POPULATION DYNAMICS AND ECOFRIENDLY MANAGEMENT OF *MELANAGROMYZA OBTUSA* (MALLOCH) INFESTING *CAJANUS CAJAN* (L.)

Thesis submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Zoology

By

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DECLARATION

I, hereby declared that the presented work in the thesis entitled **"Population Dynamics and Ecofriendly Management of *Melanagromyza obtusa* (Malloch) infesting *Cajanus cajan* (L.)"** in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of **Dr. Sunil Kumar Dwivedi** working as **Assistant Professor**, in the **Department of Entomology, School of Agriculture** of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of another investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled **"Population Dynamics and Ecofriendly Management of *Melanagromyza obtusa* (Malloch) infesting *Cajanus cajan* (L.)"** submitted in fulfilment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the **Zoology** is a research work carried out by **Manoj Kumar Singh (12109713)** is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

(Signature of Supervisor)

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ABSTRACT

The present investigation entitled **"Population Dynamics and Ecofriendly Management of *Melanagromyza obtusa* (Malloch) infesting *Cajanus cajan* (L.)"** were conducted for two following *Kharif* seasons crop, 2022-23 and 2023-24. The highest population of *M. obtusa* was observed in 46th (70.67 maggots /100 pods) and 44th (72.67 maggots /100 pods) Standard Meteorological Weeks (SMW) and lowest population was observed during the 2nd (1.33 maggots / 100 pods) and 1st (2.67 maggots /100 pods) SMW, respectively whereas *Helicoverpa armigera* population peaked during 47th and 46th and lowest population was observed during 52nd and 51st SMW in 2022-23 and 2023-24, respectively. Maximum population of *Mylabris pustulata* was observed during 43rd and 41st SMW and minimum population was observed in 47th and 48th SMW during both the year and the highest population of *Clavigralla gibbosa* was recorded in 46th and 44th SMW during both years. The lowest population was observed in 41st and 49th SMW during both years. The highest population of *Lampides boeticus* attained peak at 44th SMW in both years and minimum population was observed at 48th SMW of both years, respectively. The high occurrence of *M. obtusa* (pod fly) maggot and pupae was noted in 47th & 50th SMW and 44th & 45th, respectively. The correlation between the occurrence of *Melanagromyza obtusa*, *Helicoverpa armigera*, *Mylabris pustulata*, *Clavigralla gibbosa* and *Lampides boeticus* with abiotic factors exhibited both positive and negative relationships with significant and non-significant during both years. Pod fly larvae exhibited a substantial positive correlation (r = 0.646*) with maximum temperature and the correlation was highly significant (r = 0.746**). Pod fly larvae exhibited non-significant negative correlation with min. Rh% (r= -0.515) in first year but highly negative significant correlation in second year (r = -0.776**). Regarding pod fly pupae, there was a negative significant correlation (=-0.541*) with minimum temp. in 2023-24, while other factors showed non-significant correlations in both years. Initially, during the 2022-23 season, 11.76 percent larval parasitism was observed in the 43rd SMW, while pupal parasitism was 9.37 percent in the 44th SMW. Larval parasitism peaked at 31.82 percent in the 46th

SMW and pupal parasitism reached 25.64 percent in the 47th SMW. In the 2023-24 season, larval parasitism was observed as 4.17 percent in the 41st SMW and pupal parasitism was 11.53 percent in the 42nd SMW. Larval parasitism peaked at 29.72 percent in the 45th SMW, while the highest pupal parasitism was 24.32 percent in the 44th SMW. Treatment P4 and P5 showed the lowest pod and grain damage percentages in 2022-23 and 2023-24 respectively but had relatively high weight loss. Conversely, the control treatment had the lowest grain damage percentage across both years.

However, it exhibited the maximum weight loss. Timely sowing is crucial for achieving maximum yields. Late sowing from the 1st date of sowing (1DOS) to the 7th date of sowing (7DOS) leads to a progressive decrease in yield, indicating that earlier sowing results in higher yields. The yields were consistently higher in first year compared to second year. Across all sowing dates, suggesting more favorable growing conditions in first year. However, the trend of declining yield with late sowing was consistent in both years and the pooled mean, further emphasizing the importance of timely sowing for maximizing yields. Dimethoate 30% EC @ 2ml/Lit treatment resulted in the highest pooled mean yield (17.07 q/ha), followed by NSKE @ 5ml/Lit (15.85 q/ha). The control treatment had the lowest pooled mean yield (13.40 q/ha). The yield differences among treatments highlight the effectiveness of various pest management strategies in improving crop productivity.

Key words: *Cajanus cajan, Euderus lividus, Ormyrus orientalis*, Pod fly, Weather parameters

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LIST OF ABBREVIATIONS AND SYMBOLS USED

Abbreviated Form	Full Form	Abbreviated Form	Full Form
%	Percentage	Min. Temp.	Minimum Temperature
@	at the rate of	Max. Temp.	Maximum Temperature
±	Plus-Minus Sign	OPSTAT	Operational Statistics
°C	Degree Celsius	ppm	Parts per million
=	Is equal to	q	Quintal
:	Ratio	R	Replication
&	And	r	Correlation coefficient
a. i.	Active ingredient	RBD	Randomized Block Design
ANOVA	Analysis of Variance	Rh%	Relative Humidity%
DMRT	Duncan's New Multiple Range Test	Rh (Max.)	Relative Humidity (Maximum)
EC	Emulsifiable concentrate	Rh (Min.)	Relative Humidity (Minimum)
E.g.	For Example,	SC	Suspension concentrates
et al.,	and others	SD	Standard Deviation of the mean
Etc.	Et cetera	SE	Standard Error
ETL	Economic Threshold Level	SMW	Standard Meteorological Week
Fig.	Figure	SPSS	Statistical Package for Social Sciences
gm	Gram	Sp.	Species
Kg	Kilogram	Sq. mt	Square Meter
Lit.	Liter	T	Treatment
mg	milligram	WP	Wettable Powder
ml	Milliliter		
m	meter		

***Chapter*-I**

INTRODUCTION

Pigeonpea, scientifically named *Cajanus cajan* (L.) Millspaugh is a significant pulse crop that is grown in tropical and subtropical regions. It thrives particularly well in semi-arid regions through rainfed agriculture because of its ability to develop a deep taproot, tolerate heat and grow quickly (Mallikarjuna *et al.*, 2011). Pigeonpea is extensively cultivated across South & Southeast Asia, serving as a primary source of vegetable protein in the region. In India, pigeonpea holds the second position among crops, following chickpea (Das *et al.,* 2022). Pigeonpea is cultivated widely for its high protein composition and is a significant part of our daily diet. In developing nations, where pulses are more affordable compared to non-veg, they are demoted to as "poor man's meat" in general (Somasundaram *et al*., 2017).

The term 'pigeonpea' originated in Barbado, where its seeds held significant value as feed for pigeons (Upadhyaya *et al.*, 2015). Pigeonpea belong to the Fabaceae family and the Fabales order, where it is it is classified as a perennial plant (Sarkar *et al*., 2020). Although known by various regional names, they all refer to the same highly valued pulse crop, *Cajanus cajan* (L.). Which holds significant importance in Indian agriculture. Its popularity in India is notable due to its ability to offer a rich source of protein in diets, particularly catering to the vegan community (Bhattacharjee and Sharma, 2015). Pigeonpea is very nutritious legume crop that contains proteins as well as amino acids, examples being lysine, methionine and tryptophan, among others (Jeevarathinam and Chelladurai, 2020). Dry pigeonpea seeds in their chemical composition include 22.3 percent protein, 1.7 percent fat, 3.5 percent minerals, 1.5 percent fiber and 57.6 percent carbohydrates (Khamoriya *et al*., 2017). Also, they are laden with calcium (73 mg per 100 g), Phosphorus (304mg per 100 gram) and iron (5.8 mg per 100 gram). Pigment contains 13.4 percent of moisture and that is with a calorific value of 335 Kcal per 100 grams. Pigeonpea served with grain food forms a nutritious diet for humans. Pigeonpea has the capacity to diminish hunger and malnutrition while ensuring the sustainable productivity of smallholder crop systems. Pigeonpea (*Cajanus* *cajan*) served with grain food forms a nutritious diet for humans. The husk of tur seed provides valuable fodder for milch animals. The dry sticks of pigeonpea plant are also used for making baskets, thatches, fencing and storage bins. It is a resistant and rapidly growing plant that succeed in various conditions showing remarkable adaptability and resistant to drought. Pigeonpea is help of improve soil by forming a beneficial partnership with Rhizobia bacteria to fix nitrogen (Bopape *et al.*, 2022). Inclusion of pigeonpea during the crop rotation method is to ensure an environmental system that will stand the taste of time: it is a response to soil erosion. Pigeonpea is usually cultivated as an additional crop or intercrop to other crops such as in regions of cotton, sorrel and soyabean, with little attention given to it by the farmers. (Sharma *et al.*, 2011). India is a leading global producer of pigeonpea 90% total production in the world (Saxena *et al*., 2021).

In India, total pulse crop production was 25.58 million MT during 2020-21 of which Chickpea and Pigeonpea contributed by 49.3% 16.2% respectively (Gurusamy *et al.,* 2022). Pigeonpea cultivation spans an average of 5.05 million hectares in India. Resulting a productivity of 859 kg/hectare and production of 4.34 million tonnes (desagri.gov.in). While the cultivation of Arhar made 1.2 thousand hectares and the total quantity of the harvest makes 1.3 thousand tonnes during 2022-23. while average yield constituting 11.07 quintals per hectare (Anonymous, 2024).

In pigeonpea, Coleopteran, Dipteran, Hymenopteran and Lepidopteran group of insects are major problems (Yadav *et al*., 2016). Pod fly is responsible for 10-50% of losses among pigeonpea pests (Sharma *et al*., 2017).

In terms of biotic stresses, insect pests, diseases and weeds present significant threats to achieving targeted yields. The crops are attacked by about 250 insect pests, especially *Melanagromyza obtusa* (Malloch) *Helicoverpa armigera* (Hubner), *Maruca vitrata* (Gayer) and *Clavigralla gibbosa* (Spinola) causing significant grain yield reductions (Srivastava and Joshi, 2011). The most dangerous and important pest *M. obtusa* and the pod borer, *H. armigera* which together are responsible for 80–90% of the damage caused to pigeonpea (Saxena *et al*., 2018).

