
V_6	Sweet Charlie	11.00^{bc}	20.00^{de}	11.13^{c}	122.62^{c}	6.43^{c}
V_7	Hadar	7.83^{cd}	21.67^{bc}	11.43^{bc}	89.72^{d}	6.33^{c}
V_8	E1-13#33	10.00^{c}	20.33^{d}	9.30^{d}	92.77^{d}	6.21^{cd}
V_9	E1-13#31	11.00^{bc}	19.67^{d}	9.70^{d}	107.08^{cd}	8.17^{c}
V_{10}	Yamini	11.17^{bc}	21.33^{c}	11.23^{c}	125.13^{c}	9.28^{bc}
V_{11}	E-22	6.67^{d}	19.33^{e}	9.17^{d}	61.00^{e}	3.87^{d}
V_{12}	Shani	12.33^{b}	19.67^{de}	10.80^{c}	133.20^{bc}	10.33^{bc}
Mean		**11.54**	**21.19**	**11.11**	**130.52**	**10.43**
P≤0.05						
C.D.		**2.27**	**0.98**	**0.55**	**26.32**	**2.35**
SE(m)		**0.77**	**0.33**	**0.19**	**8.92**	**0.80**
SE(d)		**1.09**	**0.47**	**0.26**	**12.61**	**1.12**
C.V.		**11.56**	**2.71**	**2.90**	**11.83**	**13.20**

4.1.3.8. Yield per plant (g)

Different genotypes of strawberry had shown variation among themselves under Punjab conditions in term of yield per plant which varied from 61g to 193.87g (Table-4.6). The highest (193.87 g) yield per plant was produced in genotype 'Camarosa' (V_3) which was statistically at par with 'Winter Dawn' (V_2) (184.9 g) and 'Chandler' (V_1) (181.93 g) while lowest plant yield (61 g) was found in 'E-22' (V_{11}). The yield per plant in 'Shani' (153.56) and 'E1-13#32' (153.57 g) were statistically at par with each other. This variation in yield was mainly due to maximum flower number and weight of fruit. The above results come according to findings of Gaikwad

et al. (2018) who reported that 'Winter Dawn' showed maximum (839 g) yield per plant. Neetu and Sharma (2018) reported that the cultivar 'Nabila', 'Camarosa' and 'Kamila' gave maximum yield per plant. The results are in similarty with findings of Belakhud *et al.* (2015) who found the chandler gave highest yield per plant.

4.1.3.9. Yield per hectare (tonnes per hectare)

The data obtained on yield per hectare showed significant differences in different genotypes (Table-4.6). The genotype 'Camarosa' was found to have highest yield per hectare (19.17 tonnes / hec) which was at par with 'Chandler' (V_1) (17.32 tonnes/hec) and 'Winter Dawn' (V_2) (16.99 tonnes/hec) whereas, lowest yield per hectare was recorded in the 'E-22' (V_{11}) (3.87 tonnes/hec) which was followed by 'E1-13#33' (V_8) (6.21 tonnes/hec).

These results in yield per hectare indirectly influenced by flowering characters like number of flowers per plant. The variation in yield per hectare may be impact of environmental parameters like photoperiods, temperature and light intensity on different strawberry (Avidov and Shaul, 1986). The present result was also in trends with the outcomes of work done by Sahu and Chandel (2014) who showed cultivar Chandler was produced maximum (35.10MT per ha). Sharma and Thakur (2008) also recorded greatest yield in 'Chandler'. The resulted yield per plant and hectare are in similar trends with work of Neetu and Sharma (2018) who recorded that the maximum yield in cultivar 'Nabila', 'Camarosa' and 'Kamila'. Gaikwad *et al.* (2018) reported that cultivar 'Winter Dawn' showed highest yield.

4.1.3.10. Total soluble solids ($^{\circ}$B)

The significant differences in total soluble solids ($^{\circ}$B) were recorded in different genotypes under Punjab conditions (Table-4.7) which varied between 7.6°B and 10°B**.** The genotype 'Shani' (V_{12}) had recorded maximum TSS (10°B) which was statistically at par with 'Sweet Charlie' (V_6) (9.8°B), 'Camarosa' (V_3) (9.7°B) and 'Chandler' (V_1) (9.5°B). The minimum (7.6°B) TSS was registered in genotype 'E1-13#33' (V_8) which was at par with 'E1-13#31' (V_9) (7.8°B) and 'FL-09-127' (V_4) (8°B) as compared to other genotypes. Sharma and Sharma (2002) registered that total soluble solids value ranged from 9.46°B to 11.82°B in different strawberry cultivars. Shaw (1990) suggested that environmental condition during the growing and development period was more influenced the total soluble solids content than genetic

inheritance. The differences in genotype with respect to TSS may be attributed with response of genotypes to the growing conditions and the genotypes preferring warm days and cooler nights resulted good TSS and acid content in comparison to the genotypes facing cloudy and warm-humid night (Avidov and Shaul, 1986; Kidmose *et al.*, 1996).

4.1.3.11. Titratable acidity (%)

The data in Table-4.7 shows that titratable acidity content observed in different strawberry genotypes and significant differences were found in all genotypes. The titratable acidity varied from 0.78 % in 'Hadar' (V_7) to 0.97 % in 'E1-13#33' (V_8). The highest acidity was obtained in genotype 'E1-13#33' which was at par with 'Shani' (V_{12}) (0.91%) and 'E1-13#31' (V_9) while minimum acidity (0.78%) was obtained in 'Hadar' which was followed by 'Sweet Charlie' (V_6) (0.79%), 'FL-09-127' (V_4) (0.83%), 'Yamini' (V10) (0.83%), 'Winter Dawn' (V2) (0.83%), 'E1-13#32' (V_5) (0.83%) and 'Camarosa' (V_3) (0.84%). The results recorded in the present investigation have been related to the work of Veazie (1995) who also observed that the acidity content in berries ranged from 0.45% to 1.81%. The differences in genotype with regards to acidity may be attributed with response of genotypes to the growing conditions. The genotypes are preferring warm days and cooler nights which resulted in good TSS and acid content as compared to the genotypes facing cloudy and warm-humid night (Avidov and Shaul, 1986; Kidmose *et al.*, 1996).

4.1.3.12. TSS/acid ratio

There was a significant variation in TSS/acid ratio in different genotypes (Table-4.7). The genotype Sweet Charlie (V_6) showed the highest value (12.42) which was statistically at par with 11.39 in 'Camarosa' (V_3) while the lowest was found in 'E1-13#33' (V_8) (7.83) followed by 'E1-13#31' (V_9) (8.57). The results are in a similarity to findings by Singh (2016) who had noticed the highest (12.5) TSS/acid ratio in cultivar 'Sweet Charlie'. Gupta (1998) also reported significant variation among different strawberry cultivars in TSS/acid ratio. This maximum TSS/ acid ratio might be attributed to the maximum content of TSS in 'Sweet Charlie' and 'Camarosa' as compared to other cultivars

Table-4.7. Evaluation of different strawberry genotypes on the basis of fruit quality parameters (TSS (°B), Titratable Acidity (%) and TSS/Acid)

Genotypes		TSS (°B)	Titratable Acidity (%)	TSS/Acid ratio
V_1	Chandler	9.47^{ab}	0.86^{b}	11.07^{b}
V_2	Winter Dawn	9.00^{bc}	0.83^{bc}	10.80^{bc}
V_3	Camarosa	9.60^{ab}	0.84^{bc}	11.39^{ab}
V_4	FL-09-127	7.97^{cd}	0.83^{bc}	9.62^{c}
V_5	E1-13#32	9.10^{b}	0.83^{bc}	10.94^{b}
V_6	Sweet Charlie	9.77^{a}	0.79^{c}	12.42^{a}
V_7	Hadar	8.60^{bc}	0.78^{c}	10.98^{b}
V_8	E1-13#33	7.57^{d}	0.97^{a}	7.83^{d}
V_9	E1-13#31	7.77^{d}	0.91^{ab}	8.57^{d}
V_{10}	Yamini	8.50^{c}	0.83^{bc}	10.25^{bc}
V_{11}	E-22	8.67^{bc}	0.88^{b}	9.87^{c}
V_{12}	Shani	10.00^{a}	0.91^{ab}	11.04^{b}
Mean		**8.83**	**0.86**	**10.40**
P≤0.05				
C.D.		**0.575**	**0.06**	**1.044**
SE(m)		**0.195**	**0.02**	**0.354**
SE(d)		**0.275**	**0.03**	**0.5**
C.V.		**3.819**	**3.93**	**5.89**

4.1.3.13. Total sugars (%)

The performance of strawberry genotype had shown significant variation with respect to total sugars (Table 4.8) and varied from 5.17 to 6.12 percent. The maximum (6.12%) total sugar was obtained in 'Camarosa' (V_3) which was at par with 'Winter Dawn' (V_2) (6.07%), 'E1-13#33' (V_8) (6.05 %), 'Shani' (V_{12}) (6.01 %), 'Chandler' (V_1) (5.99%) and 'E1-13#31' (V_9) (5.94 %). The least total sugar was found in 'Sweet Charlie' (V_6) (5.17 %) followed by 'FL-09-127' (V_4) (5.25%) and 'E-22' (V_{11}) (5.27%). Sullivan and Enzie (1961) and Polovyanov (1985) found that variation in results of the total sugar of strawberry fruits may be due to variation in climate and growing condition.

4.1.3.14. Reducing Sugars (%)

The observations of reducing sugar found significant variation in genotypes and which ranged from 4.17 % in Sweet Charlie to 5.34 % in 'Camarosa' and 'Winter

Dawn' (5.22 %) (Table-4.8). The genotype 'Chandler', 'E1-13#33', 'E1-13#31' and 'Shani' were significantly at par with each other. The present results are similar to the findings by Singh (2016) who observed that the maximum reducing sugar was recorded in cultivar 'Camarosa' (5.88%).

Table-4.8. Evaluation of different strawberry genotypes on the basis of fruit quality parameters (Total Sugar (%), Reducing Sugar (%), Non-reducing Sugar (%), Total Sugar: acid ratio)

Genotypes		Total Sugar (%)	Reducing Sugar (%)	Non-Reducing Sugar (%)	Total Sugar/Acid Ratio
V_1	Chandler	5.99^{a}	5.13^{b}	0.86^{bc}	7.00^{ab}
V_2	Winter Dawn	6.07^{a}	5.22^{ab}	0.84^{bc}	7.28^{a}
V_3	Camarosa	6.12^{a}	5.34^{a}	0.79^{bc}	7.26^{a}
V_4	FL-09-127	5.25^{c}	4.48^{d}	0.77^{c}	6.34^{bc}
V_5	E1-13#32	5.62^{b}	4.74^{cd}	0.88^{bc}	6.76^{b}
V_6	Sweet Charlie	5.17^{c}	4.17^{e}	1.00^{ab}	6.56^{bc}
V_7	Hadar	5.55^{b}	4.64^{d}	0.91^{b}	7.09^{ab}
V_8	E1-13#33	6.05^{a}	5.00^{bc}	1.05^{a}	6.26^{c}
V_9	E1-13#31	5.94^{a}	4.99^{bc}	0.95^{ab}	6.55^{bc}
V_{10}	Yamini	5.69^{b}	4.87^{c}	0.82^{bc}	6.86^{ab}
V_{11}	E-22	5.27^{c}	4.51^{d}	0.76^{c}	6.00^{c}
V_{12}	Shani	6.01^{a}	4.97^{bc}	1.04^{ab}	6.63^{bc}
Mean		**5.73**	**5.73**	**0.89**	**6.72**
P≤0.05					
C.D.		**0.202**	**0.199**	**0.129**	**0.49**
SE(m)		**0.069**	**0.067**	**0.044**	**0.166**
SE(d)		**0.097**	**0.095**	**0.062**	**0.235**
C.V.		**2.073**	**2.411**	**8.498**	**4.277**

4.1.3.15. Non-reducing sugars (%)

The observations presented in Table-4.8 regarding non-reducing sugar content recorded in different strawberry genotypes shows significant variations in all genotypes.The highest non reducing sugar (1.05 %) was registered in genotype 'E1-13#33' which was at par with 'Shani' (V_{12}) (1.04%), 'Sweet Charlie' (V_6) (1.0 %) and 'E1-13#31' (V_9) (0.95 %) while minimum non reducing sugar (0.76 %) was obtained in 'E-22' which was followed by 'FL-09-127' (V_4) (0.77%), 'Camarosa' (V_3) (0.79%), 'Yamini' (V_{10}) (0.82%), 'Winter Dawn' (V_2) (0.84%), Chandler (V_1) (0.86

%) and 'E1-13#32' (V_5) (0.88%). The reasons for variation in fruit sugar may be due to the variations in climate and growing conditions (Sharma and Thakur, 2008).

4.1.3.16. Total sugar/acid ratio

There was a significant difference noted in total sugar/acid ratio in different genotypes (Table-4.8). The genotype Winter Dawn (V_2) had shown (7.28) highest total sugar/acid ratio which was statistically followed by 'Camarosa' (V_3) (7.26), 'Hadar' (V_7) (7.09), 'Chandler' (V_1) (7.0) and 'Yamini' (V_{10}) (6.86) while lowest was found in E-22 (V_{11}) (6.0) followed by 'E1-13#33' (V_8) (6.26) and 'FL-09-127' (V_4) (6.34). The present results are similar to the findings by Garg (2013) who recorded the second highest total sugars/acid ratio for cultivar Chandler.

4.1.3.17. pH of fruit juice

The data shown in Table-4.9 showed a significant difference in different genotype in terms of pH value of fruit juice. The maximum value of (2.88) pH was noticed in 'Shani' (V_{12}) which was followed by 'Sweet Charlie' (2.80). The minimum value of (2.34) pH was observed in 'E1-13#33' followed by 'Yamini' (V_{10}) (2.37), 'FL-09-127' (V_4) (2.39) and 'Hadar' (V_7) (2.45). The significant variation was found in strawberry genotypes under the present investigation.

4.1.3.18. Specific gravity

The average data of specific gravity was significantly different in all genotype (Table-4.9) and values of specific gravity ranged from 0.973 to 1.08. The highest specific gravity was noted in 'Camarosa' (V_3) (1.08) followed by 'Chandler' (V_1) (1.06) and Winter Dawn (V_2) (1.06) while the lowest was found in 'E1-13#31' (V_9) (0.97) which was statistically at par with 'E-22' (V_{11}) (0.98), 'FL-09-127' (V_4) (0.98), 'Sweet Charlie' (V_6) (0.99) and 'E1-13#33' (V_8) (1.0). The specific gravity of different strawberry genotypes recorded in the present investigation was in the same trend as the investigation of Kumar (2018) who observed the specific gravity varied from 0.96 to 1.03. The results may be due to the different time of fruit maturity in genotype and environmental conditions.

4.1.3.19. Vitamin C content (mg per 100g)

The significant variations in Vitamin C content were registered in different genotypes under Punjab conditions as given in Table-4.9 which was varied from 49.33 mg/100g in 'Yamini' to 74.82 mg/100g in 'Sweet Charlie' genotype of

strawberry. The genotype 'Camarosa' (70.11 mg/100g) and 'Shani' (68.85 mg/100g) was at par with each other in terms of Vitamin C content. The results were supportive with the outcomes of work done by Singh (2016) who had reported the maximum value of Vitamin C content in 'Ofra' and 'Sweet Charlie', respectively.

Table-4.9. Evaluation of different strawberry genotypes on the basis of fruit quality parameters (pH, Specific gravity, Vitamin C content and Anthocyanin content)

Genotypes		pH	Specific gravity	Vitamin C (mg/100g)	Anthocyanin (mg/100g)
V_1	Chandler	2.48^{c}	1.06^{ab}	65.03^{d}	55.91^{bc}
V_2	Winter Dawn	2.60^{bc}	1.06^{ab}	67.34^{c}	59.79^{a}
V_3	Camarosa	2.55^{c}	1.08^{a}	68.85^{bc}	56.72^{b}
V_4	FL-09-127	2.39^{d}	0.98^{d}	58.92^{e}	54.83^{c}
V_5	E1-13#32	2.49^{cd}	1.04^{bc}	61.31^{d}	52.27^{d}
V_6	Sweet Charlie	2.80^{ab}	0.99^{d}	74.82^{a}	49.90^{e}
V_7	Hadar	2.45^{cd}	1.02^{c}	53.84^{f}	47.67^{f}
V_8	E1-13#33	2.34^{d}	1.00^{cd}	54.59^{f}	52.95^{d}
V_9	E1-13#31	2.49^{cd}	0.97^{d}	58.10^{e}	54.10^{cd}
V_{10}	Yamini	2.37^{d}	1.03^{bc}	49.33^{g}	60.44^{a}
V_{11}	E-22	2.70^{b}	0.98^{d}	60.22^{de}	50.13^{e}
V_{12}	Shani	2.88^{a}	1.05^{b}	70.11^{b}	49.60^{e}
Mean		**2.55**	**1.02**	**61.87**	**53.69**
P≤0.05					
C.D.		**0.125**	**0.024**	**1.829**	**1.532**
SE(m)		**0.042**	**0.008**	**0.62**	**0.519**
SE(d)		**0.06**	**0.012**	**0.876**	**0.734**
C.V.		**2.885**	**1.38**	**1.735**	**1.674**

4.1.3.20. Anthocyanin content (mg/100g)

The data of different genotypes of strawberry had shown significant variation for anthocyanin content which varied from 47.67 mg/100g to 60.44 mg/100g (Table-4.9). The genotype 'Yamini' (V_{10}) had shown maximum anthocyanin content (60.44 mg/100g) which was significantly at par with 'Winter Dawn' (V_2) (59.79 mg/100g) while, minimum anthocyanin content (47.67 mg/100g) was recorded in 'Hadar' (V_7) followed by 'Shani' (V_{12}) (49.6 mg/100g) and 'Sweet Charlie' (V_6) (49.90 mg /100g). The variation in results of anthocyanin content in genotype might be associated with

variation in genetice makeup which determined the synthesis and accumulation of anthocyanin and sugar content (Crespo *et al.*, 2010).

4.1.4. QUALITATIVE TRAITS

4.1.4.1. Leaf shape

The different shape of leaf was observed in different genotypes of strawberry and presented in Table-4.10. The genotypes 'Chandler', 'Camarosa', 'WinterDawn', 'Sweet Charlie', 'E-22', 'Hadar', 'E1-13#31', 'Yamini' were having obovate shape of leaf while leaf shape of genotypes 'FL-09-127', 'E1-13#32', 'E1-13#33' and 'Shani' were ovate-obovate shape.

4.1.4.2. Leaf base

The leaf base characteristics are shown in Table-4.10. All different genotypes were having obtuse leaf base except only genotype 'E1-13#31' which showed acute-obtuse leaf shape under investigation.

4.1.4.3. Leaf apex

All the genotypes characters of leaf apex are presented in Table-4.10. The leaf apex obtuse was shown in all genotypes but acute-obtuse leaf apex was obtained in 'Winter Dawn' and 'Sweet Charlie' genotypes.

4.1.4.4. Nature of leaf

The nature of leaf was recorded to be rough in all genotypes of strawberry and presented in Table-4.10.

4.1.4.5. Leaf surface

The upper surface of leaf colour was showed the dark green to green color and apubescent to slightly pubescent (Table-4.10). The dark green colour of upper surface was found in 'Chandler', 'Winter Dawn', 'Camarosa', 'FL-09-127', 'E1-13#31' and 'Shani' while the green colour was recorded in the 'E1-13#33', 'Hadar', 'Sweet Charlie', 'Yamini', 'E1-13#32' and 'E-22'. The genotypes 'Chandler', 'Winter Dawn', 'FL-09-127', 'E1-13#31', 'E1-13#33' and 'Shani' showed apubescent while another genotype like 'Hadar', 'Sweet Charlie', 'Yamini', 'E1-13#32', 'E-22' and 'Camarosa' showed slightly pubescent.

4.1.4.6. Leaf margin

All genotypes of strawberry were observed different type leaf margin like medium or slightly serrated which is shown in Table- 4.10. The medium serrated leaf margin was found in 'Chandler', 'Winter Dawn', 'E-22', 'Shani', 'E1-13#31', 'E1-13#32' and 'E1-13#33' while, shallow serrated leaf margin was recorded in 'Sweet Charlie', 'Yamni', 'Camarosa', 'FL-09-127' and 'Hadar'.

4.1.4.7. Flower types

All the genotypes were reported to bear hermaphrodite flowers (Table-4.11). Similar findings for cultivated strawberry genotypes were also reported by Lata (2016).

4.1.4.8. Petal shape

The results pertaining to the shape of petals in the genotype taken for study under Punjab conditions is presented in Table-4.11. The shape of petal in genotype 'Chandler', 'Winter Dawn', 'Camarosa', 'FL-09-127', 'Hadar', 'Yamini', 'Shani' and 'E1-13#31' was orbicular-ovate shape while genotype 'E-22' and 'E1-13#33' had orbicular-obovate shape. Ovate-obovate shape of petals was found in genotype 'E1-13#32' and 'Sweet Charlie'. Similar variations were reported by Gupta (1998) and Garg (2013).

4.1.4.9. Petal colour

In this study, all genotypes of strawberry showed the white colour of petals under Punjab conditions (Table 4.11).

4.1.4.10. Anther attachments

Anther attachment in all different genotype under Punjab conditions is presented in Table-4.11. The dorsifixed type of another attachment was recorded in all genotypes of strawberry in this investigation.

Table 4.10 Evaluation of different strawberry genotype on the basis qualitative traits of leaf

Genotypes		Leaf Shape	Leaf base	Leaf tip	Leaf surface upper surface	Nature of leaf	Leaf margins
V_1	Chandler	Obovate	Obtuse	Obtuse	Dark green apubescent	Rough	Medium serrated
V_2	Winter Dawn	Obovate	Obtuse	Acute-Obtuse	Dark green apubescent	Rough	Medium serrated
V_3	Camarosa	Obovate	Obtuse	Obtuse	Dark green slightly pubescent	Rough	Shallowly serrated
V_4	FL-09-127	Ovate-Obovate	Obtuse	Obtuse	Dark green apubescent	Rough	Shallowly serrated
V_5	E1-13#32	Ovate-Obovate	Obtuse	Obtuse	Green, slightly pubescent	Rough	Medium serrated
V_6	Sweet Charlie	Obovate	Obtuse	acute-Obtuse	Green, slightly pubescent	Rough	Shallowly serrated
V_7	Hadar	Obovate	Obtuse	Obtuse	Green, slightly pubescent	Rough	Shallowly serrated
V_8	E1-13#33	Ovate-Obovate	Obtuse	Obtuse	Green apubescent	Rough	Medium serrated
V_9	E1-13#31	Obovate	Acute-Obtuse	Obtuse	Dark green apubescent	Rough	Medium serrated
V_{10}	Yamini	Obovate	Obtuse	Obtuse	Green, slightly pubescent	Rough	Shallowly serrated
V_{11}	E-22	Obovate	Obtuse	Obtuse	Green, slightly pubescent	Rough	Medium serrated
V_{12}	Shani	Ovate-Obovate	Obtuse	Obtuse	Dark green apubescent	Rough	Medium serrated

Table 4.11 Evaluation of different strawberry genotypes on the basis of qualitative traits of flower

Code	Genotypes	Flower type	Petal shape	Petal colour	Anther attachment
V1	Chandler	Hermaphrodite	Orbicular-ovate	White	Dorsifixed
V2	Winter Dawn	Hermaphrodite	Orbicular-ovate	White	Dorsifixed
V3	Camarosa	Hermaphrodite	Orbicular-ovate	White	Dorsifixed
V4	FL-09-127	Hermaphrodite	Orbicular-ovate	White	Dorsifixed
V5	E1-13#32	Hermaphrodite	Ovate-obovate	White	Dorsifixed
V6	Sweet Charlie	Hermaphrodite	Ovate-obovate	White	Dorsifixed
V7	Hadar	Hermaphrodite	Orbicular-ovate	White	Dorsifixed
V8	E1-13#33	Hermaphrodite	Obovate-orbicular	White	Dorsifixed
V9	E1-13#31	Hermaphrodite	Orbicular-ovate	White	Dorsifixed
V10	Yamini	Hermaphrodite	Orbicular-ovate	White	Dorsifixed
V11	E-22	Hermaphrodite	Orbicular-Obovate	White	Dorsifixed
V12	Shani	Hermaphrodite	Orbicular-ovate	White	Dorsifixed

4.1.4.11. Fruit shape

The shape of fruits in different genotypes of strawberry was different and presented in Table-4.12. The conic shape of fruits was noted in genotype ‘Sweet Charlie’, ‘E1-13#33’, and ‘E-22’ while genotype ‘Chandler’ and ‘WinterDawn’ showed conic and long wedge shape of fruits. The genotype ‘Camarosa’ had flat conic and long wedge fruit shape. The globose conic fruit shape was found in genotype ‘FL-09-127’, ‘E1-13#31’ and ‘E1-13#32’ while genotype ‘Hadar’, ‘Yamini’ and ‘Shani’ had long conic fruit shape. Fruit shape is the characteristics of cultivars and is used for the identification of cultivars. Garg (2013) observed different shapes of fruits in different cultivars of strawberry. Sahu and Chandel (2014) also observed various fruit

shapes in thirteen cultivars of strawberry. The variation in shapes of fruit of different genotype is the main reason due to their genetic makeup.

4.1.4.12. Calyx removal/Ease of capping

The ease of capping has expressed as the extent of calyx attachment (loose and tight) to the fruit (Table-4.12). The genotype 'Shani', 'FL-09-127', 'Winter Dawn', 'Sweet Charlie', 'E1-13#32' and 'E1-13#33' were having loose calyx attachment on fruit while tight calyx attached on fruit was found in genotype 'E-22', 'E1-13#31', 'Hadar,' 'Chandler', 'Yamini', 'Camarosa'.

4.1.4.13. Flesh colour

The colour of flesh of various genotypes of strawberry was different from each other (Table-4.12). The bright red and creamish white flesh colour were found in 'Yamini' (V_{10}) and 'Winter Dawn' (V_2). The genotypes 'Camarosa' (V_3), 'E1-13#32' (V_5), 'Chandler' (V_1), 'FL-09-127' (V_4), and 'E1-13#33' (V_8) showed red flesh colour. The genotype 'E1-13#31' (V_9) had red and creamish white colour of flesh. The crimson flesh colour was recorded in 'Shani' (V_{12}), 'E-22' (V_{11}), 'Sweet Charlie' (V_6) and 'Hardar' (V_7). The flesh colour was different from each other which might be associated with variation in anthocyanin synthesis and accumulation in fruits resulting in white to deep red coloured fruits (Veazea, 1995). This can be further confirmed as the genetically governed attribute and shows a significant extent of genotypic variation.

Table-4.12. Evaluation of different strawberry genotypes on the basis of qualitative traits of fruit

Genotypes		Calyx removal/ ease of capping	Core	Flesh colour	Achene colour	Achene Placement	Fruit Shape
V_1	Chandler	Tight	Compact	Red	Yellowish green	Sunken into flesh	Conic and long wedge
V_2	Winter Dawn	Loose	Hollow	Bright red to creamish white	Greenish yellow	Raised above the fruit surface	Conic to long wedge
V_3	Camarosa	Tight	Compact	Red	Yellowish green	Sunken into flesh	Flat conic & long wedge
V_4	FL-09-127	Loose	Compact	Red	Yellowish green	Raised above the fruit surface	Globose conic
V_5	E1-13#32	Loose	Hollow	Red	Greenish yellow	Raised above the fruit surface	Globose conic
V_6	Sweet Charlie	Loose	Hollow	Crimson	Greenish yellow	Raised above the fruit surface	Conic
V_7	Hadar	Tight	Compact	Crimson	Yellowish green	Raised above the fruit surface	Long conic
V_8	E1-13#33	Loose	Hollow	Red	Yellowish green	Sunken into flesh	conic
V_9	E1-13#31	Tight	Compact	Red to creamish white	Yellowish green	Raised above the fruit surface	Globose conic
V_{10}	Yamini	Tight	Hollow	Bright Red	Greenish yellow	Sunken into flesh	Long conic
V_{11}	E-22	Tight	Compact	Crimson	Yellowish green	Sunken into flesh	Conic
V_{12}	Shani	Loose	Compact	Crimson	Greenish yellow	Raised above the fruit surface	Long conic

4.1.4.14. Core

The core of different strawberry genotypes was observed (Table-4.12) and varied from compact ('Chandler', 'Camarosa', 'Shani', 'FL-09-127', 'Hadar', 'E-22' and 'E1-13#31') to hollow ('Yamini', 'Winter Dawn', 'Sweet Charlie', 'E1-13#32' and 'E1-13#33'). The present outcomes are in a similar line with the findings of Lata (2016).

4.1.4.15. Achene colour

The genotype 'Yamini' (V_{10}), 'Shani' (V_{12}), 'Winter Dawn' (V_2), 'E1-13#32' (V_5), and 'Sweet Charlie' (V_6) showed greenish-yellow achene colour while genotypes 'Chandler' (V_1), 'E-22' (V_{11}), 'Camarosa' (V_3), 'FL-09-127' (V_4), 'Hadar' (V_7) and 'E1-13#33' (V_8), and 'E1-13#31' (V_9) were found yellowish-green achene (Table-4.12). A similar variation in achene colour was also reported by Garg (2013).

4.1.4.16. Achene placements

Achene placement is an important character for the identification of cultivars. The achenes placement in genotypes like 'Winter Dawn' (V_2), 'Hadar' (V_7), 'Shani' (V_{12}), 'FL-09-127' (V_4), 'E1-13#32' (V_5), 'E1-13#31' (V_9) and 'Sweet Charlie' (V_6) showed raised above the fruit surface while genotypes 'Chandler' (V_1), 'E-22' (V_{11}), 'Camarosa' (V_3), 'Yamini' (V_{10}), and 'E1-13#33' (V_8) showed sunken into flesh (Table-4.12). Similar results were observed by Gupta (1998).

4.1.5. GENETIC VARIABILITY

The study of genetic variability of octaploid species confirmed the polyploidy and allogamous behavior (Hytonen *et al*., 2018) such as the formation of unreduced gametes during interspecific hybridization of diploids; hybridization followed by induction of tetraploidy; hexaploid (*F. moschata*) × diploid hybridization; tetraploid derivative from an octoploid (*F.* × *ananassa*) × diploid hybridization (Ahokas, 1999). The genetic variability study for 12 strawberry genotypes for 36 characters has been discussed under the following parameters:

4.1.5.1. Range:

The range of the 36 quantitative traits of different strawberry genotype plants under Punjab conditions has been shown in Table-4.13. Among all the traits investigated, the widest range was recorded for yield per hectare (3.87 t/ha - 19.17t/ha) followed by

mortality percent (11.11%-52.38%), average yield per plant (61g/plant-193.87g/plant), number of runners (3.61-10.33), number of fruits (6.67-15.33) and number of flowers (10.83-21.67)

The lowest range among all the characters was observed in specific gravity (0.97-1.08) followed by flower size (1.76 cm-1.97 cm), number of anthers (20-22.67) and days to runner formation after planting (162.77 to 187.7 days). The existence of a high degree of range for yield and related traits provides evidence of the possible existence of a high degree of variability in such traits and is in conformity with findings of Verma *et al.* (2002) in respect of 19 quantitative characters in 30 genotype of strawberry.

4.1.5.2. Phenotypic and Genotypic Coefficient of Variation (%):

The coefficient of variability at phenotypic and genotypic level for all 36 characters of strawberry plants cultivated under Punjab conditions has been demonstrated in Table-4.13.

Coefficient of phenotypic variance (PCV) of a given trait was higher in comparison to the coefficient of genetic variance (GCV). Yield per hectare (t/ha) was the maximum PCV (48.51%) and GCV (46.68%) followed by mortality rate (%) as PCV (40.29%) and GCV (39.95%), number of runners as PCV (33.78%) and GCV (30.55%), yield per plant (33.13% and 30.94%, respectively), number of fruit (24.65% & 21.77%, respectively), number of flowers (23.01% and 19.38%, respectively), fruit length (17.70% and 17.57%) and fruit breadth (14.50% and 14.7%, respectively). The minimum PCV and GCV were observed in specific gravity (3.68% and 3.41%) and flower size (3.70 % to 3.09%).

PCV ranged from 3.68% to 48.51% and GCV ranged from 3.09% to 46.68%. The high magnitude of GCV provides greater scope for the genetic improvement of strawberry genotypes. Further, the traits for which difference of GCV and PCV was very less confirmed little influence of the environment, while traits (yield and yield-related traits and mortality) with relatively high differences indicates a significant influence of environmental factors over genotypes. The present finding is in conformity with the outcomes inferred by Verma *et al.* (2002); Singh *et al.* (2011); Kumar *et al.* (2012); and Mishra *et al.* (2015).

4.1.5.3. Heritability (%) and Genetic Advances:

The accomplishment of fruit breeding is achieved through effective exploitation of the heritability and variability shown by the population. The potential for fruit breeding of cultivars with better taste containing high nutrients, high resistance to biotic and abiotic stress which is the function of bioactive compounds is based on their variability and heritability. The genotype has a great impact on the metabolic processes of fruits and determines the nutritional and organoleptic values in strawberry (Scalzo *et al*., 2005; Diamanti *et al*., 2012; Najda *et al*., 2014; Schwieterman *et al*., 2014). Heritability value in combination with genetic advance as a percentage of mean (GAPM) value for various characters is the most reliable index for performing the selection of a genotype for traits under investigation. The heritability and GAPM for 36 characters have been depicted in Table-4.13 and described below:

Heritability (%):

A greater number of traits have expressed a high degree of heritability. The highest heritability (> 80%) was obtained in fruit length (98.45%) followed by days to flowering (98.21%), Vitamin C content (98%), duration of flowering (97.46%), fruit breadth (96.87%), number of achene (95.51%), anthocyanin content (95.24%), mortality rate (94.25%), days to runners formation (93.89%), average berry weight (93.49%), yield per hectare (92.60%), petiole length (91.89%). total sugar (89.39%), reducing sugar (89.17%), petal breadth (88.98%), number of leaves (88.57%), yield per plant (87.24%), petal length (86%), specific gravity (85.94%), plant height (85.03), duration of fruit maturity (85.03%), TSS (84.03%), pH of fruit juice (83.46%) and number of runners (81.79%). Whereas it was moderate (40%-80%) for the traits like TSS-acid ratio (79.90%), number of fruits (78%), number of anthers (75.84%), leaf area (74.58%), number of flowers (70.94%), number of calyx (70.15%), flower size (69.77%), titratable acidity (67.72%), plant spread (66.86%), total sugar-acid ratio (62.06%) and non reducing sugar (60.51%). The substantially low (0-40) heritability (%) was estimated in number of petal (20%).

Genetic Advance as Percentage of Mean (%):

Estimates of genetic advance and the genetic advance as percentage of mean (GAPM) for 12 strawberry genotypes and 36 traits ranged from 0.07 to 77.71 and 3.84% to 92.54%, respectively. The GAPM of various traits studied was reported as plant height (18.92%), plant spread (13.46%), number of leaves (25.54%), leaf area (17.72%), number of runners (56.92%), days to runner formation after planting (8.82%), petiole length (24.82%, mortality rate (78.23%), flower size (5.31%), petal length (9.92%), petal breadth (10.75%), number of anthers (7.62%), days to flowering (12.35%), duration of flowering (9.69%), number of flowers (33.63%), number of petals (3.84), fruit length (35.90%), fruit breadth (28.94%), number of calyx (11.20%), number of achenes (20.53%), duration of fruit maturity (12.29%), TSS (16.55%), titratable acidity (9.64%), total sugar (11.73%), reducing sugar (13.45%), non reducing sugar (16.86%), TSS-acid ratio (21.47%), total sugar-acid ratio (8.88%), pH of fruit juice (12.20%), specific gravity (6.51%), Vitamin C content (24.76%), anthocyanin content (15.06%), number of fruits (39.60%), average berry weight (21.91%), yield per plant (59.54%) and yield per hectare (92.54%)

A high heritability estimate with high estimates of genetic advance as percentage of mean was reported in yield per hectare (t/ha), mortality rate (%), yield per plant (gm/plant), number of runners (count), number of fruits (count), number of flowers (count), number of leaves (count), petiole length (cm), average berry weight (gm) and plant height (cm) which indicates the existence of additive effect in these traits so phenotypic performance may be exploited to perform a selection of genotypes on the basis of these traits and in a breeding program while selecting the parents these characters need to be evaluated (Morishita, 1994). Similar observations were also recorded from the work of Verma *et al.* (2002); Singh *et al.* (2011); and Mishra *et al.* (2015). In the current study, the existence of high estimates of heritability in broad sense for most of the traits provides opportunities for fair selection as such traits reflect less influence of environment and so there is a close correlation between the genotype and phenotype. There were no traits for which genetic advance as percentage of mean reported to be low or moderate so the influence of environment overall genotypes for each trait might be an indicator of fair opportunity for selection on the basis of phenotypic observation.

Table-4.13: Parameters of genetic variability for 36 traits of strawberry cultivated under Punjab conditions								
Characters	**Range**		**Mean**	**Coefficient of variation (%)**		**Heritability h^2 (%)**	**Genetic Advance**	**Genetic advance as percentage of mean (%)**
	High	**Low**		**PCV (%)**	**GCV (%)**			
X1	12.07	8.83	10.31	10.80	9.96	85.03	1.95	18.92
X2	13.83	10.67	12.15	9.77	7.99	66.86	1.64	13.46
X3	14.17	9.5	11.94	14.00	13.17	88.57	3.05	25.54
X4	74.03	54.47	65.19	11.54	9.96	74.58	11.55	17.72
X5	10.33	3.67	6.75	33.78	30.55	81.79	3.84	56.92
X6	187.7	162.77	174.19	4.56	4.42	93.89	15.36	8.82
X7	9.63	6.17	8.23	13.11	12.57	91.89	2.04	24.82
X8	52.38	11.11	30.95	40.29	39.12	94.25	24.21	78.23
X9	1.97	1.76	1.87	3.70	3.09	69.77	0.10	5.31
X10	0.88	0.74	0.82	5.60	5.19	86.00	0.08	9.92
X11	0.89	0.73	0.82	5.87	5.53	88.98	0.09	10.75
X12	22.67	20	21.06	4.88	4.25	75.84	1.61	7.62
X13	88	72.33	80.94	6.11	6.05	98.21	10.00	12.35
X14	88	75.67	82.81	4.83	4.77	97.46	8.03	9.69
X15	21.67	10.83	16.97	23.01	19.38	70.94	5.03	33.63
X16	6	5.00	5.39	9.33	4.17	20.00	0.21	3.84
X17	3.87	2.33	3.01	17.70	17.57	98.45	1.08	35.90
X18	3.28	2.14	2.68	14.50	14.27	96.87	0.78	28.94
X19	12	9.67	10.61	7.75	6.49	70.15	1.19	11.20
X20	188.67	136.67	160.19	10.44	10.20	95.51	32.89	20.53
X21	23.67	19.33	21.19	7.01	6.47	85.03	2.60	12.29
X22	10	7.57	8.83	9.56	8.76	84.03	1.46	16.55
X23	0.97	0.78	0.86	6.91	5.69	67.72	0.08	9.64
X24	6.12	5.17	5.73	6.37	6.02	89.39	0.67	11.73
X25	5.34	4.17	4.84	7.32	6.92	89.17	0.65	13.45
X26	1.05	0.76	0.89	13.52	10.52	60.51	0.15	16.86
X27	12.42	7.83	10.4	13.07	11.67	79.70	2.23	21.47
X28	7.28	6	6.72	6.94	5.47	62.06	0.60	8.88
X29	2.88	2.34	2.55	7.10	6.48	83.46	0.31	12.20
X30	1.08	0.97	1.02	3.68	3.41	85.94	0.07	6.51
X31	74.82	49.33	61.87	12.27	12.14	98.00	15.32	24.76
X32	60.44	47.67	53.69	7.67	7.49	95.24	8.08	15.06
X33	15.33	6.67	11.54	24.65	21.77	78.00	4.57	39.60
X34	12.77	9.17	11.11	11.38	11.00	93.49	2.44	21.91
X35	193.87	61	130.52	33.13	30.94	87.24	77.71	59.54
X36	19.17	3.87	10.43	48.51	46.68	92.60	9.65	92.54

X1: Plant height (cm); X2: Plant spread (cm); X3: Number of leaves (Count); X4: Leaf area (cm^2); X5: No. of runners (count); X6: Days to runner formation after planting (Days); X7: Petiole Length (cm); X8: Mortality rate (%); X9: Flower size (cm); X10: Petal Length (cm); X11: Petal breadth (cm); X12: Number of anthers; X13: Days to flowering (Days); X14: Duration of flowering (days); X15: Number of flowers; X16: Number of petals; X17: Fruit length (cm); X18: Fruit Breadth (cm); X19: Number of Calyx; X20: Number of achenes; X21: Duration of fruit maturity (Days); X22: TSS (^{O}B); X23: Titratable acidity (%); X24: Total Sugar (%); X25: Reducing Sugar (%); X26: Non Reducing Sugar (%); X27: TSS/Acid ratio; X28: Total sugar/Acid ratio; X29: pH of fruit juice; X30: Specific gravity; X31: Vitamin C content (mg/100g); X32: Anthocyanin (mg/100g); X33: Number of fruits; X34: Average berry weight (gm); X35: Yield per plant (gm); X36: Yield per hectare (tonnes)

4.1.6. Correlation Coefficient

4.1.6.1. Correlation Coefficient at Genotypic Level:

The estimates of the genotypic correlation coefficient for most of the traits of different strawberry genotypes evaluated under Punjab conditions were reported to be significant and positive but some traits were negative. The estimated value has been presented in Table-4.14.

Plant height was having a positive correlation with most of the parameters under estimation and the highest (0.943) correlation was shown with number of runners followed by plant spread (0.909). However, the negative highest correlation of plant height was recorded with days to runner formation after planting (-0.721) followed by mortality rate (-0.712). Plant spread was significantly and positively correlated with number of runners (0.953) and number of anthers (0.924); however, it was negatively correlated with mortality rate (-0.789) and days to runner formation after planting (-0.775).

Number of leaves per plant was having positive correlation with leaf area (0.924) followed by yield per plant (0.775) and number of fruits (0.774), yield per hectare (0.769); however, negative correlation was recorded with mortality rate (-0.657) and days to runner formation after planting (-0.657). Leaf area was having positive correlation with specific gravity (0.984) followed by yield per plant (0.842), number of fruits (0.828) and yield per hectare (0.825) whereas negatively correlated with days to runner formation after planting (-0.764) and mortality rate (-0.670).

Number of runners was reported to be positively associated with duration of flowering (0.796) and yield per hectare (0.786); however, it was negatively correlated with days to runner formation after planting (-0.880) and mortality rate (-0.732). Days to runner formation after planting was having positive association with mortality rate (0.672) and negative correlation was observed with number of fruit (-0.901) and number of flowers per plant (0.890). The petiole length was reported to be in positive association with highest in reducing sugar (0.746) followed by number of anthers (0.631) and negatively with mortality (-0.605). The mortality rate had a strong negative association with yield per hectare (-0.924), while it was positively correlated with non reducing sugar (0.504).

Table-4.14: Genotypic correlation coefficient (r) between different 36 traits of strawberry under Punjab conditions

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31	X32	X33	X34	X35	X36
X1	1																																			
X2	0.909**	1																																		
X3	0.468**	0.588**	1																																	
X4	0.585**	0.617**	0.924**	1																																
X5	0.943**	0.953**	0.596**	0.621**	1																															
X6	-0.721**	-0.775**	-0.657**	-0.764**	-0.880**	1																														
X7	0.739**	0.532**	0.066NS	0.259NS	0.532**	-0.364*	1																													
X8	-0.712**	-0.789**	-0.657**	-0.670**	-0.732**	0.672**	-0.605**	1																												
X9	-0.054NS	-0.112NS	0.362*	0.544**	-0.074NS	-0.332*	-0.044NS	-0.275NS	1																											
X10	-0.193NS	-0.250NS	0.382*	0.482**	-0.179NS	-0.244NS	-0.012NS	-0.274NS	1.009**	1																										
X11	0.002NS	-0.040NS	0.447**	0.574**	0.086NS	-0.290NS	0.167NS	-0.543**	0.745**	0.776**	1																									
X12	0.786**	0.924**	0.407*	0.668**	0.751**	-0.755**	0.631**	-0.739**	0.111NS	-0.034NS	0.245NS	1																								
X13	0.300NS	0.434**	-0.352*	-0.341*	0.153NS	-0.091NS	0.493**	-0.167NS	-0.375*	-0.388*	-0.446**	0.315NS	1																							
X14	0.643**	0.792**	0.569**	0.594**	0.796**	-0.873**	0.434**	-0.887**	0.311NS	0.270NS	0.432**	0.756**	0.176NS	1																						
X15	0.575**	0.760**	0.753**	0.808**	0.695**	-0.890**	0.289NS	-0.838**	0.531**	0.486**	0.446**	0.757**	0.019NS	0.970**	1																					
X16	-0.147NS	0.141NS	-0.197NS	-0.527**	-0.338*	0.561**	0.045NS	-0.530**	-0.271NS	-0.242NS	0.142NS	-0.088NS	0.388*	-0.009NS	-0.047NS	1																				
X17	0.578**	0.465**	0.738**	0.813**	0.565**	-0.581**	0.383*	-0.747**	0.500**	0.452**	0.616**	0.541**	-0.370*	0.660**	0.807**	-0.087NS	1																			
X18	0.340*	0.314NS	0.638**	0.598**	0.329NS	-0.366*	0.257NS	-0.648**	0.421*	0.439**	0.507**	0.303NS	-0.307NS	0.557**	0.752**	-0.016NS	0.923**	1																		
X19	0.243NS	-0.250NS	0.402*	0.445**	0.172NS	-0.243NS	0.261NS	-0.317NS	0.647**	0.708**	0.559**	-0.074NS	-0.533**	0.244NS	0.321NS	-0.391*	0.661**	0.547**	1																	
X20	0.571**	0.491**	0.729**	0.808**	0.588**	-0.593**	0.341*	-0.746**	0.476**	0.399*	0.592**	0.595**	-0.386*	0.688**	0.837**	-0.056NS	0.996**	0.908**	0.574**	1																
X21	0.321NS	0.371*	0.742**	0.671**	0.445**	-0.447**	0.264NS	-0.613**	0.295NS	0.376*	0.575**	0.264NS	-0.360*	0.556**	0.633**	-0.107NS	0.853**	0.905**	0.422*	0.835**	1														
X22	0.402*	0.112NS	0.289NS	0.545**	0.200NS	-0.401*	0.108NS	-0.208NS	0.540**	0.300NS	0.316NS	0.387*	-0.225NS	0.213NS	0.463**	-0.421*	0.559**	0.396*	0.329NS	0.525**	0.226NS	1													
X23	0.152NS	0.199NS	-0.006NS	-0.006NS	0.166NS	-0.202NS	0.254NS	0.025NS	0.072NS	0.086NS	-0.290NS	0.049NS	0.568**	-0.013NS	-0.026NS	-0.287NS	-0.455**	-0.526**	-0.085NS	-0.483**	-0.473**	-0.409*	1												
X24	0.546**	0.589**	0.488**	0.683**	0.533**	-0.687**	0.585**	-0.641**	0.496**	0.496**	0.398*	0.747**	0.183NS	0.642**	0.708**	-0.257NS	0.445**	0.281NS	0.353*	0.451**	0.277NS	0.073NS	0.548**	1												
X25	0.685**	0.736**	0.508**	0.659**	0.634**	-0.690**	0.746**	-0.801**	0.375*	0.385*	0.406*	0.815**	0.282NS	0.737**	0.742**	-0.097NS	0.552**	0.413*	0.310NS	0.557**	0.420*	0.060NS	0.437**	0.963**	1											
X26	-0.438**	-0.461**	-0.018NS	0.162NS	-0.304NS	-0.064NS	-0.515**	0.504**	0.486**	0.454**	0.016NS	-0.160NS	-0.335*	-0.267NS	-0.045NS	-0.602**	-0.334*	-0.441**	0.193NS	-0.329NS	-0.479**	0.056NS	0.457**	0.244NS	-0.027NS	1										
X27	0.201NS	-0.037NS	0.211NS	0.399*	0.052NS	-0.188NS	-0.080NS	-0.117NS	0.363*	0.178NS	0.345*	0.224NS	-0.477**	0.129NS	0.323NS	-0.235NS	0.605**	0.513**	0.300NS	0.597**	0.367*	0.910**	-0.746**	-0.210NS	-0.185NS	-0.115NS	1								
X28	0.431**	0.434**	0.540**	0.754**	0.400*	-0.528**	0.377*	-0.710**	0.452**	0.445**	0.726**	0.761**	-0.396*	0.695**	0.778**	0.001NS	0.945**	0.838**	0.471**	0.981**	0.789**	0.482**	-0.414*	0.535**	0.603**	-0.183NS	0.517**	1							
X29	0.082NS	-0.106NS	-0.182NS	0.012NS	-0.250NS	0.048NS	-0.137NS	0.217NS	0.363*	0.101NS	-0.126NS	0.126NS	0.053NS	-0.234NS	-0.005NS	-0.044NS	-0.035NS	-0.104NS	-0.012NS	-0.037NS	-0.435**	0.776**	-0.088NS	-0.151NS	-0.256NS	0.357*	0.605**	-0.094NS	1						
X30	0.683**	0.668**	0.742**	0.984**	0.649**	-0.780**	0.540**	-0.710**	0.528**	0.404*	0.576**	0.798**	-0.109NS	0.689**	0.808**	-0.419*	0.858**	0.682**	0.309NS	0.860**	0.710**	0.660**	-0.181NS	0.662**	0.720**	-0.135NS	0.544**	0.907**	0.080NS	1					
X31	0.291NS	0.123NS	0.320NS	0.406*	0.148NS	-0.299NS	-0.178NS	-0.151NS	0.576**	0.316NS	0.102NS	0.171NS	-0.254NS	0.160NS	0.451**	-0.137NS	0.416*	0.306NS	0.390*	0.416*	0.004NS	0.809**	-0.185NS	0.052NS	-0.004NS	0.205NS	0.687**	0.226NS	0.814**	0.339*	1				
X32	0.640**	0.782**	0.259NS	0.235NS	0.776**	-0.631**	0.491**	-0.629**	-0.202NS	-0.225NS	-0.060NS	0.664**	0.344*	0.802**	0.684**	-0.029NS	0.415*	0.404*	-0.028NS	0.475**	0.419*	-0.134NS	-0.010NS	0.445**	0.601**	-0.507**	-0.116NS	0.487**	-0.443**	0.397*	-0.152NS	1			
X33	0.632**	0.699**	0.774**	0.828**	0.742**	-0.901**	0.309NS	-0.796**	0.585**	0.503**	0.462**	0.656**	-0.077NS	0.932**	0.984**	-0.228NS	0.852**	0.755**	0.452**	0.866**	0.656**	0.537**	-0.054NS	0.654**	0.684**	-0.036NS	0.399*	0.746**	0.026NS	0.807**	0.529**	0.633**	1		
X34	0.456**	0.431**	0.672**	0.760**	0.499**	-0.572**	0.218NS	-0.677**	0.419*	0.343*	0.587**	0.583**	-0.386*	0.667**	0.807**	-0.076NS	0.952**	0.893**	0.424*	0.965**	0.838**	0.605**	-0.636**	0.298NS	0.407*	-0.357*	0.719**	0.968**	0.029NS	0.853**	0.392*	0.434**	0.816**	1	
X35	0.648**	0.668**	0.775**	0.842**	0.717**	-0.820**	0.337*	-0.807**	0.521**	0.440**	0.495**	0.669**	-0.162NS	0.876**	0.958**	-0.166NS	0.936**	0.842**	0.475**	0.947**	0.744**	0.589**	-0.232NS	0.569**	0.639**	-0.187NS	0.518**	0.840**	0.041NS	0.865**	0.519**	0.603**	0.979**	0.911**	1
X36	0.753**	0.768**	0.769**	0.825**	0.786**	-0.792**	0.499**	-0.924**	0.426**	0.368*	0.516**	0.738**	-0.042NS	0.902**	0.934**	0.105NS	0.917**	0.798**	0.457**	0.921**	0.716**	0.472**	-0.140NS	0.638**	0.754**	-0.342*	0.380*	0.824**	-0.047NS	0.853**	0.412*	0.640**	0.942**	0.853**	0.965**	1

X1: Plant height (cm); X2: Plant spread (cm); X3: Number of leaves (Count); X4: Leaf area (cm^2); X5: No. of runners (count); X6: Days to runner formation after planting (Days); X7: Petiole Length (cm); X8: Mortality rate (%); X9: Flower size (cm); X10: Petal Length (cm); X11: Petal breadth (cm); X12: Number of anthers; X13: Days to flowering (Days); X14: Duration of flowering (days); X15: Number of flowers; X16: Number of petals; X17: Fruit length (cm); X18: Fruit Breadth (cm); X19: Number of Calyx; X20: Number of achenes; X21: Duration of fruit maturity (Days); X22: TSS (^{O}B); X23: Titratable acidity (%); X24: Total Sugar (%); X25: Reducing Sugar (%); X26: Non Reducing Sugar (%); X27: TSS/Acid ratio; X28: Total sugar/Acid ratio; X29: pH of fruit juice; X30: Specific gravity; X31: Vitamin C content (mg/100g); X32: Anthocyanin (mg/100g); X33: Number of fruits; X34: Average berry weight (gm); X35: Yield per plant (gm); X36: Yield per hectare (tonnes)

Flower size was perfectly and positively correlated with petal length (1.0) while the negative correlation was reported with days to flower (-0.375). Petal length was positively correlated with petal breadth (0.776) followed by number of calyx (0.708) whereas the negative association was noticed with days to flowering (-0.388). Petal breadth was positively correlated with total sugar-acid ratio (0.726) and negatively correlated with days to flowering (-0.446). Number of anthers was positive closely correlated with reducing sugar (0.815) followed by specific gravity (0.798). Days to flowering were average positively correlated with titratable acidity (0.568) and negative lycorrelated with TSS acid ratio (-0.477). Duration of flowering was closely positively associated with number of flower (0.970) followed by number of fruit (0.932) and yield per hectare (0.902). The number of flowers was recorded to be positively correlated with highest value for number of fruits (0.984) followed by yield per plant (0.958) and yield per hectare (0.934). The number of petals was negatively correlated with non reducing sugar (-0.602).

Fruit length was strongly positively associated with number of achene (0.996) and average berry weight (0.956), while, it was having a negative relation with titratable acidity (-0.455). Fruit breadth was having a positive and close correlation with number of achenes (0.908) followed by duration of fruit maturity (0.905) and average berry weight (0.893) while negatively with titratable acidity (-0.526).

The number of calyxes was positively correlated with number of achenes (0.574). The number of achenes was strongly and positively associated with total sugar-acid ratio (0.981) followed by average berry weight (0.965), yield per plant (0.947) and yield per hectare (0.921); however, it was negatively associated with titratable acidity (-0.483). Duration of fruit maturity was positive correlated with average berry weight (0.838) and total sugar-acid ratio (0.789).

TSS was in strong positive associated with TSS: acid ratio (0.910) followed by vitamin C content (0.809) while negatively correlated with titratable acidity (-0.409). Titratable acidity was in positive correlation with total sugar (0.548) while it was negatively associated with TSS: acid ratio (-0.746). Total sugar was strongly correlated with reducing sugar (0.963). Reducing sugar was positive related with yield per hectare (0.754), specific gravity (0.720), number of fruit (0.684) and yield per plant (0.639). Non-reducing sugar was lightly correlated with pH of fruit juice

(0.357) while non reducing sugar was negatively related with (-0.507). TSS: acid ratio was positively correlated with average berry weight (0.719). Total sugar: acid ratio was strongly and positively associated with average berry weight (0.968) followed by specific gravity (0.907). pH of fruit juice has positive correlation with vitamin C content (0.814) while negative was found with anthocyanin content (-0.443). Specific gravity was closely and positively associated with yield per plant (0.865) followed by average berry weight and yield per hectare (0.853). Vitamin C content was found to be in positive correlation with number of fruits (0.529). Anthocyanin content was correlated with yield per hectare (0.640) followed by number of fruits (0.633).

A strong and positive correlation of the number of fruits was found with yield per plant (0.979) and yield per hectare (0.942). Average berry weight was closely correlated with yield per plant (0.911). Yield per plant was positively correlated with yield per hectare (0.965).

4.1.6.2. Correlation Coefficient at Phenotypic Level:

The estimates of the phenotypic correlation coefficient for various characters of strawberry genotypes evaluated under Punjab conditions have been presented in Table-4.15.

Plant height has a positive correlation with number of runners (0.815) followed by petiole length (0.714) and yield per hectare (0.698); while, negative correlation of plant height was recorded with mortality percent (-0.660). Plant spread was having positive correlation with number of runners (0.705); however, it was having negative association with days to runner formation after planting (-0.652) followed by mortality rate (-0.609).

The number of leaves per plant was substantially and positively correlated with leaf area (0.869) followed by fruit length (0.695), number of achenes (0.662) and yield per hectare (0.662); however, it was negatively correlated with days to runner formation after planting (-0.619) and mortality percent (-0.583). Leaf area was positively correlated with a specific gravity (0.726) followed by fruit length (0.685) and negatively associated with days to runner formation after planting (-0.655) and mortality percent (-0.524). The number of runners was in close and positive correlation with the duration of flower (0.713) followed by yield per hectare (0.681)

and negatively correlated with days to runner formation after planting (-0.780) and mortality rate (-0.630). Days to runner formation after planting was positively associated with mortality rate (0.643) while, negative correlation was reported with duration of flower (-0.836) and number of fruits (-0.803). The petiole length was reported to be positively correlated with reducing sugar (0.683) followed by total sugar (0.543) and negatively correlated with mortality (-0.575). The mortality rate was reported to be positively correlated with non reducing sugar (0.357) and negatively correlated with mortality, yield per hectare (-0.893) and duration of flowers (-0.838).

The flower size was reported to be positively correlated with petal length (0.820) while petal length was reported to be positively correlated with petal breadth (0.757) and negatively with days to flowering (-0.334). Petal breadth was reported to be positively correlated with total sugar: acid ratio (0.643) while negatively correlated with days to flowering (-0.403). The number of anthers was reported to be positively correlated with specific gravity (0.666) and also positively correlated with duration of flower (0.634).

The days to flowering was reported to be positively correlated with titratable acidity (0.457) and was in negative correlation with number of calyx (-0.474). The correlation of duration of flowering was observed to be positive with yield per hectare (0.851) and also with numbers of flowers (0.821).

The number of flowers was reported to be positively associated with numbers of fruits (0.954) followed by yield per plant (0.923). The number of petals was reported to be negatively correlated with non reducing sugars (-0.375).

The fruit length was in strong and positive correlation with number of achenes (0.968) followed by average berry weight (0.913) while, it was negatively correlated with titratable acidity (-0.362). The fruit breadth was reported to be positively correlated with number of achenes (0.872) and negatively with titratable acidity (-0.426). The number of calyx was positively correlated with number of flowers (0.454) and number of fruits (0.448). The number of achenes was reported to be positively correlated and was highest in average berry weight (0.937) followed by yield per hectare (0.866) and negatively correlated with titratable acidity (-0.419). The duration

of fruit maturity was recorded to be in positive correlation with berry weight (0.766) and negatively associated with titratable acidity (-0.381).

TSS was recorded to be positively correlated with TSS: acid ratio (0.867) followed by vitamin C content (0.744). Titratable acidity was in positive association with total sugar (0.451) and negative with TSS: acid ratio (-0.744). The positive correlation of total sugar was observed with reducing sugar (0.945). The reducing sugar was reported to be positively correlated with yield per hectare (0.688) followed by specific gravity (0.614). Non-reducing sugar was in negative correlation with anthocyanin content (-0.373). The TSS: acidity was in positive correlation with average berry weight (0.667). Total sugar: acidity ratio was reported to be positively correlated with average berry weight (0.794) followed by yield per hectare (0.666). The pH of fruit juice was in close and positive association with vitamin C content (0.737) and negatively associated with anthocyanin content (-0.402).

The highest positive correlation with yield per hectare was recorded in specific gravity followed by yield per plant and average berry weight. Vitamin C content was reported to be positively correlated with yield per plant (0.464). Anthocyanin content was observed to be in positive correlation with yield per hectare (0.608).

The number of fruits was shown in positive association with yield per plant (0.968). Average berry weight was most closely related to yield per plant (0.837) and yield per plant was positively correlated with yield per hectare (0.955)

4.1.7. Path coefficient analysis

The data showing path coefficient for predicting the direct and indirect effects of various traits on the yield of strawberry genotypes evaluated under Punjab Punjab conditions has been presented in Table-4.16.

4.1.7.1. Direct effects of traits on estimated yield per hectare:

Among the different characters of strawberry studied reducing sugar (3.636), yield per plant (2.35), non reducing sugar (0.892), fruit length (0.271), petal length (0.224), leaf area (0.194), duration of flower (0.129), specific gravity (0.104), plant spread (0.077), petiole length (0.033), flower size (0.013), number of petal (0.006) and plant height (0.004) had positively and directly contributed towards the strawberry yield per hectare grown under Punjab conditions. However, the negative and direct contribution

for yield per hectare was identified through total sugar: acid ratio (-2.604), TSS (-1.751), titratable acidity (-1.521), number of fruit (-1.222), total sugar (-0.949), mortality (-0.66), petal breadth (-0.386), fruit breadth (-0.324), number of achene (-0.253), number of runner (-0.242), duration of fruit maturity (-0.201), vitamin C (-0.193), number of leaves (-0.19), anthocyanin (-0.159), day to flowering (-0.142), number of anthers (-0.103), pH of fruit juice (-0.096), average berry weight (-0.078), number of calyx (-0.058), number of flower (-0.056), days to runner formation after planting (-0.014).

Thus, all the traits under study which have a direct positive contribution towards the yield per hectare can be taken into consideration while executing the selection of parental lines as these traits are truly associated with the improvement of yield. However, the traits which are contributing negatively to the yield can be further identified for indirect effect through other traits for positive contribution towards yield per hectare of strawberry.

4.1.7.2. Indirect effects of traits on estimated yield per hectare:

The traits which have reflected direct negative effects were further evaluated for the indirect positive effect on yield per hectare. All such traits were observed to impart positive and indirect effects to yield per hectare through plant height (cm), plant spread, leaf area (cm^2), days to runner formation after planting (days), petiole length (cm), mortality rate (%), flower size (cm), petal length (cm), days to flowering (days), duration of flowering (days), fruit length, titratable acidity (%), reducing sugar, TSS:acid ratio, specific gravity, yield per plant.

Thus, all the traits have positive effect on estimated yield of strawberry either direct or indirect through other traits. The high positive indirect effects on yield per hectare were of Total sugar: acid ratio via mortality rate followed by TSS: acid ratio via titratable acidity and number of fruits via days to runner formation after planting (days). During the selection programme it is necessary to keep in account the direct effect and indirect effect of traits via other traits and summation of all these effects should be high enough to have positive impact on estimated yield per hectare.

Among all the traits studied, yield per plant had the highest positive contribution (0.964) followed by number of fruits per plant (0.940), number of flowers (0.932), number of achenes (0.921), fruit length (0.916), duration of flowering, (0.901), average berry weight (0.853), specific gravity (0.852), leaf area (0.824), total sugar: acidity ratio (0.824) and fruit breadth (0.798) through direct and indirect effects. However, mortality percent was having the highest negative in (-0.923) effect on yield per hectare followed by days to runner formation after planting (-0.790) totality (direct and indirect effect). Thus, such traits should be excluded from the breeding programme and genotypes with low mortality should be taken or selected.

4.1.7.3. Residual effect on yield per hectare (tonnes/hectare):

The residual effect was reported to be 0.0036 which reflects a very low value and only 0.3% contribution of other traits that have not been taken into study. The characters taken under path analysis have the contribution of 99.7% to the yield per hectare. The results deciphered from the present experimentation can be confirmed by the findings of Hortynski (1989) and Das *et al.* (2006).

Similarly, Sharma and Sharma (2006) had performed path coefficient analysis which revealed that fruit number per plant had maximum positive direct contribution towards fruit yield per plant followed by fruit length and fruit width and can be confirmed by findings of Rao *et al.* (2010); Singh *et al.* (2010); and Haque *et al.* (2015) for different genotypes of strawberry.

Table-4.15: Phenotypic correlation coefficient (r) between different 36 traits of strawberry under Punjab conditions

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31	X32	X33	X34	X35	X36
X1	1																																			
X2	0.673**	1																																		
X3	0.383*	0.487**	1																																	
X4	0.422*	0.477**	0.869**	1																																
X5	0.815**	0.705**	0.552**	0.531**	1																															
X6	-0.647**	-0.652**	-0.619**	-0.655**	-0.780**	1																														
X7	0.714**	0.423*	0.084NS	0.208NS	0.492**	-0.345*	1																													
X8	-0.660**	-0.609**	-0.583**	-0.524**	-0.630**	0.643**	-0.575**	1																												
X9	-0.053NS	-0.077NS	0.314NS	0.430**	-0.054NS	-0.302NS	-0.019NS	-0.235NS	1																											
X10	-0.142NS	-0.179NS	0.338*	0.399*	-0.118NS	-0.214NS	-0.009NS	-0.283NS	0.820**	1																										
X11	0.017NS	-0.029NS	0.401*	0.469**	0.047NS	-0.266NS	0.158NS	-0.520**	0.623**	0.757**	1																									
X12	0.647**	0.617**	0.321NS	0.490**	0.570**	-0.642**	0.537**	-0.608**	0.078NS	0.002NS	0.186NS	1																								
X13	0.272NS	0.359*	-0.339*	-0.311NS	0.130NS	-0.084NS	0.472**	-0.163NS	-0.307NS	-0.334*	-0.403*	0.275NS	1																							
X14	0.603**	0.623**	0.527**	0.496**	0.713**	-0.836**	0.413*	-0.838**	0.252NS	0.231NS	0.399*	0.634**	0.172NS	1																						
X15	0.470**	0.492**	0.549**	0.510**	0.528**	-0.759**	0.204NS	-0.676**	0.420*	0.327NS	0.334*	0.517**	0.018NS	0.821**	1																					
X16	-0.002NS	-0.000NS	0.026NS	-0.056NS	-0.057NS	0.256NS	-0.021NS	-0.184NS	-0.243NS	-0.105NS	0.050NS	0.049NS	0.100NS	0.025NS	-0.143NS	1																				
X17	0.530**	0.371*	0.695**	0.685**	0.504**	-0.562**	0.372*	-0.733**	0.417*	0.422*	0.582**	0.448**	-0.363*	0.650**	0.667**	-0.057NS	1																			
X18	0.320NS	0.265NS	0.614**	0.531**	0.288NS	-0.358*	0.242NS	-0.613**	0.371*	0.415*	0.475**	0.291NS	-0.303NS	0.543**	0.609**	0.072NS	0.897**	1																		
X19	0.186NS	-0.134NS	0.259NS	0.239NS	0.151NS	-0.216NS	0.168NS	-0.272NS	0.397*	0.503**	0.413*	-0.060NS	-0.474**	0.175NS	0.282NS	-0.049NS	0.522**	0.441**	1																	
X20	0.524**	0.456**	0.662**	0.680**	0.521**	-0.567**	0.320NS	-0.707**	0.414*	0.382*	0.561**	0.481**	-0.366*	0.669**	0.671**	-0.085NS	0.968**	0.872**	0.454**	1																
X21	0.237NS	0.282NS	0.616**	0.556**	0.341*	-0.363*	0.227NS	-0.525**	0.308NS	0.337*	0.507**	0.208NS	-0.311NS	0.493**	0.491**	-0.203NS	0.762**	0.818**	0.268NS	0.763**	1														
X22	0.303NS	0.168NS	0.263NS	0.418*	0.197NS	-0.359*	0.110NS	-0.175NS	0.436**	0.272NS	0.270NS	0.325NS	-0.199NS	0.187NS	0.264NS	-0.219NS	0.507**	0.362*	0.258NS	0.501**	0.217NS	1													
X23	0.112NS	0.181NS	-0.033NS	-0.024NS	0.048NS	-0.141NS	0.177NS	0.016NS	-0.107NS	-0.005NS	-0.317NS	0.015NS	0.457**	-0.006NS	-0.080NS	0.007NS	-0.362*	-0.426**	-0.057NS	-0.419*	-0.381*	-0.322NS	1												
X24	0.462**	0.463**	0.477**	0.600**	0.471**	-0.660**	0.543**	-0.609**	0.375*	0.436**	0.363*	0.575**	0.165NS	0.589**	0.528**	-0.107NS	0.436**	0.248NS	0.293NS	0.403*	0.192NS	0.060NS	0.451**	1											
X25	0.594**	0.559**	0.482**	0.582**	0.591**	-0.653**	0.683**	-0.748**	0.283NS	0.333*	0.357*	0.631**	0.253NS	0.687**	0.572**	0.016NS	0.527**	0.366*	0.290NS	0.499**	0.304NS	0.036NS	0.352*	0.945**	1										
X26	-0.348*	-0.242NS	0.027NS	0.105NS	-0.313NS	-0.078NS	-0.364*	0.357*	0.303NS	0.341*	0.050NS	-0.113NS	-0.248NS	-0.238NS	-0.084NS	-0.375*	-0.230NS	-0.327NS	0.035NS	-0.247NS	-0.312NS	0.077NS	0.332*	0.251NS	-0.081NS	1									
X27	0.136NS	-0.002NS	0.206NS	0.310NS	0.113NS	-0.171NS	-0.046NS	-0.093NS	0.376*	0.204NS	0.343*	0.197NS	-0.414*	0.105NS	0.214NS	-0.183NS	0.528**	0.452**	0.226NS	0.555**	0.336*	0.867**	-0.744**	-0.197NS	-0.173NS	-0.088NS	1								
X28	0.304NS	0.238NS	0.472**	0.579**	0.380*	-0.451**	0.321NS	-0.561**	0.447**	0.404*	0.643**	0.504**	-0.308NS	0.526**	0.549**	-0.106NS	0.746**	0.638**	0.317NS	0.772**	0.551**	0.355*	-0.573**	0.471**	0.520**	-0.102NS	0.544**	1							
X29	-0.011NS	-0.125NS	-0.162NS	0.025NS	-0.192NS	0.062NS	-0.152NS	0.191NS	0.253NS	0.067NS	-0.135NS	0.037NS	0.045NS	-0.213NS	-0.003NS	-0.040NS	-0.021NS	-0.115NS	0.014NS	-0.052NS	-0.372*	0.665**	-0.035NS	-0.106NS	-0.165NS	0.165NS	0.493**	-0.073NS	1						
X30	0.554**	0.501**	0.611**	0.726**	0.538**	-0.682**	0.454**	-0.647**	0.408*	0.384*	0.499**	0.666**	-0.092NS	0.606**	0.627**	-0.224NS	0.781**	0.634**	0.310NS	0.760**	0.657**	0.594**	-0.123NS	0.579**	0.614**	-0.054NS	0.464**	0.643**	0.096NS	1					
X31	0.267NS	0.130NS	0.302NS	0.341*	0.141NS	-0.284NS	-0.162NS	-0.148NS	0.473**	0.291NS	0.091NS	0.132NS	-0.252NS	0.155NS	0.350*	-0.033NS	0.415*	0.301NS	0.324NS	0.403*	0.001NS	0.744**	-0.116NS	0.052NS	-0.004NS	0.169NS	0.595**	0.144NS	0.737**	0.316NS	1				
X32	0.578**	0.660**	0.227NS	0.175NS	0.669**	-0.598**	0.440**	-0.593**	-0.165NS	-0.206NS	-0.060NS	0.555**	0.338*	0.777**	0.610**	-0.045NS	0.409*	0.385*	-0.039NS	0.470**	0.362*	-0.128NS	0.001NS	0.397*	0.535**	-0.373*	-0.114NS	0.351*	-0.402*	0.338*	-0.145NS	1			
X33	0.547**	0.481**	0.574**	0.544**	0.598**	-0.803**	0.237NS	-0.696**	0.468**	0.383*	0.369*	0.493**	-0.066NS	0.814**	0.954**	-0.185NS	0.733**	0.636**	0.448**	0.727**	0.531**	0.357*	-0.072NS	0.530**	0.586**	-0.118NS	0.281NS	0.542**	0.021NS	0.680**	0.442**	0.562**	1		
X34	0.424**	0.408*	0.633**	0.643**	0.452**	-0.551**	0.225NS	-0.615**	0.356*	0.320NS	0.552**	0.491**	-0.361*	0.636**	0.673**	-0.104NS	0.913**	0.853**	0.318NS	0.937**	0.766**	0.568**	-0.558**	0.281NS	0.354*	-0.191NS	0.667**	0.794**	-0.023NS	0.765**	0.373*	0.423*	0.689**	1	
X35	0.588**	0.513**	0.640**	0.622**	0.613**	-0.775**	0.291NS	-0.736**	0.465**	0.372*	0.437**	0.540**	-0.146NS	0.808**	0.923**	-0.160NS	0.856**	0.766**	0.443**	0.859**	0.651**	0.459**	-0.234NS	0.489**	0.567**	-0.186NS	0.432**	0.665**	0.017NS	0.765**	0.464**	0.564**	0.968**	0.837**	1
X36	0.698**	0.603**	0.662**	0.637**	0.681**	-0.767**	0.459**	-0.893**	0.401*	0.342*	0.481**	0.615**	-0.037NS	0.851**	0.862**	-0.039NS	0.872**	0.750**	0.421*	0.866**	0.639**	0.386*	-0.153NS	0.576**	0.688**	-0.280NS	0.329*	0.666**	-0.056NS	0.775**	0.383*	0.608**	0.912**	0.795**	0.955**	1

X1: Plant height (cm); X2: Plant spread (cm); X3: Number of leaves (Count); X4: Leaf area (cm^2); X5: No. of runners (count); X6: Days to runner formation after planting (Days); X7: Petiole Length (cm); X8: Mortality rate (%); X9: Flower size (cm); X10: Petal Length (cm); X11: Petal breadth (cm); X12: Number of anthers; X13: Days to flowering (Days); X14: Duration of flowering (days); X15: Number of flowers; X16: Number of petals; X17: Fruit length (cm); X18: Fruit Breadth (cm); X19: Number of Calyx; X20: Number of achenes; X21: Duration of fruit maturity (Days); X22: TSS (^{0}B); X23: Titratable acidity (%); X24: Total Sugar (%); X25: Reducing Sugar (%); X26: Non Reducing Sugar (%); X27: TSS/Acid ratio; X28: Total sugar/Acid ratio; X29: pH of fruit juice; X30: Specific gravity; X31: Vitamin C content (mg/100g); X32: Anthocyanin (mg/100g); X33: Number of fruits; X34: Average berry weight (gm); X35: Yield per plant (gm); X36: Yield per hectare (tonnes)

Table-4.16: Path coefficient analysis (direct and indirect effects) of different traits on yield per hectare in strawberry cultivated under Punjab Conditions