Melanagromyza obtusa (Malloch) is an obnoxious pest, leading to pod grain losses from 20 to 80% due to its destructive impact. Infestation of pigeonpea plants causes substantial damage to both seeds and pods leading to decreased germination rates and making them unfit for human consumption or any other use (Hadiya *et al*., 2020). Pod fly oviposition occurs in tender pods and inner surface of the pods. The larvae feed on green seeds and convert into pupa inside the pods (Nair *et al*., 2017). Pod fly laid fewer eggs in December & January month, when temperature is low. *M. obtusa* population increases with temperature rise (Chiranjeevi and Patange, 2018[a]). The female pod fly lays up to 80 eggs into maturing green pods. Pod fly female eggs are laid inside the pod wall with help of ovipositor. After hatching, the larva adheres to the green seeds inside the pod and begin feeding green seed surface. A single larva consumes one whole seed during its lifetime; if the first seed doesn't have enough fulfil its requirements, it is sometimes observed to move seed in same pods to continue feeding (Chiranjeevi and Patange, 2018[b]). Thereafter, larva burrows into the seeds and feeds upon tender seeds, rendering them unfit for both human consumption and further propagation. Such pods don't exhibit any visible signs of damage until the larvae emergence and same causes shot-holes in the pod walls upon maturity (Ambarish and Kalleshwaraswmy, 2021). Typically, one maggot requires only a single seed for its development (Yadav *et al*., 2016). *M. obtusa*, an internal feeder, resides within the pod wall during both larval and pupal stages, leaving a delicate papery membrane behind. Inside the pod the larvae consume the developing seeds followed by pupal development (Patange *et al*., 2017[a]). This perforation serves as an exit point for the adult flies as they emerge from the pod as described by Kumar *et al*. (2015). Egg phase typically ranges from 3 to 5 days followed by larval development duration of 6 to 11 days and further pupal stage extends from 9 to 23 days. The adult insects have a lifespan of about 6 days without nutrition, but this extends to 12 days when they provided with honey food (Yadav *et al*., 2020). Such newly emerged young ones are small and black colored. The population fluctuations of pod fly are regulated by its restricted range of hosts and feeding behaviour (Chiranjeevi and Patange, 2018[b]).

Melanagromyza obtusa is basically a hidden key pest. Pod flies undergo their entire life cycle, including egg, larval and pupal stages, exclusively within the pigeonpea pods. The full extent of the damage pods was only realised during threshing and winnowing process. As a result, managing this pest effectively is quite challenging.

Over 20 species of parasitoid (Hymenoptera) have been recorded to parasitize of pod fly pest (Patange *et al*., 2017[a]). Pesticides have negative effects on human beings and useful organisms while degrading the natural system. Chemical control has many dis-advantage viz. development of pest resistance; harmful effect on beneficial insects; residue problem in food and environment; ground water and soil pollution missing management cost and overall leading to ecological imbalanced (Srivastava and Joshi, 2011).

Euderus lividus is a species of parasitoid belonging to the family of Eulophidae. *E. lividu*s are known for their role in biological control (Taveras and Hansson, 2015). Particularly, against major pest (*M. obtusa*) that attack pigeonpea. *E. lividus* was identified as an ecto-parasitoid larva of *M. obtusa* during the study. The eggs are deposited onto the bodies of second and third instar larvae of the host. Females observed laying up to nine eggs per host (Yadav *et al*., 2011[b]). Previous reports indicate that females lay their eggs through the exit hole created by young larva of pod fly. However, Singh (1991) reported that, *E. lividus* had also parasitized the larvae in their second instar. *E. lividus*, eggs are not always laid exclusively via exit hole (window) created by larva of the pest in pod surface. Instead, the female parasitoid is capable of depositing eggs through the pod wall using its elongated ovipositor (Yadav *et al.*, 2011[b]). *Ormyrus orientalis* is belonging to the family of Ormyridae reported as major bio-control agents. The parasitoid lays its egg inside the puparium, on the body of the pupa (Chiranjeevi and Patange, 2018[a]). *Ormyrus orientalis* is a solitary nature parasitoid, as only a single individual was found developing on each pupa. Pod fly female oviposits, its eggs on the body of pod fly's pupa, possibly inside the puparium (Yadav *et al.*, 2011[b]). These two natural parasitoid species *E. lividus* and *O. orientalis* were identified as the main or dominant parasitoids attacking the pigeonpea pod fly. The high levels of parasitism reported 80.00% for *E. lividus* and 46.66% for *O. orientalis*, indicate they can be quite effective in suppressing the pod fly population. These two parasitoid species are important natural biological control agents that can help manage populations of the pest *M. obtusa* based on the information provided (Yadav *et al.*, 2012). Dry pigeonpea pods exhibit one or more perforations on upper surface, indicating infestation. Seeds within infested pods appear desiccated, wrinkled and partially consumed (Sharma and Keval, 2021). Future scope of this paper utilization of natural parasitoids effective for management of pod fly without any residual effects.

Although using insecticides to combat insect pests remains the primary defensive strategy, it comes with significant costs and various challenges and constraints. However, insects that infesting pigeonpea crops have developed resistance as a result of the extensive and indiscriminate use of insecticides. The utilization of biopesticides along with chemical insecticides to effectively manage the pod borer complex has resulted in renewed interest in study into this possibility (Jeyarani and Karuppuchamy, 2010). Biopesticides like *Bacillus thuringiensis* (*Bt.*) and NSKE 5% provide alternative and environmentally friendly options for controlling the insect pest. The main cause is repeated and unfocused application of the same insecticides, monoculture and introduction of pigeonpea variety of early maturity.

A study was conducted on the UPAS120 variety of pigeonpea at the Lovely Professional University (LPU) Experimental Field of the School of Agriculture in Jalandhar, Punjab, taking into account the previously provided information. These experiments spanned in the years 2022-23 and 2023-24, aiming to achieve specific purposes:

1. To investigate population dynamics of *M. obtusa* in pigeonpea.
2. To estimate extent of damage against *M. obtusa*.
3. To study effect of early and late sowing on the intensity of pod fly, *M. obtusa*.
4. To estimate ecofriendly management practices by using biorational pesticides due to pod fly in pigeonpea.

Chapter **II**

REVIEW OF LITERATURE

The related review literature to investigate entitled **"Population Dynamics and Ecofriendly Management of *Melanagromyza obtusa* (Malloch) infesting *Cajanus cajan* (L.)"** has been evaluated and is present under the following subheadings in this chapter.

2.1. To investigate populations dynamics of *M. obtusa* in pigeonpea

The main pests & insects exhibit significant fluctuations in pigeon pea under natural environmental conditions. There is a scarcity of information concerning the impact of non-living aspects on population dynamics. The population of pod flies exhibits dramatic fluctuations in their natural environment. The consistent trend in population increase has aided in controlling these pests by exploiting the phenomenon of host avoidance. The literature review on this topic can be accessed here.

The pod fly populations from 0.0 to 3.2 maggots in each pod, with an average of 1.24 maggots per pod. The maggots first appeared in the 43rd Standard Meteorological Week (SMW), which is the last week of October and persisted until harvest. The highest populations were observed in December and January, peaking at 3.2 maggots per pod during the 1st and 2nd SMW (Bhadani and Patel, 2019). During the *kharif* seasons of 2008-2009 and 2009-10, *Melanagromyza obtusa* exhibited clear seasonality on pigeonpea crops. The crops were sown on July 28th in 2008-09 and August 8th in 2009-10, with harvests occurring on 12th April 2009 and 17th April 2010, respectively. Pest finding began in the 2nd Standard Week (SW) after planting and persisted until the 13th SW. In 2008-2009, the highest population in the 6th SW with 53.73 maggots per pod, while the 3rd week showed 50.40 maggots. The lowest population, 20.80 maggots, occurred in the 2nd SW of the same season. In contrast, during 2009-10, the peak pod fly population was noted in the 10th week with 8.93 maggots, followed by 7.60 maggots in the 9th week and the lowest population was observed in the 4th week with just 0.73 maggots. Pod infestation rates fluctuated, ranging from 33.33% to 86.40% in 2008-09 and from 0.33% to 11.74% in 2009-10 (Keval and Srivastava, 2011). According to Srujana and Keval, 2014 the peak mean population of *Melanagromyza obtusa*, Pod fly occurred in the 9th SW, with 7.0 maggots and the second highest was 6.8 maggots in the 12th SW. The lowest population of 0.8 maggots was recorded in the 1st Standard Week (SW). In the 3rd Standard Meteorological Week (SMW), the maximum population of larvae reached 125, with 67 pupae and the highest count of pod flies per 100 pods. During this period, damage pods and grains infestation 9.00% to 93.00% and 3.00% to 52.13%, respectively, with the most severe damage occurring in the 3rd SMW, where 93% of the pods and 52.13% of the grains were affected (Chiranjeevi and Patange, 2018[a]). Jakhar *et al*. (2016) reported an average of 0.97, 0.32 and 0.30 larvae per plant from the 27th to the 3rd Standard Week (SW) in 2011, 2012 and 2013, respectively, through a mean of 0.38 larvae per plant in 2014. *Melanagromyza obtusa* first appeared during the 42nd SW in both years, persisting until the 51st week at the pod maturity stage. Peak populations were observed in the 45th week of 2015 with 2.93 maggots per 10 pods for ICPL 87 and in the 44th week of 2016 with 2.60 maggots per 10 pods. For UPAS-120, the peak occurred in the 45th week with 2.80 and 2.73 maggots per 10 pods in 2015 and 2016, respectively, during pod filling. The lowest populations for ICPL 87 were recorded in the 51st week with 0.13 and 0.20 maggots per 10 pods and for UPAS-120, the minimum was 0.13 and 0.16 maggots per 10 pods during the pod maturity stage (Keval *et al*., 2018). The pigeonpea pod fly invasion, which began late in the *Kharif* season, persisted through harvest with the initial population recorded in October 2016 at 0.10 larvae per fourth week and 0.06 maggots per ten pods per month. This infestation steadily increased, reaching a range of 0.10 to 0.67 maggots per 10 pods per week, with an averaging of 0.36 maggots per 10 pods in November 2016. By the first week of December 2016 (49th week), maggot counts rose further, fluctuating between 0.03 to 1.2 larvae per 10 pods per with an average of 0.70 maggots per 10 pods during the month (Kumar *et al*., 2018). According to Pandey *et al*. (2016) focused on the occurrence patterns of the pod fly and pod bug, with the pod fly first appearing in the 42nd SW at an average population of 0.10 maggots per plant. Its population peaked during the 45th SW, reaching an average of 0.30 maggots per plant during the 2010-11 season. Similarly, *C. gibbosa* was first observed in the 40th SW with an initial populace of 0.03 maggots per plant. Its population peaked during the 44th and 45th SW, with average populations of 0.40 larvae per plant during both weeks. According to Pillai and Agnihotri (2013), *Melanagromyza obtusa* exhibited significant activity during the 46th Standard Week (SW), though its population declined to 31 per 100 pods by the 49th SW. The 47th SW recorded a weekly parasitization rate of 6.52%. Rathore *et al*. (2017) noted that pod fly, pod borer plum moth infestations began in the 32nd, 40th and 41st weeks of the cropping season, respectively. The pod fly larvae population peaked during the 46th week, reaching 6.00 larvae per five plants. Pod damage from borers peaked at 14.32% in the 42nd SMW, while pod fly damage reached 8.47% in the 46th SMW. The seasonal activity of the pod fly in the NDA2 pigeonpea variety revealed that during the 15th Standard Week (SW), the percentage of soft grain damage peaked at 14.33% and 18.98%. The larval population reached its peak of 8.66 per 100 pods in the 8th week, while the pupal population peaked at 24.66 per 100 pods in the 11th week. Analysis of the relationship between *M. obtusa* and climate factors showed that the maggot population had a non-significant correlation with both the lowest temperature (0.279) and highest temperatures (0.111), whereas the pupal population demonstrated a significant correlation with both the lowest temperature (0.650) and highest temperatures (0.667) (Shanker *et al*., 2021[a]). Additionally, the study on pod fly by Soni *et al*. (2018), observations from October to December 2016 revealed that the initial larval population averaged 0.10 and 0.06 larvae per 10 pods in October. This number gradually increased, reaching an average of 0.10 to 0.67 larvae per 10 pods per week in November, with a mean of 0.36 larvae per 10 pods. Weekly larvae populations varied from 0.03 to 1.2 larvae per 10 pods with an overall average of 0.70 larvae per 10 pods and continued to be monitored until the end of December 2016. According to Srinivas *et al*. (2019), pod fly activity peaked in the 4th Standard Meteorological Week (SMW) with 36.00 and 30.96 larvae per 50 pods, continuing until the 8th SMW before declining to its low levels (0.94 & 0.70 larvae per 50 pods) in both conventional and organic farming methods. Infestation rates during the filling stage of the pod ranged from 1.23% to 2.00% in the 3rd SW of January, with the highest infestations occurring in the 3rd week of February in the first year (15.56%) and week earlier in the second year (13.72%) during the 2nd SW of February (Subharani and Singh, 2007). Additionally, the study on pigeonpea crops observed various insect pests at different growth stages, with pod fly first appearing in the 3rd week of 2012, peaking in the 10th week and pod bug first noticed in the 1st week and also peaking in the 10th week. Despite a decrease in pest incidence after their peaks, both pests remained present until harvest, with the pod fly's appearance in the 3rd week according with the late vegetative period of the pigeonpea crop (Vikram *et al*., 2015). The presence of *Melanagromyza obtusa* was first detected during the initial Standard Week of October, when the pigeonpea crop was approximately 90-100 days old, reaching its peak by the 47th week at the start of November, coinciding with the crop's age of 100 to 125 days. The population then gradually declined, reaching zero levels by the 1st week of December, aligning with the pest's activity over about two months and the ripening of the crop. Larval growth began as temperatures fell below 32°C, peaking as temperatures continued to decrease, with maximum temperatures below 30°C, minimum temperatures ranging from 8.1 to 17.0°C and mean Rh% of approximately 60-70 per cent creating favorable conditions for the pest's proliferation (Yadav *et al*., 2011[a]). Pigeonpea (*Cajanus cajan*) attracts a variety of insect pests and their natural predators, including jassids (*Empoasca fabae*), cow bugs (*Otinotus oneratus*), pod bugs (*C. gibbosa*), red pumpkin beetles, green stink bugs (*Nezara viridula*), grasshoppers (*Cyrtacanthacris* sp.), thrips (*Megalurothrips usitatus*), pod flies (*Melanagromyza obtusa*), leaf webbers (*Grapholita critica*), gram pod borers (*Exelastis atomosa*), spiders (*Hognan lenta*), ladybird beetles (*Coccinella septempunctata*), green lacewings (*Chrysoperla* sp.) and wasps (*Cotessia* sp.). Beneficial predators such as ladybird beetles, green lacewings and parasitic wasps play a crucial role in managing these pests and preserving ecological balance (Bijewar *et al*., 2019). According to Borah (2002), *Helicoverpa armigera* began egg laying in early November and continued through to March, with peak egg deposition occurring in January. The tur plume moth and *H. armigera* were first observed from the 47th to the 50th Standard Meteorological Week (SMW), while leaf roller infestations started from the 31st to the 50th SMW. During the 48th SMW, the highest larval populations of the tur plume moth (4.00 per million larvae) and pod fly (0.3%) were recorded, influenced by minimum temperatures of 28.59°C and maximum temperatures of 33.76°C. Morning humidity was recorded at