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31	X32	X33	X34	X35	Sum
X1	0.004	0.070	-0.089	0.114	-0.228	0.010	0.024	0.470	-0.001	-0.043	-0.001	-0.081	-0.043	0.083	-0.032	-0.001	0.157	-0.110	-0.014	-0.144	-0.064	-0.704	-0.232	-0.518	2.492	-0.391	0.473	-1.122	-0.008	0.071	-0.056	-0.102	-0.772	-0.035	1.574	0.751
X2	0.003	0.077	-0.112	0.120	-0.230	0.011	0.017	0.520	-0.001	-0.056	0.016	-0.095	-0.062	0.103	-0.043	0.001	0.126	-0.102	0.015	-0.124	-0.075	-0.196	-0.303	-0.559	2.676	-0.411	-0.087	-1.130	0.010	0.070	-0.024	-0.124	-0.854	-0.033	1.623	0.766
X3	0.002	0.045	-0.190	0.179	-0.144	0.009	0.002	0.433	0.005	0.085	-0.172	-0.042	0.050	0.074	-0.042	-0.001	0.200	-0.207	-0.023	-0.185	-0.149	-0.506	0.010	-0.463	1.848	-0.016	0.495	-1.407	0.017	0.077	-0.062	-0.041	-0.945	-0.052	1.882	0.768
X4	0.002	0.047	-0.176	0.194	-0.150	0.010	0.008	0.442	0.007	0.108	-0.222	-0.069	0.048	0.077	-0.045	-0.003	0.220	-0.194	-0.026	-0.205	-0.135	-0.954	0.009	-0.648	2.395	0.145	0.938	-1.963	-0.001	0.103	-0.078	-0.037	-1.012	-0.059	2.044	0.824
X5	0.003	0.073	-0.113	0.121	-0.242	0.012	0.017	0.483	-0.001	-0.040	-0.033	-0.077	-0.022	0.103	-0.039	-0.002	0.153	-0.106	-0.010	-0.149	-0.089	-0.351	-0.253	-0.505	2.306	-0.271	0.123	-1.042	0.024	0.068	-0.028	-0.124	-0.906	-0.039	1.741	0.784
X6	-0.003	-0.059	0.125	-0.148	0.213	-0.014	-0.012	-0.443	-0.004	-0.055	0.112	0.078	0.013	-0.113	0.050	0.003	-0.157	0.118	0.014	0.150	0.090	0.702	0.308	0.651	-2.508	-0.057	-0.443	1.375	-0.005	-0.081	0.058	0.100	1.101	0.044	-1.992	-0.790
X7	0.003	0.041	-0.013	0.050	-0.129	0.005	0.033	0.399	-0.001	-0.003	-0.065	-0.065	-0.070	0.056	-0.016	0.000	0.104	-0.083	-0.015	-0.086	-0.053	-0.190	-0.386	-0.555	2.714	-0.459	-0.189	-0.981	0.013	0.056	0.034	-0.078	-0.377	-0.017	0.817	0.496
X8	-0.003	-0.060	0.125	-0.130	0.177	-0.009	-0.020	-0.660	-0.004	-0.061	0.210	0.076	0.024	-0.115	0.047	-0.003	-0.202	0.210	0.018	0.189	0.123	0.364	-0.037	0.608	-2.913	0.449	-0.275	1.849	-0.021	-0.074	0.029	0.100	0.973	0.052	-1.959	-0.923
X9	0.000	-0.009	-0.069	0.106	0.018	0.005	-0.001	0.182	0.013	0.226	-0.287	-0.011	0.053	0.040	-0.030	-0.002	0.136	-0.136	-0.038	-0.121	-0.059	-0.945	-0.110	-0.470	1.364	0.433	0.854	-1.176	-0.035	0.055	-0.111	0.032	-0.715	-0.032	1.265	0.424
X10	-0.001	-0.019	-0.073	0.094	0.043	0.003	0.000	0.181	0.013	0.224	-0.299	0.004	0.055	0.035	-0.027	-0.001	0.123	-0.142	-0.041	-0.101	-0.075	-0.525	-0.131	-0.470	1.398	0.405	0.419	-1.157	-0.010	0.042	-0.061	0.036	-0.614	-0.027	1.069	0.367
X11	0.000	-0.003	-0.085	0.111	-0.021	0.004	0.005	0.358	0.010	0.173	-0.386	-0.025	0.063	0.056	-0.025	0.001	0.167	-0.164	-0.033	-0.150	-0.115	-0.553	0.441	-0.377	1.475	0.014	0.811	-1.890	0.012	0.060	-0.020	0.009	-0.565	-0.045	1.202	0.517
X12	0.003	0.071	-0.077	0.130	-0.181	0.010	0.021	0.488	0.001	-0.008	-0.094	-0.103	-0.045	0.098	-0.042	-0.001	0.147	-0.098	0.004	-0.151	-0.053	-0.678	-0.075	-0.709	2.963	-0.143	0.527	-1.981	-0.012	0.083	-0.033	-0.106	-0.801	-0.045	1.625	0.737
X13	0.001	0.033	0.067	-0.066	-0.037	0.001	0.016	0.110	-0.005	-0.087	0.172	-0.032	-0.142	0.023	-0.001	0.002	-0.100	0.099	0.031	0.098	0.072	0.393	-0.863	-0.173	1.025	-0.298	-1.121	1.030	-0.005	-0.011	0.049	-0.055	0.094	0.030	-0.393	-0.044
X14	0.002	0.061	-0.108	0.115	-0.192	0.012	0.014	0.585	0.004	0.060	-0.167	-0.078	-0.025	0.129	-0.054	0.000	0.179	-0.180	-0.014	-0.174	-0.112	-0.373	0.020	-0.609	2.678	-0.238	0.303	-1.809	0.022	0.072	-0.031	-0.128	-1.139	-0.052	2.126	0.901
X15	0.002	0.058	-0.143	0.157	-0.168	0.012	0.009	0.553	0.007	0.109	-0.172	-0.078	-0.003	0.126	-0.056	0.000	0.219	-0.244	-0.019	-0.212	-0.127	-0.810	0.039	-0.671	2.699	-0.040	0.760	-2.025	0.001	0.084	-0.087	-0.109	-1.202	-0.063	2.326	0.932
X16	-0.001	0.011	0.037	-0.102	0.082	-0.008	0.001	0.350	-0.004	-0.054	-0.055	0.009	-0.055	-0.001	0.003	0.006	-0.024	0.005	0.023	0.014	0.021	0.737	0.436	0.244	-0.352	-0.537	-0.553	-0.002	0.004	-0.044	0.026	0.005	0.279	0.006	-0.404	0.106
X17	0.002	0.036	-0.140	0.158	-0.136	0.008	0.013	0.493	0.007	0.101	-0.238	-0.056	0.053	0.085	-0.045	-0.001	0.271	-0.299	-0.038	-0.252	-0.171	-0.979	0.692	-0.422	2.006	-0.298	1.422	-2.460	0.003	0.090	-0.080	-0.066	-1.041	-0.074	2.273	0.916
X18	0.001	0.024	-0.121	0.116	-0.079	0.005	0.008	0.428	0.006	0.098	-0.196	-0.031	0.044	0.072	-0.042	0.000	0.250	-0.324	-0.032	-0.230	-0.182	-0.693	0.800	-0.266	1.500	-0.393	1.206	-2.182	0.010	0.071	-0.059	-0.064	-0.923	-0.069	2.044	0.798
X19	0.001	-0.019	-0.076	0.086	-0.042	0.003	0.009	0.209	0.009	0.158	-0.216	0.008	0.076	0.032	-0.018	-0.002	0.179	-0.177	-0.058	-0.145	-0.085	-0.576	0.130	-0.335	1.126	0.172	0.705	-1.226	0.001	0.032	-0.075	0.004	-0.553	-0.033	1.153	0.457
X20	0.002	0.038	-0.139	0.157	-0.142	0.008	0.011	0.492	0.006	0.089	-0.228	-0.061	0.055	0.089	-0.047	0.000	0.270	-0.294	-0.033	-0.253	-0.168	-0.920	0.734	-0.428	2.025	-0.293	1.403	-2.555	0.004	0.090	-0.080	-0.076	-1.058	-0.075	2.299	0.921
X21	0.001	0.028	-0.141	0.130	-0.108	0.006	0.009	0.404	0.004	0.084	-0.222	-0.027	0.051	0.072	-0.035	-0.001	0.231	-0.293	-0.025	-0.211	-0.201	-0.395	0.720	-0.263	1.526	-0.427	0.862	-2.053	0.042	0.074	-0.001	-0.067	-0.801	-0.065	1.807	0.716
X22	0.001	0.009	-0.055	0.106	-0.048	0.005	0.004	0.137	0.007	0.067	-0.122	-0.040	0.032	0.028	-0.026	-0.003	0.152	-0.128	-0.019	-0.133	-0.045	-1.751	0.621	-0.070	0.218	0.050	2.140	-1.255	-0.074	0.069	-0.156	0.021	-0.656	-0.047	1.431	0.470
X23	0.001	0.015	0.001	-0.001	-0.040	0.003	0.008	-0.016	0.001	0.019	0.112	-0.005	-0.081	-0.002	0.001	-0.002	-0.123	0.170	0.005	0.122	0.095	0.715	-1.521	-0.520	1.589	0.407	-1.753	1.078	0.008	-0.019	0.036	0.002	0.066	0.049	-0.564	-0.142
X24	0.002	0.045	-0.093	0.133	-0.129	0.009	0.019	0.423	0.007	0.111	-0.153	-0.077	-0.026	0.083	-0.040	-0.002	0.120	-0.091	-0.021	-0.114	-0.056	-0.128	-0.833	-0.949	3.500	0.218	-0.494	-1.393	0.015	0.069	-0.010	-0.071	-0.799	-0.023	1.383	0.636
X25	0.003	0.056	-0.097	0.128	-0.153	0.009	0.024	0.528	0.005	0.086	-0.156	-0.084	-0.040	0.095	-0.042	-0.001	0.150	-0.134	-0.018	-0.141	-0.084	-0.105	-0.665	-0.913	3.636	-0.024	-0.434	-1.569	0.025	0.075	0.001	-0.096	-0.836	-0.032	1.552	0.751
X26	-0.002	-0.035	0.003	0.032	0.073	0.001	-0.017	-0.332	0.006	0.101	-0.006	0.016	0.048	-0.035	0.003	-0.004	-0.091	0.143	-0.011	0.083	0.096	-0.097	-0.695	-0.232	-0.100	0.892	-0.270	0.477	-0.034	-0.014	-0.040	0.081	0.044	0.028	-0.454	-0.342
X27	0.001	-0.003	-0.040	0.077	-0.013	0.003	-0.003	0.077	0.005	0.040	-0.133	-0.023	0.068	0.017	-0.018	-0.001	0.164	-0.166	-0.017	-0.151	-0.074	-1.594	1.134	0.199	-0.671	-0.102	2.351	-1.345	-0.058	0.057	-0.132	0.018	-0.488	-0.056	1.259	0.380
X28	0.002	0.033	-0.103	0.146	-0.097	0.007	0.012	0.469	0.006	0.099	-0.280	-0.078	0.056	0.090	-0.044	0.000	0.256	-0.271	-0.027	-0.248	-0.158	-0.844	0.630	-0.507	2.191	-0.163	1.215	-2.604	0.009	0.095	-0.044	-0.077	-0.912	-0.075	2.041	0.824
X29	0.000	-0.008	0.035	0.002	0.060	-0.001	-0.005	-0.143	0.005	0.023	0.049	-0.013	-0.008	-0.030	0.000	0.000	-0.009	0.034	0.001	0.009	0.087	-1.359	0.133	0.144	-0.930	0.319	1.422	0.244	-0.096	0.008	-0.157	0.070	-0.032	-0.002	0.099	-0.049
X30	0.003	0.051	-0.141	0.191	-0.157	0.011	0.018	0.469	0.007	0.090	-0.222	-0.082	0.016	0.089	-0.045	-0.003	0.233	-0.221	-0.018	-0.218	-0.142	-1.156	0.276	-0.628	2.620	-0.120	1.278	-2.362	-0.008	0.104	-0.065	-0.063	-0.986	-0.066	2.101	0.852
X31	0.001	0.009	-0.061	0.079	-0.036	0.004	-0.006	0.100	0.008	0.071	-0.040	-0.018	0.036	0.021	-0.025	-0.001	0.113	-0.099	-0.023	-0.105	-0.001	-1.416	0.281	-0.049	-0.015	0.183	1.616	-0.590	-0.078	0.035	-0.193	0.024	-0.646	-0.030	1.260	0.411
X32	0.002	0.060	-0.049	0.046	-0.188	0.009	0.016	0.415	-0.003	-0.050	0.023	-0.068	-0.049	0.104	-0.038	0.000	0.112	-0.131	0.002	-0.120	-0.084	0.234	0.015	-0.422	2.184	-0.452	-0.273	-1.267	0.042	0.041	0.029	-0.159	-0.773	-0.034	1.465	0.639
X33	0.002	0.054	-0.147	0.161	-0.179	0.012	0.010	0.525	0.008	0.112	-0.178	-0.067	0.011	0.121	-0.055	-0.001	0.231	-0.245	-0.026	-0.219	-0.132	-0.940	0.082	-0.620	2.487	-0.032	0.938	-1.943	-0.003	0.084	-0.102	-0.101	-1.222	-0.063	2.377	0.940
X34	0.002	0.033	-0.128	0.148	-0.121	0.008	0.007	0.447	0.006	0.077	-0.226	-0.060	0.055	0.086	-0.045	0.000	0.258	-0.289	-0.025	-0.244	-0.168	-1.060	0.967	-0.283	1.481	-0.319	1.690	-2.521	-0.003	0.089	-0.076	-0.069	-0.997	-0.078	2.211	0.853
X35	0.002	0.051	-0.147	0.163	-0.173	0.011	0.011	0.532	0.007	0.098	-0.191	-0.069	0.023	0.113	-0.054	-0.001	0.254	-0.273	-0.028	-0.240	-0.149	-1.032	0.353	-0.540	2.324	-0.167	1.218	-2.188	-0.004	0.090	-0.100	-0.096	-1.196	-0.071	2.428	0.964

X1: Plant height (cm); X2: Plant spread (cm); X3: Number of leaves (Count); X4: Leaf area (cm^2); X5: No. of runners (count); X6: Days to runner formation after planting (Days); X7: Petiole Length (cm); X8: Mortality rate (%); X9: Flower size (cm); X10: Petal Length (cm); X11: Petal breadth (cm); X12: Number of anthers; X13: Days to flowering (Days); X14: Duration of flowering (days); X15: Number of flowers; X16: Number of petals; X17: Fruit length (cm); X18: Fruit Breadth (cm); X19: Number of Calyx; X20: Number of achenes; X21: Duration of fruit maturity (Days); X22: TSS (^{O}B); X23: Titratable acidity (%); X24: Total Sugar (%); X25: Reducing Sugar (%); X26: Non Reducing Sugar (%); X27: TSS/Acid ratio; X28: Total sugar/Acid ratio; X29: pH of fruit juice; X30: Specific gravity; X31: Vitamin C content (mg/100g); X32: Anthocyanin (mg/100g); X33: Number of fruits; X34: Average berry weight (gm); X35: Yield per plant (gm);

4.2. EXPERIMENT-II: STANDARDIZATION OF NUTRIENT MANAGEMENT SCHEDULE OF STRAWBERRY UNDER PUNJAB CONDITIONS

The three best genotypes/cultivars selected from the first experiment combined with thirteen nutrient management schedules tested with respect to vegetative, floral and fruit characters during 2018-19 and the results with discussion have been shown below after statistical analysis.

4.2.1 VEGETATIVE CHARACTERS

4.2.1.1. Mortality rate (%)

It was noticed from the observations that the mortality rate of the strawberry plant was significantly influenced by nutrient treatments and different genotypes; however, the interaction effect was not significant (Table-4.17). The lowest mortality rate (6.37 %) was observed in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in genotype 'Camarosa' (V_3) which was followed by T_{12} (75% NPK + FYM + vermicompost + *Azotobacter*) and T_8 (100% NPK + FYM + *Azotobacter*) while maximum mortality rate (38.13 %) was found in T_1 (Control). The minimum mortality rate in genotype 'Winter Dawn' (9.53 %) was also obtained in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) which was at par with T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) and T_8 (100%NPK + FYM + *Azotobacter*) whereas highest mortality rate (41.3%) was in T_1 (Control). The mortality rate in genotype Chandler was recorded lowest in T_{11} followed by T_{12}. The interaction between the genotype and treatment of nutrient was not significant with each other and the least mortality was noticed in V_3T_{11} followed V_3T_8 and V_3T_{12}. These results may be due to increased availability of organic carbon, NPK status and microbial biomass to plant through inorganic fertilizer and bio-fertilizer along with organic matter. The application of biofertilizers might be responsible for the synthesis of biostimulants and plant growth factors which have increased survival of the strawberry plants under integrated treatments (Iqbal *et al.,* 2009; Kirad *et al.,* 2010).

Table-4.17. Influence of genotypes and different nutrient combination on mortality rate (%) of strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	49.27	41.30	38.13	**42.90^{a}**
T_2	27.03	25.47	20.70	**24.40^{c}**
T_3	30.20	25.47	23.87	**26.51^{c}**
T_4	34.97	31.77	27.03	**31.26^{b}**
T_5	20.70	15.90	12.70	**16.43^{de}**
T_6	25.47	23.87	22.30	**23.88^{c}**
T_7	31.80	27.03	25.47	**28.10^{bc}**
T_8	15.90	12.70	7.93	**12.18^{ef}**
T_9	17.50	14.33	11.10	**14.31^{e}**
T_{10}	19.10	20.70	14.30	**18.03^{d}**
T_{11}	9.53	9.53	6.37	**8.48^{f}**
T_{12}	12.70	11.10	7.93	**10.58^{f}**
T_{13}	17.50	17.50	12.70	**15.90^{de}**
Mean (V)	**23.97^{a}**	**21.28^{b}**	**17.73^{c}**	
CD ($p<0.05$)				
V	**1.79**			
T	**3.726**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.1.2 Plant height (cm)

The data related to the height of plant was analyzed and shown in the Table-4.18. The height of plant was observed maximum in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in genotype 'Camarosa' while least was notified in T_3 (75% NPK) and improved in T_1 and T_4 (50%NPK) in 'Camarosa'. The treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) showed the maximum height of plant in 'Winter Dawn' while the minimum was in T_4 (50 % NPK) and T_1 (Control). In genotype, 'Chandler' was shown with maximum plant height with application of T_{11}. The interaction between genotype and nutrient treatments was not statistically different from each other and the highest plant height was registered in the treatment V_3T_{11} followed by V_2T_{11} and V_3T_8 (100%NPK + FYM + *Azotobacter*) while the

lowest was found in V_1T_1 followed by V_1T_4 (Control) and V_2T_4 (50 % NPK). The combined application of inorganic and organic sources of nutrients had resulted in sustainability in the growth of strawberry plants from beginning to end while the application of biofertilizers might be responsible for release of plant growth promoting factors and bioprotectants which had minimized the impact of biotic and abiotic stresses resulting better growth of plants as confirmed by Singh *et al.* (2012) and Mishra and Tripathi. (2012) in 'Chandler' cultivar, Wani *et al.* (2015) in 'Sweet Charlie' cultivars of strawberry.

Table-4.18. Influence of genotypes and different nutrient combination on plant height (cm) of strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	6.833	7.2	7.7	**7.244^{i}**
T_2	8.7	10	9.733	**9.478^{e}**
T_3	7.633	7.567	7.667	**7.622^{h}**
T_4	7	7.067	7.733	**7.267^{i}**
T_5	8.967	9.633	10.267	**9.622^{e}**
T_6	8.667	8.933	9.533	**9.044^{f}**
T_7	8.167	8.567	8.867	**8.533^{g}**
T_8	11.467	11.833	12.367	**11.889^{bc}**
T_9	11.367	11.533	12	**11.633^{c}**
T_{10}	11.067	11.133	11.567	**11.256^{d}**
T_{11}	12.267	12.567	12.967	**12.6^{a}**
T_{12}	11.567	12.3	12.2	**12.022^{b}**
T_{13}	11.233	11.2	11.6	**11.344^{cd}**
Mean (V)	**9.61^{c}**	**9.964^{b}**	**10.323^{a}**	
CD ($p<0.05$)				
V	**0.14**			
T	**0.291**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

These current observations are also in similarity with the outcomes of work done by Singh *et al.* (2015) who observed that biofertilizer and vermicompost increased the height of plant because vermicompost helped to improve the soil properties like cation exchange capacity and soil microbial activity. Similarly, maximum plant height in papaya have been concluded by Yadav *et al.* (2011) who used that 100%NPK + biofertilizer along with vermicompost. The present results were closely related with working of Rana and Chandel (2003) who observed that maximum plant height in application of inorganic N and *Azotobacter* in strawberry cv. Chandler.

4.2.1.3 Plant spread (cm)

The data related to effect of nutrient treatments on the plant spread of genotypes under Punjab conditions was observed and shown in Table-4.19. The maximum plant spread (18.83 cm) in 'Camarosa' was found in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) while lowest (9.6 cm) was noticed in T_4 (50 % NPK) which was at par to T_1 (Control). The highest (16.97 cm) plant spread in 'WinterDawn' was obtained in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) while least was in T_1 (Control) followed by T_4 (50 % NPK) and T_7 (50% NPK+ FYM). The maximum (16.2 cm) spread of plant in 'Chandler' was obtained in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*). The interaction between genotype and nutrient treatment was not found significant and the largest value of plant spread was recorded in V_3T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) followed by V_2T_{11} and V_1T_{11} whereas treatment V_1T_1 (Control) was recorded the lowest spread of plant followed by V_1T_4, V_2T_1 and V_2T_4. These present results are also in agreement with the outcomes of work done by Lata *et al.* (2013) who recorded greater vegetative growth in the treatment *Azotobacter +Azospirillum* + NPK+FYM. The similar findings have been noticed by Nowsheen *et al.* (2006) and Tripathi *et al.* (2010) in strawberry. Iqbal *et al.* (2009) concluded in strawberry that the treatment of 25 percent nitrogen through FYM combination with *Azotobacter* showed the maximum plant spread (28.16 cm) in strawberry cv. Chandler. The combined application of inorganic and organic sources of nutrients had resulted in sustainability in the growth of strawberry plants from beginning to end while the

application of biofertilizers might be responsible for the release of plant growth promoting factors and bioprotectants which had minimized the impact of biotic and abiotic stresses resulting better growth of plants as confirmed by Singh *et al.* (2012) and Mishra and Tripathi (2012) in 'Chandler' cultivar, Wani *et al.* (2015) in 'Sweet Charlie' cultivars of strawberry.

Table-4.19. Influence of genotypes and different nutrient combination on plant spread (cm) of strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	8.97	9.33	9.97	**9.42^{g}**
T_2	12.70	12.77	13.97	**13.14^{e}**
T_3	10.03	10.07	12.30	**10.80^{f}**
T_4	9.13	9.37	9.60	**9.37^{g}**
T_5	13.20	14.23	14.97	**14.13^{de}**
T_6	12.47	13.13	14.60	**13.40^{e}**
T_7	9.80	9.80	11.73	**10.44^{f}**
T_8	14.33	14.90	16.43	**15.22^{c}**
T_9	13.07	14.90	15.67	**14.54^{d}**
T_{10}	12.50	13.67	14.60	**13.59^{e}**
T_{11}	16.20	16.97	18.83	**17.33^{a}**
T_{12}	14.67	15.93	17.40	**16.00^{b}**
T_{13}	13.73	14.00	15.27	**14.33^{d}**
Mean (V)	12.37^{c}	13.01^{b}	14.26^{a}	
CD ($p<0.05$)				
V	**0.263**			
T	**0.548**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.1.4 Number of leaves (count)

The count of leaves in different genotypes and different nutrient treatments of strawberry was significantly influenced and presented in Table-4.20. The highest (19.87) number of leaves was counted in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) whereas lowest was registered in T_1 (Control) in 'Camarosa'. The treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) also produced the maximum leaves in genotypes 'Winter Dawn' and 'Chandler' while T_4 and T_1 had produced the lowest leaves count. There was no significant difference between different genotypes and nutrient treatments. The largest value of leaves count was obtained in the treatment V_3T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*), V_2T_{11} and V_1T_{11} while the least value was recorded in V_1T_1 (Control), V_1T_4 (50%NPK) and V_3T_1. The present outcomes are in same trend with the findings of Kushwah *et al.* (2018) who had reported maximum (17.93) leave count per plant in strawberry *cv*. 'Chandler' when RDF and vermicompost were applied in 3:1 ratio in combination with *Azotobacter* and PSB (5kg/ha each).

The results are also in agreement with Beer *et al.* (2017) in strawberry and Marathe & Bharambe (2005) in sweet orange. According to Arancon *et al.* (2003), these results may be due to integration of vermicompost, *Azotobacter* and inorganic fertilizer which improved aeration in soil, regulated temperature, micro and macronutrient status of soil and gave a suitable environment to plant for the uptake of nutrient and translocation of these nutrients by plants.

4.2.1.5 Leaf area (cm^2)

Significant difference in leaf area of strawberry was observed in different genotypes after nutrient treatments and presented in Table-4.21.

The highest leaf area in 'Chandler' (98.4 cm^2) and 'Camarosa' (109.93 cm^2) was measured in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) whereas the lowest was registered in T_1 (Control). The treatment T_{11} in 'Winter Dawn' showed the (94.1 cm^2) maximum leaf area whereas the minimum was in control. The significant variation was recorded due to the genotype and nutrient treatment interaction where the maximum leaf area was recorded in V_3T_{11} as compared to other all treatments. The least leaf area was registered in the treatment V_1T_1 (42.23 cm^2) which was at par with V_2T_1 (44.05 cm^2), V_2T_4 (44.08 cm^2) and V_1T_4 (44.08 cm^2). The

ability of biofertilizers to release biostimulant when supplied with sufficient organic matter might be responsible for better growth of leaves resulting in greater leaf area under the treatments consisting of inorganic and organic sources supplemented with microbial inoculation (Beer *et al.*, 2017). The present findings are in line with the outcomes of work done by Kamatyanatti *et al.* (2019) in plum, Gupta *et al.* (2013) in strawberry, and Singh *et al.* (2015) in strawberry.

Table-4.20. Influence of genotypes and different nutrient combination on number of leave of strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	8.067	8.867	8.7	**8.544^{k}**
T_2	14.933	15.267	15.733	**15.311^{e}**
T_3	12.2	13	14	**13.067^{g}**
T_4	8.4	8.933	9.6	**8.978^{k}**
T_5	15.4	15.933	16.1	**15.811^{d}**
T_6	13	13.8	14.767	**13.856^{f}**
T_7	9.067	9.4	10.3	**9.589^{j}**
T_8	16.867	17.6	18.3	**17.589^{b}**
T_9	15.867	16.067	16.133	**16.022^{d}**
T_{10}	11.267	11.4	12.133	**11.6^{i}**
T_{11}	18.333	18.467	19.867	**18.889^{a}**
T_{12}	15.967	16.933	16.733	**16.544^{c}**
T_{13}	11.267	12.2	13.1	**12.189^{h}**
Mean (V)	13.126^{c}	13.682^{b}	14.267^{a}	
CD ($p<0.05$)				
V	**0.201**			
T	**0.419**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

Table-4.21. Influence of genotypes and different nutrient combination on leaf area (cm^2) per plant strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	42.23	44.05	47.55	**44.61^{l}**
T_2	81.65	76.84	86.00	**81.50^{e}**
T_3	65.12	65.01	76.53	**68.89^{g}**
T_4	45.08	44.08	52.16	**47.11^{k}**
T_5	81.83	80.21	89.08	**83.71^{de}**
T_6	68.90	68.54	81.22	**72.89^{f}**
T_7	48.65	46.39	56.31	**50.45^{j}**
T_8	90.51	89.17	101.88	**93.86^{b}**
T_9	85.16	79.79	89.79	**84.91^{d}**
T_{10}	58.93	55.86	67.13	**60.64^{i}**
T_{11}	98.40	94.15	109.93	**100.83^{a}**
T_{12}	86.38	86.36	93.14	**88.63^{c}**
T_{13}	60.47	62.22	72.49	**65.06^{h}**
Mean (V)	**70.25^{b}**	**68.67^{c}**	**78.71^{a}**	
CD ($p<0.05$)				
V	**1.146**			
T	**2.386**			
V * T	**4.133**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.1.6 Number of Runners per plant (count)

The genotypes and nutrient treatments in strawberry had shown significant variation in number of runners which varied from 7 in 'Winter Dawn' to 16.33 in 'Camarosa' (Table-4.22). The treatment T_{11} in genotype 'Camarosa' had produced (16.33) highest number of runners which was at par with T_8 (75% NPK +FYM + *Azotobacter*) (16) while the lowest was obtained in T_1 (Control) (8.33) followed by T_4 (50%NPK) (8.67), T_3 (75%NPK) and T_7 (50%NPK +FYM). The largest value (16) of number of runners was counted in treatment T_{11} in 'Chandler' and the smallest value was in T_1 (Control) (7.67). In 'Winter Dawn', the treatment T_{11} performed better in terms of number of runners in comparison to other nutrient treatments. The interaction

between genotypes and nutrient treatments was not significant and the maximum number of runners counted in V_3T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) which was closely related to V_1T_{11} and V_3T_8 while treatment V_2T_1 (Control) showed the lesser number of runners followed by V_1T_1. The present findings may be due to increased plant height and leave number per plant resulting in the accumulation of a high degree of photosynthates which could have promoted the growth of runners in these treatments. The present result is in conformity with the finding of Singh *et al.* (2012) and Beer *et al.* (2017).

Table-4.22. Influence of genotypes and different nutrient combination on number of runners of strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	7.67	7.00	8.33	**7.67^{h}**
T_2	10.00	9.33	10.33	**9.89^{f}**
T_3	9.67	8.33	8.67	**8.89^{g}**
T_4	8.33	8.67	8.67	**8.56^{g}**
T_5	10.33	9.67	11.33	**10.44^{f}**
T_6	10.00	9.33	10.00	**9.78f^{g}**
T_7	9.33	9.00	9.00	**9.11^{g}**
T_8	14.33	13.67	16.00	**14.67^{b}**
T_9	12.33	11.33	14.33	**12.67^{d}**
T_{10}	11.00	10.33	12.67	**11.33^{e}**
T_{11}	16.00	14.33	16.33	**15.56^{a}**
T_{12}	13.67	13.00	14.67	**13.78^{c}**
T_{13}	11.67	11.33	13.33	**12.11^{d}**
Mean (V)	**11.10^{b}**	**10.41^{c}**	**11.82^{a}**	
CD ($p<0.05$)				
V	**0.362**			
T	**0.754**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.1.7 Days to runner formation (days)

The results of days taken to runner formation under Punjab conditions ranged from 147.3 days to 170 days and were presented in Table-4.23. The runner formation was earlier in treatment T_{11} (147.3 days) in 'Chandler' but delayed production of the runner was reported in T_4 (50% NPK). The genotype 'Camarosa', in the treatment T_{11} took minimum days for runner formation while the maximum was in treatment T_1 and T_7. The same result was found in 'Winter Dawn' that treatment T_{11} (156.67 days) which showed minimum days taken to runner formation followed by T_{12} (158.33 days).

Table-4.23. Influence of genotypes and different nutrient combination on days to runner formation (days) of strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	163.67	170.00	166.00	**166.56^{a}**
T_2	151.67	162.00	156.67	**156.78^{cd}**
T_3	159.33	165.00	163.67	**162.67^{b}**
T_4	164.67	169.00	165.67	**166.44^{a}**
T_5	153.33	162.33	159.67	**158.44^{c}**
T_6	161.33	164.67	162.00	**162.67^{b}**
T_7	163.00	167.33	166.00	**165.44^{a}**
T_8	150.67	159.00	154.00	**154.56^{d}**
T_9	158.67	164.00	159.33	**160.67^{bc}**
T_{10}	160.33	168.00	159.67	**162.67^{b}**
T_{11}	147.33	156.67	150.67	**151.56^{e}**
T_{12}	152.33	158.33	154.00	**154.89^{d}**
T_{13}	155.67	163.33	156.33	**158.44^{c}**
Mean (V)	**157.077^{c}**	**163.821^{a}**	**159.513^{b}**	
CD ($p<0.05$)				
V	**1.29**			
T	**2.685**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

Although interaction effect was not significant, the treatment V_1T_{11} had taken (147.33 days) minimum days to runner formation followed by V_3T_{11} (150.66 days)

and V_1T_{12} (152.33 days) while the maximum days taken to runner formation was recorded in treatment V_2T_1 followed by V_2T_4. These results might be possible due to synthesis of plant growth regulators like auxins, gibberellins, cytokinin, biostimulants etc., by *Azotobacter* which helped in early production of runners (Martinez *et al.*, 1996). Further, integration of inorganic and organic sources had also ensured sustainable growth of runners throughout (Singh *et al.*, 2012; Beer *et al.*, 2017).

4.2.2. FLOWER CHARACTERS

4.2.2.3. Flower Size (cm)

It was noticed from this study that there was negligible variation in the different treatments for flower size (Table-4.24).

Table-4.24. Influence of genotypes and different nutrient combination on flower size (cm) of strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	1.74	1.70	1.78	**1.74^{b}**
T_2	1.78	1.71	1.96	**1.81^{ab}**
T_3	1.72	1.69	1.88	**1.76^{b}**
T_4	1.74	1.68	1.92	**1.78^{ab}**
T_5	1.76	1.71	1.92	**1.79^{ab}**
T_6	1.74	1.68	1.88	**1.77^{b}**
T_7	1.72	1.69	1.86	**1.76^{b}**
T_8	1.79	1.69	1.96	**1.81^{ab}**
T_9	1.82	1.72	1.83	**1.79^{ab}**
T_{10}	1.82	1.66	1.84	**1.77^{b}**
T_{11}	1.82	1.73	1.97	**1.84^{a}**
T_{12}	1.84	1.72	1.96	**1.84^{a}**
T_{13}	1.78	1.68	1.88	**1.78^{ab}**
Mean (V)	**1.77^{b}**	**1.70^{c}**	**1.90^{a}**	
CD ($p<0.05$)				
V	**0.03**			
T	**0.062**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

The maximum flower size (1.97 cm) was recorded in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in genotype 'Camarosa' which was followed by T_8 (1.96 cm), T_{12} (1.96 cm), T_2, T_4 and T_5 while the lowest (1.74 cm) was found in the T_1, T_9 and T_{10}. The highest size of flower was measured in treatment T_{11} (1.73 cm) followed by all other treatments except T_1 which showed minimum flower size in 'Winter Dawn'.

The treatment T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) in 'Chandler' showed the maximum size of flower followed by T_{11} (1.84 cm), T_9, T_{10}, T_8 and T_{13} whereas the minimum was recorded in treatment T_7 (1.72 cm) closely related with treatment T_3, T_4, T_6, T_1, T_5 and T_2. The interaction between genotype and nutrient treatment was not significant with each other and the largest flower size was measured in V_3T_{11} which was followed by V_3T_{12} while the smallest was recorded in V_2T_{10} (1.66 cm).

4.2.2.5. Days to flowering (days)

The results of days taken to flowering in a strawberry after various treatments are given in Table-4.25 which ranged from 66 days to 78 days.

The earliest flowering (66.33 days) was produced in treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in 'Camarosa' strawberry after planting which was at par to T_8 (100%NPK + FYM + *Azotobacter*) and T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) while treatment T_4 (50%NPK) had taken highest days (74 days) to produce flowering after planting followed by T_1 (73.67 days). The maximum number of days taken for flowering in 'WinterDawn' was notified in treatment T_1 (Control) (78 days) which was at par to T_4 (50%NPK) (77.33 days) while earliest (71.33 days) was recorded in T_{11}. The treatment T_2 (100%NPK) in 'Chandler' produced the earliest flowering followed by treatment T_{11}. The genotype and nutrient treatments interactions were not significant and the treatment V_3T_{11} showed the earliest flowering after planting followed by V_3T_8 and V_3T_{12} while late was found in V_2T_1. The early flowering in these treatments may be due to balanced nutrient supply through the application of organic and inorganic sources and plant growth hormones in balance amount during crop seasons which helped in overall development of plants and more photosynthesis. The present results are in accordance with the findings of Tripathi *et al.* (2015) in strawberry and Umar *et al.* (2010).

Kushwah *et al.* (2018) noticed that the treatment 75% RDF + 25% Vermicompost + *Azotobacter* @ 5kg/ha + PSB@ 5kg/ha showed the lowest (58.43) days taken to flowering.

Table-4.25. Influence of genotypes and different nutrient combination on days to flowering (days) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	76.00	78.00	73.67	**75.89^{a}**
T_2	68.67	75.33	68.67	**70.89^{d}**
T_3	74.33	75.67	71.00	**73.67^{bc}**
T_4	75.00	77.33	74.00	**75.44^{ab}**
T_5	70.67	74.33	68.00	**71.00^{d}**
T_6	72.67	75.33	70.00	**72.67^{c}**
T_7	73.67	76.33	72.67	**74.22^{b}**
T_8	70.00	73.00	66.67	**69.89^{de}**
T_9	71.67	73.00	68.00	**70.89^{d}**
T_{10}	72.00	73.67	70.67	**72.11^{cd}**
T_{11}	69.67	71.33	66.33	**69.11^{e}**
T_{12}	70.67	73.33	67.33	**70.44^{d}**
T_{13}	72.00	73.67	70.00	**71.89^{cd}**
Mean (V)	**72.077^{b}**	**74.641^{a}**	**69.769^{c}**	
CD ($p<0.05$)				
	V	**0.612**		
	T	1.274		
	V * T	**N/A**		

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.2.6. Duration of flowering (days)

The observation on flowering duration was significantly influenced by treatments and ranged from 39 days to 79 days (Table-4.26). The largest period of flowering (79.33 days) was registered in treatment T_{11} in 'Camarosa' while smallest period (47.67 days) was in treatment T_1 (Control). Similar, results were obtained in 'WinterDawn' and 'Chandler' that treatment T_{11} produced flowering for longest period but treatment T_1 produced flowering for smallest period. The genotype and

nutrient treatment interactions showed significant variation and the largest period of flowering was observed in V_3T_{11} which was statistically at par with V_2T_{11} in comparison to other treatments whereas the smallest period of flowering was recorded in V_1T_1. The present results are in accordance with working of Tripathi *et al.* (2010), Singh and Singh (2009) in strawberry. Singh (2016) observed that treatment 100 %NPK and 75%NPK +vermicompost + *Azotobacter* + PSB showed longest duration of flowering which might be associated with ability of vermicompost to release plant growth factors which helped to increase plant growth and extended duration of flowering.

Table-4.26. Influence of genotypes and different nutrient combination on duration of flowering (days) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	39.00	41.67	47.67	42.78^{j}
T_2	67.33	64.33	67.67	66.44^{e}
T_3	64.33	60.00	62.67	62.33^{g}
T_4	53.33	43.33	50.33	49.00^{i}
T_5	69.33	66.33	69.33	68.33^{d}
T_6	65.33	63.33	64.67	64.44^{f}
T_7	55.67	48.00	57.33	53.67^{h}
T_8	75.67	72.00	76.00	74.56^{b}
T_9	71.67	65.33	69.33	68.78^{d}
T_{10}	68.00	58.67	67.67	64.78^{f}
T_{11}	77.33	74.33	79.33	77.00^{a}
T_{12}	73.33	71.33	72.67	72.44c
T_{13}	68.67	65.33	71.00	68.33^{d}
Mean (V)	**65.31^{a}**	**61.08^{b}**	**65.82^{a}**	
CD ($p<0.05$)				
V	**0.779**			
T	**1.621**			
V * T	**2.808**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.2.7. Number of flowers per plant (count)

The significant variation was recorded due to impact of genotype and nutrient treatments for flower counts per plant which varied from 13 to 25.47 (Table-4.27).

Table-4.27. Influence of genotypes and different nutrient combination on number of flowers per plant in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	13.00	13.67	15.40	**14.02^{j}**
T_2	19.93	20.47	21.53	**20.64^{e}**
T_3	18.53	19.93	20.67	**19.71^{fg}**
T_4	16.53	16.87	17.33	**16.91^{i}**
T_5	22.00	22.20	22.93	**22.38^{c}**
T_6	21.33	21.80	22.20	**21.78^{d}**
T_7	17.33	17.93	17.80	**17.69^{h}**
T_8	23.07	23.80	24.53	**23.80^{b}**
T_9	22.07	22.53	23.20	**22.60^{c}**
T_{10}	19.13	18.73	19.80	**19.22^{g}**
T_{11}	23.80	24.20	25.47	**24.49^{a}**
T_{12}	23.27	23.13	24.20	**23.53^{b}**
T_{13}	19.73	20.60	19.33	**19.89^{f}**
Mean(V)	**19.98^{c}**	**20.45^{b}**	**21.11^{a}**	
CD ($p<0.05$)				
V	**0.283**			
T	**0.589**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

The greatest count of flowers per plant (23.8) was noticed in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in genotype 'Chandler' but the lowest (13) was counted in treatment T_1 (Control). The maximum number of flowers in 'Winter Dawn' (24.2) and 'Camarosa' (25.47) were reported in T_{11} and the lowest number of fruits was counted in treatment T_1 (Control). The genotype and nutrient treatment interaction showed no significant effect on flowers count. The maximum flowers were

counted in V_3T_{11} which was closely related to V_3T_8 and V_2T_{11} while lowest was in treatment V_1T_1 and V_2T_1. Similar outcomes were advocated by Yadav *et al.* (2010) who recorded that application of half N through vermicompost and remaining half nitrogen through inorganic source resulted in maximum (29.60) flowers number. Beer *et al*. (2017) also reported that the treatment consisting of vermicompost (25 ton/ha) + *Azotobacter* (6 kg/Ha) + NPK (70:80:80) produced highest flower numbers per plant which might be associated with the availability of plant growth factors including nutrients and hormones which was ideally supplied throughout the crop period. These results might be the result of the optimum amount of nutrients as NPK and plant hormones provided by vermicompost which promoted bud breaking after removing dormancy and increased buds for flowering during flowering as suggested by Taglivani *et al.* (2005)

4.2.3. FRUIT CHARACTERS

4.2.3.1. Fruit length (cm)

The observations related to fruit length in different treatments of strawberry under Punjab conditions were varied from 2.47 cm to 3.87 cm and presented in Table-4.28. The largest length of fruit (3.79 cm) was reported in treatment T_{11} in 'Chandler' while lowest (2.47 cm) length was found in treatment T_4 and T_1. Similar results were found in the 'WinterDawn' genotype. The treatment T_{11} (3.87 cm) in genotype 'Camarosa' showed maximum length of fruit which was at par with T_8 whereas treatment T_1 (2.7) and T_4 (2.6) was having lowest fruit length. The interaction between genotype and nutrient treatment had not significantly influenced the fruit length. The maximum fruit length was measured in treatment V_3T_{11} which was closely followed by V_1T_{11} (3.79 cm) and V_3T_8 (3.77 cm) while minimum was in V_1T_1 (2.47 cm) and V_1T_4 (2.48 cm).

The present results are closely similar with outcomes of work done by Singh *et al.* (2016) who recorded that the treatment of 75% NPK+ vermicompost+*Azotobacter* +PSB showed highest length of fruit (33.50mm). The present results are in conformity with the outcomes of work done by Shukla *et al.* (2009) in tomato, Rana and Chandel (2003) in strawberry and Bairwa *et al.* (2009) in okra.

Table-4.28. Influence of genotypes and different nutrient combination on fruit length (cm) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	2.467	2.54	2.7	**2.533^{f}**
T_2	3.233	3.033	3.333	**3.2^{d}**
T_3	3.133	3.167	3.367	**3.222^{d}**
T_4	2.48	2.533	2.6	**2.533^{f}**
T_5	3.267	3.267	3.533	**3.356^{c}**
T_6	3.067	3.167	3.467	**3.233^{cd}**
T_7	2.867	3	3.167	**3.011^{e}**
T_8	3.567	3.467	3.767	**3.6^{b}**
T_9	3.533	3.433	3.633	**3.533^{b}**
T_{10}	3.2	3.267	3.467	**3.311^{cd}**
T_{11}	3.793	3.633	3.867	**3.764^{a}**
T_{12}	3.5	3.567	3.6	**3.556^{b}**
T_{13}	3.267	3.333	3.433	**3.344^{cd}**
Mean (V)	**3.182^{b}**	**3.185^{b}**	**3.372^{a}**	
CD ($p<0.05$)				
V	**0.062**			
T	**0.129**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.3.2. Fruit breadth (cm)

The results of breadth of fruit in different treatment were significantly varied from 1.77 to 3.33 cm (Table-4.29).

The maximum (3.33 cm) width of fruit in genotype 'Camarosa' was registered in treatment T_{11} (3.28 cm) with respect to rest of the treatments whereas minimum fruit breadth was noticed in treatment T_1 (Control). In 'Chandler', the treatment T_{11} showed (3.23 cm) maximum breadth of fruit which was at par with T_8 (100%NPK + FYM + *Azotobacter*) (3.1 cm). Similarly, the treatment T_{11} (2.93 cm) was reported with highest fruit breadth followed by T_8 (2.83 cm) and T_{12} (2.83 cm) while lowest fruit breadth was in treatment T_4 (1.77 cm) and T_1 (1.87 cm). The interaction between

the germaplasm and nutrient treatments was not significantly varied in results and treatment V_3T_{11} was closely followed by V_1T_{11}, V_1T_8 and V_3T_{12}. These results might be associated with greater photosynthetic activity of plant treated with vermicompost, biofertilizers and inorganic fertilizer which increased accumulation of dry matter. The correlation of dry matter with fruit size have been suggested by Kachot *et al.* (2001). The present results are closely similar with outcomes of work done by Singh *et al.* (2016) who recorded that the treatment of 75% NPK+ vermicompost+*Azotobacter* +PSB showed highest breadth of fruit (25.14mm). The present results are in conformity with the outcomes of work done by Shukla *et al.* (2009) in tomato, Rana and Chandel (2003) in strawberry and Bairwa *et al.* (2009) in okra.

Table-4.29. Influence of genotypes and different nutrient combination on fruit breadth (cm) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	2.03	1.87	2.10	**2.00^{f}**
T_2	2.73	2.40	2.80	**2.64^{cd}**
T_3	2.60	2.30	2.73	**2.54^{d}**
T_4	2.07	1.77	2.30	**2.04^{f}**
T_5	2.80	2.50	2.77	**2.69^{cd}**
T_6	2.53	2.33	2.77	**2.54^{d}**
T_7	2.23	2.17	2.27	**2.22^{e}**
T_8	3.10	2.83	3.03	**2.99^{b}**
T_9	2.97	2.73	3.07	**2.92^{b}**
T_{10}	2.67	2.53	2.63	**2.61^{cd}**
T_{11}	3.23	2.93	3.33	**3.17^{a}**
T_{12}	3.00	2.83	3.10	**2.98^{b}**
T_{13}	2.67	2.60	2.83	**2.70^{c}**
Mean (V)	**2.66^{b}**	**2.45^{c}**	**2.75^{a}**	
CD ($p<0.05$)				
V	**0.071**			
T	**0.147**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.3.3. Number of fruits per plant (count)

The significant difference in the results of fruit count per plant was obtained from various treatments under Punjab conditions and given in the Table-4.30. The highest (21.67) fruit count per plant was obtained in treatment T_{11} in genotypes 'Camarosa' (22.06), 'Winter Dawn' (20.73) and 'Chandler' (19.73) while lowest was in treatment T_1 (Control) and T_4 (50% NPK). The variation in fruit count was significantly influenced by interaction of genotype and nutrient treatments and the greatest number of fruits was produced in V_3T_{11} (22.07) in comparison to rest of the treatments while least was reported in V_1T_1. The treatments V_1T_{11}, V_3T_8, V_3T_{12} and V_2T_8 were statistical at par with each other.

Table-4.30. Influence of genotypes and different nutrient combination on fruit count per plant

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	6.67	7.33	8.07	**7.36^{i}**
T_2	15.20	15.53	16.60	**15.78^{d}**
T_3	12.53	12.93	15.27	**13.58^{f}**
T_4	7.60	7.47	8.20	**7.76^{h}**
T_5	15.40	15.53	16.40	**15.78^{d}**
T_6	13.53	14.27	14.73	**14.18^{e}**
T_7	11.87	12.40	12.87	**12.38^{g}**
T_8	17.73	19.20	19.80	**18.91^{b}**
T_9	16.60	17.80	18.40	**17.60^{c}**
T_{10}	13.53	14.13	14.53	**14.07^{e}**
T_{11}	19.73	20.73	22.07	**20.84^{a}**
T_{12}	18.40	18.87	19.87	**19.04^{b}**
T_{13}	13.07	15.47	14.67	**14.40^{e}**
Mean (V)	**13.99^{c}**	**14.74^{b}**	**15.50^{a}**	
CD ($p<0.05$)				
V	**0.167**			
T	**0.347**			
V * T	**0.6**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

The results are in the same trend with findings of Arancon *et al.* (2014) in strawberry who advocated treatment having vermicompost had produced more fruits per plant as vermicompost helped to increase nutrient availability in soil and nitrogen reduced the abortion of female flowers which enhanced the fruit numbers per plants. The present results are in agreement with outcomes of work done by Devi *et al.* (2012) in guava, Kushwah *et al.* (2018) and Jain *et al.* (2017) in strawberry.

4.2.3.4. Days to maturity (days)

The observations related to days taken for fruit maturity after flowering in different treatments showed significant variation (Table-4.31) and ranged from 18.2 days to 22.87 days.

Table-4.31. Influence of genotypes and different nutrient combination on number of days to fruit maturity in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	21.47	22.20	22.67	**22.11^{a}**
T_2	19.40	20.13	20.73	**20.09^{c}**
T_3	20.13	21.20	21.33	**20.89^{b}**
T_4	21.40	22.27	22.87	**22.18^{a}**
T_5	19.20	20.33	20.67	**20.07^{c}**
T_6	20.07	20.53	21.13	**20.58^{b}**
T_7	21.00	22.07	22.27	**21.78^{a}**
T_8	18.67	19.33	18.73	**18.91^{e}**
T_9	18.93	19.87	19.80	**19.53^{d}**
T_{10}	19.80	21.00	20.67	**20.49^{bc}**
T_{11}	18.20	19.00	18.20	**18.44^{f}**
T_{12}	18.53	19.73	19.80	**19.36^{d}**
T_{13}	19.73	20.80	20.47	**20.33^{c}**
Mean (V)	**19.73^{b}**	**20.65^{a}**	**20.71^{a}**	
CD ($p<0.05$)				
V	**0.192**			
T	**0.4**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

Maximum numbers of days taken for fruit maturity in 'WinterDawn' i.e. 22.27 were recorded in T_4 (50%NPK) which was at par with treatment T_1 (22.2 days) and T_7 (50%NPK + FYM) as compared to other treatments; however, T_{11} took lowest (19 days) days to maturity which was at par with treatment T_8 (19.33 days). The least number of days taken for fruit maturity after flowering in genotype 'Camarosa' was observed in treatment T_{11} (18.2 days) while maximum days taken for maturity was found in treatment T_4 (22.87 days) and T_1 (22.67 days). In genotype 'Chandler', the treatment T_1 (21.47 days) took maximum days for fruit maturity followed by T_4 (21.4 days). The interaction between genotype and nutrient treatment was not significant with each other and maximum days taken to maturity were found in treatment V_3T_4 followed by V_3T_1, V_2T_4 and V_2T_1 while the minimum was found in V_1T_{11}, V_3T_{11} and V_2T_{11}. The results have a trend similar with the outcomes of work done by Yadav *et al.* (2010) in peach, Ali *et al.* (2003) and Verma and Rao (2014) strawberry.

4.2.3.5. Average berry weight (g)

The treatment of nutrient and genotype of strawberry had significantly influenced the average berry weight (gram) which ranged from 6.85g to 12.93g (Table-4.32). The maximum average berry weight in genotype 'Camarosa' was recorded in treatment T_{11} (12.97 g) while the least berry weight (7.53 g) was found in treatment T_1, followed by T_4 (7.66 g). The highest average berry weight in 'Chandler' (11.82 g) and 'Winter Dawn' (11.7g) was also recorded in treatment T_{11} while the lowest berry weight in 'Chandler' (7.18 g) and 'Winter Dawn' (6.85 g) was found in T_1 which was at par with T_4.

The genotype 'Camarosa' showed better results in terms of average berry weight as compared to other genotypes. A significant variation was reported in the interaction effect of genotype and nutrient treatments and maximum berry weight was found in V_3T_{11} (12.97 g) followed by V_3T_8 (12.44 g) while least weight of berry was in V_2T_1 (6.85 g) which was at par with V_2T_4 (6.93 g), V_1T_1 (7.18 g), V_1T_4 (7.19 g) and V_2T_7 (7.23g). The results are closely related to outcomes of work done by Verma and Rao (2014), who notified maximum berry weight in treatment *Azotobacter*+ PSB + vermicompost + 50 % RDF. Similarly, outcomes were acknowledged by Wani *et al.* (2015), Ahmadi *et al*. (2017) and Kushwah *et al.* (2018) in strawberry.

Table-4.32. Influence of genotypes and different nutrient combination on average berry weight (g) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	7.18	6.85	7.53	**7.19^{h}**
T_2	9.67	9.79	10.50	**9.98^{de}**
T_3	8.80	8.38	10.13	**9.10^{f}**
T_4	7.19	6.96	7.67	**7.27^{gh}**
T_5	9.70	10.16	10.67	**10.18^{d}**
T_6	8.92	8.95	10.23	**9.37^{e}**
T_7	7.50	7.23	7.97	**7.56^{g}**
T_8	11.57	10.85	12.44	**11.62^{b}**
T_9	10.06	9.60	11.05	**10.24^{d}**
T_{10}	9.03	7.57	10.42	**9.01^{f}**
T_{11}	11.82	11.07	12.93	**11.94^{a}**
T_{12}	10.62	9.97	12.32	**10.97^{c}**
T_{13}	9.63	8.92	10.74	**9.76^{e}**
Mean (V)	**9.36^{b}**	**8.95^{c}**	**10.35^{a}**	
CD ($p<0.05$)				
V	**0.146**			
T	**0.304**			
V * T	**0.526**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.3.6. Yield per plant (g)

The data pertaining to yield per plant showed significant variations due to different genotypes and different nutrient treatments (Table-4.33).

The treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) showed the highest value with respect to yield per plant in genotype 'Camarosa' (285.25 g), 'Chandler' (233.15 g) and 'Winter Dawn' (229.58 g). The minimum yield per plant was recorded in treatment T_1 in 'Chandler' (47.90 g), 'Winter Dawn' (50.27 g) and 'Camarosa' (60.74g) which was statistically at par with treatment T_4 in genotype 'Winter Dawn' (52 g) and 'Camarosa' (62.84 g). The significant variation

was reported due to the interaction between genotype and nutrient treatment. The highest yield was recorded in treatment V_3T_{11} (285.25 g/plant). V_2T_8 and V_1T_8 were statistically at par with each other. The lowest yield was recorded in V_1T_1 which was followed by V_2T_1, V_2T_4 and V_1T_4. The present results are in line with the findings of Kushwah *et al.* (2018), who recorded that highest (276.36 g) yield per plant in the treatment consisting of 75% RDF + 25% Vermicompost + *Azotobacter* @ 5kg/ha + PSB@ 5kg/ha. The present results are confirmed with the work of Jain *et al.* (2017) in strawberry and Bairwa *et al.* (2009) in okra.

Table-4.33. Influence of genotypes and different nutrient combination on yield per plant (g) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	47.90	50.27	60.74	**52.97^{j}**
T_2	147.00	152.01	174.36	**157.79^{e}**
T_3	110.31	108.41	154.64	**124.45^{h}**
T_4	54.57	52.00	62.84	**56.47^{j}**
T_5	149.41	157.80	175.03	**160.74^{e}**
T_6	120.68	127.67	150.82	**133.06^{g}**
T_7	88.92	89.70	102.50	**93.71^{i}**
T_8	205.22	208.25	246.37	**219.95^{b}**
T_9	167.06	170.89	203.36	**180.44^{d}**
T_{10}	122.18	107.05	151.49	**126.91^{h}**
T_{11}	233.15	229.59	285.25	**249.33^{a}**
T_{12}	195.53	188.13	244.64	**209.43^{c}**
T_{13}	125.86	137.90	157.48	**140.42^{f}**
Mean (V)	**135.98^{b}**	**136.90^{b}**	**166.89^{a}**	
CD ($p<0.05$)				
V	**2.861**			
T	**5.956**			
V * T	**10.317**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.3.7. Yield per hectare (tonnes/ha)

The data pertaining to yield per hectare showed significant variations in different genotypes and different nutrient treatments and ranged from 2.69 tons/ha to 29.67 tons/ha (Table-4.34).

Table-4.34. Influence of genotypes and different nutrient combination on yield per hectare (tonnes) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	2.69	3.28	4.18	**3.38^{j}**
T_2	11.91	12.59	15.38	**13.29^{e}**
T_3	8.55	8.97	13.10	**10.21^{g}**
T_4	3.95	3.94	5.10	**4.33^{i}**
T_5	13.18	14.76	16.96	**14.97^{d}**
T_6	9.98	10.80	13.02	**11.27^{f}**
T_7	6.74	7.30	8.49	**7.51^{h}**
T_8	19.17	20.20	25.21	**21.53^{b}**
T_9	15.31	16.29	20.09	**17.23^{c}**
T_{10}	10.98	9.46	14.47	**11.64^{f}**
T_{11}	23.45	23.08	29.67	**25.40^{a}**
T_{12}	18.95	18.61	25.03	**20.86^{b}**
T_{13}	11.53	12.64	15.26	**13.14^{e}**
Mean (V)	**12.03^{b}**	**12.46^{b}**	**15.84^{a}**	
CD ($p<0.05$)				
V	**0.442**			
T	**0.921**			
V * T	**1.595**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

The maximum yield per hectare (29.67 tons/ha) in 'Camarorsa' was observed in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) while the lowest was recorded in T_1 (Control) (4.18 tons/ha). The highest yield per hectare in genotype 'Winter Dawn' (23.08 tons/ha) and 'Chandler' (23.45 tons/ha) was observed in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*). The

interaction between genotype and nutrient treatment was found to have a significant influence on yield. The treatment V_2T_8, V_3T_9, V_1T_8 and V_1T_{12} were at par with each other. The lowest yield was registered in treatment V_1T_1 (2.69 tons/ha) which was at par with V_2T_1 (3.28 tons/ha), V_2T_4 (3.94 tons/ha), V_1T_4 (3.95 tons/ha) and V_3T_4 (4.18tons/ha).

The results might be associated with the adequate supply of nutrient and plant growth promoters during cropping season which encouraged the vegetative growth of plants then more photosynthesis which produced the higher amount of carbohydrates in the system of plant and a greater number of flowering resulted maximum fruit yield per plants. These results with respect to yield per hectare may be associated with the application of vermicompost producing plant hormones, antibacterial, antifungal and enzymes which can improve the yield. The present outcomes are confirmed with the work of Ahmad and Mohammad (2012), Singh *et al.* (2008), Rana and Chandel (2003) in strawberry.

4.2.3.8. Total Soluble Solid (^oB)

The observation in Table-4.35 pertaining to total soluble solid (TSS) observed in different treatments was ranged from 7.93^{o}B to 10.43^{o}B.

Maximum TSS in genotype 'Camarosa' (10.43^{o}B) and 'Chandler' (10.17^{o}B) was obtained in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) while lowest in genotype 'Chandler' was in treatment T_4 (8.17^{o}B) followed by T_1 (8.27^{o}B) and T_7 (8.37^{o}B). The lowest TSS in 'Camarosa' was found in treatment T_1 and T_4. There was no significant effect of interaction between genotype and nutrient treatment and V_3T_{11} showed highest TSS content in fruits while minimum was found in V_1T_1. The treatment V_1T_{11}, V_3T_{12}, V_2T_{11}, V_2T_{12} and V_3T_8 were statistically significant with each other. The current findings are associated with the fast-metabolic conversion of polysaccharides into water soluble compound and translocation of sugar to developing fruits. The findings are closely related with the outcomes of work done by Umar *et al.* (2009), Verma *et al.* (2013) in Strawberry and Attia *et al.* (2009) in banana.

Table-4.35. Influence of genotypes and different nutrient combination on Total soluble solid (°B) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	7.93	8.27	8.27	**8.16^{g}**
T_2	9.07	8.93	9.20	**9.07^{d}**
T_3	8.80	8.53	8.93	**8.76^{ef}**
T_4	8.27	8.17	8.47	**8.30^{fg}**
T_5	9.50	9.27	9.70	**9.49^{c}**
T_6	9.47	9.00	8.97	**9.14^{d}**
T_7	8.63	8.37	8.53	**8.51^{f}**
T_8	9.90	9.67	9.97	**9.84^{b}**
T_9	9.67	9.23	9.57	**9.49^{c}**
T_{10}	8.73	8.63	9.00	**8.79^{e}**
T_{11}	10.17	10.00	10.43	**10.20^{a}**
T_{12}	9.80	10.00	10.07	**9.96^{ab}**
T_{13}	9.53	9.30	9.87	**9.57^{c}**
Mean (V)	**9.19^{a}**	**9.03^{b}**	**9.31^{a}**	
CD ($p<0.05$)				
V	**0.12**			
T	**0.249**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.3.9. Titratable acidity (%)

The significant variations in titratable acidity (%) were observed in different treatments under Punjab conditions as shown in Table-4.36 and varied from 0.80 to 0.91 %**.** The treatment T_1 (Control) in 'Chandler' showed the (0.91%) highest acidity in fruits followed by T_3 (75%NPK) whereas lesser amount of acidity (0.84%) was recorded in treatment T_{12} and T_{11} followed by T_8 (0.85%). The genotype 'Camarosa' with treatment T_1 (0.90%) showed maximum acidity in fruits while minimum (0.80%) was in treatment T_{11}. The treatment T_1 (0.89%) in genotype 'Winter Dawn' had shown the highest acidity which was at par with treatment T_4 (0.88%) while the lowest was recorded in T_{11} (0.81%). Significant effect of interaction between

genotype and nutrient treatment was not reported for acidity and the maximum acidity was found in V_1T_1 followed by V_3T_1 while lowest was in treatment V_3T_{11} and V_2T_{11}. The present results are according to outcomes of an experiment done by Singh *et al.* (2012) who observed the lower acidity (0.481%) in strawberry in treatment consisting of vermicompost + *Azotobacter*+ *Azospirillum*+PSB which may be due to greater synthesis of organic acids. These findings are in accordance with the outcomes of Singh *et al.* (2008) and Umar *et al.* (2009) in strawberry.

Table-4.36. Influence of genotypes and different nutrient combination on Titratable acidity (%) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	0.91	0.89	0.90	**0.90^{a}**
T_2	0.87	0.85	0.85	**0.86^{bc}**
T_3	0.89	0.86	0.86	**0.87^{b}**
T_4	0.88	0.88	0.88	**0.88^{ab}**
T_5	0.87	0.85	0.85	**0.86^{bc}**
T_6	0.88	0.86	0.86	**0.86^{bc}**
T_7	0.88	0.87	0.87	**0.87^{b}**
T_8	0.85	0.83	0.83	**0.84^{c}**
T_9	0.86	0.83	0.84	**0.84^{c}**
T_{10}	0.85	0.85	0.85	**0.85^{bc}**
T_{11}	0.84	0.81	0.80	**0.82^{c}**
T_{12}	0.84	0.83	0.83	**0.84^{c}**
T_{13}	0.86	0.84	0.84	**0.85^{bc}**
Mean (V)	**0.867^{a}**	**0.85^{b}**	**0.851^{b}**	
CD (p<0.05)				
V	**0.009**			
T	**0.019**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.3.10. TSS/acid ratio

Significant variation was noticed in TSS/acid ratio due to different treatment of strawberry under Punjab conditions (Table 4.37). The treatment T_{11} (100%NPK +

FYM + vermicompost + *Azotobacter*) in genotype 'Camarosa' had shown (13.05) maximum TSS/acid ratio while lowest was registered in treatment T_1 (Control) (9.19). The highest TSS/acid ratio in 'Winter Dawn' was recorded in treatment T_{11} (12.36) followed by T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) (12.05) while treatment T_1 showed (9.25) minimum TSS/acid ratio and was at par with treatment T_4 (50%NPK) (9.28). The maximum (12.12) TSS/acid ratio in 'Chandler' was obtained in treatment T_{11} whereas least was in treatment T_1 (8.69).

Table-4.37. Influence of genotypes and different nutrient combination on TSS/acid ratio in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	8.69	9.25	9.19	**9.05^{g}**
T_2	10.38	10.47	10.82	**10.56^{d}**
T_3	9.93	9.97	10.35	**10.08^{e}**
T_4	9.44	9.28	9.63	**9.45^{f}**
T_5	10.92	10.86	11.46	**11.08^{c}**
T_6	10.80	10.51	10.47	**10.59^{d}**
T_7	9.83	9.67	9.79	**9.76^{ef}**
T_8	11.65	11.70	11.96	**11.77^{b}**
T_9	11.29	11.09	11.39	**11.26^{c}**
T_{10}	10.24	10.16	10.59	**10.33^{de}**
T_{11}	12.12	12.36	13.05	**12.51^{a}**
T_{12}	11.63	12.06	12.08	**11.92^{b}**
T_{13}	11.13	11.02	11.79	**11.32^{c}**
Mean (V)	**10.619^{b}**	**10.646^{b}**	**10.967^{a}**	
CD (p<0.05)				
V	**0.188**			
T	**0.391**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

There was no significant effect of genotype and nutrient treatment interaction and the maximum TSS/acid ratio was found in V_3T_{11} but the lowest was found in V_1T_1, followed by V_3T_1, V_2T_1, V_2T_4 and V_1T_4. The outcomes are in similar trend with

results obtained by Gupta *et al.* (2012) and Singh *et al.* (2008) in strawberry.

4.2.3.11. Total sugars (%)

The individual treatment of genotypes and nutrients had significant influence on total sugars (Table 4.38) which ranged from 4.4 to 6.73 percent. The maximum (6.73%) total sugar in genotype 'Camarosa' was measured in treatment T_{11} while the lowest was obtained in treatment T_1 (4.87%) which was at par with T_4 (4.90%). The genotype 'Winter Dawn' (V_2) with treatment T_{11} registered (6.38%) maximum total sugar which was closely followed by T_8 (6.28%) whereas the least total sugar was found in treatment T_1 (4.67%) followed by treatment T_4 (4.71%).

Table-4.38. Influence of genotypes and different nutrient combination on Total sugar (%) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	4.40	4.67	4.87	**4.65^{g}**
T_2	5.15	5.22	5.69	**5.35^{e}**
T_3	4.72	5.00	5.06	**4.93^{f}**
T_4	4.57	4.71	4.90	**4.73^{g}**
T_5	5.42	5.56	5.79	**5.59^{d}**
T_6	5.26	5.39	5.30	**5.32^{e}**
T_7	4.90	4.98	5.14	**5.01^{f}**
T_8	5.93	6.28	6.42	**6.21^{b}**
T_9	5.67	5.94	6.08	**5.90^{c}**
T_{10}	5.39	5.71	5.89	**5.66^{d}**
T_{11}	6.25	6.38	6.73	**6.45^{a}**
T_{12}	5.85	6.07	6.31	**6.08^{b}**
T_{13}	5.62	5.90	6.12	**5.88^{c}**
Mean (V)	**5.32^{c}**	**5.52^{b}**	**5.72^{a}**	
CD ($p<0.05$)				
V	**0.067**			
T	**0.14**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

The treatment T_1 in 'Chandler' (4.4%) obtained the lowest total sugar and the highest total sugar (6.25%) was found in treatment T_{11}. There was no significant influence of interaction between nutrient treatment and genotypes. The largest value of total sugar was obtained in treatment V_3T_{11} closely followed by V_3T_8, V_2T_{11}, V_3T_{12}, V_2T_8 and V_1T_{11}. These present results may be due to the availability of balanced nutrients which promoted sugar accumulation in fruits. These findings were in similarity with the findings of Kushwah *et al.* (2018) who recorded that maximum sugar was found in treatment 75% RDF + 25% Vermicompost + *Azotobacter* @ 5kg/ha + PSB@ 5kg/ha. Singh *et al.* (2012) also notified that treatments of organic matter and vermicompost increases the sugar content in strawberry fruits.

4.2.3.12. Reducing Sugars (%)

The observations of reducing sugar had shown significant variation and (Table-4.39) varied from 2.34 percent to 3.93 percent. The genotype 'Chandler' with combination of treatment T_{11} showed (3.74%) the largest value of reducing sugar and the lowest value was found in treatment T_1 (2.34%). The maximum reducing sugar in genotype 'Camarosa' (3.93%) and 'Winter Dawn' (3.75%) was found in treatment T_{11} which was closely related to T_8 while the lowest reducing sugar in 'Camarosa' (2.68%) and 'Winter Dawn' (2.53%) was found in treatment T_1 followed by T_4. The interaction between genotype and nutrient treatment was shown non-significant and maximum total sugar was estimated in V_3T_{11} (3.93%) closely related to V_3T_8 (3.83%), V_2T_{11} (3.75%), V_1T_{11} (3.73%), V_2T_8 (3.70%). The results are in accordance with the findings of Wang and Lin (2002) which obtained maximum reducing sugar content with the use of organic fertilizers. The present investigation results were found to be similar trends with the finding of Singh *et al.* (2012) and Gupta *et al.* (2012) in strawberry.

4.2.3.13. Non-reducing sugars (%)

The observations in Table-4.40 shown non-reducing sugar content recorded in different treatments and significant variations were found in individual genotype and nutrient treatment. The treatment T_{11} in genotype 'Winter Dawn' obtained (2.63%) maximum non-reducing sugar at par with T_8 (2.57%) while treatment T_1 showed lowest (2.15%) non-reducing sugar followed by T_4 and T_7. The highest non-reducing sugar in 'Camarosa' was registered in treatment T_{11} (2.80%) whereas the least

(1.19%) was found in treatment T_1 and T_4. The treatment T_{11} in 'Chandler' was registered (2.51%) highest estimates of non-reducing sugar while the lowest was determined in T_1 (2.06%) and was at par with T_4 (2.11%) and T_3 (2.12%). There was no significant relationship between genotype and nutrient treatments. The highest estimates of non-reducing sugar were determined in V_3T_{11} closely followed by V_3T_{12}, V_2T_{11} and V_1T_{11} whereas lowest was recorded in the treatment V_1T_1 related with V_1T_4 and V_1T_3. The present results were in close trend with the finding of Singh *et al.* (2016) and Baksh *et al.* (2008).

Table-4.39. Influence of genotypes and different nutrient combination on reducing sugar (%) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	2.34	2.53	2.68	**2.51^{f}**
T_2	2.90	2.95	3.27	**3.04^{d}**
T_3	2.60	2.76	2.86	**2.74^{e}**
T_4	2.47	2.53	2.71	**2.57^{f}**
T_5	3.12	3.18	3.31	**3.21^{c}**
T_6	3.03	3.14	2.96	**3.04^{d}**
T_7	2.73	2.78	2.86	**2.79^{e}**
T_8	3.53	3.71	3.83	**3.69^{ab}**
T_9	3.37	3.52	3.58	**3.49^{b}**
T_{10}	3.16	3.34	3.47	**3.32^{c}**
T_{11}	3.74	3.75	3.93	**3.81^{a}**
T_{12}	3.51	3.61	3.67	**3.60^{b}**
T_{13}	3.34	3.51	3.61	**3.49^{b}**
Mean (V)	**3.07^{c}**	**3.18^{b}**	**3.29^{a}**	
CD ($p<0.05$)				
V	**0.057**			
T	**0.119**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

Table-4.40. Influence of genotypes and different nutrient combination on non-reducing sugar (%) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	2.06	2.15	2.19	**2.13^{f}**
T_2	2.25	2.27	2.42	**2.31^{d}**
T_3	2.12	2.24	2.20	**2.19^{e}**
T_4	2.11	2.18	2.19	**2.16^{e}**
T_5	2.30	2.37	2.47	**2.38^{cd}**
T_6	2.23	2.25	2.34	**2.27^{de}**
T_7	2.17	2.20	2.28	**2.22^{e}**
T_8	2.40	2.57	2.60	**2.52^{b}**
T_9	2.30	2.42	2.50	**2.41^{c}**
T_{10}	2.23	2.38	2.42	**2.34^{cd}**
T_{11}	2.51	2.63	2.80	**2.65^{a}**
T_{12}	2.34	2.46	2.63	**2.48^{bc}**
T_{13}	2.28	2.39	2.51	**2.39^{cd}**
Mean (V)	**2.25^{c}**	**2.35^{b}**	**2.43^{a}**	
CD (p<0.05)				
V	**0.037**			
T	**0.077**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.3.14. Total sugar/acid ratio

A significant difference was noted in total sugar /acid ratio in different treatments of strawberry under Punjab conditions (Table-4.41). The treatment T_{11} in 'Camarosa' (8.42) had shown the highest total sugar/acid ratio while the lowest was found in treatment T_1 (5.42) and T_4 (5.57). The maximum total sugar/acid ratio in genotype 'Chandler' and 'Winter Dawn' was recorded in the treatment T_{11} whereas least in genotype 'Winter Dawn' was registered in the treatment T_1 (5.23) which was statistically followed by T_4 (5.35). There was no significant interaction between genotype and nutrient treatments. The maximum total sugar: acid ratio was registered in V_3T_{11} followed by V_3T_8, V_2T_{11} and V_2T_8 while treatment V_1T_1 treatment showed

minimum total sugar: acid ratio followed by V_1T_4, V_2T_1 and V_2T_4. The present finding might be due to the high TSS and sugar content associated with the application of biofertilizers and INM practices and can be confirmed by the findings of Singh *et al.* (2016).

Table-4.41. Influence of genotypes and different nutrient combination on total sugar/acid ratio in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	4.82	5.23	5.42	**5.16^{g}**
T_2	5.89	6.12	6.70	**6.24^{e}**
T_3	5.32	5.84	5.86	**5.68^{f}**
T_4	5.22	5.35	5.57	**5.38^{g}**
T_5	6.24	6.51	6.83	**6.53^{d}**
T_6	6.00	6.29	6.18	**6.16^{e}**
T_7	5.57	5.75	5.90	**5.74^{f}**
T_8	6.98	7.60	7.71	**7.43^{b}**
T_9	6.62	7.13	7.25	**7.00^{c}**
T_{10}	6.31	6.73	6.93	**6.66^{d}**
T_{11}	7.45	7.88	8.42	**7.92^{a}**
T_{12}	6.95	7.31	7.57	**7.28^{b}**
T_{13}	6.56	7.00	7.32	**6.96^{c}**
Mean (V)	**6.15^{c}**	**6.52^{b}**	**6.74^{a}**	
CD ($p<0.05$)				
V	**0.104**			
T	**0.217**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.3.15. pH of fruit juice

The observation in Table-4.42 presented pH values recorded in different treatments and significant variations were found in individual genotype and nutrient treatment. The maximum value of pH fruit juice in genotype 'Winter Dawn' (3.30) and 'Camarosa' (3.24) was recorded in treatment T_1 (Control) while the lowest pH value of fruit juice in genotype 'Winter Dawn' (2.63) and 'Camarosa' (2.58) was

obtained in treatment T_{11}. The highest value of (3.13) pH fruit juice in 'Chandler' was observed in treatment T_4 (50% NPK) followed by treatment T_1 (Control) (3.12) while the lowest pH value (2.58) was recorded in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*).

Table-4.42. Influence of genotypes and different nutrient combination on pH of fruit juice in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	3.12	3.30	3.24	**3.22^{a}**
T_2	2.90	3.02	2.95	**2.96^{cd}**
T_3	3.03	3.16	3.10	**3.09^{b}**
T_4	3.13	3.25	3.18	**3.19^{a}**
T_5	2.78	2.88	2.84	**2.83^{ef}**
T_6	2.93	3.05	2.98	**2.99^{c}**
T_7	2.91	2.96	2.92	**2.93^{d}**
T_8	2.69	2.78	2.70	**2.73^{g}**
T_9	2.77	2.85	2.80	**2.80^{f}**
T_{10}	2.83	2.90	2.87	**2.87^{e}**
T_{11}	2.58	2.63	2.58	**2.60^{h}**
T_{12}	2.67	2.70	2.68	**2.68^{g}**
T_{13}	2.68	2.75	2.69	**2.71^{g}**
Mean(V)	**2.85^{c}**	**2.94^{a}**	**2.89^{b}**	
CD ($p<0.05$)				
V	**0.023**			
T	**0.048**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

There was no significant variation in pH was found in genotypes and nutrient treatment under the present investigation. The treatment V_2T_1 (3.30) showed maximum pH value followed by V_2T_4 (3.25) and V_3T_1 (3.23). The present experimental findings were in close trend with the finding of Jain *et al.* (2017) who reported the lowest pH (2.66) in INM treatments in combination with biofertilizers. The present investigation results were found in a similar trend with the finding of

Rayees *et al.* (2017) and Singh *et al.* (2008) in strawberry.

4.2.3.16. Specific gravity

The mean data of specific gravity was significantly varied due to genotype and treatments (Table-4.43) and ranged from 0.967 to 1.17. The highest value of specific gravity in genotype 'Camarosa' was noticed in treatment T_{11} whereas the least was reported in treatment T_1 (control). The treatment T_{11} in 'Winter Dawn' showed (1.11) the highest value of specific gravity which was at par with treatment T_8 (100%NPK + FYM + *Azotobacter*) (1.10) whereas the lowest was in treatment T_1.

Table-4.43. Influence of genotypes and different nutrient combination on specific gravity fruit in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	0.98	0.97	0.97	**0.97^{h}**
T_2	1.08	1.04	1.09	**1.07^{d}**
T_3	1.05	1.02	1.04	**1.04^{ef}**
T_4	0.99	0.99	1.01	**0.99^{g}**
T_5	1.09	1.07	1.09	**1.08^{cd}**
T_6	1.07	1.04	1.06	**1.06^{de}**
T_7	1.00	0.99	1.01	**1.00^{g}**
T_8	1.11	1.10	1.15	**1.12^{b}**
T_9	1.09	1.07	1.12	**1.09^{c}**
T_{10}	1.03	1.02	1.05	**1.03^{f}**
T_{11}	1.14	1.11	1.17	**1.14^{a}**
T_{12}	1.11	1.08	1.13	**1.11^{b}**
T_{13}	1.05	1.02	1.08	**1.05^{e}**
Mean (V)	**1.06^{b}**	**1.04^{c}**	**1.08^{a}**	
CD ($p<0.05$)				
V	**0.005**			
T	**0.011**			
V * T	**0.02**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

The maximum value of specific gravity of strawberry in genotype 'Chandler' was observed in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*)

(1.14) and the smallest value of specific gravity was found in the treatment T_1 (0.98) followed by T_4 (0.99). The specific gravity of fruits is strongly and positively correlated with the dry matter content and the level of photosynthates. Further, biofertilizers involved in nitrogen metabolism are known for accumulation of dry matter and promote the synthesis of plant growth factors. The specific gravity recorded in the present investigation is in the same trend as investigation of Singh *et al.* (2016) who observed the specific gravity varied from 0.94 to 1.07.

4.2.3.17. Anthocyanin content (mg/100g)

The data of different treatments of strawberry had showed significant variation in anthocynin content which varied from 46.74mg/100g to 61.72 mg/100g (Table-4.44).

Table-4.44. Influence of genotypes and different nutrient combination on Anthocyanin content (mg/100g of fruit) in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	46.74	48.99	47.11	**47.61^{i}**
T_2	54.15	55.74	55.29	**55.06^{e}**
T_3	52.82	54.60	53.70	**53.71^{f}**
T_4	49.34	50.48	49.72	**49.85^{h}**
T_5	56.41	58.85	57.19	**57.49^{c}**
T_6	53.97	56.28	54.71	**54.99^{e}**
T_7	51.90	52.08	51.62	**51.87^{g}**
T_8	58.54	60.34	59.58	**59.49^{a}**
T_9	56.87	59.50	57.47	**57.95^{bc}**
T_{10}	55.59	57.27	56.40	**56.42^{d}**
T_{11}	58.74	61.72	59.66	**60.04^{a}**
T_{12}	57.89	59.40	57.82	**58.37^{b}**
T_{13}	56.58	57.66	56.83	**57.02^{cd}**
Mean (V)	**54.58^{c}**	**56.38^{a}**	**55.16^{b}**	
CD ($p<0.05$)				
V	**0.29**			
T	**0.604**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

The maximum value of anthocyanin content in genotype 'Camarosa' (59.66 mg/100g) and 'Chandler' (58.74 mg/100g) was found in the T_{11} which was closely followed by treatment T_8 (59.58 mg/100g and 58.54 mg/100g) while the minimum in genotype 'Camarosa' (47.11mg/100g) and 'Chandler' (46.74 mg/100g) was in treatment T_1. The treatment T_{11} in 'Winter Dawn' showed (61.72 mg/100g) highest value of anthocyanin content while the lowest value (48.98 mg/100g) was found in treatment T_1. There was no significant interaction between genotype and nutrient treatments over anthocyanin content.

The maximum value of anthocyanin was obtained in the treatment V_2T_{11} closely followed by V_2T_8, V_3T_{11}, V_3T_8, V_2T_9, and V_1T_{11}. The maximum accumulation of anthocyanin pigments might be associated with biofertilizer application which ensured high level of metabolites during fruit development and ripening (Kushwah *et al.*, 2018).

4.2.3.18. Shelf life (days)

The data regarding the shelf life of fruit after different nutrient treatments was shown significant variations (Table-4.45) and ranged from 2.57 days to 4.90 days.

The shelf life of strawberry fruit genotype 'Chandler' was found (4.80 days) maximum in treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) as compared to other treatments while the least shelf life of fruit was recorded in the control (T_1). The treatment of T_5 and T_6 was shown statistically at par with others. The results were the same in the genotype 'Camarosa' (4.83 days) and 'Winter Dawn' (4.90 days) where treatment T_{11} showed the best shelf life as compared to other treatments and lowest was in control (T_1). There was no significant difference reported due to the interaction between genotype and nutrient treatments. The maximum shelf of fruit after harvesting was recorded in V_2T_{11} which was closely related to V_3T_{11} and V_1T_{11} while the lowest was found in V_2T_1 (2.47 days) followed by V_3T_1 (2.50 days) and V_1T_1 (2.57 days). These results may be the reason of biofertilizer and vermicompost which helped in the improvement of the fruit quality and increased the shelf life of fruit. The physiological and fruit biochemistry influenced by the inorganic and organic fertilizer along with biofertilizer leads to reduce transpiration and respiration rate in fruits which extended the shelf life. The results are in similar trend with findings of Jain *et al.* (2017) who reported that

application of Vermicompost + Poultry manure +*Azotobacter*+ PSB showed (5.69 days) maximum shelf life and similar findings were reported by Kumar *et al.* (2017) in guava and Kirad *et al.* (2010) in strawberry.

Table-4.45. Influence of genotypes and different nutrient combination on shelf life of fruit in strawberry

Treatments	Cultivars/ genotypes			Mean (T)
	Chandler (V_1)	WinterDawn (V_2)	Camarosa (V_3)	
T_1	2.57	2.47	2.50	**2.51^{j}**
T_2	3.43	3.63	3.53	**3.53^{g}**
T_3	3.27	3.47	3.37	**3.37^{h}**
T_4	2.77	2.60	2.73	**2.70^{i}**
T_5	3.77	3.83	3.67	**3.76^{f}**
T_6	3.70	3.63	3.57	**3.63^{g}**
T_7	3.27	3.33	3.27	**3.29^{h}**
T_8	4.63	4.67	4.63	**4.64^{b}**
T_9	4.47	4.57	4.50	**4.51^{c}**
T_{10}	4.13	4.27	4.20	**4.20^{e}**
T_{11}	4.80	4.90	4.83	**4.84^{a}**
T_{12}	4.50	4.60	4.57	**4.56^{bc}**
T_{13}	4.30	4.43	4.37	**4.37^{d}**
Mean (V)	**3.82**	**3.88**	**3.83**	
CD (p<0.05)				
V	**N/A**			
T	**0.121**			
V * T	**N/A**			

T_1: Control; T_2: 100% NPK; T_3: 75% NPK; T_4: 50% NPK; T_5: 100%NPK + FYM; T_6: 75% NPK +FYM; T_7: 50% NPK +FYM; T_8: 100%NPK + FYM + *Azotobacter*, T_9: 75% NPK +FYM + *Azotobacter*; T_{10}: 50% NPK +FYM + *Azotobacter*; T_{11}: 100%NPK + FYM + vermicompost + *Azotobacter*; T_{12}: 75% NPK +FYM + vermicompost + *Azotobacter*; T_{13}: 50% NPK +FYM + vermicompost + *Azotobacter*

4.2.4. Benefit: Cost ratio

The results of benefit:cost ratio was reported with variation due to different genotype and nutrient treatments and results were present in Table -4.46. The maximum benefit:cost ratio in genotype 'Chandler' was measured in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) (10.32) which was followed by treatment T_8 (100%NPK + FYM + *Azotobacter*) (8.82) and T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) (8.19) and the maximum net income was also observed in these treatments T_{11} (Rs.44,90,050), T_8 (Rs. 36,16,250) and T_{12} (Rs 35,46,107).

The lowest net income (Rs. 1, 79, 845) and benefit: cost ratio (0.47) was measured in the treatment T_1 (Control) followed by T_4 (50% NPK) (1.13). In the genotype 'Winter Dawn', the highest (10.14) value of benefit: cost was noted in treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) which was closed with treatment T_8 (100%NPK + FYM + *Azotobacter*) (9.35) and T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) (8.03) while minimum value of benefit cost ratio was calculated in the treatment T_1 (control) (0.79) closely related with T_4 (50% NPK) (1.12). The treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in genotype 'Camarosa' showed highest value of benefit: cost ratio (13.32) and net income (Rs. 57,96,250) which was nearly followed by T_8 (100%NPK + FYM + *Azotobacter*) (11.91) and T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) (11.14) while lowest was found in treatment T_1 (control) (1.28) closely followed by T_4 (50%NPK) (1.75). Among all genotype, 'Camarosa' genotype showed the maximum net income and benefit: cost ratio. These results are closely related to the finding of Kushwah *et al.* (2018), Jain *et al.* (2017) and Singh (2016) in strawberry, Dass *et al.* (2008) in tomato. These may be due to fact that yield per plant was good in these treatments due to proper nutrient supply through organic and inorganic fertilizer including biofertilizer.