78.00%, evening humidity at 33.43%, with no rainfall, while leaf roller populations peaked during the 33rd Standard Meteorological Week (SMW) at 8.4, supported by minimum temperatures of 31.60°C, maximum temperatures of 32.83°C, morning humidity of 99.14%, evening humidity of 88.57% and 23.50 mm of rainfall. Damage from *Helicoverpa armigera* was highest during the 47th SMW. The peak population of leaf webbers (0.3 per plant) was noted during the 35th SMW, influenced by minimum temperatures of 31.66°C, maximum temperatures of 33.20°C, morning humidity of 96.86%, evening humidity of 81.71% and 4.00 mm of rainfall. The maximum occurrence of spiders (0.4 per plant) was observed during the 40th SMW, with minimum temperatures of 31.96°C, maximum temperatures of 33.94°C, morning humidity of 96.14%, evening humidity of 77.00% and 36.20 mm of rainfall (Charan *et al.*, 2017). Additionally, a study focusing on pod bug, pod borer and gram pod flies found that pod fly was first detected in the 6th SMW, peaking at 10.66 maggots per plant by the 11th week in 2015. *C. gibbosa* appeared in the 5th week, reaching a peak of 7.33 nymphs per plant by the 10th week, while *H. armigera* was first detected in the 4th week, peaking at 7.66 larvae per plant by the 11th week. Despite a decrease in pest numbers after their peaks, pod bugs remained present in the field until harvest (Indrasen *et al.*, 2017). According to the study, *Helicoverpa armigera* larvae began their activity on pigeonpea in early October and persisted throughout the crop season, with peak populations coinciding with the pod development stage in the fourth week of November. This was marked by a negative correlation between mean vapor pressure, evening vapor pressure and mean relative humidity (Jha, 2003). Additionally, blister beetles, specifically *Mylabris pustulata* (Thunberg), were first observed on pigeonpea crops towards the end of the 3rd week of August, initially absent in any counts per 4-meter row length. Their population surged, reaching a maximum of 21.04 beetles per 4-meter row length during the 4th Standard Meteorological Week (SW) of September and persisted until the 4th week of October, according with the high of flowering period of the pigeonpea crops. AL 1489 recorded the lowest average beetle population at 2.7 beetles per plot of 4×2.25 meters, while H 2004-24 had the highest at 5.9 beetles *Mylabris pustulata* per plot, with corresponding flower damage of 16.6% and 27.5%, respectively (Dhakla *et al.*, 2010;

Singh *et al.*, 2021). Blister beetles, particularly *Mylabris pustulata* (Thunberg) have caused substantial damage to pigeonpea and mung-bean crops, with reductions in pod setting, seed setting and grain yield being significant under controlled conditions; for instance, in pigeonpea, 200 beetles per cage led to decreases of 54.18%, 20.15% and 64.88%, respectively, while in mung-bean, 4 beetles per cage resulted in reductions of 67.14%, 26.65% and 75.29% (Singh *et al.*, 2022). The peak adult population of the pod bug, *Clavigralla gibbosa* was recorded in the 9th standard week with 6.4 bugs, followed by 5.8 bugs in the 8th standard week. The lowest adult population of 0.2 bugs was observed in the 1st SW. The highest pod damage occurred in the 9th standard week at 26.8%, with the 8th standard week showing 21.2% damage (Srujana and Keval, 2014). Pod bugs, *Clavigralla gibbosa*, first appeared in the 2nd week and persisted until the 14th week each year, peaking in the 9th week of 2015-16 with 6.00 bugs per plant and in the 10th week of 2016-17 with 5.50 bugs per plant. Their population showed a strong positive correlation with maximum temperature and a significant negative correlation with average relative humidity, with weather variables explaining around 82.6% and 85.6% of the population fluctuations in each year (Khamoriya *et al.*, 2017). However, a research experiment conducted in Uttar Pradesh between 1994 and 1996 found that meteorological parameters had a non-significant impact on the pest populations affecting pigeonpea, with temperature, relative humidity and water evaporation exhibiting inverse relationships with the blue butterfly (*Lampides boeticus*) and pod bug (*Clavigralla gibbosa*) (Kumar and Nath, 2005). The occurrence pattern of the blue butterfly, *Lampides boeticus*, was first observed in the 42nd Standard Meteorological Week (SMW) of 2010, with larvae present from the 42nd to the 50th SMW and peaking at 0.20 larvae per plant between the 47th and 49th SMW before declining until harvest (Pandey *et al.*, 2015). During the 2018-19 pigeonpea crop, *Lampides boeticus* was detected in the 4th SMW, with genotypes AVT1-707 and AVT2-904 showing the highest (0.14 larvae/plant) and lowest (0.04 larvae/plant) populations, respectively, in the initial week. The larval population persisted from the 4th to the 12th SMW, with mean populations ranging from 0.20 larvae per plant in AVT2-903 to 0.27 larvae/plant in MAL-13 and AVT1-704, with AVT1-704 yielding between 617 kg/ha and 1434 kg/ha and AVT1-708 being the highest-yielding genotype (Sharma *et al.*, 2022).