Table 4.46. Influence of genotypes and different nutrient combination on benefit cost ratio of strawberry cultivation

Treatment	Treatment Cost	Total cost	Chandler			Winter Dawn			Camarosa		
			Yield/ ha (q)	Net income (Rs)	Benefit cost ratio	Yield/ ha (q)	Net income (Rs)	Benefit cost ratio	Yield/ ha (q)	Net income (Rs)	Benefit cost ratio
Control	0	385055	26.90	179845	0.47	32.80	303745	0.79	41.77	492115	1.28
100%NPK	9275	394330	119.07	2106140	5.34	125.87	2248940	5.70	153.77	2834840	7.19
75%NPK	6958	392013	85.47	1402857	3.58	89.70	1491687	3.81	131.00	2358987	6.02
50%NPK	4624	389679	39.47	439191	1.13	39.40	437721	1.12	51.00	681321	1.75
100%NPK + FYM	24275	409330	131.83	2359100	5.76	147.60	2690270	6.57	169.60	3152270	7.70
75%NPK +FYM	21958	407013	99.83	1689417	4.15	108.03	1861617	4.57	130.23	2327817	5.72
50%NPK +FYM	19624	404679	67.40	1010721	2.50	72.97	1127691	2.79	84.87	1377591	3.40
100%NPK + FYM + *Azotobacter*	25025	410080	191.73	3616250	8.82	202.03	3832550	9.35	252.07	4883390	11.91
75%NPK +FYM + *Azotobacter*	22708	407763	153.13	2807967	6.89	162.87	3012507	7.39	200.93	3811767	9.35
50%NPK +FYM + *Azotobacter*	20374	405429	109.77	1899741	4.69	94.63	1581801	3.90	144.67	2632641	6.49
100%NPK + FYM + vermicompost + *Azotobacter*	50025	435080	234.53	4490050	10.32	230.83	4412350	10.14	296.73	5796250	13.32
75%NPK +FYM + vermicompost + *Azotobacter*	47708	432763	189.47	3546107	8.19	186.07	3474707	8.03	250.27	4822907	11.14
50%NPK +FYM + vermicompost + *Azotobacter*	45374	430429	115.33	1991501	4.63	126.40	2223971	5.17	152.57	2773541	6.44

4.3. EXPERIMENT-III: EFFECT OF DIFFERENT PACKAGING MATERIALS AND STORAGE CONDITIONS ON SHELF-LIFE OF STRAWBERRY FRUITS

4.3.1. Weight loss (%)

Data pertaining to weight loss of fruit during ambient and refrigerator conditions had shown significant variation in different packaging material and at different storage periods and have been shown in Table-4.47. All the three genotypes 'Chandler', 'Winter Dawn' and 'Camarosa' were investigated separately. The two factors were studied that packaging material viz control, LDPE 50 micron, LDPE 75 micron and storage period viz 2, 4, 6 days at two different storage conditions.

A significant difference was found between packaging material and storage conditions. In genotype Chandler (Table-4.47), the maximum weight loss of fruit (7.41%) was recorded in P_1 Control (no packaging) under both storage conditions viz S_1 and S_2 while the minimum was found in the packaging treatment P_2 (LDPE 50 micron) at ambient (5.28%) and refrigerate temperature (1.12%). The maximum fruit loss was registered on the 6^{th} day of storage period under both conditions whereas the minimum was recorded on the 4^{th} day of storage period under refrigerated conditions. The significant interaction between packaging material and storage period under different storage conditions was reported. The least weight loss was obtained in the treatment P_2S_2 (refrigerated conditions) and maximum was observed in P_1S_1 (ambient condition) in 'Chandler'.

Similar results were recorded in genotype 'WinterDawn' and 'Camarosa'. The minimum weight loss in genotype 'Winter Dawn' was registered in the treatment P_2S_2 (refrigerated temperature) (1.33%) while the highest fruit weight loss was found in treatment P_1S_1 (ambient temperature) (7.79%) as compared to other treatments. The minimum loss of fruit weight was found in the refrigerated temperature in all genotypes. The treatment LDPE 50-micron packaging material in genotype 'Camarosa' had shown minimum weight loss at refrigerated temperature while the maximum loss was in treatment P_1 (Control). The Camarosa showed the minimum weight loss in treatment P_2S_2 in comparison to other combinations. The results were in accordance with the findings of Panda *et al.* (2016) who also notified the minimum loss of weight in fruit packed in LDPE-50-micron packaging film.

Table- 4.47. Weight loss (%) of strawberry fruits subjected to different packaging and storage conditions

Packaging material	Storage conditions (Chandler)		Mean (P)	Storage conditions (Winter Dawn)		Mean (P)	Storage conditions (Camarosa)		Mean (P)
	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	
P_1 (Control)	7.41^{a}	2.263^{d}	4.837^{a}	7.79^{a}	2.48^{d}	5.14^{a}	7.232^{a}	2.064^{d}	4.648^{a}
P_2 (LDPE 50 micron)	5.282^{c}	1.122^{f}	3.202^{c}	5.53^{c}	1.33^{f}	3.43^{c}	4.877^{c}	0.992^{f}	2.934^{c}
P_3 (LDPE 75 micron)	5.65^{b}	1.373^{e}	3.512^{b}	5.78^{b}	1.62^{e}	3.70^{b}	5.183^{b}	1.264^{e}	3.224^{b}
Mean (S)	6.114^{a}	1.586^{b}		6.37^{a}	1.81^{b}		5.764^{a}	1.44^{b}	
CD (P≤0.05)									
S	**0.08**			**0.08**			**0.077**		
P	**0.098**			**0.10**			**0.095**		
S X P	**0.139**			**0.14**			**0.134**		
Storage period	**S1 (Ambient Temperature)**	**S_2 (Refrigerated Temperature)**	**Mean (D)**	**S1 (Ambient Temperature)**	**S_2 (Refrigerated Temperature)**	**Mean (D)**	**S1 (Ambient Temperature)**	**S_2 (Refrigerated Temperature)**	**Mean (D)**
D_0 (0 days)	0^{g}	0^{g}	0^{d}	0^{g}	0^{g}	0^{d}	0^{g}	0^{g}	0^{d}
D_1 (2 days)	2.578^{c}	1^{f}	1.789^{c}	2.83^{c}	1.22^{f}	2.03^{c}	2.438^{c}	0.846^{f}	1.642^{c}
D_2 (4 days)	5.512^{b}	1.572^{e}	3.542^{b}	5.68^{b}	1.84^{e}	3.76^{b}	4.988^{b}	1.449^{e}	3.218^{b}
D_3 (6 days)	10.252^{a}	2.187^{d}	6.219^{a}	10.59^{a}	2.38^{d}	6.48^{a}	9.867^{a}	2.027^{d}	5.947^{a}
Mean (S)	6.114^{a}	1.586^{b}		6.37^{a}	1.81^{b}		5.764^{a}	1.44^{b}	
CD (P≤0.05)									
D	**0.098**			**0.098**			**0.095**		
S	**0.08**			**0.08**			**0.077**		
D X S	**0.139**			**0.139**			**0.134**		
D X P	**0.17**			**0.17**			**0.164**		
P X S X D	**0.241**			**0.241**			**0.232**		

The results may be due to packaging material that resulted in the reduction of the respiration rate of strawberry by low the level of oxygen and high carbon dioxide concentration have been reported by Li and Kader, (1989) and fruit without packing was a result of maximum weight loss due to exposure of fruit in open atmosphere which leads to high transpiration rate and respiration rate. The current outcomes can further be confirmed with the findings of Kumar and Nagpal (1996), Siddiqui and Gupta (1997) and Sonkar and Ladaniya (1998) that established fruits packed in various packaging materials were able to maintain better fruit quality for a longer period when compared with fruits without packaging.

4.3.2. Total Soluble Solid (^oB)

The results of TSS content in strawberry fruits had shown significant variation in packaging material and storage period under two storage conditions with lieu to different genotypes. The fruits of three different genotypes were packed in different packaging material and were stored under two different storage conditions. The maximum TSS content in genotype 'Chandler' was observed in fruit packed in LDPE 50 micron (9.82^oB) under both conditions viz. ambient and refrigerated storage which was statistically at par with treatment P_3 (LDPE 75 micron) (9.79^oB) while minimum was observed in control. The highest value of TSS in fruit was recorded on the 2nd day of storage period under refrigerated temperature (9.85^oB) while the least TSS in 'Chandler' was obtained on the 6th day of storage period under ambient temperature.

The fruit packed in LDPE 75 micron under refrigerated temperature showed more retaintion of (9.58^oB) TSS in fruits of Winter Dawn which was statistically at par with all treatments (Table-4.48) while lower value (9.18^oB) of TSS content was in control under ambient temperature. The highest value of TSS (9.64^oB) was measured on the 2nd day of storage period under refrigerated storage and minimum (8.86^oB) was on the 6th day of storage period under ambient storage. There was no significant effect on the interaction of packaging material, storage period and storage conditions.

The highest value of TSS content in genotype 'Camarosa' was observed in fruit packed with (9.90^oB) LDPE 50 micron (P_2) which was at par with (9.88^oB) LDPE 75 micron (P_3) at refrigerated temperature whereas less retention of TSS was in control at ambient temperature. A significant variation was found in the storage temperature with the storage period (Table-4.48).

Table- 4.48.TSS (ºB) of strawberry fruits subjected to different packaging and storage conditions

Packaging material	Storage conditions (Chandler)		Mean (P)	Storage conditions (Winter Dawn)		Mean (P)	Storage conditions (Camarosa)		Mean (P)
	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	
P_1 (Control)	9.43^{c}	9.78^{a}	9.61^{b}	9.18^{d}	9.57^{a}	9.38^{b}	9.53^{d}	9.87^{a}	9.7^{c}
P_2(LDPE 50 micron)	9.56^{b}	9.82^{a}	9.69^{a}	9.34^{b}	9.57^{a}	9.46^{a}	9.68^{b}	9.9^{a}	9.79^{a}
P_3 (LDPE 75 micron)	9.55^{b}	9.79^{a}	9.67^{a}	9.24^{c}	9.58^{a}	9.41^{b}	9.59^{c}	9.88^{a}	9.74^{b}
Mean (S)	9.51^{b}	9.8^{a}		9.25^{b}	9.57^{a}		9.6^{b}	9.88^{a}	
CD (P≤0.05)									
S	**0.02**			**0.02**			**0.02**		
P	**0.03**			**0.03**			**0.02**		
S X P	**0.04**			**0.04**			**0.03**		
Storage period	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)
D_0 (0 days)	9.8^{b}	9.78^{bc}	9.79^{a}	9.54^{cd}	9.56^{cd}	9.55^{a}	9.88^{b}	9.88^{b}	9.88^{a}
D_1 (2 days)	9.69^{d}	9.85^{a}	9.77^{b}	9.42^{e}	9.64^{a}	9.53^{a}	9.75^{d}	9.94^{a}	9.85^{a}
D_2 (4 days)	9.48^{e}	9.8^{b}	9.64^{c}	9.2^{f}	9.58^{b}	9.39^{b}	9.54^{e}	9.89^{b}	9.72^{b}
D_3 (6 days)	9.09^{f}	9.74^{c}	9.42^{d}	8.86^{g}	9.52^{d}	9.19^{c}	9.22^{f}	9.82^{c}	9.52^{c}
Mean (S)	9.51^{b}	9.8^{a}		9.25^{b}	9.57^{a}		9.6^{b}	9.88^{a}	
CD (P≤0.05)									
D	**0.03**			**0.03**			**0.02**		
S	**0.02**			**0.02**			**0.02**		
D X S	**0.04**			**0.04**			**0.03**		
D X P	**0.05**			**0.05**			**0.04**		
P X S X D	**0.08**			**N/A**			**0.05**		

The maximum TSS (9.94^{o}B) was observed on the 2nd Day of storage period at refrigerated temperature while the lowest (9.22^{o}B) was on the 6th day at ambient temperature. The genotype 'Camarosa' had shown maximum TSS content among genotype.

The negligible variation in TSS irrespective of packaging materials and storage duration under refrigerated condition might have resulted due to the inactivation of enzymatic breakdown of larger biomolecules at lower temperatures while it was greater under ambient storage as discussed by Safari *et al*. (2016). Further, variation due to number of days of storage might be the result of quality degradation which was minimal under refrigerated storage in comparison to ambient storage conditions. Variation due to packaging materials was not significant under refrigerated conditions while under ambient conditions LDPE 50 micron maintained greater TSS and can be confirmed by findings of Panda *et al.* (2016).

4.3.3. Titratable Acidity (%)

The acidity of strawberry fruit genotype Chandler was significantly affected by the interaction effect of packaging material and storage conditions (Table-4.49). The higher acidity content was found when 'Chandler' fruit packed in LDPE 50 micron (0.82%) and LDPE 75 micron (0.82%) under refrigerated storage which was at par with control while lower value was (0.71) found when the fruit was not packed with any material and stored at ambient temperature (P_1S_1). There was a significant interaction between storage period and storage condition and the lowest value (0.66%) of acidity was recorded on the 6th day of storage period at ambient temperature while highest (0.86%) value of acidity was found on 0th day of storage period which was followed by 2nd Day of storage period at refrigerated storage (0.84%).

The fruits of 'Winter Dawn' packed with (P_2) LDPE 50 micron showed (0.78%) maximum value of acidity under refrigerated temperature which was statistical at par with P_3 LDPE 75 micron (0.77%) under refrigerated temperature (Table-4.49) while lowest was in control (P_1) (0.69%) under ambient temperature. There was no significant interaction effect of packaging material and storage conditions. The minimum value of acidity (0.59%) was on the 6th day of storage period at ambient temperature.

Table- 4.49. Titratable Acidity (%) of strawberry fruits subjected to different packaging and storage conditions

Packaging material	Storage conditions (Chandler)		Mean (P)	Storage conditions (Winter Dawn)		Mean (P)	Storage conditions (Camarosa)		Mean (P)
	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	
P_1 (Control)	0.71^{d}	0.81^{a}	0.76^{b}	0.69	0.77	0.73^{b}	0.68	0.75	0.71^{b}
P_2 (LDPE 50 micron)	0.78^{b}	0.82^{a}	0.80^{a}	0.72	0.78	0.75^{a}	0.72	0.76	0.74^{a}
P_3 (LDPE 75 micron)	0.75^{c}	0.82^{a}	0.78^{ab}	0.71	0.77	0.74^{ab}	0.71	0.76	0.74^{a}
Mean (S)	0.75^{b}	0.82^{a}		0.70^{b}	0.77^{a}		0.70^{b}	0.76^{a}	
CD (P≤0.05)									
S	**0.01**			**0.01**			**0.01**		
P	**0.02**			**0.01**			**0.02**		
S X P	**0.02**			**N/A**			**N/A**		
Storage period	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)
D_0 (0 days)	0.84^{a}	0.86^{a}	0.85^{a}	0.82^{ab}	0.83^{a}	0.82^{a}	0.80^{ab}	0.81^{a}	0.81^{a}
D_1 (2 days)	0.77^{b}	0.84^{a}	0.81^{b}	0.74^{c}	0.80^{b}	0.77^{b}	0.73^{c}	0.78^{b}	0.76^{b}
D_2 (4 days)	0.72^{c}	0.80^{b}	0.76^{c}	0.67^{e}	0.75^{c}	0.71^{c}	0.67^{e}	0.74^{c}	0.71^{c}
D_3 (6 days)	0.66^{d}	0.77^{b}	0.71^{d}	0.59^{f}	0.71^{d}	0.65^{d}	0.60^{f}	0.70^{d}	0.65^{d}
Mean (S)	0.75^{b}	0.82^{a}		0.70^{b}	0.77^{a}		0.70^{b}	0.76^{a}	
CD (P≤0.05)									
D	**0.02**			**0.01**			**0.018**		
S	**0.01**			**0.01**			**0.013**		
D X S	**0.03**			**0.02**			**0.025**		
D X P	**N/A**			**N/A**			**N/A**		
P X S X D	**N/A**			**N/A**			**N/A**		

In the case of 'Camarosa', the fruits packed with (P_2) LDPE 50 micron (76%) and (P_3) LDPE 50 micron (76%) had shown the maximum value of acidity in fruit which was at par with (75%) control under refrigerated temperature while minimum was in control (P_1) (0.68%). The lowest value of acidity was recorded on 6th Day of storage period at ambient temperature.

Titratable acidity was also noticed to show negligible variation irrespective of packaging materials and storage duration under refrigerated conditions might be due to inactivation of enzymatic breakdown of organic acids at lower temperature while it was greater under ambient storage as discussed by Babarinde and Fabunmi (2009). Further, decrease in acidity during storage duration could have been resulted due to the oxidative breakdown of organic acids under ambient conditions. Among packaging materials, it was LDPE 50 micron which had reflected lesser breakdown so maintained the quality of fruits (Panda *et al.*, 2016).

4.3.4. TSS/Acid ratio

In this investigation, it is observed that significant variation in TSS/acid ratio in different packaging materials and storage condition was noted (Table 4.50) in the different genotype viz. 'Chandler', 'Winter Dawn' and 'Camarosa'.

The genotype 'Chandler' fruit packed in (P2) LDPE 50 micron showed (11.97) lower value of TSS/acid ratio which was statistically at par with fruit packed in (P3) LDPE 75 micron under refrigerated conditions (11.98) as compared to other treatments (Table-4.50) while the maximum was found in the control treatment under ambient temperature (13.41). There was no significant relationship between the storage period and storage conditions. The maximum value was reported on the 6th Day of storage period under ambient temperature (13.83) but the minimum was found on the 2nd day of storage period under refrigerated condition (11.74).

In genotype 'Winter Dawn', the maximum TSS/acid ratio was measured in the treatment P_1 (Control) (13.60) at ambient temperature as compared to other treatments while the minimum (12.25) was found in treatment P_2 (LDPE 50 micron) under refrigerated conditions. A significant variation was observed in the treatment storage condition and storage period. The ambient temperature treatment showed the highest TSS/acid ratio on the 6th day of storage period while the minimum was found on the 0th day of storage period. It was found that TSS/ acid ratio increased with time.

Table- 4.50.TSS/acidityof strawberry fruits subjected to different packaging and storage conditions

Packaging material	Storage conditions (Chandler)		Mean (P)	Storage conditions (Winter Dawn)		Mean (P)	Storage conditions (Camarosa)		Mean (P)
	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	
P_1 (Control)	13.41^{a}	12.10^{c}	12.75^{a}	13.60	12.51	13.06^{a}	14.23	13.22	13.73^{a}
P_2 (LDPE 50 micron)	12.27^{c}	11.97^{c}	12.12^{b}	13.07	12.25	12.66^{b}	13.63	13.10	13.36^{b}
P_3 (LDPE 75 micron)	12.84^{b}	11.98^{c}	12.41^{b}	13.23	12.53	12.88^{a}	13.63	13.02	13.32^{b}
Mean (S)	12.84^{a}	12.02^{b}		13.30^{a}	12.43^{b}		13.83^{a}	13.11^{b}	
CD (P≤0.05)									
S	**0.24**			**0.20**			**0.25**		
P	**0.30**			**0.25**			**0.30**		
S X P	**0.42**			**N/A**			**N/A**		
Storage period	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)
D_0 (0 days)	11.74	11.37	11.55^{d}	11.70^{ef}	11.53^{f}	11.61^{d}	12.33^{e}	12.20^{e}	12.27^{d}
D_1 (2 days)	12.53	11.74	12.14^{c}	12.70^{d}	12.05^{e}	12.38^{c}	13.32^{c}	12.81^{de}	13.06^{c}
D_2 (4 days)	13.26	12.25	12.75^{b}	13.82^{b}	12.82^{d}	13.32^{b}	14.34^{b}	13.30^{cd}	13.82^{b}
D_3 (6 days)	13.83	12.72	13.27^{a}	14.98^{a}	13.33^{c}	14.16^{a}	15.34^{a}	14.13^{b}	14.73^{a}
Mean (S)	12.84^{a}	12.02^{b}		13.30^{a}	12.43^{b}		13.83^{a}	13.11^{b}	
CD (P≤0.05)									
D	**0.344**			**0.289**			**0.348**		
S	**0.243**			**0.204**			**0.246**		
D X S	**N/A**			**0.408**			**0.492**		
D X P	**N/A**			**N/A**			**N/A**		
P X S X D	**N/A**			**N/A**			**N/A**		

The fruit packed with treatment (P_3) LDPE 75 micron in genotype 'Camarosa' under refrigerated conditions was noticed with (13.02) lowest value of TSS/acid ratio which was closely followed by treatment (P_2) LDPE 50 micron (13.10) and control (P_1) (13.22) while the highest value was recorded in P_1 treatment under ambient temperature.

There was a significant relation between period storage and storage conditions. The TSS/acid ratio was significantly increased with the period of storage under both storage conditions. The highest was found on the 0^{th} day of storage period under both condition and the lowest was recorded on the 6^{th} day of period storage under ambient (15.34) and refrigerate storage (14.13). TSS/Acid ratio was also followed the similar trend; however, it was not significant for most of the interaction effect except D X S interaction which showed gradual change in TSS/Acid ratio during storage (Panda *et al.*, 2016).

4.3.5. Total Sugar (%)

The average transformed data on total sugars observed significant variation in all treatments (Table 4.51) under different genotypes. The significant variation in genotype 'Chandler' was recorded in treatment and its interaction. The highest total sugar content (5.89 %) was noticed in packed fruit with P_2 (LDPE-50 micron) under refrigerated and ambient temperature while the lowest was in control (P_1) (5.44 %). The sugar content was going to decline in both the storage conditions. It was noticed that the fruit stored at ambient temperature had rapidly decreasing sugar content with respect to storage period as compared to refrigerated conditions. The lowest value was observed on the 6^{th} day of storage period under ambient conditions.

The significant variation in genotype 'Winter Dawn' was observed in all treatments. The maximum sugar was recorded in P_3 (LDPE-75 micron) under refrigerated condition (6.11%) which was statistically at par with P_2 treatment (LDPE-50 micron) under refrigerated temperature (6.9%). The highest value of sugar content (5.99 %) was recorded in treatment P_2 (LDPE-50 micron) under ambient temperature while the lowest was in the control (P_1) (5.58 %). A significant decrease in the sugar content was found during the passage of time under ambient and refrigerated conditions. The lowest sugar content was on 6^{th} day of the storage period at ambient conditions (5.31%). The 'Camarosa' fruits packed in P_2 (LDPE-50 micron) were

noticed to contain higher sugar under ambient conditions (6.11%) and refrigerated conditions (6.12%) while the lowest was found in control (P_1). The sugar content significantly decreased under both conditions with period of storage. The sugar content varied from 5.53 % on the 6th day of storage period to 6.31% on the 0th day of storage period under ambient condition. Relatively greater sugar content in fruits stored under refrigerated conditions confirmed the good keeping quality of strawberry fruits which was reported to be decreased with the progress of storage duration (Giuggioli *et al.*, 2015). Further, packaging with LDPE 50 micron was reported to have fruits containing high sugar which might be associated with lesser respiration rate to minimize breakdown of sugar (Safari *et al*., 2016).

4.3.6. Reducing Sugar (%)

All the treatments of packaging material and storage conditions were tested under different genotype of strawberry and shown significant variation in terms of reducing sugar (%). The highest reducing sugar content (3.60 %) in genotype 'Chandler' was measured in treatment (P_2) LDPE-50 micron under refrigerated condition while the lowest was in control (P_1) (3.22 %). A significant difference was observed in the treatment storage conditions and storage period as shown in Table-4.52. The decrease in the sugar content at ambient temperature was quickly as compared to refrigerated conditions.

In 'Winter Dawn', the reducing sugar content was influenced by packaging material under different storage conditions and durations (Table-4.52) and the highest value of reducing sugar was retained in the packed fruit with P_3 (LDPE-75 micron) (3.81) under refrigerated condition which was closely related with P_2 (LDPE-50 micron) under ambient condition (3.55%) while lowest was in control (P_1). The storage at refrigerated condition fruit was fresher on the 6th day of storage period as compared to ambient temperature with respect to reducing sugar. The treatment P_2 (LDPE-50 micron) in genotype 'Camarosa' showed significantly higher reducing sugar (3.81 %) as compared to other treatments while least reducing sugar content in control (P_1) (3.72%) under refrigerated storage conditions. Under ambient condition, the fruit packed in P_3 (LDPE-75 micron) maintained the highest reducing sugar than others.

Table- 4.51.Total sugar content (%) of strawberry (Chandler) fruits subjected to different packaging and storage conditions

Packaging material	Storage conditions (Chandler)		Mean (P)	Storage conditions (Winter Dawn)		Mean (P)	Storage conditions (Camarosa)		Mean (P)
	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	
P_1 (Control)	5.44^{e}	5.73^{c}	5.58^{c}	5.58^{d}	5.82^{c}	5.70^{c}	5.82^{d}	5.99^{c}	5.91^{c}
P_2 (LDPE 50 micron)	5.89^{a}	5.89^{a}	5.89^{a}	5.99^{b}	6.09^{a}	6.04^{a}	6.11^{a}	6.12^{a}	6.12^{a}
P_3 (LDPE 75 micron)	5.66^{d}	5.82^{b}	5.74^{b}	5.85^{c}	6.11^{a}	5.98^{b}	6.02^{c}	6.06^{b}	6.04^{b}
Mean (S)	5.66^{b}	5.81^{a}		5.81^{b}	6.01^{a}		5.98^{b}	6.06^{a}	
CD (P≤0.05)									
S	**0.02**			**0.04**			**0.02**		
P	**0.03**			**0.04**			**0.02**		
S X P	**0.04**			**0.06**			**0.03**		
Storage period	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)
D_0 (0 days)	6.02^{a}	5.95^{b}	5.98^{a}	6.18^{a}	6.12^{a}	6.15^{a}	6.31^{a}	6.18^{b}	6.25^{a}
D_1 (2 days)	5.90^{bc}	5.85^{c}	5.88^{b}	6.02^{b}	6.04^{b}	6.03^{b}	6.19^{b}	6.13^{c}	6.16^{b}
D_2 (4 days)	5.57^{f}	5.77^{d}	5.67^{c}	5.72^{d}	6.01^{b}	5.87^{c}	5.90^{e}	6.02^{d}	5.96^{c}
D_3 (6 days)	5.16^{g}	5.67^{e}	5.42^{d}	5.31^{e}	5.85^{c}	5.58^{d}	5.53^{f}	5.90^{e}	5.72^{d}
Mean (S)	5.66^{b}	5.81^{a}		5.81^{b}	6.01^{a}		5.98^{b}	6.06^{a}	
CD (P≤0.05)									
D	**0.034**			**0.05**			**0.028**		
S	**0.024**			**0.036**			**0.02**		
D X S	**0.048**			**0.071**			**0.039**		
D X P	**0.059**			**0.087**			**0.048**		
P X S X D	**0.084**			**0.123**			**0.068**		

Table- 4.52. Reducing Sugar (%) of strawberryfruits subjected to different packaging and storage conditions

Packaging material	Storage conditions (Chandler)		Mean (P)	Storage conditions (Winter Dawn)		Mean (P)	Storage conditions (Camarosa)		Mean (P)
	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	
P_1 (Control)	3.22^{e}	3.44^{b}	3.33^{b}	3.34^{c}	3.54^{b}	3.44^{b}	3.51^{f}	3.72^{c}	3.61^{b}
P_2 (LDPE 50 micron)	3.39^{c}	3.68^{a}	3.54^{a}	3.55^{b}	3.81^{a}	3.68^{a}	3.60^{e}	3.84^{a}	3.72^{a}
P_3 (LDPE 75 micron)	3.26^{d}	3.44^{b}	3.35^{b}	3.53^{b}	3.85^{a}	3.69^{a}	3.65^{d}	3.77^{b}	3.71^{a}
Mean (S)	3.29^{b}	3.52^{a}		3.48^{b}	3.73^{a}		3.59^{b}	3.78^{a}	
CD (P≤0.05)									
S	**0.02**			**0.03**			**0.02**		
P	**0.03**			**0.03**			**0.02**		
S X P	**0.04**			**0.04**			**0.03**		
Storage period	**S_1 (Ambient Temperature)**	**S_2 (Refrigerated Temperature)**	**Mean (D)**	**S_1 (Ambient Temperature)**	**S_2 (Refrigerated Temperature)**	**Mean (D)**	**S_1 (Ambient Temperature)**	**S_2 (Refrigerated Temperature)**	**Mean (D)**
D_0 (0 days)	3.60^{a}	3.59^{a}	3.59^{a}	3.80^{a}	3.79^{a}	3.80^{a}	3.89^{a}	3.81^{b}	3.85^{a}
D_1 (2 days)	3.52^{b}	3.55^{ab}	3.54^{b}	3.70^{bc}	3.76^{ab}	3.73^{b}	3.82^{b}	3.81^{b}	3.81^{b}
D_2 (4 days)	3.20^{d}	3.49^{bc}	3.34^{c}	3.39^{d}	3.72^{b}	3.55^{c}	3.51^{d}	3.76^{c}	3.63^{c}
D_3 (6 days)	2.84^{e}	3.45^{c}	3.15^{d}	3.02^{e}	3.65^{c}	3.33^{d}	3.12^{e}	3.72^{c}	3.42^{d}
Mean (S)	3.29^{b}	3.52^{a}		3.48^{b}	3.73^{a}		3.59^{b}	3.78^{a}	
CD (P≤0.05)									
D	**0.033**			**0.035**			**0.027**		
S	**0.023**			**0.025**			**0.019**		
D X S	**0.046**			**0.05**			**0.038**		
D X P	**0.056**			**0.061**			**0.047**		
P X S X D	**0.08**			**0.086**			**0.066**		

The reducing sugar was significantly decreasing at a slow rate in refrigerated storage. The highest reducing sugar content (3.81%) was on the 0^{th} and 2^{nd} day of the storage period under refrigerated condition.

4.3.7. Vitamin C content (mg/100g)

There was significant variation in 'Chandler' observed in all treatments with respect to vitamin C content (Table-4.53). The maximum vitamin C content was found in fruit packed with P_2 (LDPE-50 micron) under ambient (45.54 mg/100g) and refrigerated conditions (54.83 mg/100g) while the lowest vitamin C content was in control under ambient (39.45 mg/100g) and refrigerated condition (49.41 mg/100g). The significant variation was also observed in storage period and storage conditions and lower vitamin C content was recorded on the 6^{th} day of storage period at ambient condition (43.11 mg/100g) which was lower than refrigerated fruits (52.46 mg/100g) on 6^{th} day of storage period. The maximum value of vitamin C content (51.92 mg/100g) in 'Winter Dawn' was measured in fruit packed in P_2 (LDPE-50 micron) which was statistically followed by P_3 (LDPE-75 micron) (50.52 mg/100g) under refrigerated conditions. The vitamin C content was statistically decreasing at slow rate in refrigerated condition than under ambient condition (Table-4.53).

The lowest vitamin C was recorded on 0^{th} day of storage period at ambient condition. The treatment fruit packed in LDPE-50 micron in genotype 'Camarosa' was found maximum retain vitamin C content at ambient (49.56 mg/100g) and refrigerated condition (59.08 mg/100g) while lower vitamin C was (45.37 mg/100g and 51.84 mg/100g) in control (P_1). A significant variation was found in all treatments (Table-4.53).

The vitamin C content was steadily decreased with storage period but under refrigerated storage decrease in vitamin C was at slow rate. The lowest (33.79 mg/100g) was recorded on the 6^{th} day of the storage period at ambient temperature. Vitamin C content was reported to be significantly maintained by storage of fruits under refrigerated storage condition and LDPE 50-micron packaging while it was reported to be decreased during the later stage of storage, sharply under ambient condition and slowly under refrigerated condition. The oxidative breakdown of ascorbic acid at the beginning and non-enzymatic breakdown at the later phase of storage (Bhatia *et al.*, 2015).

Table- 4.53. Vitamin C content (mg/100g) of strawberryfruits subjected to different packaging and storage conditions

Packaging material	Storage conditions (Chandler)		Mean (P)	Storage conditions (Winter Dawn)		Mean (P)	Storage conditions (Camarosa)		Mean (P)
	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)		S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	
P_1 (Control)	39.45^{f}	49.41^{c}	44.43^{c}	36.71	45.27	40.99^{c}	45.37^{f}	51.84^{c}	48.60^{c}
P_2 (LDPE 50 micron)	45.54^{d}	54.83^{a}	50.19^{a}	42.68	51.92	47.30^{a}	49.56^{d}	59.08^{a}	54.32^{a}
P_3 (LDPE 75 micron)	44.33^{e}	53.13^{b}	48.73^{b}	42.09	50.52	46.30^{b}	48.00^{e}	58.15^{b}	53.08^{b}
Mean (S)	43.11^{b}	52.46^{a}		40.49^{b}	49.24^{a}		47.64^{b}	56.36^{a}	
CD (P≤0.05)									
S	**0.36**			**0.54**			**0.44**		
P	**0.44**			**0.67**			**0.53**		
S X P	**0.63**			**N/A**			**0.76**		
Storage period	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)	S_1 (Ambient Temperature)	S_2 (Refrigerated Temperature)	Mean (D)
D_0 (0 days)	56.48^{a}	55.97^{a}	56.23^{a}	53.46^{a}	53.10^{a}	53.28^{a}	61.41^{a}	60.32^{b}	60.87^{a}
D_1 (2 days)	47.13^{e}	53.29^{b}	50.21^{b}	45.05^{d}	50.43^{b}	47.74^{b}	52.16^{e}	57.11^{c}	54.64^{b}
D_2 (4 days)	38.55^{f}	51.48^{c}	45.01^{c}	36.12^{e}	47.95^{c}	42.03^{c}	43.22^{f}	55.17^{d}	49.19^{c}
D_3 (6 days)	30.27^{g}	49.10^{d}	39.68^{d}	27.35^{f}	45.47^{d}	36.41^{d}	33.79^{g}	52.82^{e}	43.31^{d}
Mean (S)	43.11^{b}	52.46^{a}		40.49^{b}	49.24^{a}		47.64^{b}	56.36^{a}	
CD (P≤0.05)									
D	**0.511**			**0.768**			**0.616**		
S	**0.362**			**0.543**			**0.436**		
D X S	**0.723**			**1.086**			**0.872**		
D X P	**0.886**			**1.33**			**1.068**		
P X S X D	**1.253**			**1.88**			**1.51**		

4.3.9. Shelf life (days)

The results of the shelf life of fruits of different cultivars were shown significant variation in packaging material and storage conditions with regards to different genotypes (Table-4.54).

The treatment P_2S_2 (LDPE-50 micron) showed the highest shelf life under ambient (5.54 days) and refrigerated conditions (11.22 days) while the lowest was found in the (control) P_1S_1 under ambient (4.33 days) and refrigerated conditions (7.15 days) with respect to other treatments. The treatment P_2 (LDPE-50 micron) and P_3 (LDPE-75 micron) under ambient conditions were statistically at par with each other. The genotype 'Camarosa' had shown maximum shelf life under ambient (5.30 days) and refrigerated conditions (10.20 days) while the lowest value was found in genotype 'Winter Dawn' under both storage conditions. The shelf life of fruits stored under various conditions was reported to be good under refrigerated storage and LDPE 50 micron due to the maintenance of various quality parameters as discussed. The continuous loss in quality of fruits during storages had restricted the storage of strawberry fruits up to 9-10 days under refrigerated condition and for 4-5 days under ambient condition (Panda *et al.*, 2016).

4.3.10. Polyphenol content (mg/100g)

The results presented in Fig 4.1 noticed a significant variation in respect to polyphenol content present in the fruits. In genotype Chandler, the minimum polyphenol content was observed in fruit without packaging material (control P_1) (177.44 mg/100g) under ambient condition. There was a significant decline in the polyphenol content in all treatments and presented in Fig.-4.1. The treatment (P_2S_2) fruits packed with LDPE-50 micron film showed lesser decline under refrigerate condition and ranged from 224.16 mg/100 g on 0^{th} day to 213.16 mg/ 100g on 4^{th} day of storage period. The highest decline was observed in control under ambient conditions. The treatment P2S2 (LDPE-50 micron) in genotype 'Winter Dawn' showed the lesser decline rate as compared to other treatments under refrigerated conditions which varied from 224.24 on the 0^{th} day to 213.58 mg/100g on 4^{th} day of storage period under refrigerated conditions. The highest decline rate was found in the treatment control (P_1) under ambient conditions. There was significant variation found

in all treatments. In genotype Camarosa, the lowest polyphenol content was recorded in control (196.44 mg/100g).

Table-4.54. Shelf life of fruits of different strawberry genotypes subjected to different packaging and storage conditions

	Storage conditions		
Packaging material	**S_1 (Ambient Temperature)**	**S_2 (Refrigerated Temperature)**	**Mean (P)**
P_1 (Control)	4.33^{e}	7.15^{c}	5.74^{c}
P_2(LDPE 50 micron)	5.54^{d}	11.22^{a}	8.38^{a}
P_3 (LDPE 75 micron)	5.43^{d}	10.81^{b}	8.12^{b}
Mean (S)	5.10^{b}	9.73^{a}	
CD (P≤0.05)			
S	**0.16**		
P	**0.20**		
S X P	**0.28**		
Genotype	**S_1 (Ambient Temperature)**	**S_2 (Refrigerated Temperature)**	**Mean (V)**
V_1(Chandler)	5.07^{de}	9.69^{b}	7.38^{b}
V_2(Winter Dawn)	4.93^{e}	9.30^{c}	7.11^{c}
V_3(Camarosa)	5.30^{d}	10.20^{a}	7.75^{a}
Mean (S)	5.10^{b}	9.73^{a}	
CD (P≤0.05)			
V	**0.199**		
S	**0.163**		
V X S	**0.282**		
V X P	**N/A**		
P X S X V	**N/A**		

The polyphenol content was significantly decreased with storage period in all treatments. The fruits packed with LDPE-50 micron film showed decline at slow rate under refrigerated condition and ranged from 229.83 mg/100g on the 0^{th} day to 216.32 mg/100g on 4^{th} day of storage period. All the treatments under refrigerated conditions reflected the lesser decline than ambient conditions.

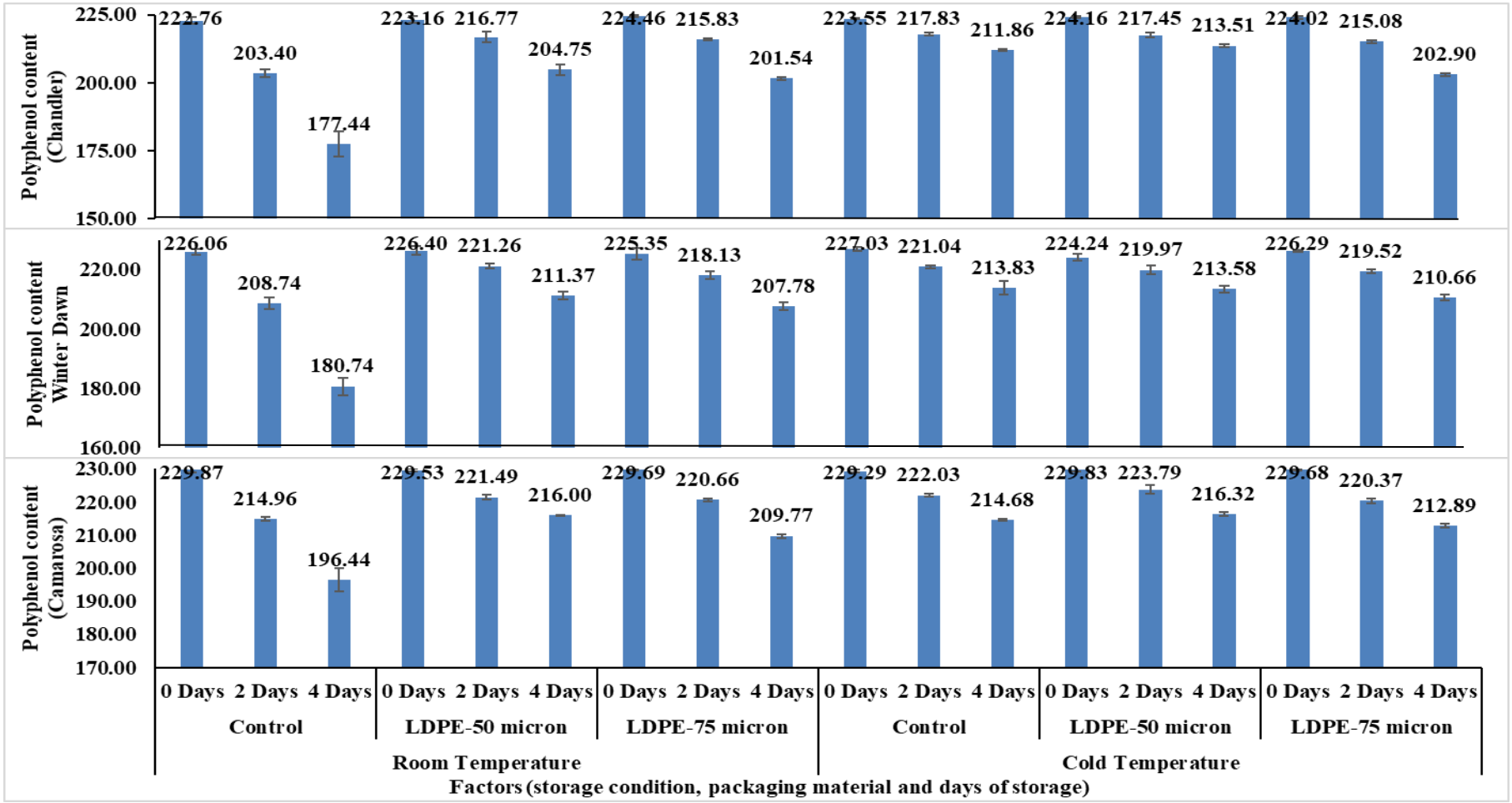


Fig4.1 Polyphenol content (mg/100g) of strawberry fruits subjected to different packaging and storage conditions

Polyphenols are an indicator of the quality of fruits which was very high in strawberry and show a rapid trend of breakdown after harvest. This breakdown was relatively smaller under refrigerated storage due to low enzymatic activities. However, this is accelerated in ambient storage conditions due to oxidation followed by degradation due to increased microbial load in stored products. Further, both LDPE 50 micron and LDPE 75 micron, of packaging materials have significantly maintained the polyphenols in the strawberry fruits due to the existence of a barrier between fruits and atmosphere, resulting in poor oxygen availability and microbial or metal contamination (Bhatia *et al*. 2015).