Additionally, the study identified three parasitoids- *E. agromyzae*, *E. lividus* and *O. orientalis*- as natural predators of the pod fly with the highest parasitization rate of *Melanagromyza obtusa* recorded at 17.3% during the 51st SMW; however, no significant correlation was found between parasitization rates and abiotic factors, though multiple regression analysis revealed that weather parameters accounted for 85.9% of the variation in *M. obtusa* population and 92.6% of the variation in its parasitization rate (Chakravarty *et al.*, 2016[a]). The study identified three different parasitoid wasp species- *Euderus* sp. (Eulophidae), *Systasis dasyneurae* and *Torymus* sp. (Torymidae)- that target the larvae of pigeon pea pod flies, with parasitism rates increasing as pest populations rose. On genotype ICP-8863, *Euderus* sp. peaked at 52.38% during the 5th Standard Meteorological Week (SMW), *Torymus* sp. peaked at 61.54% during the 3rd SMW and *S. dasyneurae* peaked at 4.76% during the 4th SMW. Conversely, on genotype BSMR- 736, *Euderus* sp. was the most parasitic at 25.53%, while *Torymus* sp. was most parasitic on ICP-8863 at 12.16% (Chiranjeevi *et al.*, 2019). Additionally, four parasitoid species- *Eurytoma* sp., *Euderus* sp., *Ormyrus* sp. and *Torymus* sp.-were found to act on both larvae and pupae of the pod fly, with natural parasitism levels ranging from 5.56% to 69.57% for larvae, 13.79% to 50.00% for pupae and 10.64% to 56.14% overall, peaking at 69.17% in the 5th SW, 50.00% in the 4th SW and 56.14% in the 5th SW, respectively (Chiranjeevi and Patange, 2018[a]). *O. orientalis* was noted as the primary parasitoid of *Melanagromyza obtusa*, with average parasitization rates of 24.0% on NA1, 22.5% on Bahar and 8.4% on SL12-1 during 2000-01, reflecting significant variation in *M. obtusa* populations among pigeon pea cultivars and showing higher parasitism in susceptible genotypes compared to the resistant variety (Dar *et al.*, 2005[b]). According to Durairaj *et al.* (2005) a study of parasitoid activity and diversity, 75 pupae of pod flies were collected monthly from infested pigeonpea cv. Vamban-1 plots, revealing three species of pupal parasitoids, namely *Ormyrus* sp., *Eupelmus* sp. and *Eurytoma* sp., as natural enemies of *Melanagromyza obtusa*. The highest parasitism rate (87.5%) occurred during May, June and August, with the lowest (2.5%) observed in December. Parasitism rates exceeding 50% were noted in the April, June, September and October with *Ormyrus* sp. being the predominant species throughout the year, particularly from October to April and in September with parasitism levels ranging from 64.1% to 100%. In contrast, *Eurytoma* sp. exhibited parasitism rates between 0% and 15.4%, while *Eupelmus* sp. ranged from 0% to 20.5%. Further studies in Hisar, Haryana, India, identified *Euderus lividus* and *Eurytoma* sp. as active parasitoids of *M. obtusa*, with parasitism rates ranging from 5.45% to 10.00% for *E. lividus* and from 3.69% to 5.00% for *Eurytoma* sp., peaking in late October, coinciding with the host's immature stages (Moudgal *et al*., 2005). Research on cultivar ICP-8863 (Maruthi) revealed a peak larval population of 60 larvae per 100 pods during the 51st SW, with the pupal population peaking at 47 pupae per 100 pods in the 4th SW. Pod damage peaked at 81%, with soft grain damage reaching 54.34% before declining to 5.18% by the 10th SW. Six parasitoid families were observed attacking the pod fly's immature stages, with natural parasitization peaking at 60.00%, 51.61% and 55.81% for larvae and pupae in the 2nd SW (Patange *et al*., 2017[a]). A study evaluating the natural parasitization of *Melanagromyza obtusa* (Malloch) pupae identified three parasitoids of hymenopteran i.e. *Eurytoma* sp., *Epitranus* sp. and *Ormyrus* sp. Parasitism rates ranged from 3.23% to 35.14% for *Ormyrus* sp., 2.44% to 14.89% for *Eurytoma* sp. and 2.13% to 4.88% for *Epitranus* sp. with respective means of 14.06%, 3.34% and 0.47%. Natural parasitization of *M. obtusa* pupae was first time observed during the 51st SW, gradually increasing until it peaked at 48.78% by the 3rd SW with *Ormyrus* sp. contributing the highest level of parasitization (35.14%) and being the primary cause of *M. obtusa* pupae mortality, followed by *Eurytoma* sp. A significantly negative correlation was found between weather conditions and parasitization levels (Patange and Chiranjeevi, 2017). Additionally, a significantly negative correlation between weather conditions and natural parasitization was observed, suggesting that weather may influence parasitoid activity. Sebastian (1993) identified three parasitoid species, *Euderus lividus* (Ashmead) (Eulophidae), *Ormyrus orientalis* (Walker) (Ormyridae) and *Eurytoma* sp. (Eurytomidae), as key natural enemies of *Melanagromyza obtusa* during the period from 1987 to 1989, with the overall incidence of these parasitoids peaking in January and February. Among these, *Euderus lividus* and *Ormyrus orientalis* were more prevalent compared to *Eurytoma* sp., though the latter's presence was also significant. Both early and late varieties of pigeonpea were infested by the immature stages of pod flies and were parasitized by these three species. *Euderus lividus* typically deposited eggs through exit holes created by mature larvae in the pigeonpea pods; however, no such exit holes were observed in this study, with eggs found inside the pods adjacent to or on the bodies of second- instar larvae (Singh, 1991). In an extensive study on the parasitization of *Melanagromyza obtusa*, the larval parasitoid *Euderus lividus* was first observed in the 2nd week of January on late pigeonpea varieties and 4th week of October on early varieties. Parasitism rates on the late variety ranged from a low of 2.50 % in late January to a high of 80.00% in late May, while on the early variety, they varied from 25.00% in late December to 50.00% in late November. For the early variety, parasitism increased from 25.00% in October to 50.00% in November but dropped again to 25.00% by late December. Parasitism rates closely correlated with temperature fluctuations, rising as temperatures increased from 13.0°C in January to 33.6°C in May and decreasing as temperatures fell to 14.1°C in December (Yadav *et al*., 2011[a]). A survey conducted in pigeonpea cultivation areas around Agra also revealed three primary parasitoids-*Euderus lividus, Ormyrus orientalis* and *Eurytoma* sp.-with parasitism rates ranging from 2.9% in November to 11.0% in January, primarily affecting late varieties of pigeonpea. *E. lividus* showed parasitism rates between 9.1% and 72.7%, while *O. orientalis* exhibited rates between 8.0% and 18.8%, with climatic variations playing a significant role in the distribution and incidence of parasitism, even leading to the elimination of one parasitoid species from the pest population (Yadav *et al*., 2011[b]). Further studies identified *E. lividus* and *O. orientalis* as effective biological control agents for *M. obtusa*, with *E. lividus* demonstrating an 80.00% parasitism rate and *O. orientalis* showing a 46.66% rate, establishing *E. lividus* as the more effective species in controlling *M. obtusa* (Yadav *et al*., 2012).

2.2. To estimate extent of damage against *M. obtusa*

During the *Kharif* season of 2015-16, a study was conducted to control ETL of pod fly across various pigeonpea genotypes, revealing significant differences. The ETL reached since 6.44 to 13.06 larvae 2.64% to 8.38% damage of pods and 1.09% to 3.56% damage grains among genotypes such as -201-1 and ICP-8863 with an overall average ETL of 7.76 maggots, damaged pods 4.60 per cent and damaged grain 2.05 per cent (Chiranjeevi and Patange, 2017). In a related study during the same season, Chiranjeevi and Patange (2018[b]) explored the variation in infestation levels among different Arhar genotypes. The infestation levels varied widely, with maggot counts ranging from 0.00 to 277.64 per 100 pods and pupae from 0.0 to 101.26 per100 pigeonpea pods. Notably, the BRG-2 genotype showed the highest infestation, while *Cajanus scarabaeoides* demonstrated complete resistance with no maggots or pupae detected, highlighting its potential for developing resistant pigeonpea varieties. These studies underscore the critical importance of identifying genotypic resistance and setting appropriate economic thresholds to manage *M. obtusa* effectively and minimize its impact on pigeonpea crops. Additionally, grain weight loss against pod fly ranged from 0.00 to 14.38 grams with the highest loss recorded in BRG-1 (14.38 grams) and pod damage reached 85.72% in BDN-2013-41, while *C. scarabaeoides* exhibited no damage, underscoring its genetic potential for resistance. The population dynamics of pod flies were monitored from the fourth to the twelfth week, with the highest population observed in the ninth week across all varieties. Among the genotypes, NDA-5-25 had the highest average pod fly infestation at 0.57 maggots per 10 pods, while KAWR 92-2 had the lowest population at 0.21 larvae per 10 pigeonpea pods (Keval *et al.*, 2010). These findings highlight the potential for genetic resistance in breeding programs and the importance of monitoring infestation levels to inform pest management strategies. During the *Kharif* seasons of 2013-14 and 2014-15, *Melanagromyza obtusa* infestation was found to be particularly significant in the pigeonpea genotype IPA 7-10, with 1.50 and 1.41 maggots per plant, respectively, while the KA 12-2 genotype exhibited the lowest infestation at 0.58 and 0.56 maggots per plant. The IPA 7-10 genotype also experienced the highest pod and grain damage, with percentages reaching 46.67% and 23.11% in 2013-14 and 45% and 20.96% in 2014-15. In contrast, KA 12-2 displayed the lowest damage, with 25.67% pod damage and 11.97% grain damage in 2013-14 and 21.33% pod damage and 10.07% grain damage in 2014-15. The lower susceptibility ratings for KA 12-2, at 4 and 5 for pod and grain damage, respectively, reflected its superior resistance when compared to the local check 'Bahar'. Additionally, KA 12-2 achieved the highest grain yields, with 1960 kg/ha in 2013-14 and 1785 kg/ha in 2014-15, indicating its potential as a high-yielding, resistant genotype (Kumar *et al.*, 2015). In a subsequent study, ten long-duration pigeonpea cultivars were evaluated, showing significant variation in insect-induced grain loss, with Bahar exhibiting the least damage and KA-12-2 experiencing the highest, although the grain yields ranged from 658 kg/ha in KA-12-2 to 1200 kg/ha in Bahar (Keval *et al.*, 2017[b]). Further research during the *Kharif* season of 2015-16 assessed the potential yield reductions caused by the pod borer complex, with findings revealing that up to 57.71% of yield losses could be avoided through effective pest management, leading to a maximum grain yield of 1497 kg/ha (Patel and Patel, 2018). Notably, pod and grain destruction caused by different pod borers varied across pigeonpea cultivars with long duration pigeonpea suffering the most damage from *H. armigera*, *Exelastis atomosa* and *M. obtusa,* while *Maruca vitrata* inflicted the most damage on short duration pigeonpea. Intercropping pigeonpea with crops such as sorghum and castor significantly reduced damage from *M. obtusa*, *H. armigera* and *M. vitrata* leading to increased yields and improved land equivalent ratios (Rao *et al.*, 2003). According to Revathi *et al.* (2015), an investigation into the tolerance of twenty medium-duration pigeonpea genotypes to pod fly (*Melanagromyza obtusa*) revealed that the numbers of larvae (0-4 per pod) and pupae (0-6 per pod) varied significantly among genotypes, with the highest infestation reaching 1.5 larvae and 1.7 pupae per pod. The pod fly infestation led to an average weight reduction of 60.0%, with a range between 47.8% and 86.6% across the different genotypes studied. Similarly, Vidya *et al.* (2022) conducted field surveys during the 2020-21 pigeonpea growing season and observed varied levels of pod fly infestation across multiple locations and pigeonpea varieties. The most severe pod damage (92%) and grain damage (65.22%) were reported in Honnayyanapalya village, Magadi taluk, Ramanagara district, while the lowest levels of pod damage (18%) and grain damage (7.45%) were recorded in Basavapura village, Gowribidanur taluk, Chikkaballapur district. These findings underscore the significant impact of *M. obtusa* on pigeonpea crops, emphasizing the need for effective pest management strategies tailored to specific regions and genotypes to mitigate yield losses. The current result according to Singh *et al.* (2017) the first occurrence of pod fly was noted during the 4th SW for all genotype except IVT-509, AVT-607 and AVT- 605, with the population continuing until the 12th SW across all genotypes. the peak population of pod flies, regardless of genotype or cultivar was recorded in the 11^{th} SW. Pod damage due to pod flies varied significantly with IVT-520 experiencing 22.33% damage and IVT-510 showing 46.67% damage. Similarly, grain damage was highest in IVT-510 at 20.96% and lowest in IVT-520 at 10.67%. Grain yields differed notably among genotypes of IVT-510 and IVT-520 ranging from 479Kg/ha and 3314 Kg/ha. The current result according to Tyagi *et al*. (2022) yield loss was reduced in genotypes that had pod and grain damage from insects. For example, genotypes such as IVT-208 (with pod damage of 31.3% from *M. obtusa*, 12.6% from *C. gibbosa* and 4.8% from *H. armigera*) and IVT-12-904 (with 29.5% damage from *M. obtusa*, 12.8% from *C. gibbosa* and 7.3% from *H. armigera*) showed lower susceptibility to the insect pest complex.

2.3. To study of early and late sowing on the intensity of pod fly, *M. obtusa*

The extent of seed damage caused by the *M. obtusa* fluctuated from one year to another. Dialoke *et al*. (2014) embarked on a journey to unravel the effects of planting time on seed damage caused by pod fly on pigeonpea. They discovered that the seed damage fluctuated markedly between years, with ICPL 87 suffering the highest levels of infestation, reflecting its vulnerability to the pest. The study revealed that the timing of planting was crucial: seeds planted in April faced severe damage, peaking at 21.20% in 2009, while those planted later in August experienced much lower damage, down to 5.36%. This insight highlighted the importance of strategic planting to mitigate pest impact. Building on these findings, Dialoke *et al*. (2018) explored the role of plant population density in influencing pod and seed yields during the 2009/2010 seasons. Their research illuminated a complex relationship: higher plant densities initially boosted pod yields, reaching 665.00 kg/ha, but led to diminished seed yields (147.90 kg/ha) due to competition and reduced space. In contrast, lower densities, although producing fewer pods, resulted in higher seed yields (233.33 kg/ha) and improved pod and seed weights. This nuanced understanding underscored that optimal plant density and planting timing are critical for maximizing both pod and seed yields while minimizing pest-induced damage. Together, these studies narrate a story of balancing agricultural practices with pest management to enhance crop resilience and productivity.

As a researcher studying pigeonpea cultivation, I delved into the intricate relationship between sowing dates and pest infestations, particularly focusing on pod flies. The data revealed a compelling pattern: the later the sowing, the less damage the crops sustained. On August 10th, the pod damage was lowest, with only 21.05% affected, while crops sown earlier on June 10th faced much higher damage rates of 29.40%. This trend pointed to a clear conclusion-late sowing could help avoid the peak activity of pod flies. However, there was a compromise. While late-sown crops were better protected from pests, they also yielded less. The June 10th sowing produced a robust 1219 kg/ha, compared to a more modest 747 kg/ha for the August 10th crops. I also noted the superior performance of the summer-sown genotypes like 'Vamban 1' and 'ICPL 86012', which yielded 765-850 kg/ha far surpassing the 405-525 kg/ha yields of the rainy-season crops. This resistance to pests like Lepidopteron pod borers and pod flies in the summer crops was remarkable, showing that careful timing and the right genotypes could combine host evasion and pseudo-resistance to great effect. The data shows variations in grain damage caused by pod fly during different sowing periods (24th, 26th, 28th, 31st and 33rd Standard Meteorological Week) and with different pigeonpea varieties across several years. In the 2014-15 season, the lowest damage (19.37%) was noted when sown on the 24th SMW compared to other sowing periods. Vaishali variety exhibited the least damage (20.01%) compared to BDN-2 with the highest (31.82%) in that season. However, in 2015-16, neither sowing periods nor varieties significantly impacted grain damage. The 2016-17 season saw significant variations with the 24th SMW having the lowest damage (28.03%) and Vaishali variety with the lowest (31.12%) compared to BDN-2 with the highest (42.55%). In 2017-18, similar trends were observed with the lowest damage (14.68%) seen in the 24th SMW sowing period and Vaishali variety again exhibiting the least damage (22.06%). Overall, across the years, the lowest damage occurred with the 24th SMW sowing period and Vaishali variety, consistent with findings from previous studies (Hadiya *et al.*, 2020). The experiment spanning 2017-18 and 2018-19, employing a design featuring three replications. The research focused on four pigeonpea varieties (Vipul, Rajeshwari-Phule T 0122, BDN 711 and ICPH 2740) as main plot treatments, alongside four sowing dates (24th MSW, 26th MSW, 28th MSW and 30th MSW) as subplot treatments. They examined the relationship between weather parameters and the seasonal occurrence of *M. obtusa,* observing positive relationship with morning Rh%, sunshine hours & wind speed. Conversely, negative relationships were observed by max. and min. temp., evening relative humidity and rainfall during the *Kharif* season crop of both years. Forecasting *M. obtusa* population involved employing multiple linear regression equations, with the treatment combination of 24th MSW and ICPH 2740 yielding the highest R2 value of 0.841 (Nagaraju *et al.*, 2022). During the rainy season of 1988-89, in the fields of Ghumusar Udayagiri, Orissa, I embarked on a detailed study of pigeonpea cultivation. We planted four varieties of *Cajanus cajan* on different dates-June 1st, June 15th, June 30th and July 15th-with row spacings of either 30 or 45 × 20 cm. The results were clear: delaying planting beyond June 1st consistently led to reduced seed yields across all varieties. An intriguing interaction emerged between the choice of variety and row spacing, highlighting that planting decisions were critical to optimizing yields. Among the varieties, Manak stood out as the top-yielding option, with UPAS 120 coming in a close second, as noted by Padhi in 1995. Years later, in 2010-11, I conducted a follow-up study to observe the occurrence patterns of *Melanagromyza obtusa* and *C. gibbosa* in pigeonpea fields. This study tracked the emergence and population levels of these pests throughout the crop's growth stages. Pod flies were first detected in the 42nd Standard Meteorological Week (SMW), with an average of 0.10 maggots per plant, peaking in the 45th SMW at 0.30 maggots per plant. Similarly, pod bugs appeared in the 40th week with an average of 0.03 larvae per plant and reached their peak in the 44th and 45th weeks with 0.40 larvae per plant. Despite a decline in pest populations after their peaks, pod bugs persisted in the fields until harvest. These findings underscore the necessity of accurate, location-specific data on pest occurrence and seasonal fluctuations to effectively apply integrated pest management (IPM) strategies, as highlighted by Pandey *et al*. (2016). In a comprehensive study of pigeonpea cultivation, researchers explored the effects of five distinct sowing dates on insect and pest complexes. The sowing dates were categorized as follows: June 15th (24th SMW), July 1st (26th SMW), July 15th (28th SMW), July 30th (31st SMW) and August 14th (33rd SMW). The study assessed how these dates affected pest damage and crop yield across three pigeonpea. The findings revealed that sowing earlier in the season significantly influenced pest dynamics. Early-sown crops experienced less damage from the pod fly *Melanagromyza obtusa* compared to the later-season pest *Helicoverpa armigera*, which was more detrimental but ultimately led to higher grain production. This trend highlighted the importance of timely sowing for optimizing yield and pest management, aligning with Patel *et al*. (2019). In another facet of the research, the impact of row spacing on intercropping with cereals was examined. The study found that the optimal spacing for different crops varied according to their maturity. For instance, finger millet benefited from a spacing of 5cm sorghum from 15cm and pigeonpea from a broader spacing of 15-30 cm. Intercropping pigeonpea in double rows between two rows of cereals proved advantageous, enhancing overall yield. Additionally, applying Nurelle-D, a pest control agent, twice-from flower bud initiation to maturity for short-term pigeonpea and from seedling establishment to maturity for medium-term cultivars-improved crop protection and efficacy while keeping seed costs low. This approach, established by Rubaihayo *et al*. (2000), underscored the value of strategic pest management and intercropping practices in maximizing pigeonpea yields and ensuring sustainable cultivation.

2.4. To estimate ecofriendly management practices by using biorational pesticide due to pod fly in pigeonpea

In a detailed exploration of pest management in Arhar crops, researchers assessed the effectiveness of various biopesticides against *Helicoverpa armigera* and *Melanagromyza obtusa*. Monitoring larval populations over several days post-application revealed no significant differences from the control treatments. Despite this, certain biopesticides showed promise. Chlorantraniliprole 18.5 SC, applied at 30 grams of active ingredient per hectare, stood out by significantly reducing *H. armigera* populations to 6.25%. Azadirachtin 1500 ppm and *Bt. kurstaki* also showed effectiveness, with incidences of 7.33% and 9.33%, respectively. Grain damage varied considerably with *M. obtusa* causing 8.42 to 27.63% damage and *H. armigera* resulting in 3.35 to 13.89% damage. Chlorantraniliprole consistently demonstrated superior results, with subsequent applications of Azadirachtin maintaining pest control efficacy (Ahmad, 2020). Further experiments with insecticides revealed that Chlorantraniliprole, Flubendiamide and Dimethoate achieved the lowest pod fly populations on the 3rd, 7th

and 14th days post-application. This effectiveness was statistically comparable to previous applications of Chlorantraniliprole, Indoxacarb and Acetamiprid, which also minimized pod damage and improved grain yield. These findings, reported by Bantewad *et al.* (2018), highlighted the importance of choosing the right insecticide to balance pest control and crop productivity, ultimately ensuring a healthier and more bountiful pigeonpea harvest. Bhandari and Ujagir (2002) embarked on a thorough investigation to tackle the formidable pod borer complexes affecting the early-maturing pigeonpea variety UPAS120. Their study revealed that Quinalphos @ 500 grams per hectare, Monocrotophos @ 600 grams per hectare combined with Deltamethrin @ 12 grams per hectare and Profenofos @ 750 grams per hectare were highly effective. They also highlighted the efficacy of Chlorpyrifos @ 500 grams per hectare and a blend of Chlorpyrifos-methyl @ 1000 grams per hectare with *HaNPV* @ 500 LE per hectare and NSKE @ 5% concentration. This diverse treatment approach illustrated the crucial role of selecting appropriate insecticide combinations to combat pod borers. In contrast, Bhosale *et al.* (2009) concentrated on controlling pod fly infestations and discovered that ten days post-application, the treatment E2Y45 @ 40 grams a.i./hectare achieved an impressively low infestation rate of 0.33%, outperforming other methods. The second most effective was E2Y45 @ 30 grams a.i./hectare with a 1.67% infestation rate. The untreated control group experienced the highest infestation at 6.33%. When comparing effectiveness ten days after a second spray and at harvest, *HaNPV* @ 125 LE/ha combined with endosulfan @ 175 grams a.i./hectare was as effective as E2Y45 @ 30 grams a.i./hectare and Dimethoate @ 170 grams a.i./hectare. NSKE @ 5% followed by Dimethoate also delivered notable results. Together, these studies underscore the need for targeted pest management strategies to enhance the health and yield of pigeonpea crops. Chiranjeevi and Patange (2018[d]) conducted a thorough evaluation of treatments aimed at controlling the pod fly *Melanagromyza obtusa* and found chlorantraniliprole 18.5 SC to be the standout performer. Applied @ 30 grams of active ingredient per hectare, this treatment significantly reduced larval, pupal and overall populations of *M. obtusa*. The study highlighted a stark contrast in effectiveness among various treatments. Neem oil @ 3% concentration, was the second most effective option, providing a notable reduction in pest populations. On the other hand, Eucalyptus oil @