CHAPTER-V

SUMMARY&CONCLUSIONS

The study entitled "Germplasm evaluation and nutrient management in strawberry (*Fragaria* × *ananassa* Duch.) under Punjab conditions" was performed at Research Farm, Baba Farid College, Bathinda (Punjab) India from 2017 to 2019. The summary and conclusion inferred on the basis of the experimental findings mentioned in chapter-iv are being listed as following:

5.1. SUMMARY OF EXPERIMENT-I: GERMPLASM EVALUATION OF STRAWBERRY UNDER PUNJAB CONDITIONS

5.1.1. Vegetative characters

- The lowest mortality rate of plant (11.11 per cent) was observed in 'Camarosa' (V_3) which was statistically at par with 'Chandler' (V_1) whereas the highest mortality rate (52.38 per cent) was found in 'Sweet Charlie' (V_6).
- The highest plant height (12.07 cm) was observed in 'Chandler' (V_1) which was statistically followed by 'Camarosa' (V_3) (11.90 cm), and 'Winter Dawn' (V_2) (11.37 cm) whereas minimum height of plant was obtained in 'Hadar' (V_7) (8.83 cm) which was followed by 'E1-13#31' (V_9) (9.30 cm), 'E1-13#32' (V_5) (9.37 cm), and 'Sweet Charlie' (V_6) (9.47 cm).
- The 'Winter Dawn' (V_2) showed the highest (13.83 cm) plant spread followed by 'Camarosa' (V_3) (13.43 cm), 'Yamni' (V_{10}) (12.73 cm) and 'Chandler' (V_1) (12.70 cm) among all genotypes while, least plant spread (10.67 cm) was found in 'Hadar' which was almost similar to 'Sweet Charlie' (V_6) (10.75 cm).
- The highest leaves count (14.17) was found in the 'Chandler' (V_1) trailed by 'WinterDawn' (V_2) (13.58) and 'Camarosa' (V_3) (13.33) while minimum (9.50) was obtained in 'E-22' which was followed by 'E1-13#31' (V_9) (9.67) and 'Yamni' (V_{10}) (10.00).
- The greatest total leaf area of plant (74.03 cm^2) was observed in 'Camarosa' (V_3) which was statistically similar with 'Chandler' (V_1) (73.29 cm^2), 'WinterDawn' (V_2) (72.08 cm^2) whereas lowest (54.47 cm^2) was found in 'E-22' (V_{11}).

- The maximum runners per plant (10.33) were counted in 'Chandler' (V_1) which was at par with 'Camarosa' (V_3). The genotype 'Chandler' (V_1) took the minimum (162.77) days for runner formation which was closely followed by 'Camarosa' (V_3) (165.83).

5.1.2. Floral characters

- The genotype 'Camarosa' (V_3) recorded the maximum flower size (1.97 cm) which was significantly different from the other genotypes and was followed by 'Shani' (V_{12}) (1.94 cm), 'E1-13#32' (V_5) (1.92 cm), and 'E1-13#31' (V_9) (1.91 cm) while the lowest (1.76 cm) flower size was found in 'E-22' (V_{11}).
- The highest petal length in genotypes was recorded in 'E1-13#32' (0.88 cm) which was statistically at par with 'Camarosa' (0.87 cm), 'E1-13#31' (0.87 cm) and 'Shani' (0.86 cm) while lowest was observed in 'E-22' (0.74 cm) and closely related by (0.76 cm) 'Yamini'.
- The maximum breadth of petals was found in 'Hadar' (0.89 cm) which was statistically at par with 'Camarosa' (0.89 cm) while lowest was observed in 'E-22' (0.73 cm).
- The genotype 'E1-13#32', 'Sweet Charlie' showed the minimum stamens count (20) followed by 'FL-09-127' (20.33), E1-13#31' (20.33), 'E-22' (20.33), 'Hadar' (20.77) and 'E1-13#33' (20.77). The maximum (22.67) was found in Winter Dawn followed by 'Shani' (22),' Yamini' (22) and 'Camarosa' (22).
- The largest period of flowering (88 days) was obtained in 'Camarosa' which was statistically at par with genotype 'Chandler' (87.3 days) whereas smallest period of flowering (75.3 days) was recorded in genotype 'E-22'.
- The earliest flowering was produced in genotype 'Sweet Charlie' (72.33 days) while genotype E-22 took maximum day (88 days) to produce flowers after planting. The genotypes 'Chandler', 'Camarosa' and 'Winter Dawn' took 78.67 days, 79.67 days and 82 days respectively to produce flowers after planting.
- The maximum (21.67) flowers count per plant was registered in genotype 'Camarosa' which was at par with 'Winter Dawn' (20.66) and 'Chandler' (19.67) while genotype 'E-22' had produced the minimum flowers per plant.

5.1.3 Fruit characters

- The greatest fruit length was registered in genotype 'Camarosa' (3.87 cm) which was significantly at par with 'Chandler' (3.77 cm) while lowest (2.33 cm) fruit length was found in genotype 'E-22'. The maximum breadth of fruit was obtained in genotype 'E1-13#32' (3.28 cm) which was significantly at par with 'Camarosa' (3.22 cm) and 'Chandler' (3.17 cm) while minimum (2.17 cm) fruit breadth was registered in genotype 'E1-13#33'.
- The highest (12) calyx number per fruit was counted in genotype Chandler which was followed by 'E1-13#31' (11.33) and 'Camarosa' (11.33). The maximum (188.67) achene number per fruit was counted in genotype 'Camarosa' which was followed by 'Winter Dawn' (183.33).
- The highest fruit count (15.33) was noticed in genotype 'Camarosa' (V_3) which was followed by 'Chandler' (V_1) (14.67) and 'Winter Dawn' (V_2) (14.5). Maximum numbers of days taken for fruit maturity i.e. 23.67 were registered in genotype 'E1-13#32' followed by 'Camarosa' (23 days).
- The berry weight (12.77g) in 'Winter Dawn' was significantly heavier than other genotypes, which was at par with 'Camarosa' (12.63g) and 'Chandler' (12.4g).
- The highest (193.87g) yield per plant was produced in 'Camarosa' which was statistically at par with 'Winter Dawn' (184.9 g) and 'Chandler' (181.93g). 'Camarosa' was found to have highest yield per hectare (19.17 tonnes/hec) which was at par with 'Chandler' (V_1) (17.32 tonnes/hec) and 'Winter Dawn' (V_2) (16.99 tonnes/hec).
- The genotype 'Shani' (V_{12}) had recorded maximum (10°B) TSS which was statistically at par with 'Sweet Charlie' (V_6) (9.8°B), 'Camarosa' (V_3) (9.7°B) and 'Chandler' (V_1) (9.5°B). The titratable acidity varied from 0.78 % in 'Hadar' (V_7) to 0.97 % in 'E1-13#33' (V_8). The genotype 'Sweet Charlie' (V_6) showed (12.42) highest value of TSS-acid ratio which was statistically at par with 11.39 in 'Camarosa' (V_3) while the lowest value was found in 'E1-13#33' (V_8) (7.83).
- The maximum (6.12 percent) total sugar was obtained in 'Camarosa' (V_3) which was at par with 'Winter Dawn' (V_2) (6.07%), 'E1-13#33' (V_8) (6.05

%), ‘Shani’ (V_{12}) (6.01 %), ‘Chandler’ (V_1) (5.99%) and ‘E1-13#31’ (V_9) (5.94 %).

- The estimates of reducing sugar was having significant variation in genotypes and ranged from 4.17 % in ‘Sweet Charlie’ to 5.34 % in ‘Camarosa’ and ‘Winter Dawn’ (5.22 %). The highest non reducing sugar (1.05 %) was registered in genotype ‘E1-13#33’ which was at par with ‘Shani’ (V_{12}) (1.04%), ‘Sweet Charlie’ (V_6) (1.0 %) and ‘E1-13#31’ (V_9) (0.95 %) while minimum non reducing sugar (0.76 %) was obtained in ‘E-22’.
- The genotype ‘Winter Dawn’ (V_2) showed (7.28) highest Total sugar/acid ratio which was statistically followed by ‘Camarosa’ (V_3) (7.26), ‘Hadar’ (V_7) (7.09), ‘Chandler’ (V_1) (7.0) and ‘Yamini’ (V_{10}) (6.86).
- The genotype ‘Camarosa’ (70.11mg/100g) and ‘Shani’ (68.85 mg/100g) were at par with each other in terms of Vitamin C content.
- The genotype ‘Yamini’ (V_{10}) showed maximum (60.44 mg/100g) anthocynin content which was significantly at par with ‘Winter Dawn’ (V_2) (59.79 mg/100g) while minimum anthocyanin content was recorded in ‘Hadar’ (V_7).
- The maximum (2.88) pH of fruit juice was noticed in ‘Shani’ (V_{12}) which was followed by ‘Sweet Charlie’ (2.80).
- The highest specifc gravity was noted in ‘Camarosa’ (V_3) (1.08) followed by ‘Chandler’ (V_1) (1.06) and ‘Winter Dawn’ (V_2) (1.06) while the lowest was found in ‘E1-13#31’ (V_9) (0.97).

5.1.4. Parameters of variability

- High coefficients of variability were found for yield per hectare, number of fruits, yield per plant, mortality rate, number of flowers and number of runners per plant and may be used for improvement through selection.
- High heritability coupled with high genetic advance mean was observed for yield per hectare (92.54%), mortality rate (78.23%), yield per plant (59.54%), number of runners (56.92%) and number of fruits per plant (39.60%). The genetic advance was the highest for yield per plant (77.71) and number of achenes per fruit (34.89).

5.1.5. Correlation studies

- The correlation coefficients among the different characters were worked out at both phenotypic and genotypic levels. Genotypic correlations in general, were higher in magnitude than phenotypic ones.
- Plant height (0.943) and Plant spread (0.909) had positively correlated with maximum the parameters under estimation and highest correlation was shown with number of runners. Number of leaves per plant was having positive correlation with leaf area (0.924) and yield per hectare (0.775). Leaf area was positive correlation with specific gravity (0.984).
- Duration of flowering was closely positively associated with the number of flowers (0.970), number of fruit (0.932) and yield per hectare (0.902). The number of flowers was recorded to be positively correlated with number of fruits (0.984), yield per plant (0.958) and yield per hectare (0.934).
- Fruit length was strongly positively associated with number of achenes (0.996) and average berry weight (0.956). Fruit breadth was closely related to number of achenes (0.908). The duration of fruit maturity was positively correlated with average berry weight (0.838).
- TSS was closely associated with TSS: acid ratio (0.910) and vitamin C content (0.809). Reducing sugar was positively correlated with yield per hectare (0.754). TSS: acid ratio was positive correlated with average berry weight (0.719). Total sugar: acid ratio was positively associated with average berry weight (0.968). pH of fruit juice was positively correlation recorded with vitamin C content (0.814). Specific gravity was closely positively associated with yield per plant (0.865), average berry weight and yield per hectare (0.853).
- A strong positive correlation of the number of fruits was found with yield per plant (0.979) and yield per hectare (0.942). Average berry weight was closely correlated with yield per plant (0.911). Yield per plant was positive correlated with yield per hectare (0.965).

5.1.6. Path coefficient analysis

- The path coefficient analysis revealed that among the different characters of strawberry studied reducing sugar (3.636), yield per plant (2.35), non

reducing sugar (0.892), fruit length (0.271), petal length (0.224), leaf area (0.194), duration of flower (0.129), specific gravity (0.104), plant spread (0.077), petiole length (0.033), flower size (0.013), number of petal (0.006) and plant height (0.004) found to have positive direct effect on yield per hectare cultivated under Punjab conditions. The high positive indirect effects on yield per hectare were of Total sugar: acid ratio via mortality rate followed by TSS: acid ratio via titratable acidity and number of fruits via days to runner formation after planting (days)

Conclusion: The varieties/genotypes 'Winter Dawn', 'Chandler' and 'Camarosa' were reported to perform better under Punjab conditions on the basis of various growth, flowering, fruiting, yield and quality-related parameters.

5.2. SUMMARY OF EXPERIMENT-II: STANDARDIZATION OF NUTRIENT MANAGEMENT SCHEDULE OF STRAWBERRY UNDER PUNJAB CONDITIONS

5.2.1. Vegetative characters

- The lowest mortality rate (8.48 percent) was observed in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in three genotypes, T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) and T_8 (100%NPK + FYM + *Azotobacter*) while maximum mortality rate was found in the T_1 Treatment (Control) for all strawberry cultivars studied. The interaction between the genotype and treatment of nutrient was not significant.
- The height (12.6 cm) and spread (17.33 cm) of plants were observed maximum in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in all the three genotypes studied. The interaction between genotype and nutrient treatment was not statistically different from each other.
- The highest (19.87) number of leaves was counted in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) whereas the lowest was registered in T_1 (Control) in all the genotypes studied.
- The highest leaf area in 'Winter Dawn' (94.1 cm^2), 'Chandler' (98.4 cm^2) and 'Camarosa' (109.93 cm^2) was measured in treatment T_{11} (100%NPK + FYM +

vermicompost + *Azotobacter*) whereas the lowest was registered in T_1 (Control).

- The treatment T_{11} in genotype 'Camarosa' had produced (16.33) highest number of runners which was at par with T_8 (16) while the lowest was obtained in the treatment (8.33) T_1 followed by (8.67) T_4 (50%NPK), T_3 (75%NPK) and T_7 (50%NPK +FYM). The largest value (16) of number of runners was counted in treatment T_{11} in Chandler and smallest value was in T_1 (Control) (7.67). In 'Winter Dawn', the treatment T_{11} was performed better in terms of number of runners in comparison to other nutrient treatments. There was no significant effect shown with interaction with genotypes and nutrient treatments.
- The runner formation was produced (147.3 days) earlier in treatment T_{11} in 'Chandler' but late production of the runner was found in T_4 (50% NPK). The genotype 'Camarosa', the treatment T_{11} took minimum days taken for runner formation while the maximum was in treatment T_1 and T7. The same result was found in 'Winter Dawn' that treatment T_{11} (156.67 days) showed minimum days taken to runner formation followed by T_{12} (158.33 days).

5.2.2. Flower characters

- The earliest flowering (69.11 days) was produced in treatment T_{11}(100%NPK + FYM + vermicompost + *Azotobacter*) in strawberry after planting which was at par to T_8(100%NPK + FYM + *Azotobacter*) and T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*).
- The largest period of flowering (79.33 days) was registered in treatment T_{11} in 'Camarosa' while the smallest period (47.67 days) was in treatment T_1 (Control). Similarly, results were obtained in 'Winter Dawn' and 'Chandler' that treatment T_{11} produced flowering for the longest period but treatment T_1 produced flowering for smallest period. The genotype and nutrient treatment interactions showed significant variation and the largest period of flowering was observed in V_3T_{11} which was statistically at par with V_2T_{11} in comparison to other treatmentswhereas the smallest period of flowering was recorded in V_1T_1 (Control).

- The greatest count of flowers (24.49) per plant was noticed in T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in three genotypes but the lowest (14.02) was counted in treatment T_1 (Control). Among genotypes, it was in the order of 'Camarosa', 'Winter Dawn' and 'Chandler'.

5.2.3. Fruit characters

- The largest length of fruit was registered in treatment T_{11} in 'Chandler' (3.79 cm) while lowest (2.47 cm) length was found in treatment T_4 and T_1. Similar results were found in the 'Winter Dawn' genotype. The treatment (3.87 cm) T_{11} in genotype 'Camarosa' showed maximum length of fruit which was at par with T_8 whereas treatment T_1 (2.7) and T_4 (2.6) was the lowest fruit length. There was a nonsignificant difference between genotype and nutrient treatment. Similar trend was reported for fruit breadth.
- The highest (22.07) fruit count per plant was obtained in treatment T_{11} in genotype 'Camarosa', 'Winter Dawn' (20.73) and (19.73) 'Chandler' while lowest was in treatment T_1 (Control) and T_4 (50% NPK). The variation in fruit count was significantly influenced by the interaction of genotype and nutrient treatments and the greatest number of fruits was produced in (22.07) V_3T_{11} in comparison to the rest of the treatments.
- The treatment T_{11} took lesser days to fruit maturity which was at par with treatment T_8 in all the cultivars. The interaction between genotype and nutrient treatment was not significant.
- The maximum berry weight in genotype 'Camarosa' was recorded in (12.97 g) treatment T_{11} while least berry weight was found in treatment T_1 (7.53 g) followed by T_4 (7.66 g). A similar trend was noticed in 'Chandler' and 'Camarosa'. A significant variation was reported in the interaction effect of genotype and nutrient treatments and maximum berry weight was found in V_3T_{11} (12.97 g) followed by V_3T_8 (12.44g) while least weight of berry was in V_2T_1 (6.85 g).
- The treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) showed highest value with respect to yield per plant in genotype 'Camarosa' (285.25 g), 'Chandler' (233.15 g) and 'Winter Dawn' (229.58 g). A similar

observation was noticed for yield in tonnes per hectare. The interaction between genotype and nutrient treatment was found a significant difference with each other. The treatment V_2T_8, V_3T_9, V_1T_8 and V_1T_{12} were at par with each other.

- Maximum TSS in genotype 'Chandler' (10.17 ^oB) and 'Camarosa' (10.43^oB) was obtained in the treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) whereas lesser amount of acidity was recorded in treatment T_{12} and T_{11} followed by T_8 for all the three varieties. The treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) in all genotype had shown the maximum TSS/acid ratio.
- The maximum (6.73 percent) total sugar in genotype 'Camarosa' was measured in treatment T_{11} while the lowest was obtained in treatment T_1 (4.87 percent) which was at par T_4 (4.90 percent). The genotype 'Winter Dawn' (V_2) with treatment T_{11} registered (6.38 per cent) maximum total sugar which was closely related by (6.28 percent) T_8 whereas the least total sugar was found in treatment (4.67 percent) T_1 followed by treatment (4.71 percent) T_4. The treatment T_1 in 'Chandler' (4.4 percent) obtained lowest total sugar and highest total sugar (6.25 percent) was found in treatment T_{11}. A similar trend was noticed for total sugar: acid ratio, non-reducing and reducing sugar.
- The maximum value of anthocyanin content in genotype 'Camarosa' (59.66 mg/100g) and 'Chandler' (58.74 mg/100g) was found in the treatment T_{11} which was closely followed by treatment (59.58 mg/100g and 58.54 mg/100g) T_8 while minimum in genotype 'Camarosa' (47.11mg/100g) and 'Chandler' (46.74 mg/100g) was in treatment T_1. The treatment T_{11} in 'Winter Dawn' showed (61.72 mg/100g) highest value of anthocyanin content while the lowest value (48.98 mg/100g) was found in treatment T_1. There was no significant impact on the interaction of genotype and nutrient treatments over anthocyanin content.
- The shelf life of strawberry fruit genotype 'Chandler' was found (4.80 days) maximum in treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*). The results were the same found in the genotype 'Camarosa'

(4.83 days) and 'Winter Dawn' (4.90 days) that treatment T_{11} showed the best shelf life as compared to other treatments and lowest was in control (T_1).

5.2.4. Benefit-Cost ratio

- The maximum benefit cost ratio was measured in the (10.32, 10.14, 13.32) treatment T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*) which was followed by treatment (8.82, 9.35, 11.91) T_8 (100%NPK + FYM + *Azotobacter*) and (8.19, 8.03, 11.14) T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) and the maximum net income also observed in these treatments T_{11}, T_8 and T_{12} for genotypes 'Chandler', 'Winter Dawn' and 'Camarosa', respectively.

Conclusion: On the basis of various growth, flowering, fruiting, yield, quality and Benefit-cost ratio related parameters it can be confirmed that the INM practices T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*), T_8 (100%NPK + FYM + *Azotobacter*) and T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*) are best for the cultivation of three cultivars viz. Chandler, Winter Dawn and Camarosa under Punjab conditions.

5.2. SUMMARY OF EXPERIMENT-III: EFFECT OF DIFFERENT PACKAGING MATERIAL AND STORAGE CONDITION ON SHELF-LIFE EXTENSION OF STRAWBERRY FRUITS

- The minimum weight loss was found in the packaging treatment P_2 (LDPE 50 micron) at ambient and refrigerated temperatures. A significant interaction between packaging material and storage period under different storage conditions. The least weight loss was obtained in the treatment P_2S_2 (refrigerated condition) and the maximum was in P_1S_1 (ambient condition) in 'Chandler'. Similar results were recorded in genotype 'Winter Dawn' and 'Camarosa'.
- The maximum TSS content in genotype 'Chandler' was observed in fruit packed in (9.82 ^oB) LDPE 50 micron under both conditions viz. ambient and refrigerated storage. The fruit packed in LDPE 75 micron under the refrigerated temperature showed more retain (9.58^oB) TSS in fruit genotype

'Winter Dawn'. The highest value of TSS content in genotype 'Camarosa' was observed in fruit packed with (9.90 ^{o}B) LDPE 50 micron (P_2) at refrigerated temperature.

- The higher acidity content was found when 'Chandler' fruit packed in LDPE 50 micron (0.82 percent) and LDPE 75 micron (0.82 percent) under the refrigerated storage. The genotype 'Winter Dawn' fruit packed with (P_2) LDPE 50 micron showed (0.78 percent) maximum value of acidity under refrigerated temperature. In the case of 'Camarosa', the fruits packed with (76 percent) (P_2) LDPE 50 micron and (P_3) LDPE 75 micron (76 percent) had shown the maximum value of acidity in fruit.
- The genotype 'Chandler' fruit packed in (P_2) LDPE 50 micron showed (11.97) lower value of TSS/acid ratio which was statistically at par with (11.98) fruit packed in (P_3) LDPE 75 micron under the refrigerated condition. In genotype 'Winter Dawn', the minimum (12.25) was found in treatment P_2 (LDPE 50 micron) under the refrigerated condition. The fruit packed with treatment (P_3) LDPE 75 micron in genotype 'Camarosa' under the refrigerated conditions was noticed (13.02) lowest value of TSS/acid ratio which was closely followed by treatment (P_2) LDPE 50 micron (13.10).
- The highest total sugar content (5.88 %) was noticed in packed fruit with P_2 (LDPE-50 micron) under refrigerated temperature in 'Chandler', (6.11%) treatment P_3 (LDPE-75 micron) under refrigerated condition in 'Winter Dawn' and P_2 (LDPE-50 micron) noticed the higher sugar content under (6.11%) ambient and (6.12%) refrigerated conditions. A similar trend was noticed for reducing.
- The maximum vitamin C content was found in fruit packed with P_2 (LDPE-50 micron) under (54.83 mg/100g) refrigerated conditions in 'Chandler', (51.92 mg/100g) fruit packed in P_2 (LDPE-50 micron) under the refrigerated condition in 'Winter Dawn' and in LDPE-50 micron in genotype 'Camarosa' under (59.08 mg/100g) refrigerated condition.
- The treatment P_2S_2 (LDPE-50 micron) showed hte highest shelf life under refrigerated conditions in three cultivars.

- The treatment (P_2S_2) fruit packed with LDPE-50 micron film showed lesser decline in polyphenol content under refrigerate condition and ranged from 224.16 mg/100 g on 0^{th} day to 213.16 mg/ 100g on 4^{th} day of storage period. The highest decline was observed in control under ambient conditions.

Conclusion: On the basis of various quality parameters during the storage of strawberry fruits after packaging with LDPE-50micron film under refrigerated temperature was reported to be best.

Thus, on the basis of experimental findings and summary reports it can be concluded that the varieties Winter Dawn, Chandler and Camarosa are suitable for cultivation under Punjab conditions. The farmers can adopt INM practices for getting the higher income which may include T_{11} (100%NPK + FYM + vermicompost + *Azotobacter*), T_8 (100%NPK + FYM + *Azotobacter*) and T_{12} (75%NPK + FYM + vermicompost + *Azotobacter*). The shelf life of fruits can be enhanced by packaging the fruits with LDPE-50 micron film and storing under refrigerated temperature.

BIBLIOGRAPHY

Ahmad, D., & Mohammad, J. (2012). Impact of integrated organic nutrient handling on fruit yields and quality of strawberry. *J. of Ornamental and Horticultural Plants*, *2*(4), 251-256.

Ahmadi, E., Honnabyraiah, M. K., Alur, A. S., Adiga, J. D., & Rao, V. (2017). Impact of Integrated Nutrient Management on Yield and Quality Parameters of Strawberry (*Fragaria*× *ananassa*Duch.) cv.‟ Sabrina" under Polyhouse. *Int. J. Curr. Microbiol. App. Sci*, *6*(9), 3481-3487.

Ahmed, Q., Roy, S., Islam, M., Hoque, A., & Islam, M. (2019). Investigation of vegetative growth, flowering and fruiting in different strawberry genotypes at Narsingdi District. *Int. J. Expt. Agric.*, *9*(1), 6-10.

Ahokas, H. (1999). Spontaneous tetraploidy in strawberry (Fragaria sp., Rosaceae). *Nordic Journal of Botany*, *19*(2), 227-234.

Akash, S., Singh, D. B., Sharma, R. K., & Umar, I. (2009). Comparative evaluation of strawberry (Fragaria× *ananassa* Duch.) cultivars under Allahabad conditions. *Asian Journal of Horticulture*, *4*(1), 178-180.

Akash, S., Wali, V. K., Bakshi, P., & Jasrotia, A. (2013). Effect of organic and inorganic fertilizers on quality and shelf life of guava (*Psidium guajava* L.) cv. Sardar. *The Bioscan*, *8*(4), 1247-1250.

Akiyama, Y., Yamamoto, Y., Ohmido, N., Ohshima, M., & Fukui, K. (2001). Estimation of the nuclear DNA content of strawberries (*Fragaria* spp.) compared with Arabidopsis thaliana by using dual-step flow cytometry. *Cytologia*, *66*(4), 431-436.

Ali, Y., Iqbal, M., Shah, S. Z. A., & Ahmed, M. J. (2003). Effect of different combinations of nitrogen, phosphorous and farm yard manure on yield and quality of strawberry. *Sarhad Journal of Agriculture, 19, 185-188.*

Al-Jibouri, H., Miller, P. A., & Robinson, H. F. (1958). Genotypic and Environmental Variances and Covariances in an Upland Cotton Cross of Interspecific Origin 1. *Agronomy journal*, *50*(10), 633-636.

Allard, R. W. (1960). Principles of Plant Breeding, John Willey and Sons Inc. *New York*, 36.

Amjad, M., Iqbal, J., Iqbal, Q., Nawaz, A., Ahmad, T., & Rees, D. (2009, April). Effect of packaging material and different storage regimes on shelf life and biochemical composition of green hot pepper fruits. In *X International Controlled and Modified Atmosphere Research Conference 876* (pp. 227-234).

AOAC. (1990). Official and Tentative Methods of Analysis, Association of Official Agric chemists, 15th Ed. Washington, DC, USA.

AOAC. (2000). Official Methods of Analysis, 15th Edition. Association of Agric Analytical chemists, Washington DC, USA.

Arancon, N. Q, Edwards, C.A., Beriman, P., Metzger, J.D., Lee, S., & Weich, C. (2003). Effect of vermicompost on growth and marketable fruit of field grown strawberry. *Pedbiologia, 47*(5-6), 731–5.

Arancon, N. Q., Edwards, C. A., Bierman, P., Welch, C., & Metzger, J. D. (2004). Influences of vermicomposts on field strawberries: 1. Effects on growth and yields. *Bioresource technology*, *93*(2), 145-153.

Asrey, R., & Singh, R. (2004). Evaluation of strawberry varieties under semi-arid irrigated region of Punjab. *Indian Journal of Horticulture*, *61*(2), 122-124.

Athani, S.I., Ustad, A.I., Prabhuraj, H. S., Swamy G. S.K., Patil, P.B., & Kotikal, Y.K. (2007). Influence of vermicompost on growth, fruit, yield and quality of guava cv. Sardar. *Acta Horticulturae*, 73(5), 381-385.

Attia, M., Ahmed, M.A., & El-Sanbaty, M.R. (2009). Use of biotechnologies to increase growth, productivity and fruit quality of Moghrabi banana under different rates of phosphorus. *World J. Agril. Sci*., *5*, 211-20.

Avidov, H. A., & Shaul, P. (1986). Handbook of fruit set and development. Florida, CRC press, Inc.

Ayaz, M., Ahad, S. F., & Ur Rehman, K. (1998). Evaluation of strawberry varieties for Malakand division. *Sarhad Journal of Agriculture, 14*(4), 317-320

Babarinde, G. O., & Fabunmi, O. A. (2009). Effects of packaging materials and storage temperature on quality of fresh okra (*Abelmoschus esculentus*) fruit. *Agricultura Tropica Et. Subtropica*, *42*(4), 151-156.

Bailey, J. S., & Rossi, A. W. (1965). Effect of fall chilling, forcing temperature and day length on the growth and flowering of catskill strawberry plants. In *Proc. Amer. Soc. Hort. Sci, 87,* 245-252.

Bairwa, H. L., Shukla, A. K., Mahawer, L. N., Kaushik, R. A., Shukla, K. B., & Ameta, K. D. (2009). Response of integrated nutrient management on yield, quality and physico-chemical characteristics of okra cv. Arka Anamika. *Indian Journal of Horticulture, 66*(3), 310-314.

Baksh, H., Yadav, R., & Dwivedi, R. (2008). Effect of INM on growth, yield, yield attributing characters and quality of guava (*P. guajava* L.) cv. Sardar. *Progressive Agriculture, 8*(2), 141-144.

Bartczak, M., Lisiecka, J., & Knaflewski, M. (2010). Correlation between selected parameters of planting material and strawberry yield. *Folia Horticulturae, 22*(1), 9-12.

Baumann, T. E., Eaton, G. W., & Spaner, D. (1993). Yield components of day-neutral and short day strawberry varieties on raised beds in British Columbia. *Horticultural Science, 28*(9), 891-894.

Baviskar, M. N., Bharad, S. G., Dod, V. N., & Barne, V. G. (2011). Effect of Integrated Nutrient Management on yield and quality of sapota. *Plant Archives, 11*(2), 661-663.

Beer, K., Kumar, S., Alok, K., Gupta, & Syamal, M.M. (2017). Effect of organic, inorganic and bio-fertilizer on growth, flowering, yield and quality of strawberry (*Fragaria × ananassa* Duch.) cv. Chandler. *Int. J. Curr. Microbiol. App. Sci.*, 6(5), 2932-2939.

Belakhud, B., Bahadur, V. & Prasad, V.M. (2015). Performance of strawberry *(Fragaria x ananassa Duch.)* varieties for yield and biochemical parameters. *Pharma Innovation Journal, 4*(10), 05-08.

Beniwal, L. S., Daulta, B. S. & Bisla, S. S. (1989). Evaluation of different strawberry (*Fragaria ananassa*) cultivars under Hisar conditions. *Haryana Journal of Horticultural Sciences, 18*(1-2), 34-39.

Bhatia, K., Asrey, R., & Varghese, E. (2015). Correct packaging retained phytochemical, antioxidant properties and increases shelf life of minimally processed pomegranate (*Punica granatum* L.) arils cv. Mridula. *Journal of Scientific and Industrial Research, 74*(3), 141-144.

Brown, G. R., & Moore, J. N. (1975). Inheritance of fruit detachment in strawberry. *Journal American Society for Horticultural Science, 100*(5), 569-572.

Brown, T., & Wareing, P. F. (1965). The genetical control of the everbearing habit and three other characters in varieties of Fragaria vesca. *Euphytica*, *14*(1), 97-112.

Burmistrov, L. A. (1988). Analysis of yield components in foreign bred varieties in North West of the country. Sbornik Nauchnykh Trudov po PrikladnoiBotanike. *Genetikei Selekstsii*, *119*, 124-130.

Burton, G. W., & Devane, E. H. (1953). Estimating heritability in tall fescue (Festuca arundinacea) from replicated clonal material 1. *Agronomy Journal*, *45*(10), 478-481.

Burton, G.W., 1952. Quantitative inheritance in grasses. Proc. Int. Grassland Congr., *1*, 277-283.

Chandel, J. S. & Badiyala, S. D. (1997). Performance of strawberry cultivars in foothills of Himachal Pradesh. *Ann. Agric. Res.*, *17*, 375-78.

Chandler, C. K., Legard, D. E., Dunigan, D., Crocker, T. E., & Sims, C. A. (2000). 'Strawberry festival'strawberry. *HortScience*,*35*(7), 125.

Changotra, P., Bashir, D., Hussain, S., & Kaur, A. (2017). Cultivation of strawberry (*Fragaria*× *ananassa* Duch.) cv. Chandler as affected by bio and inorganic fertilizers under open conditions. *Global Journal of Bio science and Biotecnology*, *6*(2), 332-343.

Chumyani, S.P., Kanaujia, S., Singh, V.B., & Singh, A.K. (2010). Effect of Integrated Nutrient Management on growth, yield and quality of tomato. *J. Soil & Crop.*, 22(1), 67-71.

Cordrey, T. D., Lockwood, D. W., Mullins, C. A., & Brown, J. F. (1980). Evaluation of strawberry cultivars for Tennessee. *Tennessee Farm and Home Science*, (113), 54-56.

Craig, D. L., & Brown, G. L. (1977). Influence of digging date, chilling, cultivars and culture on glasshouse strawberry production in Nova Scotia. *Canadian Journal of Plant Science*, *57*(2), 571-576.

Crespo, P., Bordonaba, J. G., Terry, L. A., & Carlen, C. (2010). Characterisation of major taste and health-related compounds of four strawberry genotypes grown at different Swiss production sites. *Food Chemistry*, *122*(1), 16-24.

Dadashpour, A., & Jouki, M. (2012). Impact of integrated organic nutrient handling on fruit yields and quality of strawberry cv. Kurdistan in Iran. *Journal of ornamental plants, 2*(4), 251-256.

Dar, G. A., Reshi, T. A., Sheikh, M. A., & Shagoo, P. A. (2010). Effect of nitrogen, phosphorus and potassium on growth, yield and quality of strawberry (*Fragaria× ananassa* Duch) cv Sweet Charlie. *Environment and Ecology*, *28*(2B), 1216-1219.

Darrow, G. M. (1936). Interaction of temperature and photoperiodism in the production of fruit buds and runners in the strawberries. *Proc Amer Hort Sci*, 34, 360-63.

Darrow, G. M. (1966). *The strawberry* . New York, Holt, Rinehart and Winston, Pp. 348.

Das, A. K., Singh, B., & Sahoo, R. K. (2006). Correlation and path analysis in strawberry (*Fragaria x ananassa* Duch). *Indian Journal of Horticulture*, *63*(1), 83-85.

Das, A. K., Singh, K. P., Prasad, B., & Ravindra, K. (2015). Evaluation of cultivars of strawberry, a temperate fruit for its adaptability as well as productivity in sub-tropical agro-climatic condition of Supaul district in Bihar. *Asian Journal of Horticulture*, *10*(2), 278-281.

Das, B., Nath, V., Jana, B. R., Dey, P., Pramanick, K. K., & Kishore, D. K. (2007). Performance of strawberry cultivars grown on different mulching materials under sub-humid subtropical plateau conditions of Eastern India. *Indian Journal of Horticulture*, *64*(2), 136-143.

Dass, A., Lenka, N. K., Patnaik, U. S., & Sudhishri, S. (2008). Integrated nutrient management for production, economics, and soil improvement in winter vegetables. *International Journal of Vegetable Science*, *14*(2), 104-120.

Dass, A., Lenka, N. K., Sudhishri, S., & Patnaik, U. S. (2008). Influence of integrated nutrient management on production, economics and soil properties in tomato (Lycopersicon esculentum) under on-farm conditions in Eastern Ghats of Orissa. *Indian Journal of Agricultural Sciences*, *78*(1), 40.

Davis, T.M., Denoyes-Rothan, B., Lerceteau-Köhler, E., & Kole, C., (2007) Strawberry, Genome Mapping and Molecular Breeding Inplants. *Fruit and Nuts, 4*, 189-205.

Debnath, S. C. (2016). Genetic diversity and erosion in berries. In *Genetic Diversity and Erosion in Plants*, 75-129.

Deepa, D. H., Chaturvedi, S. K., Ram, R. B., & Maurya, D. (2012). Flowering, fruiting and yield of some strawberry cultivars under Lucknow conditions. *Progressive Horticulture*, *43*(2), 200-202.

Dermen, H., & G. M. Darrow (1938). Colchicine induced terraploid and 16-ploid strawberries. *Proc. Amer. Soc. Hort. Sci., 36,* 300-301.

Devi, H. L., Mitra, S. K., & Poi, S. C. (2012, April). Effect of different organic and biofertilizer sources on guava (*Psidium guajava* L.) 'Sardar'. In *III International Symposium on Guava and other Myrtaceae 959* (pp. 201-208).

Dewey, D. R., & Lu, K. (1959). A Correlation and Path-Coefficient Analysis of Components of Crested Wheatgrass Seed Production. *Agronomy journal*, *51*(9), 515-518.

Dhaliwal, G. S., & Singh, K. (1983). Evaluation of strawberry cultivars under Ludhiana conditions. *Haryana Journal of Horticultural Sciences*. 12(1/2), 36- 40.

Diamanti, J., Capocasa, F., Balducci, F., Battino, M., Hancock, J., & Mezzetti, B. (2012). Increasing strawberry fruit sensorial and nutritional quality using wild and cultivated germplasm. *PLoS One*, *7*(10), e46470.

Durner, E. F., & Poling, E. B. (1987). Flower bud induction, initiation, differentiation and development in the 'Earliglow'strawberry. *Scientia Horticulturae*, *31*(1-2), 61-69.

Durner, E. F., Barden, J. A., Himelrick, D. G., & Poling E.B. (1984). Photoperiod and temperature effects on flower and runner development in day-neutral, June-bearing and ever-bearing strawberries. *Journal of the American Society for Horticultural Science*, 110, 808-811.

Fernandez, G. E. (2001). Fall applied row covers enhance yield in plasticulture strawberries. *Hort Tech*, 2, 46-51.

Finn, C. E., Retamales, J. B., Lobos, G. A., & Hancock, J. F. (2013). The Chilean strawberry (*Fragaria chiloensis*): Over 1000 years of domestication. *HortScience*, *48*(4), 418-421.

Funaro, M., Mercuri, F., & Spagnolo, G. (2000). Evaluation of strawberry varieties in Calabria. *Informatore Agrario*, *56*(27), 41-45.

Gaikwad, S. P., Sali, V. M., & Chalak, S. U. (2018). Performance of strawberry cultivars under Mahabaleshwar conditions. *Journal of Pharmacognosy and Phytochemistry*, *7*(4), 1850-1852.

Garg, S. (2013).Variability and association studies in strawberry (*Fragaria x ananassa*). (MSc. Thesis), Dr. Y.S. Parmar University of Horticulture and Forestry.

Garg, S., Sharma, G., Lata, S., & Yadav, A. (2014). Correlation and path analysis among different vegetative, floral and fruit characters in strawberry (*Fragaria* x *ananassa* Duch.). *The Ecoscan*, 379-384.

Germain, P., Navatel, J. C., & Roudeillac, P. (1996). For quality strawberries; what to plant tomorrow. *Pourdes Fraises de qualite: que planter demain Infos (Paris),119*, 40-44.

Giongo, L. A. R. A., Grisenti, M. A. R. C. E. L. L. A., Eccher, M., Ieri, F., Vrhovsek, U., Mattivi, F., & Faedi, W. (2006). First evaluation of strawberry genotypes grown in Italian mountain areas. *Acta horticulturae*, (*708*), 535-539.

Giuggioli, N. R., Briano, R., Baudino, C., & Peano, C. (2015). Effects of packaging and storage conditions on quality and volatile compounds of raspberry fruits. *CyTA-Journal of Food*, *13*(4), 512-521.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John Wiley & Sons.

Grewal, G. S., & Dhaliwal, G. S. (1984). Vegetative growth and fruiting of strawberry plants under sub-tropical conditions (India). *Journal of Research-Punjab Agricultural University (India)*, *21*(2), 191-198.

Gunduz, K., & Ozdemir, E. (2003). The determination of flowering, harvesting period and yield of some strawberry cultivars cultivated in the field and in high tunnels in Amik plain. *ZirFak Der Mustafa Univ*, 8, 9-17.

Gupta, A. K., & Tripathi, V. K. (2012). Efficacy of *Azotobacter* and vermicompost alone and in combination on vegetative growth, flowering and yield of strawberry (*Fragaria* x *ananassa* Duch.) cv. Chandler. *Progressive Horticulture*, *44*(2), 256-261.

Gupta, U. (1998). *Description and evaluation of strawberry cultivars under mid hills of* H.P. (Thesis, M.Sc.), Dr. YSPUHF, Solan (HP), India.

Guttridge, C. G. (1958). The effects of winter chilling on the subsequent growth and development of the cultivated strawberry plant. *Journal of Horticultural Science*, *33*(2), 119-127.

Haffner, K., & Vestrheim, S. (1997). fruit quality of strawberry cultivars. *Acta Horticltuae*, 439, 1 (Abstr).

Hancock Jr, J. F., & Bringhurst, R. S. (1978). Inter-populational differentiation and adaptation in the perennial, diploid species *Fragaria* vesca. *American Journal of Botany*, *65*(7), 795-803.

Hancock, J. F., Lavín, A. R. T. U. R. O., & Retamales, J. B. (1999). Our southern strawberry heritage: *Fragaria chiloensis* of Chile. *HortScience*, *34*(5), 814-816.

Hancock, J. F., Luby, J. J., Dale, A., Callow, P. W., Serce, S., & El-Shiek, A. (2002). Utilizing wild *Fragaria virginiana* in strawberry cultivar development: Inheritance of photoperiod sensitivity, fruit size, gender, female fertility and disease resistance. *Euphytica*, *126*(2), 177-184.

Hancock, J. F., Siefker, J. H., & Schulte, N. L. (1983). Cultivar variation in yield components of strawberries. *HortScience (USA)*.

Hancock, J. F., Sjulin, T. M., & Lobos, G. A. (2008). Strawberries. In *Temperate fruit crop breeding*, 393-437.

Hancock, J. F., Sjulin, T. M., & Lobos, G. A. (2008). Strawberries. In Temperate fruit crop breeding (pp. 393-437). Springer, Dordrecht.

Hansche, P. E., Bringhurst, R. S., & Voth, V. (1967). Estimates of genetic and environmental parameters in strawberry. *Proceedings of American Society for Horticultural Science*, *92*, 338-345.

Hanson, E. J. (1989). Performance of strawberry cultivars in the north central region of The United-States. *Fruit Varieties Journal*, *43*(4), 151-154.

Haque, M. S., Nath, U. K., Iqbal, M. S., ara Khatun, R., & Jani, A. H. A. A. (2015). Assessment of field performance and genetic diversity analysis of tissue culture variants of strawberry. *Journal of Agricultural Technology*, *11*(1), 107-125.

Hassan, G. I. Godara, A. K., Kumar, J. and Huchche, A. D. (2001). Evaluation of different strawberry (*Fragaria* x *ananassa* Duch.) cultivars under Haryana conditions. *Haryana Journal of Horticultural Sciences, 30(1-2),* 41-43.

Hazarika, T. K., Nautiyal, B. P., & Bhattacharya, R. K. (2011). Effect of INM on productivity and soil characteristics of tissue cultured banana cv. Grand Naine in Mizoram, India. *Progressive Horticulture*, *43*(1), 30-35.

Herbert, S.J. (1998). Deptt. Of Plant and Soil Sci., Univ. of Massachusetts Amherst Crops, Dairy, Livestock News. 3:1.

Hoashi-Erhardt, W., Moore, P., Collins, D., Bary, A., & Cogger, C. (2013). Evaluation of day-neutral cultivars for organic strawberry production in Washington. *Acta Horticulturae,* 1001, 167-174.

Hoashi-Erhardt, W., Moore, P., Collins, D., Bary, A., & Cogger, C. (2012, June). Evaluation of day-neutral cultivars for organic strawberry production in Washington. In *II International Organic Fruit Symposium 1001* (pp. 167-174).

Hortynski, J. A. (1979). Correlation and path analysis in strawberry seedlings (*Fragaria* x *ananassa* Duch.). *Genetica-Polonica, 20(4),* 549-566.

Hortynski, J. A. (1989). Correlation in strawberry breeding programmes. *Acta Horticulturae, 265*, 169-173.

Hortynski, J., Flis, I. and Hulewicz, T. (1976). Phenotypic correlations concerning generative and vegetative characters in the strawberry (*Fragaria* x *ananassa* Duch.). *Zeitschrift-fur-Pflanzenzuchtung, 77(2),* 121-132.

Hytönen, T., Graham, J., & Harrison, R. (Eds.). (2018). *The genomes of Rosaceous berries and their wild relatives*.

Iqbal, U. M. A. R., Wali, V. K., Ravi, K., &Jamwal, M. (2009). Effect of FYM, Urea and *Azotobacter* on growth, yield and quality of strawberry cv. Chandler. *NotulaeBotanicaeHortiAgrobotanici Cluj-Napoca*, *37*(1), 139-143.

Iqbal, U., Wali, V. K., Kher, R., & Sharma, A. (2008). Impact of integrated nutrient management on strawberry yield and soil nutrient status. *Applied Biological Research*, *10*, 22-25.

Isobe, S. N., Hirakawa, H., Sato, S., Maeda, F., Ishikawa, M., Mori, T., & Hashizume, F. (2013). Construction of an integrated high-density simple sequence repeat linkage map in cultivated strawberry (*Fragaria* × *ananassa*) and its applicability. *DNA Research*, *20*(1), 79-92.

Jackson, M. L.,(1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd. *New Delhi*, pp. 498.

Jahn, O. L., & Dana, M. N. (1966). Dormancy and growth of the strawberry plant. *Proc. Am. Soc. Hort. Sci.*, *89*, 322–330.

Jain, N., Mani, A., Kumari, S., Kasera, S., & Bahadur, V. (2017). Influence of INM on yield, quality, shelf life and economics of cultivation of strawberry (*Fragaria* × *ananassa* Duch.) cv. Sweet Charlie. *Journal of Pharmacognosy and Phytochemistry*, *6*(5), 1178-1181.

Jami, Y. Y., Sarkar, A., & Maiti, C. S. (2015). Evaluation of strawberry cultivars in the foothills of Nagaland. *Journal Crop and Weed*, *11*, 198-200.

Jamwal, S., Mishra, S., & Singh, S. (2018). Effect of integrated nutrient management on physical characteristics of Guava under Meadow Orcharding cv. Allahabad Safeda. *Journal of Pharmacognosy and Phytochemistry*, 2076-2079.

Jat, M. L., Parihar, C. M., Jat, S. L., Tetarwal, J. P., Jat, R. K., & Saharawat, Y. S. (2013). Fertilizer best management practices for maize systems. *Indian J. of Fertilizers*, 9, 80-94.

Johanson, H. W., Robinson, H. F. & Comstock, R. E. (1955). Estimates of genetic and environmental variability in soybean. *Agronomy Journal, 47*, 314-318.

Joolka, N. K., & Badiyala, S. D. (1983). Studies on the comparative performance of strawberry cultivars. *Haryana Journal of Horticultural Sciences*., 12(3-4), 173-177.

Kachot, N. A., Malavia, D. D., Solanki, R. M., & Sagarka, B. K. (2001). Integrated nutrient management in rainy-season groundnut (*Arachis hypogaea*). *Indian Journal of Agronomy*, *46*(3), 516-522.

Kadlage, A., Jadhav, A. B., & Raina, B. (2007). Yield and quality of tomato fruits as influenced by biofertilizer. *Asian J. Soil Sci.*, 2 (2), 95-99.

Kamangar, H., Rokhzadi, A., & Hesami, S. (2014). Evaluation of growth and morphological traits of strawberry (*Fragaria*× *ananassa* Duch.) cultivars under field conditions. *J. Bio. & Env. Sci*, *4*(2), 53-57.

Kamatyanatti, M., Kumar, A., & Dalal, R. P. S. (2019). Effect of integrated nutrient management on growth, flowering and yield of subtropical plum cv. Kala Amritsari. *Journal of Pharmacognosy and Phytochemistry*, *8*(1), 1904-1908.

Khalid, S., Qureshi, K. M., Hafiz, I. A., Khan, K. S., & Qureshi, U. S. (2013). Effect of organic amendments on vegetative growth, fruit and yield quality of

strawberry. *Pakistan Journal of Agricultural Research*, *26*(2).

Khanizadeh, S., Lareau, M., & Buszard, D. (1992, September). Effect of flower thinning on strawberry fruit weight and its relationship to achene number. In *II International Strawberry Symposium 348* (pp. 351-356)

Khokhar, U. U., Kumar Yadav, S., & Prasad, R. (2008, March). Optimization of Integrated Nutrient Supply System for Strawberry (*Fragaria× ananassa* Duch.) 'Chandler' in Himachal Pradesh (India). In *VI International Strawberry Symposium 842* (pp. 125-128).

Kidmose, U., Vang-Petersen, O., & Andersen, H. (1996). Yield and quality attributes of strawberry cultivars grown in Denmark 1990-1991. *Journal of American Pomological Society*, *50*, 160-167

Kirad, K. S., Barche, S., & Singh, D. B. (2010). Response of integrated nutrient management in strawberry. *Acta Hort*, *842*, 377-380.

Krüger, E., Josuttis, M., Nestby, R., Toldam-Andersen, T. B., Carlen, C., & Mezzetti, B. (2012). Influence of growing conditions at different latitudes of Europe on strawberry growth performance, yield and quality. *Journal of Berry Research*, *2*(3), 143-157.

Kumar, B., Kumar, S. & Yadav, Y. C. (2012). Genetic variability for some metric traits in strawberry (*Fragaria* × *ananassa* Duch.). *HortFlora Research Spectrum, 1(1)*, 86-88.

Kumar, M., Rai, P. N., & Sah, H. (2013). Effect of biofertilizers on growth, yield and fruit quality in low-chill pear cv Gola. *Agricultural Science Digest-A Research Journal*, *33*(2), 114-117.

Kumar, R. K., Jaganath, S., Guruprasad, T. R., Narayana, C. K., Balakrishna, A. N., Venugopalan, R., & Anilkumar, S. (2017). Studies on Plant Density and Integrated Nutrient Management for growth, yield, quality and shelf life of guava cv. Lalit in Rainy Season. *Int. J. Pure App. Biosci*, *5*(2), 354-366

Kumar, R., & Nagpal, R. (1996). Effect of post-harvest treatment on the storage behavior of mango cv. Dusehri. *Haryana J. hortic. Sci., 25*, 101-108.

Kumar, U. (2018). Performance of strawberry (*Fragaria* x *ananassa* Duch.) varieties under Western Malwa Plateau conditions. (M.Sc. Thesis) Rajmata Vijayaraje

Scindia Krishi Vishwa Vidyalaya, Gwalior K.N.K. College of Horticulture, Mandsaur.

Kunihisa, M. (2011). Studies using DNA markers in *Fragaria*× *ananassa*: genetic analysis, genome structure, and cultivar identification. *Journal of the Japanese Society for Horticultural Science*, *80*(3), 231-243.

Kushwah, M. S., Singh, D., Singh, S., & Bairwa, M. (2018) Effect of Integrated Nutrient Management on growth, yield and quality traits of strawberry (*Fragaria* x *ananassa* Duch.) cv. Chandler. *Journal of Pharmacognosy and Phytochemistry* SP1: 712-715.

Lacey, C. N. D. (1973). Phenotypic correlations between vegetative characters and yield components in strawberry. *Euphytica, 22,* 546-554.

Lado, J., Vicente, E., Manzzioni, A., Ghelfi, B., & Ares, G. (2012). Fruit quality and consumer liking of different strawberry cultivars. *Agrociencia (Montevideo)*, *16*(1), 51-58.

Lal, S. D., & Seth, J. N. (1981). Studies on combining ability in strawberry (*Fragaria* × *ananassa*): I. Number of inflorescences, number of flowers, days to maturity and number of fruits. *Canadian Journal of Genetics and Cytology*, *23*(3), 373-378.

Larson, K. D. (1994). Strawberry. *Handbook of environmental physiology of fruit crops*, *1*, 271-297.

Lata, R., Dwivedi, D. H., Ram, R. B., Meena, M. L., & Babu, M. (2013). Impact of integrated nutrient management on growth parameters of strawberry cv. chandler under sub-tropical conditions of Lucknow. *International J. Advanced Biological Research*, *3*(3), 418-421.

Lata, S. (2016). Pollination studies and development of day neutral cultivars in strawberry (*Fragaria x ananassa* Duch.). (Ph.D. Thesis), Dr. Y.S. Parmar University of Horticulture and Forestry.

Laugale, V., & Bite, A. (2009). Evaluation of strawberry cultivars for organic production in latvia. *Acta Horticultuae, 842*, 373-76.

Lawrence, F. J., Galletta, G. J., & Scott, D. H. (1990). Strawberry breeding work of the US Department of Agriculture. *Hort Science, 25(8),* 895-896.

Lenka, D. and B. Mishra (1973). Path coefficient analysis of yield in rice varieties. *Indian J. Agric. Sci., 43*: 376-379.

Li, C., & Kader, A.A. (1989). Residual effects of controlled atmospheres on postharvest physiology and quality of strawberries. *J. American Soc. Hort. Sci., 114*, 629-634.

Li, G. Y., Sui, W., & Ding, X. D. (1993). Comprehensive evaluation of economic characters of some principal cultivars of strawberry. *J. Northeast Agric. College*, *24*, 224-30.

Lieten, F., Kinet, J. M. & Bernier, G. (1995). Effect of prolonged cold-storage on the production capacity of strawberry plants. *Sci. Hort., 60*, 213–219.

Lush, J.L. (1949). Heritability of quantitative characters in farm animals. Heriditas(suppl.), *35*, 256-261.

Mahadeen, A. Y. (2009). Influence of organic and chemical fertilization on fruit yield and quality of plastic-house grown strawberry. *Jordan J. Agric. Sci*, *5*(2), 167-177.

Manakasem, Y., & Goodwin, P. B. (1998). Using the floral status of strawberry plants, as determined by stereomicroscopy and scanning electron microscopy, to survey the phenology of commercial crops. *Journal of the American Society for Horticultural Science*, *123*(4), 513-517.

Marathe, R. A., & Bharambe, P. R. (2005). Physical characteristics of vertisol as influenced by Integrated Nutrient Management system under sweet orange. *PKV Res. J*, *29*(2), 179-182

Martinez, G. A., Chaves, A. R., & Anon, M. C. (1996). Effect of exogenous application of gibberellic acid on color change and phenylalanine ammonia-lyase, chlorophyllase and peroxidase activities during ripening of strawberry fruit (*Fragaria x ananassa* Duch.). *Journal of Plant Growth Regulation*, *15*(3), 139-146.

Meena, R. K., Sanjay, K., Sutanu, M., Devendra, K., & Manoj, K. (2014). Effect of organic manures and biofertilizers on growth, flowering, yield and quality of tomato cv. Pusa Sheetal. *International Journal of Agricultural Sciences*, *10*(1), 329-332.

Merwin, H. D. & Peech, M. (1951). Exchangeablity of soil potassium in sand, soil and clay fractions as influenced by the nature of the complementary exchangeable cation. *Soil Science Society of America Journal, 15*(c), 125-128.

Miserendino, E. E., Arena, M., & Portela, J. A. (2009). Yield and fruit quality assessment of day-neutral strawberry cultivars at the end of the world (Ushuaia, Argentina). *Acta horticulturae*, (*842*), 919-922.

Miserendino, E. E., Kirschbaum, D. S., & Portela, J. A. (2008, March). Evaluation of Strawberry (*Fragaria× ananassa* Duch.) Runner Plants Production in Tierra del Fuego (54° 48'57" S) and Transplant Yield Performance in Subtropical Areas of Argentina. In *VI International Strawberry Symposium 842* (pp. 695-698).

Mishra, A. N., & Tripathi, V. K. (2011). Influence of different levels of *Azotobacter*, PSB alone and in combination on vegetative growth, flowering, yield and quality of strawberry Cv. Chandler. *International Journal of Applied Agricultural Research*, *6*(3), 203-10.

Mishra, A. N., & Tripathi, V. K. (2012). Effect of biofertilizers on vegetative growth, flowering, yield and quality of strawberry cv. chandler. In *Proceedings of the International Symposium on Minor Fruits and Medicinal Plants for Health and Ecological Security (ISMF & MP), West Bengal, India, 19-22 December, 2011* (pp. 211-215). Bidhan Chandra Krishi Viswandyalaya.

Mishra, P. K., Ram, R. B., & Kumar, N. (2015). Genetic variability, heritability, and genetic advance in strawberry (*Fragaria× ananassa* Duch.). *Turkish Journal of Agriculture and Forestry*, *39*(3), 451-458.

Mishra, P.K., Ram, R.B., & Kumar, N. (2015). Physico-chemical characteristics of some strawberry (*Fragaria* x *ananassa* Duch.) genotypes. *International Journal of Multidisciplinary Research and Development*, *2*(7), 216-218.

Mishra, R., & Kar, A. (2014). Effect of storage on the physico-chemical and flavour attributes of two cultivars of strawberry cultivated in Northern India. *The Scientific World J.*, 20, 1-7.

Mitra, S. K., Gurung, M. R., & Pathak, P. K. (2010, August). Organic nutrient management in high density guava orchard. In *XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium on 933* (pp. 233-238).

Molina-Hidalgo, F. J., Medina-Puche, L., Gelis, S., Ramos, J., Sabir, F., Soveral, G., & Blanco-Portales, R. (2015). Functional characterization of FaNIP1; 1 gene, a ripening-related and receptacle-specific aquaporin in strawberry fruit. *Plant Science*, *238*, 198-211.

Moncada, A., Caracciolo, G., Prinzivalli, C., & D'Anna, F. (2009). Study on new strawberry varieties evaluated in Sicily. *Acta horticulturae*, (842), 541-544.

Moore, J. N., Brown, G. R., & Brown, E. D. (1970). Comparison of factors influencing fruit size in large-fruited and small-fruited clones of strawberry. *Journal of the American Society of Horticultural Science*, *95*, 827-31.

Morgan, L. (2006). Hydroponic Strawberry production, A technical guide to the hydroponic production of Strawberries. *Suntec (NZ) Ltd, Tokomaru New Zealand*, pp118.

Morishita, M. (1994). Studies on genetic variation and inheritance of quality and yield characters for advanced strawberry breeding. *Bull. Natl. Res. Inst. Veg., Ornam. Plants & Tea*, *8*, 1-53.

Morishita, M. (2014). The status of strawberry breeding and cultivation. *Jap. Acta Horti.*, *1049*, 125–31.

Morishita, M., Honjo, M., Hamano, M., Yamazaki, H., & Yano, T. (2012). Relationship between the nodal position of the first inflorescence in first-year runner plants and the everbearing strength in everbearing strawberry cultivars. *Horticultural Research (Japan)*, *11*(2), 147-152.

Mubariz, S., Joshi, V., Ch, R., & Reddy, K. (2016). Evaluation of different packaging materials on shelf life and quality of minimally processed pomegranate arils (*Punica granatum* L.).

Mudasir, M.M., Chattoo S., Faheema, A.P., & Parry, F.A. (2009). Influence of organic and inorganic nutrients on growth and yield attributes of tomato. *The Asian J Hort.*, *7*(2), 337-339.

Nagaraju, S., & Banik, A. K. (2019). Effect of HDPE and LDPE packaging materials on chemical parameters of guava cv khaja. *Journal of Pharmacognosy and Phytochemistry*, *8*(1), 1635-1641.

Nagre, P. K., Garad, B. V., Bulbule, A. V., Patil, V. S., & Mote, P. U. (2005). Varietal performance of strawberry under Igatpuri conditions of Western Ghat Zone. *Journal-Maharashtra Agricultural Universities, 30*(1), 120.

Najda, A., Dyduch-Siemińska, M., Dyduch, J. & Gantner, M. (2014). Comparative analysis of secondary metabolites contents in *Fragaria vesca* fruits. *Ann. Agric. Environ. Med. 21,* 339–343.

Nazir, N., Singh, S. R., Aroosa, K., Masarat, J., & Shabeena, M. (2006). Yield and growth of strawberry cultivar Senga Sengana as influenced by integrated organic nutrient management system. *Environment and Ecology, 243*(3), 651-654.

Neerja, S., Arun, G., & Samnotra, R.K. (2010). Effect of Integrated Nutrient Management on growth yield and quality parameters in tomato. *The Asian J of Hort., 5,* 314-317

Neetu, & Sharma, S. P. (2018). Evaluation of Strawberry cultivars for growth and yield characteristics in plain Region of Chattisgrah India. *Int. J. Curr Microbiol, App.Sci., 7(*02), 2835-2840.

Neocleous, D. & Vasilakakis, M. (2012). Effects of Cultivars and Substrates on Soilless Strawberry Production in Cyprus. *Acta Horticulturae,* 926, 435

Nes, A. (1993). Sortarogsortsval I jordbar. *Faginfo nr, 2,* 41-47.

Nestby, R. (1989). Forcing of 18 strawberry cv. related to two cold storage periods. *Acta Hort.265,* 393–398.

NHB (2019). National Horticulture Board Database-Area Production Statistics. Area and production of horticulture crops for 2018 - 19 (1st Advance Estimates). Available at: http://nhb.gov.in/statistics/State_Level/2018-19(1st%20Adv).pdf

Nicoll, M. F. (1987). Variation in growth and flowering habits of June-bearing and everbearing strawberries. *J. Amer. Soc. Hort. Sci., 112,* 872-880.

Nicoll, M. F., & Galletta, G. J. (1987). Variation in growth and flowering habits of Junebearing and everbearing strawberries. *Journal of the American Society for Horticultural Science, 112*(5), 872-880

Nowsheen, N., Singh, S. R., Khalie, A., Jabeen, M. & Majeed, S. (2006). Yield and growth of strawberry cv. Senhga Sengana as influenced by integrated organic nutrient management system. *Environ. & Ecol.,24*(3) : 651-654.

Nunes, M. C. N., Brecht, J. K., Morais, A. M., & Sargent, S. A. (2005). Possible influences of water loss and polyphenol oxidase activity on anthocyanin content and discoloration in fresh ripe strawberry (cv. Oso Grande) during storage at 1 C. *Journal of Food Science*, *70*(1), S79-S84.

Nurbhanej, K.H., Patel, M.J., Barot, H.R., Thakkar, R.M., & Gadhvi, A.V. (2014). Effect of integrated nutrient management (INM) on growth, yield and quality of acid lime (*Citrus aurantifolia* Swinsgle) cv. Kagzi. *International Journal of Agriculture Science*, *51*(8), 2360-2363.

Olsen, S. R. (1954). Estimation of available phosphorous in soils by extraction with sodium bicarbonate (No. 939). U.S. Department of Agriculture.

Panda, A. K., Goyal, R. K., Godara, A. K., & Sharma, V. K. (2016). Effect of packaging materials on the shelf-life of strawberry cv. Sweet Charlie under room temperature storage. *Journal of Applied and Natural Science*, *8*(3), 1290-1294.

Paroussi, G., Voyiatzis, D. G., Paroussis, E. & Drogoudi, P. D. (2002). Growth, flowering and yield responses to GA_3 of strawberry grown under different environmental conditions. *Scientia Horticulturae, 96(1-4),* 103-113.

Patel, Deepti, Dikshit, S.N., Singh, J., Urkurkar, J.S., & Saxena, R. R. (2010). Effect of integrated nutrient management on growth and yield of tomato in Chhattisgarh plain zone, in "National Seminar on Precision Farming in Horticulture", December, 28-29, Jhalawar, Rajasthan, b, 502-506.

Patil, M. B., Mohammed, R. G., & Ghadge, P. M. (2004). Effect of organic and inorganic fertilizers on growth, yield and quality of tomato. *J. Maharashtra Agric. Univ*, *29*(2), 124-127.

Peano, C., Giuggioli, N.R. & Girgenti, V. (2014). Effect of different packaging materials on postharvest quality of cv. Envie-2 strawberry. *International Food Research J.*, *21*(3), 1165-1170.

Pérez de Camacaro,. M. E., Camacaro, G. J., Hadley, P., Battey, N. H. & Carew, J. G. (2002). Pattern of growth and development of the strawberry cultivars Elsanta, Bolero, and Everest. *J Amer Soc Hort Sci,* 127, 901–07.

Perkins-Veazie, P. (1995). Growth and ripening of strawberry fruit. *Horti Rev,* 17, 267-97.

Piper, C.S. (1966). Soil and Plant Analysis New York: InterScience Publications Inc

Piringer, A. A., & Scott, D. H. (1964). Interrelation of photoperiod, chilling, and flower cluster and runner production in strawberries. *Proc. Am. Soc. Hort. Sci., 84,* 295–301.

Polovyanov, G. G. (1985). Using the chemical composition of the fruit in the phylogeny and taxonomy of stone fruit crops. *Sbornik Nauchny Kh Trudov Po Prikladnol Botanike, Genetike : Selektsii,* 97,86-92.

Porlingis, I. C., & Boynton, D. (1961). Growth responses of the strawberry plant, *Fragaria chiloensis cv. Ananassa,* to gibberellic acid and to environmental conditions. *Proc. Am. Soc. Hort. Sci., 78,* 261–269

Prabhu, M., Parthiban, S., Kumar, A. R., Rani, B. U., & Vijayasamundeeswari, A. (2018). Effect of intergrated nutrient management on acidlime [*Citrus aurantifolia.* Swingle (L.)]. *Indian Journal of Agricultural Research*, *52*(3), 290-294.

Prabhu, T., Narwadkar, P. R., Sajindranath, A. K., & Rathod, N. G. (2002). Effect of integrated nutrient management on growth and yield of coriander (*Corriandrum sativum* L.). *South Indian Horticulture*, *50*(4-60), 680-684.

Pradeepkumar, T., Babu, D. S., & Aipe, K. C. (2006). Performance of strawberry varieties in Wayanad District of Kerala. *Journal of Tropical Agriculture*, *40*, 51-52.

Pramanick, K. K., Kishor, D. K. & Sharma, Y. P. (2002). Effect of polythene on behaviour and yield of strawberry (*Fragaria x ananassa*). *Journal of applied horticulture – Lucknow,* 2(2), 130-131.

Premsekhar, M., & Rajashree, V. (2009). Influence of bio-fertilizers on the growth characters, yield attributes, yield and quality of tomato. *American-Eurasian Journal of Sustainable Agriculture*, *3*(1), 68-70.

Prichko, T. G., Chalaya, L. D., & Yakovenko, V.V. (2005). Studies of cultivars of strawberry in the South of Russia.*Sadovodstvo-i-Vinogradarstvo*, (1), 14-16.

Ramírez-Gómez, H., Sandoval-Villa, M., Carrillo-Salazar, A., & Muratalla-Lúa, A. (2011, May). Comparison of hydroponic systems in the strawberry production. In *II International Symposium on Soilless Culture and Hydroponics 947* (pp. 165-172).

Rana, G. S., & Sharma, S. (2002). Effect of different intensities of shade houses onthe performance of strawberry cultivars. *Annals of Agricultural Research, 23*(4), 730-731.

Rana, R. K., & Chandel, J. S. (2003). Effect of bio-fertilizer and nitrogen on growth yield and fruit quality of strawberry.*Progressive Horticulture*, 35(1), 25-30

Rao, V. K., & Lal, B. (2010). Evaluation of promising strawberry genotypes under Garwal Himalayan conditions. *Indian J. Hort, 67*(4), 470-74.

Rao, V. K., Lal, B., Yadav, V. K., & Sharma, S. K. (2010). Correlation and path analysis in strawberry (*Fragaria* x*ananassa* Duch.). *J. of Hill Agriculture*, *1*(2), 179-182.

Rao, V., & Swamy, G. S. K. (2017). Performance of strawberry (*Fragaria* x *ananassa* Duch.) genotypes for yield and quality parameters. *Int. J. Curr. Microbiol. App. Sci*, *6*(9), 1904-1908.

Rayees A. Wani, Hakeem, S. A., Bashir, S., Geelani, S., Mughal, M.N., & Prasad, V.M. (2015). Impact of Integrated Nutrient Management on growth, yield and quality of strawberry (*Fragaria ananassa Duch*) cultivation in India. *Nature and Science* United States of America, *13*(1), 39-44.

Rinaldi, M. M., Dianese, A. D. C., Sussel, A., Faleiro, F., & Junqueira, N. (2017). Effect of different packaging materials on the shelf life of passion fruits during ambient and low temperature storage. *EmbrapaCerrados-Artigoemperiódicoindexado (ALICE)*.

Ristow,N. C., Carpenedo, S., Junior, C. R., & Krolow, A. C. R. (2009). Characterization of strawberry cultivars in Southern Brazil. *Acta Horticulturae, 842*, 515-517.

Rousseau-Gueutin, M., Lerceteau-Köhler, E., Barrot, L., Sargent, D. J., Monfort, A., Simpson, D., & Denoyes-Rothan, B. (2008). Comparative genetic mapping between octoploid and diploid Fragaria species reveals a high level of colinearity between their genomes and the essentially disomic behavior of the cultivated octoploid strawberry. *Genetics, 179(4),* 2045-2060.

Ruan, J., Lee, Y. H., & Yeoung, Y. R. (2013). Flowering and fruiting of day-neutral and ever-bearing strawberry cultivars in high-elevation for summer and autumn

fruit production in Korea. *Horticulture, Environment, and Biotechnology*, *54*(2), 109-120.

Safari, M., Veena, J., & Girwani, A. (2016). Evaluation of different packaging materials on shelf life and quality of minimally processed pomegranate arils (*Punica granatum* L.). *International Journal of Agricultural Science and Research*, *6*(3), 423-432.

Sahu, A., & Chandel, J. S. (2014). Studies on the comparative performance of strawberry cultivars under mid-hill conditions of north-western Himalayas. *Indian J. of Hort.*, *71*(3), 330-334.

Santos, B. M., Chandler, C. K., Ramírez-Sánchez, M., & Salamé, T. P. (2009). Evaluation of strawberry cultivars in Florida. *International journal of fruit science*, *9*(4), 419-424.

Scalzo, J., Politi, A., Pellegrini, N., Mezzetti, B. & Battino, M. (2005). Plant genotype affects total antioxidant capacity and phenolic contents in fruit. *Nutrition, 21*, 207–213.

Schwieterman, M. L., Colquhoun, T. A., Jaworski, E. A., Bartoshuk, L. M., Gilbert, J. L., Tieman, D. M., & Sims, C. A. (2014). Strawberry flavor: diverse chemical compositions, a seasonal influence, and effects on sensory perception. *PloS one*, *9*(2), e88446.

Selvi, D., & Rani, P. (2000). Effect of Integrated Nutrient Management on yield and economics of okra in an inceptisol. *Vegetable Science*, *27*(2), 207-208.

Serçe, S., & Hancock, J. F. (2005). The temperature and photoperiod regulation of flowering and runnering in the strawberries, *Fragaria chiloensis*, *F. virginiana*, and *F. x ananassa*. *Scientia Horticulturae*, *103*(2), 167-177.

Sharma, A., Singh, D. B., Sharma, R. K., & Iqbal, U. (2009). Comparative evaluation of strawberry (*Fragaria x ananassa* Duch.) cultivars under Allahabad conditions. *The Asian J Hort.*, *4*(1), 178-80.

Sharma, A., Wali, V. K., Bakshi, P., & Jasrotia, A. (2013). Effect of integrated nutrient management strategies on nutrient status, yield and quality of guava. *Indian Journal of Horticulture*, *70*(3), 333-339.

Sharma, G., & Sharma, O. C. (2002). Performance of strawberry (*Fragaria ananassa* Duch) condition of Himachal Pradesh. *Indian Journal of Plant Genetic Resources, 15*(1), 62-63.

Sharma, G., & Sharma, O. C. (2006). Correlation and path analysis in strawberry (*Fragaria x ananassa* Duch). *Hort J, 19*(1), 1-4.

Sharma, G., & Suman, D. K. (2006). Correlation and path analysis studies in strawberry (*Fragaria* x *ananassa* Duch.). *Haryana Journal of Horticultural Sciences, 35*(1/2), 38.

Sharma, G., & Thakur, M. S. (2008). Evaluation of different strawberry cultivars for yield and quality characters in Himachal Pradesh. *Agricultural Science Digest, 28*(3), 213-215.

Sharma, G., Yadav, A., & Garg, S. (2014). Evaluation of different strawberry cultivars for yield and quality characters in Himachal Pradesh. *Agri. Sustainable Development,* 2(1), 59-61.

Sharma, G., Yadav, A., & Thakur, M. (2014). Studies on growth and flowering attributes of different strawberry cultivars (*Fragaria* x *ananassa* Duch.) in Himachal Pradesh. *Asian J. of Adv. Basic Sci*, *3*(1), 1-4.

Sharma, N., Gupta, A. R. U. N., & Samnotra, R. K. (2010). Effect of Integrated Nutrient Management on growth yield and quality parameters in tomato (*Lycopersicon esculantum* Miller). *Asian Journal of Horticulture, 5*(2), 314-317.

Sharma, R. M., Khajuria, A. K., & Kher, R. (2002). Evaluation of some strawberry (*Fragaria* X *ananassa* Duch) cultivars in Jammu Plains. *Indian Journal of Plant Genetic Resources*, *15*(1), 64-66.

Sharma, R. R., & Sharma, V. P. (2003). Mulch type influences plant growth, albinism disorder and fruit quality in strawberry (*Fragaria*× *ananassa* Duch.). *Fruits*, *58*(4), 221-227.

Sharma, V. P., & Sharma, R. R. (2004). The Strawberry. Indian Council of agricultural Research, New Delhi.

Shaw D.V., & Famula, T.R. (2005). Complex segregation analysis of day-neutrality in domestic strawberry (*Fragaria* ×*ananassa* Duch.). *Euphytica1, 45,* 331-338

Shaw, D. V. (1990). Response to selection and associated changes in genetic variance for soluble solids and titratable acids contents in strawberries. *Journal of the*

American Society for Horticultural Science, *115*(5), 839-843.

Sherman, W. B., Janick, J., & Erickson, H. T. (1966). Inheritance of fruit size in strawberry. *Proceedings of the American Society for Horticultural Science 89*, 309–317.

Shilpi, K., Sanjay, K., Sutanu, M., & Devendra, K. (2014). Effect of organic manures and inorganic fertilizers on growth, yield and quality of brinjal (*Solanum melongena* L.) cv. Pant Rituraj. *International Journal of Agricultural Sciences*, *10*(1), 305-308.

Shukla, Y. R., Thakur, A. K., & Joshi, A. (2009). Effect of inorganic and bio-fertilizers on yield and horticultural traits in tomato. *Indian Journal of Horticulture*, *66*(2), 285-287.

Shulaev, V., Sargent, D. J., Crowhurst, R. N., Mockler, T. C., Folkerts, O., Delcher, A. L., & Burns, P. (2010). The genome of woodland strawberry (*Fragaria vesca*). *Nature genetics*, *43(2)*, 109-116.

Siddiqui, S., & Gupta, O.P. (1997). Effect of individual fruit wrapping by different materials on the shelf life of Guava cv. Allahabad Safeda. *Haryana J. hortic. Sci.*, *26*(1-2), 101-104.

Simanek, J., & Skulcova, E.(1977). Evaluation of strawberry cultivars. *Zbornik-UVTIZ,-Zahradnictvi*, *4*(1/4), 43-48.

Singh, A. K., Beer, K., & Pal, A. K. (2015). Effect of vermicompost and biofertilizers on strawberry growth, flowering and yield. *Ann. Plant. Soil Res.*, *17*(2), 196-199.

Singh, A., & Singh, J. N. (2009). Effect of biofertilizers and bioregulators on growth, yield and nutrient status of strawberry cv. Sweet Charlie. *Indian J. of Hort., 66*(2), 220-224.

Singh, A., & Singh, J. N. (2009). Effect of biofertilizers and bioregulators on growth, yield and nutrient status of strawberry cv. Sweet Charlie. *Indian Journal of Horticulture*, *66*(2), 220-224.

Singh, A., Nath, A., Buragohain, J., & Deka Bidyut, C. (2008). Quality and shelf-life of strawberry fruits in different packages during Storage. *J. Food Science & Tech.*, *45*(5), 439-442.

Singh, A., Patel, R. K., De, L. C., & Pereira, L. S. (2008). Performance of strawberry (*Fragaria xananassa*) cultivars under sub-tropics of Meghalaya. *Indian J. of Agricultural Science*, *78*(7), 575-580.

Singh, A., Singh, B. K., Brajendra, Nath, A., & Deka, B. C. (2010). Studies on the variability, inheritance, and inter-relationships of mineral macro-nutrients and micro-nutrients in strawberry (*Fragaria ananassa* Duch.). *The Journal of Horticultural Science and Biotechnology*, *85*(6), 551-555.

Singh, B. K. (2016). Impact of integrated nutrient management on growth, yield and quality attributes in strawberry (*Fragaria* × *ananassa* Duch.) cv. Chandler (Doctoral dissertation, Institute of Agricultural Sciences, Banaras Hindu University).

Singh, B. K., Pal, A. K., Verma, A., Singh, A. K., Yadev, K. S., & Tiwari, A. (2017). Impact of Integrated Nutrient Management on physico-chemical attributes in strawberry (*Fragaria* × *ananassa* duch.) cv. Chandler. *Environment & Ecology, 35* (1A), 363-367.

Singh, B. K., Verma, R. B., Singh, V. K., Singh, M., & Maurya, D. (2018). Effect of Integrated Nutrient Management on Growth, Yield and quality of Okra (Abelmoschus esculentus (L.) Moench). *International Journal of Current Microbiology and Applied Sciences*, *7*(10), 1033-1041.

Singh, J. K., & Varu, D. K. (2013). Effect of integrated nutrient management in papaya (*Carica papaya* L.) cv. Madhubindu. *Asian Journal of Horticulture*, *8*(2), 667-670.

Singh, R. (2016). Evaluation of strawberry *(Fragaria x ananassa* Duch.)cultivars under sub-tropical conditions of Punjab. (M.Sc. Thesis), Punjab Agricultural University, Ludhiana.

Singh, S. K., Chaurasia, S. N. S., Singh, T. B., & Mishra, T. D. (2008). Effect of nutrient dynamics on growth and yield of okra (*Abelmoschus esculentus* (L) Moench, L.) cv. VRO-6. *New Agriculturist*, *19*(1/2), 19-23.

Singh, S. K., Kumar, P., Kumar, M., Saravanan, S., Choudhary, M. L., & Sharma, M. C. (2012). Studies on influence of bio-fertilizers and micronutrients on growth, flowering and yield of strawberry (*Fragaria* x *ananassa* Duch) cv. chandler. *Annals of Horticulture*, *5*(2), 259-264.

Singh, S. R., Srivastava, K. K., Sharma, M. K., Singh, L., & Sharma, V. K. (2012). Screening of strawberry (*Fragaria x ananassa*) varieties under organic production system for Kashmir valley. *Indian journal of agricultural sciences*, *82*(6), 538.

Singh, S. R., Zargar, M. Y., Najar, G. R., Ishaq, M. I., & Hakeem, S. A. (2012). Effect of integrated nutrient supply on yield, fertility and quality of strawberry under rainfed temperate conditions. *Journal of the Indian Society of Soil Science*, *60*(1), 79-82.

Singh, S., & Ram, R.B. (2018). Effect of organic, inorganic and bio-fertilizers on yielding and fruiting traits of okra (*Abelmoschus esculentus* (L.) Moench). *Journal of Pharmacognosy and Phytochemistry, 7*(5), 90-93.

Singh, T. K., Vandana, D., & Singh, D. B. (2011). Integrated nutrient management in guava. *Mysore Journal of Agricultural Sciences*, *45*(4), 923-925.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical methods. 6th Edition, Ames, Lowa, the Lowa state University.

Soni, S., Kanawjia, A., Chaurasiya, R., & Singh, P. (2018). Effect of organic manure and biofertilizers on growth, yield and quality of strawberry (*Fragaria* x *ananassa* Duch) cv. Sweet Charlie. *Journal of Pharmacognosy and Phytochemistry*, *2*, 128-132.

Sonkar, R.K., & Ladaniya, M.S. (1998). Effect of tray over wrapping by heat shrinkable and stretchable films on Nagpur mandarin fruits. *Indian Food Packer*, *52(*5), 22-26.

Spangelo, L. P. S., Hsu, C. S., Fejer, S. O., Bedard, P. R., & Rousselle, G. L. (1971). Heritability And Genetic Variance Components For 20 Fruit And Plant Characters In The Cultivated Strawrerry. *Canadian Journal of Genetics and Cytology*, *13*(3), 443-456.

Stanisavljevic, M. & Gavrilovic, J. (1998). Biological and economical characters of new strawberry cultivars. *J Voc.*, *22*(4), 349-55.

Staudt, G. (1999). *Systematics and geographic distribution of the American strawberry species: Taxonomic studies in the genus Fragaria (Rosaceae: Potentilleae). Botany, 81,* 162.

Stewart, P. J., & Folta, K. M. (2010). A review of photoperiodic flowering research in strawberry (*Fragaria* spp.). *Critical reviews in plant science*, *29*(1), 1-13.