5% concentration proved to be the least effective, consistently resulting in higher maggot counts. The results showed that while chlorantraniliprole drastically lowered maggot populations-recording counts of 34.33, 16.33, 11.67, 10.67 and 18.00 larvae per 100 pods at First, Third, Seventh, Tenth- and Fourteenth-days post- spray the eucalyptus oil treatment led to persistently high maggot populations with counts of 44.67, 42.67, 38.67, 39.33 and 46.33 larvae per 100 pods at the same intervals. Chiranjeevi and Sarnaik (2017[b]) confirmed these findings, reinforcing that chlorantraniliprole 18.5 SC was the most effective treatment, showcasing its superiority in controlling *M. obtusa* infestations. The study revealed that chlorantraniliprole 18.5 SC @ 30 g active ingredient /ha was the highly actual treatment in decrease the populace of pod fly, followed by neem oil @ 3 percent, across different days after the first and second spray. Eucalyptus oil @ 5 percent was not as active insect pest populace. The utmost pod fly populace, indicating the necessity of insecticide application to suppress this pest. The effectiveness of the insecticides was evaluated based on the number of pod flies (larvae + pupae) per 100 pods, which was lowest for chlorantraniliprole and highest for the untreated control (Chiranjeevi and Sarnaik, 2017[a]). According to a study by Chiranjeevi and Patange (2018[d]) the submission of chlorantraniliprole 18.5 SC/ hectare shown to the most effective treatment in conquering the maggots, pupal and entire populations of *Melanagromyza obtusa*. This was closely surveyed by Neem oil at a 3% concentration. In contrast, eucalyptus oil @ 5% the active treatment due to *M. obtusa*. Additional actions showed reasonable effectiveness in reducing the pest population, while the highest maggot, pupal and total populations were recorded in the untreated control plots. The evaluation of spray module against pod fly and their effects on parasitoids showed that the chemo intensive IPM although it was harmful to the parasitoid complex. In comparison of the bio-intensive IPM module (Dimethoate 0.03% → NSKE5% → NSKE5%) was nearly as effective in control the pest populace but was less toxic to the parasitoids. Two sprays prove to be significantly more effective than the untreated control (Dar *et al*., 2005[a]). In their study, Keval *et al*. (2006) investigated the efficacy of various pest management strategies on two pigeonpea cultivars, ICPL 87 (local) and ICPL 4 (resistant/tolerant), using six treatments of the combinations: 0.07% endosulfan-0.04% monocrotophos, *B. thuringiensis* (1kg/ha)-0.07% endosulfan, 5% Neem Seed Kernal Extract (NSKE)-*Bt*, 5%, NSKE-5% and a control. Treatments were applied at pod initiation and every 15 days as needed. Their findings revealed that genotype did not significantly influence pod damage from *Helicoverpa armigera*, *Melanagromyza obtusa* or *Clavigralla gibbosa*, though ICPL 4 and ICPL 86012 experienced less damage compared to others. The combination of 0.07% endosulfan followed by 0.04% monocrotophos was initiate to the utmost effective, resulting in the least pest injury and highest profit. Similarly, the 5% NSKE treatment followed by 0.04% monocrotophos was effective. However, the study also noted that neem oil and *Bt*. were less effective than synthesis pesticides in managing pests and minimizing losses of seed, particularly at Kabete and Kiboko, due to their slower action and requirement for ingestion. Despite their safety advantages, biopesticides might cause greater crop losses compared to traditional chemical pesticides. Additionally, although predatory arthropods were present, they were vulnerable to non-selective insecticides, with endosulfan being recognized for its selectivity against some natural pest enemies, as noted by Minja *et al*. (2000). The current result according to Neharkar *et al*. (2018) assessed the pod borer complex on pigeonpea crop, utilizing eight different methods including NSKE @ 5%, neem oil @ 2%, Chlorantraniliprole @ 18.5 SC, Spinosad at 45 SC, Indoxacarb @ 14% and five additional treatments: 5 SC Emamectin benzoate, 5 SG Flubendiamide, 20 WDG and a control with water spray. They found that Flubendiamide @ 20 WDG exhibited the highest efficacy against the pod borer complex among all treatments. Meanwhile, Pandey *et al*. (2011) reported variability in grains and pod damage caused by pod flies between 2006 and 2007, with pod injury ranging from 14.7% to 37.0% and grain damage from 9.0% to 25.0%. Among the five genotypes with resistance or tolerance, pod damage was as low as 14.7% in PDA 88-2E and as high as 21.1% in MA3, whereas the six genotypes without resistance or tolerance experienced pod damage between 30.4% in MA24 and 37.0% in Bahar. Grain damage was also lowest in PDA 88-2E and highest in MA3 among the resistant/susceptible genotypes, while the susceptible varieties showed damage ranging from 20.8% in MA24 to 25.0% in Bahar. The study of Rahman *et al*. (2017) found that Emamectin benzoate at 0.001% and Dimethoate at 0.03% resulted in the highest adult insect mortality rates within 3 and 6 hours, respectively, followed by Indoxacarb

(0.004%), Dichlorvos (0.08%) and Fenvalerate (0.02%). They also observed that pods treated with NSKE @ 4% had the fewest eggs, demonstrating superior performance compared to other treatments. The highest seed yield, 1666.00 kg per hectare, was achieved with a combination of NSKE @ 5%, Emamectin benzoate @ 0.001% and Dichlorvos. Similarly, Reddy *et al*. (2018) reported that Dimethoate @ 30 EC, applied @ 2 ml per liter 2, 3, 4 or 5 weeks after 50% flowering, was the most effective in reducing pod and grain damage caused by pod flies while increasing yield, with an impressive incremental 17.77. Sharma *et al*. (2011) further demonstrated that a two-year study showed reduced pod fly grain damage to 13.30% and 11.95%, with the combination of Emamectine benzoate @ 5 SG and either Acetamiprid 20 SP or Dimethoate 30 EC resulting in the highest grain yields of 1399 kg/ha and 1392 kg/ha, respectively. Among various treatments, crude NSKE @ 5% proved to be superior, achieving a 31.28% increase in yield. The study by Singh *et al*., 2024 the first appearance of the pod fly was noted in the 3rd standard week. Throughout the cropping period, the highest pod damage was recorded in the 8th standard week, while the lowest damage was observed in the 12th standard week. The study found that the most effective treatment was a combination of Emamectine benzoate 5 GS @11g a.i./ha and Dimethoate 30 EC @ 300 g a.i./ha, which resulted in the least pod damage and the highest yield. Additionally, Sreekanth *et al*. (2020) found Thiacloprid 21.7 SC to the utmost active insecticide for reducing *M. obtusa* destruction, leading to increased grain yields and the highest incremental cost- benefit ratio with Diafenthiuron 50 WP, Flubendiamide 480SC and Dimethoate SC and Dimethoate 30% EC also showing strong effectiveness and economic benefits against pod fly damage.

Chapter-**III**

MATERIALS AND METHODS.

The field trial entailed **"Population Dynamics and Ecofriendly Management of *Melanagromyza obtusa* (Malloch) infesting *Cajanus cajan* (L.)"** were conducted on Lovely Professional University (LPU) Experimental Research Field of the Division of Entomology, School of Agriculture in Jalandhar, Punjab during 2022-23 ad 2023-24. The specifics of the materials utilized and the procedures methodologies throughout the study described as follows:

3.1 Experimental site

The agronomic practices implemented followed the guidance provided by Experimental Research Farm of Agriculture, Department of Entomology, School of Agriculture, Lovely Professional University (LPU), Phagwara, Punjab, India

3.1.1. Graphical site and location

Lovely Professional University is positioned in Phagwara, within Kapurthala District, situated at approximately 31° 15' 29.4804" latitude and 75° 42 28.5696 longitude with a 243-meter elevation gain above sea level. The region is situated within the central plan region of Punjab has a humid subtropical climate with very cold in winter and hot dry in summer. Summer extends from April to June, whereas winter lasts from November to February. In the summer temperatures typically vary involving 23°C and 48°C, while in the winter, they range from 4°C to 19°C. The Meteorology Department has provided the Meteorological data for the crop season, which is detailed in tables 3.1 and 3.2.

3.1.2. Land and Soil

The land was good drainage and almost flat. The soil composition is slightly acidic with a pH ranging from 5.6 to 6.0 and it features a sandy loam texture.

Table 3.1: Standard Meteorology Weekly data during crop season of 2022-23

SMW	Temperature (°C)		Relative humidity (Rh%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
39	36.00	23.00	74.00	60.00	0.00
40	34.00	22.00	50.00	42.00	0.00
41	32.00	23.00	59.00	43.00	0.00
42	31.00	20.00	56.00	46.00	0.00
43	29.00	18.00	53.00	43.00	0.00
44	34.00	19.00	56.00	42.00	0.00
45	24.00	18.00	59.00	49.00	0.20
46	28.00	13.00	52.00	47.00	0.00
47	28.00	19.00	81.00	76.00	0.00
48	25.00	11.00	89.00	77.00	0.00
49	26.00	9.00	89.00	61.00	0.00
50	25.00	10.00	97.00	65.00	0.00
51	24.00	9.00	90.00	79.00	0.00
52	21.00	9.00	98.00	88.00	2.00
1	12.00	6.00	98.00	86.00	0.00
2	12.00	10.00	94.00	86.00	0.00

Max.: Maximum and Min.: Minimum and SMW: Standard Meteorological Week

Table 3.2: standard Meteorological Weekly data during crop season 2023-24

SMW	Temperature (°C)		Relative humidity (Rh%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
39	34.30	19.96	92.65	65.50	0.00
40	34.03	17.42	92.38	51.33	0.20
41	32.51	16.32	92.81	45.53	0.00
42	28.31	13.12	92.79	51.68	0.80
43	31.16	12.36	92.95	35.87	0.00
44	31.32	13.30	94.01	45.82	0.00
45	29.05	13.57	93.23	47.22	0.60
46	27.06	10.20	93.84	49.26	0.00
47	26.70	7.38	92.48	40.96	0.20
48	22.70	10.10	91.20	59.70	0.20
49	23.33	9.44	94.00	47.00	0.00
50	20.55	7.77	94.00	52.00	0.00
51	21.11	6.66	97.00	57.00	0.00
52	16.66	10.55	95.00	74.00	0.00
1	10.00	7.22	94.00	87.00	0.00
2	11.11	5.55	94.60	80.00	0.00

Max.: Maximum and Min.: Minimum and SMW: Standard Meteorological Week

3.1.3. Field preparation and raising of crop

The land was prepared while utilizing harrow and rotavator results soil become fragile, weed free and germination capability. Pre irrigation was given to provide enough amount of moisture level for the germination of seed (viability). The soil was prepared using a combination of harrowing and rotavating until it became loose and free from weeds and make soil capable conditions for germination. Prior to sowing, the field was irrigated to ensure sufficient moisture for germination. In June of both year 2022 and 2023, irrigation sowing was conducted in soil that was saturated with a spacing of 90cm x 20cm. Post filling (15-25 days) thinning and gap filled was carried out to ensure even population distribution. Additionally, the field was divided into blocks and plots with channels provided for irrigation and drainage.

3.1.4. Fertilizers application

The ideal dose of fertilizer 20kg of nitrogen and 40kg of phosphorus was applied. The first irrigation occurred during seed germination with subsequent irrigations scheduled every 15-20 days based on field moisture levels. Regular manual weeding was done time to time and after irrigation during the crop season.

3.1.5. Irrigation and drainage

As a crop with deep roots, it can survive drought conditions. However, if the drought persists, it may require three additional rounds of irrigations.

- First irrigation occurs at the branching stage (30 days after sowing).
- Second irrigation takes place during flowering stage (70 days after sowing).
- Third irrigation is conducted at podding stage (110 days after sowing).

Proper drainage is essential for the successful cultivation of pigeon pea.

3.2.1. Population dynamics of *M. obtusa* in pigeonpea

The population dynamics of pod fly infesting pigeonpea species (UPAS120) were examined in field plots measurement 4.5x1 m with three replications. Initially, all suitable management observes were implemented for rising crops, various plant defense mechanism. Randomly 5 selected plants were plucked over one hundred pods at weekly intervals in each replication. Counting healthy, damaged pods and individual pods of pigeonpea was regularly observed and emergence of pod flies was noted. Each pod was dissected to check for the presence of *M. obtusa* larvae and pupae and their occurrence in each pod was documented. At the maturation stage, the percentage incidence of *M. obtusa* was recorded, along with the weight and quantity of both healthy and damaged seeds. The observations for population dynamics of *M. obtusa* with reference to influence of abiotic factors was also be standardized. The weekly meteorological data (Temperature, Rh% & precipitation) was taken from the meteorological department of the university. The combination of the insect population buildup and meteorological dynamics, as well as the pest's natural enemies for same period, was a simple correlation.

During the *Kharif* seasons 2022-23 & 2023-24, the pigeonpea variety (UPAS 120) was cultivated at the Experimental Agriculture Research Farm of the Department of Entomology, School of Agriculture, Lovely Professional University (LPU), situated in Jalandhar, Punjab, India. The cultivation was carried out in plots measuring 4.5m x 1m, following all appropriate agronomic practices. Weekly observations of pigeonpea were started from the germination phase and continued until the crop reached the harvest stage. The larval stage of *Helicoverpa armigera*, *Mylabris pustulata*, *Clavigralla gibbosa* and *Lampides boeticus* was observed weekly. For this purpose, five plants were chosen randomly and marked accordingly. The observation was recorded of pod fly larvae and pupae from the vegetative stage until the harvesting of pigeonpea. The amount of pods damage was noted after dissect out separate pod. Occurrences of pod fly, along with their number of pods were recorded. The percentage of larval and pupal parasitization in the pigeonpea crop variety (UPAS 120) was measured at weekly intervals. One hundred pods were plucked (collect) and brought in laboratory at weekly time interval. The collected pods containing larvae and pupae stages were placed in covered glass vials by muslin in cloth for the rearing of parasitoids with the temperature of 25-33℃.

3.2.2. Estimate extent of damage cause by pod fly on pigeonpea crop

Field studies were conducted under pesticide-free conditions with only protective measures during the flowering stage of pigeonpea crop. Each replication was covered with individual fine mosquito nets to prevent infestation by pod fly. In each replication, a controlled population of *M. obtusa* was introduced with densities of 10, 20, 30 and 40 adults per plant for the initial, second, third and fourth treatments, respectively. The introduction occurred between 45 to 50 days after flowering stage, particularly during the middle mature pods period. Additionally, one plant in each replication was kept as a control without pod fly infestation to measure the grain yield. The population of pod fly maggots, grain damage, damage pods and grain yield were noted in 45 days following the infestation.

Cost of planting: Cost of seeds + Cost of plant protection.

$$\text{Regression coefficient} = \frac{\sum XY - [(\sum X \text{ x } \sum Y) / N]}{\sum X2 - [(\sum X2) / N]} \text{x100}$$

Whereas X = Number of *M. obtusa* maggots or grain damage per plant

Y = Yield (q/ha)

N = Number of observations

$$\text{Economic Threshold Level (ETL)} = \frac{\text{Grain threshold}}{\text{Regression coefficient}}$$

Systematic position of pigeonpea pod fly

Phylum : Arthropoda

Class : Insecta

Order : Diptera

Family : Agromyzidae

Genus : *Melanagromyza*

Species : *obtusa* Malloch 1914

Morphological Characteristics

The adult fly was small with a shiny, black or metallic blue in the color. The head is clearly separated from the thorax by a noticeable narrowing at the neck and the compound eyes are typically oval and relatively small. The antennae were aristate type. The basal segment was quite short and the second antennal segment lacked grooves. The third antennal segment was always large, usually round and often swollen (Subharani and Singh, 2009). The wings are clearly visible. The pod fly female an extremely long, black ovipositor sheath. The pod fly male is like female but smaller in size and lacks an ovipositor (Steck, 2003). Based on morphological characters dimorphism of pod fly study below:

Table 3.3: Sexual dimorphism of pod fly

Characters	**Male**	**Female**
Body Size	Small	Large
Head	Rounded	Elongated
Eyes	Larger compound eyes	Smaller compound eyes
Antenna	Longer	Shorter
Abdomen	U shape	V shape
Ovipositor (Egg laying organ)	Absent	Present

(Chiranjeevi and Patange, 2018[b])

Investigational details

1. Experimental design : Randomized Block Design (RBD)
2. Treatments : Five
3. Replications : Four
4. Plot size : 1×1 m^2
5. Spacing : 90 × 20 cm
6. Variety : UPAS-120
7. Date of sowing : 13-06-2022 (1st Year) and 13-06-2023 (2nd Year)

FIELD LAYOUT-1

R_I	Water Channel	R_{II}	Water Channel	R_{III}	Water Channel	R_{IV}
1m	1m	1m	1m	1m	1m	1m
T_3		T_1		T_4		T_2
T_4		T_2		T_5		T_3
T_5		T_3		T_1		T_4
T_1		T_4		T_2		T_5
T_2		T_5		T_3		T_1
1m	1m	1m	1m	1m	1m	1m

R: Replication, T: Treatment, m: meter

3.2.3. Effect of early and late sowing on intensity of pod fly

The study investigated the impact of various sowing dates on pod fly infestation in pigeon pea, comparing them with an unsprayed control group. During the investigation, fertilizers were applied as successive fertilizers, specifically Urea (46% nitrogen) and Single Super Phosphate (16% P2O5), to each plot. At the time of sowing, the recommended amount of 25:50:50 kg NPK per hectare was administered. Seven distinct dates viz. 13th June (standard date), 20th June, 27th June, 3rd July, 10th July, 17th July and 24th July 2022 and 2023 were selected for line sowing the crop. Weekly observations on pod fly infestation in pigeon pea were conducted, targeting five randomly chosen plants from each sowing date for analysis. The buds and pods from three chosen twigs were counted for both healthy and infested ones and the percentage of pod fly infestation was calculated separately from the yield of the UPAS120 variety. The standard deviation was worked out (Islam *et al*., 2008).

Experimental details

1. Experimental design : **Randomized Block Design (RBD)**
2. Treatments : Seven
3. Replications : Three
4. Plot size : 4.5 × 1 m^2
5. Spacing : 90 × 20 cm
6. Variety : UPAS120
7. Date of sowing : 13-06-2022 (1st Year) and 13-06-2023 (2nd Year)

Sr. No.	Treatment (Date of sowing)
1.	13th June
2.	20th June
3.	27th June
4.	3rd July
5.	10th July
6.	17th July
7.	24th July

FIELD LAYOUT-II

R_I	Water Channel	R_{II}	Water Channel	R_{III}	Water Channel
4.5m	1m	4.5m	1m	4.5m	1m
T_1		T_7		T_4	
T_2		T_5		T_6	
T_3		T_1		T_2	
T_4		T_6		T_3	
T_5		T_2		T_7	
T_6		T_4		T_5	
T_7		T_3		T_1	
4.5m	1m	4.5m	1m	4.5m	1m

R: Replication, T: Treatment, m: meter

3.2.4. Ecofriendly management of pod fly through biorational pesticides

Two spraying sessions were conducted throughout the crop season. The initial round occurred when the pod formation reached 50 percent, followed by a second round 15 days after the initial, to coincide with pod fly populace reaching the ETL. The count before treatment was conducted one day prior, while the counts after treatment were conducted on days 1,3,5,7 & 10 after each spray application. The produce per hectare occurred determined for each plot for statistical analysis. Pod damage caused by the pod fly of pigeonpea was determined at harvest. When the pods were fully matured, they were harvested and collected. To assess the percentage of pod and grain damage, 100 pods were randomly collected from each treatment. The percentages of pod and gain impairment were then considered using the following method (Ganguly *et al.*, 2017).

$$\%\text{ of pod damage } = \frac{\text{No. of damage of damaged pods.}}{\text{Total number of pods}} \text{x100}$$

$$\%\text{ of grain damage } = \frac{\text{No. of damage grains}}{\text{Total number of grains}} \text{x100}$$

Investigational details

1. Experimental design	: **Randomized Block Design (RBD)**
2. Treatments	: Seven
3. Replications	: Three
4. Plot dimension	: 4.5 × 1 m^2
5. Spacing	: 90 × 20 cm
6. Variety	: UPAS120
7. Date of sowing	: 13-06-2022 (1^{st} Year) and 13-06-2023 (2^{nd} Year)

FIELD LAYOUT-II

R_I	Water Channel	R_{II}	Water Channel	R_{III}	Water Channel
4.5m	1m	4.5m	1m	4.5m	1m
T_1		T_7		T_4	
T_2		T_5		T_6	
T_3		T_1		T_2	
T_4		T_6		T_3	
T_5		T_2		T_7	
T_6		T_4		T_5	
T_7		T_3		T_1	
4.5m	1m	4.5m	1m	4.5m	1m