Strassburger, A. S., Peil, R.M.N., Schwengber, J. E., Medeiros, C. A. B., Martins, D. de. S. & Silva, B. E. J. (2010). Growth and yield of day-neutral strawberry cultivars in different plant densities in organic crop system. *Bragantia, 69*(3), 623-30.

Strik, B. C. (1988). *Photosynthesis, yield component analysis, and growth analysis of strawberry.* Dissertation-Abstracts-International,-B-Sciences-and-Engineering, *48*(8), 2175p.

Strik, B. C., & Proctor, J. T. (1988). Yield component analysis of strawberry genotypes differing in productivity. *J. Amer. Soc. Hort. Sci*, *113*(1), 124-129.

Sualeh, A., Daba, A., Kiflu, S., & Mohammed, A. (2016). Effect of storage conditions and packing materials on shelf life of tomato. *Food Science and Quality Management*, *56*, 65-67.

Subbiah, B.V., & Asija, G. L. (1956). A rapid method for estimation of nitrogen in soil. *Current Science, 26*, 259-260.

Subraya, B. K., Madaiah, D., & Kumar, M. D. (2017). Effect of integrated nutrient management on growth and physiological parameters of strawberry (*Fragaria* x ananassa Duch) under naturally-ventilated polyhouse. *International Journal of Farm Sciences*, *7*(3), 72-75.

Sudhakar, P. S., & Purushotham, K. (2008). Studies on effect of bio-fertilizer on growth, yield and quality of tomato (*Solanum lycopersicum* L.). *The Orissa J. of Hort*, *36*(2), 120-125.

Sullivan, D. T., & Enzie, J. V. (1961). The Expressible Juice Content of Richared and Jonared Apples as Related to Respiration Rate, Soluble Solids and Firmness. In *Proc. Amer. Soc. Hort. Sci* (Vol. 77, p. 43)

Suman, D. K. (2000). Genetic variability and character association studies in strawberry. (M.Sc. Thesis), Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, H.P., India.

Tagliavini, M., Baldi, E., Lucchi, P., Antonelli, M., Sorrenti, G., Baruzzi, G., &Faedi, W. (2005). Dynamics of nutrients uptake by strawberry plants (*Fragaria*× *ananassa* Dutch.) grown in soil and soilless culture. *European Journal of Agronomy*, *23*(1), 15-25

Taimatsu, T., Yoshida, N., & Nishimoto, T. (1991). The habit of flower-bud

formation and flowering in everbearing strawberries. *Nara Agri Exp St., 22*, 35–42.

Tanaka, Y., & Mizuta, M. (1974). Nutritional–physiological studies on strawberry cv. Hokowase in long term cultivation. I. Influence of nitrogen on growth, yield and absorption of nutrients. *Bul. Nara Agri. Expt. Sta*, *6*, 38-43.

Tehranifar, A., Miere, P. L., & Battey, N. H. (1998). The effects of lifting date, chilling duration and forcing temperature on vegetative growth and fruit production in the Junebearing strawberry cultivar Elsanta. *The Journal of Horticultural Science and Biotechnology*, *73*(4), 453-460.

Thompson, A.K. (2001). Controlled atmospheric storage of fruits and vegetables. CAB International Printed in UK Biddles Ltd, Guidford and Kings Lynn, UK

Tripathi, V. K., Kumar, S., & Gupta, A. K. (2015). Influence of *Azotobacter* and vermicompost on growth, flowering, yield and quality of strawberry cv. Chandler. *Indian Journal of Horticulture*, *72*(2), 201-205.

Umar, I., Wali, V. K., Kher, R., & Jamwal, M. (2009). Effect of Fym, Urea and *Azotobacter* on growth, yield and quality of Strawberry cv. Chandler. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *37*(1).

Umar, I., Wali, V. K., Kher, R., & Sharma, A. (2008). Impact of integrated nutrient management on strawberry yield and soil nutrient status. *Applied Biological Research*, *10*(1and2), 22-25.

Veazie, P. (1995). Growth and ripening of strawberry fruit. *Horticultural reviews*, *17*, 267-297.

Verma, J., & Rao, V. K. (2013). Impact of INM on soil properties, plant growth and yield parameters of strawberry cv. Chandler. *J. of Hill Agri.*, *4*(2), 61-67.

Verma, R. S., Lata, R., Ram, R. B., Verma, S. S., & Prakash, S. (2019). Effect of organic, inorganic and bio-fertilizers on vegetative characters of dragon fruit (*Hylocereus undatus* L.) plant. *The Pharma Innovation Journal*, *8*(6), 726-728.

Verma, S. K., Singh, R. K., & Arya, R. R. (2002). Variability and correlation studies in strawberry germplasm for quantitative traits. *Indian Journal of Horticulture*, *59*(1), 39-43.

Voća, S., Dobrićević, N., Družić, J., Duralija, B., Babojelić, M. S., Dermišek, D., & Čmelik, Z. (2009). The change of fruit quality parameters in day-neutral

strawberries cv. Diamante grown out of season. *International Journal of Food Sciences and Nutrition*, *60*(3), 248-254.

Wahdan, H. A., & Waister, P. D. (1984). Flower initiation, fruit production and vegetative development in non-induced strawberry plants exposed to outdoor conditions in Scotland. *Journal of Horticultural Science*, *59*(2), 187-196.

Wang, S. Y., & Camp, M. J. (2000). Temperatures after bloom affect plant growth and fruit quality of strawberry. *Scientia Horticulturae*, *85*(3), 183-199.

Wang, S. Y., & Lin, S. S. (2002). Composts as soil supplement enhanced plant growth and fruit quality of strawberry. *Journal of Plant Nutrition*, *25*(10), 2243-2259.

Wange, S. S., Patil, M. T., & Singh, B. R. (1998). Cultivar biofertiliizer interaction study in strawberry. *Recent Hort*., 4, 4349.

Wani, R. A., Baba, J. A., Hakeem, S. A., Qazi, S. R., Basu, Y. A., Umer, I., & Haq, S. A. (2017). Influence of differential combinations of fertilizer and manure combinations on vegetative growth, yield and quality of strawberry (*Fragaria* x *annanassa* Duch.) cv. Douglas. *Int. J. Curr. Microbiol. App. Sci*, *6*(11), 3396-3404.

Wani, R. A., Hakeem, S. A., Bashir, S., Geelani, S., Mughal, M.N. & Prasad, V.M. (2015). Impact of integrated nutrient management on growth, yield and quality of strawberry *(Fragaria x annanassa* Duch.) cultivation in India. *Nature and Science*, *13*(1), 39-44.

Wani, R. A., Sheema, S., Malik, T. H., Geelani, S., Bashir, S., Dar, N. A., & Prasad, V. M. (2013). Impact of integrated nutrient management on growth, yield and quality of strawberry (*Fragaria* x annanassa Duch.) cultivation in India. *Advances in Horticultural Science*, 147-151.

Watharkar, R. B., Burbade, R. G., & Landge, K. C. (2017). Effect of packaging material on shelf life and quality attributes of grapes (*Vitis vinifera*L.). *Int. Arch. App. Sci. Technol*, *8*(3), 01-08.

Wenzel, W. G. (1980). Correlation and selection indices in strawberry breeding. *Agroplantae*, *12*(3), 29-32.

Wright, S. (1921). Correlation and Causation. Journal of Agricultural Research, 20, 557-585.

Yadav, S. K., Khokhar, U. U., & Yadav, R. P. (2010). Integrated nutrient management for strawberry cultivation. *Indian journal of Horticulture*, *64*(4b), 445-449.

Yamashita, F., Miglioranza, L. H. D. S., & Miranda, L. D. A. (2002). Effects of packaging and temperature on postharvest of atemoya. *RevistaBrasileira de Fruticultura*, *24*(3), 658-660.

Yavari, S., Eshghi, S., Tafazoli, E., & Yavari, S. (2008). Effects of various organic substrates and nutrient solution on productivity and fruit quality of strawberry "Selva" (*Fragaria× ananassa* Duch.). *Journal of Fruit and Ornamental Plant Research*, *16*, 167-178.

Yeptho, V., Kanaujiasingh, V.B., & Amod, S. (2010). Effect of Integrated Nutrient Management on growth, yield and quality of tomato under poly house condition. *J. Soils and Crops.*, 22(2), 246-252.

Yusuf, A., Iqbal, M., Shah, S.Z.A., & Ahmd, M.J. (2003). Effect of different combination of nitrogen, phosphorous an-d FYM on yield and quality of strawberry. *Sarhad. J. of Agriculture*, *19*(2), 185-188.

Zargar, M. Y., Baba, Z. A., & Sofi, P. A. (2008). Effect of N, P and biofertilizers on yield and physico-chemical attributes of strawberry. *Agro Thesis*, *6*(1), 3-8.

Zielinski, Q. B. (1955). History of plant classification. Brown company, p.15.

APPENDICES – I

ANALYSIS OF VARIANCE TABLE FOR DIFFERENT PARAMETERS OF GERMPLASM EVALUATION OF STRAWBERRY

ANOVA FOR VEGETATIVE CHARACTERS AS MORTALITY (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	60.167			
Treatment	11	4,943.31	449.392	50.392	0
Error	22	196.193	8.918		
Total	35	5,199.67			

ANOVA FOR VEGETATIVE CHARACTERS AS PLANT HEIGHT (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.407			
Treatment	11	36.862	3.351	18.041	0
Error	22	4.087	0.186		
Total	35	41.355			

ANOVA FOR VEGETATIVE CHARACTERS AS PLANT SPREAD (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.086			
Treatment	11	36.209	3.292	7.051	0.00006
Error	22	10.271	0.467		
Total	35	51.566			

ANOVA FOR VEGETATIVE CHARACTERS AS NUMBER OF LEAVE

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.127			
Treatment	11	85.107	7.737	24.235	0
Error	22	7.023	0.319		
Total	35	92.257			

ANOVA FOR VEGETATIVE CHARACTERS AS LEAF AREA (cm^2)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	83.204			
Treatment	11	1,550.07	140.916	9.802	0
Error	22	316.285	14.377		
Total	35	1,949.56			

ANOVA FOR VEGETATIVE CHARACTERS AS NUMBER OF RUNNERS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.167			
Treatment	11	150.75	13.705	14.472	0
Error	22	20.833	0.947		
Total	35	174.75			

ANOVA FOR VEGETATIVE CHARACTERS AS DAYS FORMATION AFTER PLANTING (days)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	18.749			
Treatment	11	1,996.30	181.482	47.313	0
Error	22	84.386	3.836		
Total	35	2,099.43			

ANOVA FOR VEGETATIVE CHARACTERS AS PETIOLE LENGTH (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.102			
Treatment	11	36.38	3.307	35.011	0
Error	22	2.078	0.094		
Total	35	38.56			

ANOVA FOR FLORAL CHARACTERS AS FLOWER SIZE (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.004			
Treatment	11	0.125	0.011	7.926	0.00002
Error	22	0.032	0.001		
Total	35	0.161			

ANOVA FOR FLORAL CHARACTERS AS PETAL LENGTH (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.002			
Treatment	11	0.063	0.006	19.438	0
Error	22	0.007	0		
Total	35	0.072			

ANOVA FOR FLORAL CHARACTERS AS PETAL BREADTH (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0			
Treatment	11	0.07	0.006	25.211	0
Error	22	0.006	0		
Total	35	0.076			

ANOVA FOR NUMBER OF STAMENS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.056			
Treatment	11	29.222	2.657	10.416	0
Error	22	5.611	0.255		
Total	35	35.889			

ANOVA FOR DAYS TO FLOWERING (DAYS)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.722			
Treatment	11	796.556	72.414	165.757	0
Error	22	9.611	0.437		
Total	35	811.889			

ANOVA FOR DURATION OF FLOWERING (DAYS)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.389			
Treatment	11	518.306	47.119	115.894	0
Error	22	8.944	0.407		
Total	35	527.639			

ANOVA FOR NUMBER OF FLOWERS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	8.222			
Treatment	11	321.806	29.255	8.884	0.00001
Error	22	72.444	3.293		
Total	35	402.472			

ANOVA FOR NUMBER OF PETAL

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.222			
Treatment	11	3.889	0.354	1.75	0.12712
Error	22	4.444	0.202		
Total	35	8.556			

ANOVA FOR FRUIT CHARACTERS AS FRUIT LENGTH (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.096			
Treatment	11	9.283	0.844	191.542	0
Error	22	0.097	0.004		
Total	35	9.476			

ANOVA FOR FRUIT CHARACTERS AS FRUIT BREADTH (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.009			
Treatment	11	4.875	0.443	93.956	0
Error	22	0.104	0.005		
Total	35	4.988			

ANOVA FOR FRUIT CHARACTERS AS NUMBER OF ACHENE

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	40.056			
Treatment	11	8,947.64	813.422	64.851	0
Error	22	275.944	12.543		
Total	35	9,263.64			

ANOVA FOR FRUIT CHARACTERS AS NUMBER OF CALYX

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.222			
Treatment	11	17.889	1.626	8.05	0.00002
Error	22	4.444	0.202		
Total	35	22.556			

ANOVA FOR FRUIT CHARACTERS AS DAYS TO FRUIT MATURITY

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.722			
Treatment	11	65.639	5.967	18.038	0
Error	22	7.278	0.331		
Total	35	73.639			

ANOVA FOR FRUIT CHARACTERS AS BERRY WEIGHT (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.438			
Treatment	11	50.45	4.586	44.093	0
Error	22	2.288	0.104		
Total	35	53.176			

ANOVA FOR FRUIT CHARACTERS AS NUMBER OF FRUIT

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.167			
Treatment	11	227.854	20.714	11.635	0
Error	22	39.167	1.78		
Total	35	268.188			

ANOVA FOR FRUIT CHARACTERS AS YIELD PER PLANT (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	101.382			
Treatment	11	56,450.19	5,131.84	21.512	0
Error	22	5,248.14	238.552		
Total	35	61,799.71			

ANOVA FOR FRUIT CHARACTERS AS YIELD PER HECTARE

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.856			
Treatment	11	803.192	73.017	38.541	0
Error	22	41.68	1.895		
Total	35	846.729			

ANOVA FOR FRUIT CHARACTERS AS TSS (ºB)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.016			
Treatment	11	21.021	1.911	16.788	0
Error	22	2.504	0.114		
Total	35	23.541			

ANOVA FOR FRUIT CHARACTERS AS ACIDITY (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.005			
Treatment	11	0.09	0.008	7.294	0.00004
Error	22	0.025	0.001		
Total	35	0.12			

ANOVA FOR FRUIT CHARACTERS AS TOTAL SUGAR (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.052			
Treatment	11	4.082	0.371	26.322	0
Error	22	0.31	0.014		
Total	35	4.444			

ANOVA FOR FRUIT CHARACTERS AS REDUCING SUGAR (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.003			
Treatment	11	3.844	0.349	25.666	0
Error	22	0.3	0.014		
Total	35	4.146			

ANOVA FOR FRUIT CHARACTERS AS NON REDUCING SUGAR (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.053			
Treatment	11	0.351	0.032	5.597	0.0003
Error	22	0.125	0.006		
Total	35	0.529			

ANOVA FOR FRUIT CHARACTERS AS TSS/ACID RATIO

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.872			
Treatment	11	52.735	4.794	12.779	0
Error	22	8.253	0.375		
Total	35	61.86			

ANOVA FOR FRUIT CHARACTERS AS TOTAL SUGAR/ ACID RATIO

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.635			
Treatment	11	5.362	0.487	5.907	0.00021
Error	22	1.816	0.083		
Total	35	7.813			

ANOVA FOR FRUIT CHARACTERS AS pH OF FRUIT JUICE

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.002			
Treatment	11	0.958	0.087	16.144	0
Error	22	0.119	0.005		
Total	35	1.079			

ANOVA FOR FRUIT CHARACTERS AS SPECIFIC GRAVITY

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0			
Treatment	11	0.042	0.004	19.299	0
Error	22	0.004	0		
Total	35	0.047			

ANOVA FOR FRUIT CHARACTERS AS VITAMIN C CONTENT

(mg/100g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.033			
Treatment	11	1,875.34	170.485	148.008	0
Error	22	25.341	1.152		
Total	35	1,905.71			

ANOVA FOR FRUIT CHARACTERS AS ANTHOCYANIN CONTENT

(mg/100g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.489			
Treatment	11	542.471	49.316	61.015	0
Error	22	17.782	0.808		
Total	35	560.741			

APPENDICES – II

ANALYSIS OF VARIANCE TABLE FOR STANDARDIZATION OF NUTRIENT MANAGEMENT SCHEDULE OF STRAWBERRY UNDER PUNJAB CONDITIONS

ANOVA FOR VEGETATIVE CHARACTERS AS MORTALITY (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.027			
Factor V (Genotype)	2	764.272	382.136	24.366	0
Factor T (Treatments)	12	10,161.67	846.806	53.995	0
Interaction V X T	24	162.604	6.775	0.432	0.98846
Error	76	1,191.90	15.683		
Total	116	12,285.48			

ANOVA FOR VEGETATIVE CHARACTERS AS PLANT HEIGHT (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.019			
Factor V (Genotype)	2	3.671	1.836	44.036	0
Factor T (Treatments)	12	121.337	10.111	242.566	0
Interaction V X T	24	1.162	0.048	1.161	0.3041
Error	76	3.168	0.042		
Total	116	129.357			

ANOVA FOR VEGETATIVE CHARACTERS AS PLANT SPREAD (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.343			
Factor V (Genotype)	2	71.905	35.952	106.139	0
Factor T (Treatments)	12	679.395	56.616	167.142	0
Interaction V X T	24	13.175	0.549	1.621	0.05885
Error	76	25.744	0.339		
Total	116	790.562			

ANOVA FOR VEGETATIVE CHARACTERS AS NUMBER OF LEAVE

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.477			
Factor V (Genotype)	2	25.394	12.697	64.034	0
Factor T (Treatments)	12	1,219.34	101.612	512.459	0
Interaction V X T	24	7.07	0.295	1.486	0.09936
Error	76	15.07	0.198		
Total	116	1,267.35			

ANOVA FOR VEGETATIVE CHARACTERS AS LEAF AREA (cm^2)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	11.236			
Factor V (Genotype)	2	2,273.27	1,136.63	176.661	0
Factor T (Treatments)	12	35,977.15	2,998.10	465.978	0
Interaction V X T	24	276.585	11.524	1.791	0.0294
Error	76	488.983	6.434		
Total	116	39,027.22			

ANOVA FOR VEGETATIVE CHARACTERS AS NUMBER OF RUNNERS

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.53			
Factor V (Genotype)	2	38.786	19.393	30.2	0
Factor T (Treatments)	12	666.222	55.519	86.457	0
Interaction V X T	24	23.214	0.967	1.506	0.09191
Error	76	48.803	0.642		
Total	116	777.556			

ANOVA FOR VEGETATIVE CHARACTERS AS DAYS TO RUNNER FORMATION

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.171			
Factor V (Genotype)	2	909.556	454.778	55.822	0
Factor T (Treatments)	12	2,501.81	208.484	25.591	0
Interaction V X T	24	157.111	6.546	0.804	0.72123
Error	76	619.162	8.147		
Total	116	4,191.81			

ANOVA FOR FLORAL CHARACTERS AS FLOWER SIZE (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.032			
Factor V (Genotype)	2	0.782	0.391	89.605	0
Factor T (Treatments)	12	0.104	0.009	1.992	0.03642
Interaction V X T	24	0.092	0.004	0.881	0.6245
Error	76	0.332	0.004		
Total	116	1.343			

ANOVA FOR FLORAL CHARACTERS AS DAYS TO FLOWERING

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.35			
Factor V (Genotype)	2	463.248	231.624	126.356	0
Factor T (Treatments)	12	481.692	40.141	21.898	0
Interaction V X T	24	58.308	2.429	1.325	0.17793
Error	76	139.316	1.833		
Total	116	1,147.92			

ANOVA FOR FLORAL CHARACTERS AS DURATION OF FLOWERING

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.556			
Factor V (Genotype)	2	528.632	264.316	88.973	0
Factor T (Treatments)	12	10,833.90	902.825	303.904	0
Interaction V X T	24	321.59	13.4	4.51	0
Error	76	225.778	2.971		
Total	116	11,913.45			

ANOVA FOR FLORAL CHARACTERS AS NUMBER OF FLOWER

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	27.684			
Factor V (Genotype)	2	25.027	12.514	31.932	0
Factor T (Treatments)	12	998.641	83.22	212.364	0
Interaction V X T	24	15.356	0.64	1.633	0.05609
Error	76	29.782	0.392		
Total	116	1,096.49			

ANOVA FOR FRUIT CHARACTERS AS FRUIT LENGTH (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.073			
Factor V (Genotype)	2	0.926	0.463	24.774	0
Factor T (Treatments)	12	15.05	1.254	67.074	0
Interaction V X T	24	0.359	0.015	0.8	0.72552
Error	76	1.421	0.019		
Total	116	17.829			

ANOVA FOR FRUIT CHARACTERS AS FRUIT BREADTH (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.018			
Factor V (Genotype)	2	1.901	0.951	38.792	0
Factor T (Treatments)	12	13.963	1.164	47.484	0
Interaction V X T	24	0.421	0.018	0.716	0.82016
Error	76	1.862	0.025		
Total	116	18.165			

ANOVA FOR FRUIT CHARACTERS AS DAYS TO MATURITY

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	-0.023			
Factor V (Genotype)	2	23.458	11.729	64.796	0
Factor T (Treatments)	12	147.085	12.257	67.713	0
Interaction V X T	24	6.284	0.262	1.446	0.11514
Error	76	13.757	0.181		
Total	116	190.561			

ANOVA FOR FRUIT CHARACTERS AS NUMBER OF FRUIT

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.935			
Factor V (Genotype)	2	44.314	22.157	163.186	0
Factor T (Treatments)	12	1,751.86	145.988	1,075.21	0
Interaction V X T	24	15.188	0.633	4.661	0
Error	76	10.319	0.136		
Total	116	1,822.62			

ANOVA FOR FRUIT CHARACTERS AS BERRY WEIGHT (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.09			
Factor V (Genotype)	2	40.803	20.402	196.011	0
Factor T (Treatments)	12	255.084	21.257	204.227	0
Interaction V X T	24	10.917	0.455	4.37	0
Error	76	7.91	0.104		
Total	116	314.805			

ANOVA FOR FRUIT CHARACTERS AS YIELD PER PLANT

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	131.793			
Factor V (Genotype)	2	24,118.68	12,059.34	300.829	0
Factor T (Treatments)	12	379,249.33	31,604.11	788.388	0
Interaction V X T	24	6,220.20	259.175	6.465	0
Error	76	3,046.61	40.087		
Total	116	412,766.61			

ANOVA FOR FRUIT CHARACTERS AS YIELD PER HECTARE

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.387			
Factor V (Genotype)	2	340.348	170.174	177.602	0
Factor T (Treatments)	12	4,663.77	388.648	405.611	0
Interaction V X T	24	87.926	3.664	3.823	0
Error	76	72.822	0.958		
Total	116	5,166.26			

ANOVA FOR FRUIT CHARACTERS AS TSS (^{o}B)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.81			
Factor V (Genotype)	2	1.504	0.752	10.71	0.00008
Factor T (Treatments)	12	45.371	3.781	53.842	0
Interaction V X T	24	1.636	0.068	0.971	0.51263
Error	76	5.337	0.07		
Total	116	54.658			

ANOVA FOR FRUIT CHARACTERS AS ACIDITY (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0			
Factor V (Genotype)	2	0.007	0.004	8.758	0.00038
Factor T (Treatments)	12	0.052	0.004	10.426	0
Interaction V X T	24	0.003	0	0.294	0.99934
Error	76	0.032	0		
Total	116	0.095			

ANOVA FOR FRUIT CHARACTERS AS TSS ACID RATIO

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.812			
Factor V (Genotype)	2	2.936	1.468	8.512	0.00046
Factor T (Treatments)	12	111.934	9.328	54.08	0
Interaction V X T	24	2.815	0.117	0.68	0.85555
Error	76	13.109	0.172		
Total	116	132.606			

ANOVA FOR FRUIT CHARACTERS AS TOTAL SUGAR (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.039			
Factor V (Genotype)	2	3.09	1.545	69.663	0
Factor T (Treatments)	12	36.233	3.019	136.139	0
Interaction V X T	24	0.553	0.023	1.038	0.43204
Error	76	1.686	0.022		
Total	116	41.6			

ANOVA FOR FRUIT CHARACTERS AS REDUCING SUGAR (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.054			
Factor V (Genotype)	2	0.977	0.489	30.568	0
Factor T (Treatments)	12	20.121	1.677	104.883	0
Interaction V X T	24	0.34	0.014	0.886	0.61908
Error	76	1.215	0.016		
Total	116	22.707			

ANOVA FOR FRUIT CHARACTERS AS NON REDUCING SUGAR (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.009			
Factor V (Genotype)	2	0.592	0.296	43.948	0
Factor T (Treatments)	12	2.481	0.207	30.672	0
Interaction V X T	24	0.136	0.006	0.84	0.6765
Error	76	0.512	0.007		
Total	116	3.73			

ANOVA FOR FRUIT CHARACTERS AS SUGAR ACID RATIO

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.124			
Factor V (Genotype)	2	7.042	3.521	66.198	0
Factor T (Treatments)	12	75.929	6.327	118.962	0
Interaction V X T	24	1.208	0.05	0.946	0.54295
Error	76	4.042	0.053		
Total	116	88.345			

ANOVA FOR FRUIT CHARACTERS AS pH of fruit

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.022			
Factor V (Genotype)	2	0.165	0.083	31.378	0
Factor T (Treatments)	12	4.103	0.342	129.722	0
Interaction V X T	24	0.038	0.002	0.603	0.91786
Error	76	0.2	0.003		
Total	116	4.528			

ANOVA FOR FRUIT CHARACTERS AS SPECIFIC GRAVITY

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.001			
Factor V (Genotype)	2	0.022	0.011	77.827	0
Factor T (Treatments)	12	0.28	0.023	161.676	0
Interaction V X T	24	0.009	0	2.579	0.00095
Error	76	0.011	0		
Total	116	0.323			

ANOVA FOR FRUIT CHARACTERS AS ANTHOCYANIN (mg/100g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.773			
Factor V (Genotype)	2	65.655	32.827	79.551	0
Factor T (Treatments)	12	1,517.98	126.498	306.545	0
Interaction V X T	24	13.051	0.544	1.318	0.18267
Error	76	31.362	0.413		
Total	116	1,632.82			

ANOVA FOR FRUIT CHARACTERS AS SHELF LIFE (DAYS)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.029			
Factor V (Genotype)	2	0.085	0.043	2.566	0.08345
Factor T (Treatments)	12	60.864	5.072	304.943	0
Interaction V X T	24	0.277	0.012	0.693	0.84277
Error	76	1.264	0.017		
Total	116	62.52			

APPENDICES – III

ANALYSIS OF VARIANCE FOR EFFECT OF DIFFERENT PACKAGING MATERIAL AND STORAGE CONDITION ON SHELF LIFE EXTENSION

ANOVA FOR FRUIT CHARACTERS AS WEIGHT LOSS (%) IN CHANDLER

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	276.76	276.76	13,080.68	0
Factor P (PACKAGING)	2	27.137	13.568	641.293	0
Int S X P	2	2.616	1.308	61.819	0
Factor D (DAYS)	2	179.229	89.615	4,235.50	0
Int S X D	2	97.037	48.519	2,293.16	0
Int P X D	4	2.74	0.685	32.374	0
Int S X P X D	4	0.828	0.207	9.779	0.00002
Error	36	0.762	0.021		
Total	53	587.109			

ANOVA FOR WEIGHT LOSS (%) IN WINTERDAWN

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	280.395	280.395	5,365.25	0
Factor P (PACKAGING)	2	30.263	15.132	289.54	0
Int S X P	2	3.793	1.897	36.289	0
Factor D (DAYS)	2	181.745	90.873	1,738.82	0
Int S X D	2	101.429	50.715	970.406	0
Int P X D	4	2.86	0.715	13.683	0
Int S X P X D	4	0.565	0.141	2.705	0.04553
Error	36	1.881	0.052		
Total	53	602.933			

ANOVA FOR WEIGHT LOSS (%) IN CAMAROSA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	252.374	252.374	12,855.90	0
Factor P (PACKAGING)	2	30.301	15.151	771.77	0
Int S X P	2	4.812	2.406	122.561	0
Factor D (DAYS)	2	170.776	85.388	4,349.65	0
Int S X D	2	91.986	45.993	2,342.87	0
Int P X D	4	2.777	0.694	35.371	0
Int S X P X D	4	1.038	0.26	13.221	0
Error	36	0.707	0.02		
Total	53	554.772			

ANOVA FOR FRUIT CHARACTERS AS TSS (ºB) IN CHANDLER

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	1.445	1.445	678.995	0
Factor P (PACKAGING)	2	0.091	0.046	21.42	0
Int S X P	2	0.043	0.021	10.073	0.00022
Factor D (DAYS)	3	1.574	0.525	246.584	0
Int S X D	3	1.064	0.355	166.582	0
Int P X D	6	0.092	0.015	7.183	0.00002
Int S X P X D	6	0.067	0.011	5.272	0.00031
Error	48	0.102	0.002		
Total	71	4.478			

ANOVA FOR FRUIT CHARACTERS AS TSS (ºB) IN WINTER DAWN

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	1.856	1.856	898.496	0
Factor P (PACKAGING)	2	0.085	0.043	20.666	0
Int S X P	2	0.082	0.041	19.762	0
Factor D (DAYS)	2	1.505	0.502	242.908	0
Int S X D	2	0.966	0.322	155.86	0
Int P X D	4	0.043	0.007	3.451	0.00648
Int S X P X D	4	0.016	0.003	1.29	0.27988
Error	36	0.099	0.002		
Total	53	4.652			

ANOVA FOR FRUIT CHARACTERS AS TSS (ºB) IN CAMAROSA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	1.459	1.459	1,431.26	0
Factor P (PACKAGING)	2	0.098	0.049	48.213	0
Int S X P	2	0.041	0.02	19.897	0
Factor D (DAYS)	2	1.431	0.477	467.979	0
Int S X D	2	0.902	0.301	295.13	0
Int P X D	4	0.045	0.008	7.381	0.00001
Int S X P X D	4	0.022	0.004	3.637	0.0047
Error	36	0.049	0.001		
Total	53	4.047			

ANOVA FOR FRUIT CHARACTERS AS ACIDITY (%) IN CHANDLER

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	0.088	0.088	111.227	0
Factor P (PACKAGING)	2	0.019	0.009	11.876	0.00006
Int S X P	2	0.01	0.005	6.28	0.00378
Factor D (DAYS)	2	0.183	0.061	77.053	0
Int S X D	2	0.015	0.005	6.497	0.00089
Int P X D	4	0.008	0.001	1.736	0.13292
Int S X P X D	4	0.005	0.001	0.954	0.46606
Error	36	0.038	0.001		
Total	53	0.367			

ANOVA FOR FRUIT CHARACTERS AS ACIDITY (%) IN WINTER DAWN

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	0.085	0.085	193.078	0
Factor P (PACKAGING)	2	0.008	0.004	8.807	0.00055
Int S X P	2	0.002	0.001	1.744	0.18576
Factor D (DAYS)	2	0.293	0.098	222.885	0
Int S X D	2	0.027	0.009	20.38	0
Int P X D	4	0.004	0.001	1.651	0.15394
Int S X P X D	4	0.002	0	0.79	0.58225
Error	36	0.021	0		
Total	53	0.442			

ANOVA FOR FRUIT CHARACTERS AS ACIDITY (%) IN CAMAROSA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	0.055	0.055	77.957	0
Factor P (PACKAGING)	2	0.008	0.004	5.707	0.00598
Int S X P	2	0.002	0.001	1.632	0.20623
Factor D (DAYS)	2	0.243	0.081	114.809	0
Int S X D	2	0.019	0.006	9.076	0.00007
Int P X D	4	0.003	0.001	0.712	0.6419
Int S X P X D	4	0.003	0.001	0.748	0.61415
Error	36	0.034	0.001		
Total	53	0.368			

ANOVA FOR FRUIT CHARACTERS AS VITAMIN C (mg/100g) IN CHANDLER

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	1,573.96	1,573.96	2,705.05	0
Factor P (PACKAGING)	2	430.307	215.154	369.769	0
Int S X P	2	4.078	2.039	3.504	0.03797
Factor D (DAYS)	2	2,707.99	902.663	1,551.34	0
Int S X D	2	945.681	315.227	541.758	0
Int P X D	4	182.086	30.348	52.156	0
Int S X P X D	4	12.757	2.126	3.654	0.00456
Error	36	27.929	0.582		
Total	53	5,884.78			

ANOVA FOR FRUIT CHARACTERS AS VITAMIN C (mg/100g) IN WINTER DAWN

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	1,375.55	1,375.55	1,048.94	0
Factor P (PACKAGING)	2	552.42	276.21	210.627	0
Int S X P	2	2.185	1.093	0.833	0.44085
Factor D (DAYS)	2	2,854.21	951.402	725.502	0
Int S X D	2	862.244	287.415	219.171	0
Int P X D	4	227.425	37.904	28.904	0
Int S X P X D	4	32.845	5.474	4.174	0.00187
Error	36	62.946	1.311		
Total	53	5,969.82			

ANOVA FOR FRUIT CHARACTERS AS VITAMIN C (mg/100g) IN CAMAROSA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	1,366.70	1,366.70	1,616.11	0
Factor P (PACKAGING)	2	434.144	217.072	256.685	0
Int S X P	2	46.572	23.286	27.535	0
Factor D (DAYS)	2	3,042.72	1,014.24	1,199.33	0
Int S X D	2	1,021.95	340.65	402.814	0
Int P X D	4	194.808	32.468	38.393	0
Int S X P X D	4	27.433	4.572	5.407	0.00025
Error	36	40.592	0.846		
Total	53	6,174.92			

ANOVA FOR FRUIT CHARACTERS AS TSS/ACID RATIO IN CHANDLER

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	12.164	12.164	46.164	0
Factor P (PACKAGING)	2	4.748	2.374	9.009	0.00048
Int S X P	2	3.074	1.537	5.833	0.0054
Factor D (DAYS)	2	30.156	10.052	38.148	0
Int S X D	2	1.456	0.485	1.841	0.15228
Int P X D	4	2.208	0.368	1.397	0.23545
Int S X P X D	4	1.23	0.205	0.778	0.59129
Error	36	12.648	0.264		
Total	53	67.684			

ANOVA FOR FRUIT CHARACTERS AS TSS/ACID RATIO IN WINTER DAWN

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	13.563	13.563	73.163	0
Factor P (PACKAGING)	2	1.873	0.936	5.051	0.01021
Int S X P	2	0.497	0.249	1.341	0.27108
Factor D (DAYS)	2	66.245	22.082	119.118	0
Int S X D	2	5.272	1.757	9.48	0.00005
Int P X D	4	1.738	0.29	1.563	0.17864
Int S X P X D	4	0.851	0.142	0.765	0.60089
Error	36	8.898	0.185		
Total	53	98.936			

ANOVA FOR FRUIT CHARACTERS AS TSS/ACID RATIO IN CAMAROSA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	9.321	9.321	34.555	0
Factor P (PACKAGING)	2	2.363	1.181	4.38	0.0179
Int S X P	2	0.811	0.406	1.504	0.23257
Factor D (DAYS)	2	60.031	20.01	74.184	0
Int S X D	2	3.241	1.08	4.006	0.01266
Int P X D	4	1.608	0.268	0.993	0.44048
Int S X P X D	4	1.523	0.254	0.941	0.47475
Error	36	12.947	0.27		
Total	53	91.845			

ANOVA FOR FRUIT CHARACTERS AS TOTAL SUGAR (%) IN CHANDLER

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	0.388	0.388	148.942	0
Factor P (PACKAGING)	2	1.149	0.575	220.764	0
Int S X P	2	0.256	0.128	49.248	0
Factor D (DAYS)	2	3.37	1.123	431.688	0
Int S X D	2	1.029	0.343	131.786	0
Int P X D	4	0.109	0.018	6.953	0.00002
Int S X P X D	4	0.092	0.015	5.865	0.00012
Error	36	0.125	0.003		
Total	53	6.517			

ANOVA FOR FRUIT CHARACTERS AS TOTAL SUGAR (%) IN WINTER DAWN

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	0.737	0.737	130.379	0
Factor P (PACKAGING)	2	1.591	0.795	140.727	0
Int S X P	2	0.092	0.046	8.115	0.00092
Factor D (DAYS)	2	3.282	1.094	193.539	0
Int S X D	2	1.012	0.337	59.705	0
Int P X D	4	0.198	0.033	5.837	0.00013
Int S X P X D	4	0.093	0.016	2.745	0.02247
Error	36	0.271	0.006		
Total	53	7.277			

ANOVA FOR FRUIT CHARACTERS AS TOTAL SUGAR (%) IN CAMAROSA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	0.097	0.097	56.063	0
Factor P (PACKAGING)	2	0.538	0.269	155.775	0
Int S X P	2	0.087	0.043	25.104	0
Factor D (DAYS)	2	3.002	1.001	579.476	0
Int S X D	2	0.667	0.222	128.695	0
Int P X D	4	0.163	0.027	15.772	0
Int S X P X D	4	0.194	0.032	18.753	0
Error	36	0.083	0.002		
Total	53	4.83			

ANOVA FOR FRUIT CHARACTERS AS REDUCING SUGAR (%) IN CHANDLER

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	0.941	0.941	400.033	0
Factor P (PACKAGING)	2	0.628	0.314	133.445	0
Int S X P	2	0.037	0.019	7.928	0.00106
Factor D (DAYS)	3	2.203	0.734	312.072	0
Int S X D	3	1.124	0.375	159.295	0
Int P X D	6	0.113	0.019	7.999	0.00001
Int S X P X D	6	0.038	0.006	2.692	0.02469
Error	48	0.113	0.002		
Total	71	5.197			

ANOVA FOR REDUCING SUGAR (%) IN WINTER DAWN

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	1.191	1.191	431.71	0
Factor P (PACKAGING)	2	0.967	0.483	175.227	0
Int S X P	2	0.045	0.022	8.091	0.00094
Factor D (DAYS)	3	2.309	0.77	278.997	0
Int S X D	3	1.137	0.379	137.465	0
Int P X D	6	0.094	0.016	5.661	0.00017
Int S X P X D	6	0.067	0.011	4.069	0.00224
Error	48	0.132	0.003		
Total	71	5.941			

ANOVA FOR FRUIT CHARACTERS AS REDUCING SUGAR (%) IN CAMAROSA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	0.652	0.652	401.955	0
Factor P (PACKAGING)	2	0.171	0.085	52.608	0
Int S X P	2	0.041	0.021	12.691	0.00004
Factor D (DAYS)	2	2.116	0.705	435.094	0
Int S X D	2	1.249	0.416	256.832	0
Int P X D	4	0.093	0.016	9.575	0
Int S X P X D	4	0.042	0.007	4.306	0.0015
Error	36	0.078	0.002		
Total	53	4.442			

ANOVA FOR SHELF LIFE OF FRUITS IN DIFFERENT STRAWBERRY GENOTYPES

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor S (STORAGE)	1	289.352	289.352	3,329.65	0
Factor G (GENOTYPE)	2	3.705	1.852	21.316	0
Int S X G	2	0.648	0.324	3.726	0.03384
Factor P (PACKAGING)	2	76.143	38.072	438.099	0
Int S X P	2	22.41	11.205	128.937	0
Int G X P	4	0.387	0.097	1.113	0.36551
Int S X G X P	4	0.171	0.043	0.491	0.74226
Error	36	3.128	0.087		
Total	53	395.943			

PLATES

VEGETATIVE & FLOWERING CHARACTERS OF DIFFERENT GENOTYPES OF STRAWBERRY

STRAWBERRY TRANSPLANT ON BEDS

Vegetative and Fruiting characters of Camarosa, WinterDawn and Chandler Strawberry

Effect of Different Nutrient Management Schedule on Stawberry Fruits

LIST OF PUBLICATIONS

SNO.	TITLE OF PAPER WITH AUTHOR NAMES	NAME OF JOURNAL / CONFERENCE	PUBLISHED DATE	ISSN NO/ VOL NO, ISSUE NO
1.	"**EVALUATION OF PERFORMANCE OF STRAWBERRY CULTIVARS FOR VEGETATIVE ATTRIBUTES AND RUNNER PRODUCTION"** by **Wineet Chawla, Shailesh Kumar Singh and S.S. Bal**	Plant Archives	October, 2020	e-ISSN:2581-6063 (online)/Volume 20/ No. 2, 2020
2.	"**Evaluation of different strawberry genotypes for flower characters under Punjab conditions" by Wineet Chawla and Shailesh Kumar Singh**	Journal of Pharmacognosy and Phytochemistry	September, 2020	e-ISSN: 2278-4136/Volume 9, No.5 Special 2020