R: Replication, T: Treatment, m: meter

Table 3.4: Details of treatments

Sr. No.	Treatments	Dose	Trade name	Source
1	NSKE (Neem Seed Kernal Extract) (*Azadirachta indica*)	5ml/lit.	Self-prepare	Plant
2	Eucalyptus leaf extract (*Eucalyptus guinnii*)	2 ml/lit.	Self-prepare	By Plant
3	Datura leaf extract (*Datura stramonium*)	2 ml/lit.	Self-prepare	By Plant
4	*HaNPV* (*Helicoverpa armigera Nucleo Polyhedrosis virus*)	$3x10^{12}$ POB/Ha	SUN BIO *HaNPV*	Sonkul Agro Industries Pvt Ltd.
5	*Bt.* 5% WP *Bacillus thuringiensis*	5 gm/lit.	Dipel	Sumitomo
6	Dimethoate 30% EC	2 ml/lit.	TAFGOR	Rallis India Ltd.
7	Control	-	-	-

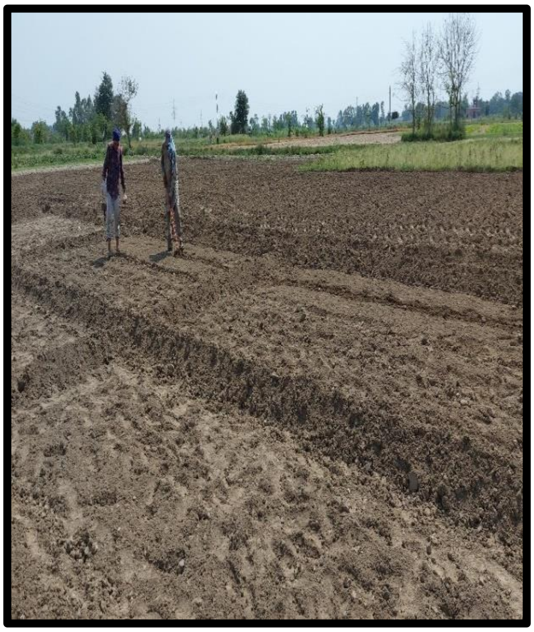
Standard preparation of treatments

- **NSKE:** Five kilograms of kernels are pounded from grinder then soaked in 10 Liters of distilled water for 24 hours. At the end of this period, the solution will turn milky white. 200 grams of soap detergent is added to the contents. The mixture is agitated again by including a wooden plank to dissolve the soap efficiently and mix together for uniform color and blend that allows it to be used further.
- **Eucalyptus leaf extract:** The standard preparation method for Eucalyptus extract is to dry and grind Eucalyptus leaves, then subjected to Soxhlet extraction or maceration in ethanol or distilled water. Upon filtration, the extract is concentrated using a rotary vacuum evaporator.
- **Datura leaf extract:** The standard method for preparing Datura extract with Kjeldahl apparatus is to dry and grind the Datura leaves, then undergo Soxhlet extraction or maceration with ethanol or distilled water. This extract is filtered after which the concentration is achieved through rotary evaporation with the help of rotary vacuum evaporator.

3.3. Analyzation of statistical tools

The observation data were statistically analyzed utilizing OPSTAT (Operational Statistics) software and SPSS (Statistical Package for the Social Sciences) to derive meaningful conclusions. This calculation was based on the net weight obtained of pigeonpea.

Measurement of land



Land Preparation

Plate 1. Measurement and preparation of land for sowing of pigeonpea

Plate 2. Sowing of pigeonpea in experimental field

Chapter-**IV**

RESULTS AND DISCUSSION

This chapter aims to analysis and explain the outcomes of different experiments conducted under the title **"Population Dynamics and Ecofriendly Management of *Melanagromyza obtusa* (Malloch) infesting *Cajanus cajan* (L.)"** conducted during the *Kharif* seasons of 2022-23 and 2023-24 at the Research experimental Farm of the School of Agriculture, LPU, Jalandhar, Punjab, India.

4.1. Population dynamics of pod fly, *M. obtusa* on *Cajanus cajan*

To investigate the seasonal occurrence of the *Melanagromyza obtusa* and its natural enemies, specifically parasitoids on the pigeonpea variety "UPAS 120". The research was conducted throughout the *Kharif* seasons of 2022-23 and 2023-24. The primary objectives were to understand the population fluctuations of the pod fly and its natural enemies, as well as determine the most favorable periods for their activity in relation to weather parameters. Observations on the presence of pod fly inhabitants and associated natural enemies were recorded at weekly intervals throughout the study period. This allowed monitoring of their occurrences and relative abundances over time.

4.1.1. Pod fly (*Melanagromyza obtusa*)

In *Kharif* season crop of 2022-23, pod fly, *Melanagromyza obtusa* were recorded maggots and pupae first time seen in the 41st SMW of 2022. The incidence was recorded at 41st SMW till 2nd SMW of 2023. The pod fly population fluctuated from 9.33 to 1.33 per 100 pods. The highest population of larvae (70.67 maggots /100 pods) was observed during the 46th SMW with maximum temperature of 28.00°C, minimum temperature of 13.00°C, highest relative humidity (Rh%) of 52.00% and lowest relative humidity (Rh%) of 47.00%. Conversely, the lowest population (1.33 maggots / 100 pods) was observed at 2nd SMW with maximum temperature of 12.00°C, minimum temperature of 10.00°C, highest relative humidity (Rh%) of 94.00% and lowest relative humidity (Rh%) of 86.00%. Pod fly activity was seen till harvesting (Table 4.1 and Fig. 4.1).

During *Kharif* season of 2023-24, pod fly, *Melanagromyza obtusa* were recorded maggots and pupae first time seen in the 40th SMW of 2023. The incidence was recorded at 40th SMW till 1st SMW of 2024. The pod fly population grew from18.67 to 72.67 per

100 pods. The highest population of *M. obtusa* (72.67 maggots/100 pods) was observed during the 44th SMW with max. temp. of 31.32°C, min. temp. of 13.30°C, max. Rh% of 94.01% and min. Rh% of 45.82%. While the lowest population (2.67 maggots/100 pods) was noted during the 1st SMW with max. temperature of 10.00°C, min. temperature of 7.22°C, maximum relative humidity of 94.00% and minimum relative humidity of 87.00%. Pod fly activity was shown till harvesting (Table 4.2 and Fig. 4.2).

In the *Kharif* season 2022-23 number of maggots and pupae were recorded from the 41st to the 2nd standard week, with recorded 16.00 to 5.00 larvae and 10.00 to 8.00 pupae/100 pods in respective weeks. The peak occurrence of maggots and pupae were noted in the 44th and 50th SMW. Highest population of maggots and pupae recorded 52.00 & 49.00 on 100 pods. Maximum infestation occurred at a maximum temperature of 34.00°C & 25.00°C, minimum temperature of 19.00°C and 10.00°C with relative humidity (Rh%) of 56.0% & 65.0%, respectively. Conversely, the lowest infestation levels were recorded at 5.0 maggots and 8.0 pupae per 100 pods during the 2nd SMW, corresponding to minimum temperatures of 10.00°C, maximum temperatures of 12.00°C, max. and min. Rh% of 94.0% and 86%, serially (Table 4.3 and Fig. 4.3).

During the *Kharif* season of 2023-24, maggot and pupae occurrences were recorded from the 39th and 52nd standard weeks, as well as the 40th to 1st Standard Meteorological Weeks with varying populations from 14.00 to 9.00 maggots and 7.00 to 14.00 pupae/ 100 pods across different weeks. The peak period for maggot and pupae presence was observed during the 44th and 45th standard weeks with the maximum populations recorded as 41.00 maggots and 40.00 pupae per 100 pods. The maximum infestation of maggots and pupae was observed at maximum temperatures of 31.32°C and 29.05°C, minimum temperatures of 13.30°C and 13.57°C, maximum relative humidity of 94.01% and 93.23%, minimum relative humidity of 45.82% and 47.22%, rainfall of 0.00 and 2.0, respectively. The minimum infestation of 8.00 maggot and 7.00 pupae per 100 pods were noted during the 51st and 40th standard weeks with maximum temperatures of 21.11°C and 34.03°C, minimum temperatures of 6.66°C and 17.42°C, maximum relative humidity of 57.00% and 51.33% and rainfall durations of 0.00 and 8.40 hours, respectively (Table 4.4 and Fig. 4.4). The current findings partially align with of Meena *et al*. (2010), who stated that the highest incidence of *M. obtusa* maggot populace was observed in the 9th standard week, with populations of 35.6 and 2.6 per plant, respectively. During 2008-09, the peak pupal activity of *M. obtusa* was recorded in the 12th standard week with 39.2 pupae, while in 2009-10, it was 9 pupae in the 11th standard. According to Kumar *et al*. (2011) a study was conducted to evaluate seed infestation by the pod fly (*Melanagromyza obtusa*) on pigeonpea, considering abiotic factors such as temperature humidity, wind, rainfall and sunshine during the years 2005-06, 2006-07 and 2007-08.the findings showed that the infestation peaked in February, with rates of 52.41%, 54.52% and 53.69%, respectively. The current results are partially aligned with findings of Keval and Srivastava (2011) The maximum average populace of pod fly, measuring 8.93 maggots, was documented in the 10th SW, with the 9th SW following closely at 7.60 maggots. Conversely, the minimal average was observed in the 4th SW, measuring just 0.73 maggots. The present study was partially akin to the findings of Yadav *et al.* (2011[a]) studied that the presence of pod fly (maggots) was earliest noticed through the initial week of October, when the crop was around 90-100 days old. It reached its peak by the 47th week around the start (1st week) of November coinciding with a crop age of 100 to 125days old. Afterward, the population gradually declined reaching zero levels by the 1st week of December. The current studied was partially agreement with findings of Pillai and Agnihotri (2013) revealed that the *M. obtusa* major activity through 46th SW populace of pod fly was minimal (31 per 100 pods) throughout 49th SW. The weekly percentage of parasitization 6.52% observed with 47th SW. The present outcome is consistent with the findings of Patange *et al*. (2017[a]) studied the population dynamics of *M. obtusa* and its natural parasitization on Cv. ICP-8863 (Maruthi) were studied. During the 51st SW, the larval population peaked at 60 larvae per 100 pods, while the pupal population peaked at 47 pupae per 100 pods during the 4th SW. Damage to pigeonpea pods peaked at 81 percent during the same period, with grain damage reaching 54.34 percent, before decreasing to 5.18 percent by the 10th SW. An analysis of the relationship between larval population, grain injury and abiotic factors like maximum temperature and evaporation revealed positive correlations. Furthermore, positive correlations between larval and pupal populations, pod and grain damage and larval, pupal and total parasitization were observed. The current findings are partially arrangement with conclusions of Shanker *et al*. (2021[b]) noticed that occurrence of the pod fly began at the 52nd standard week (SW) when 50% of the pods had formed and persisted until the crop was harvested. Pod damage commenced in the 2nd SW, ranging from 1.33% to 14.33%. the damage percentage started to rise from the 3rd SW, reaching a peak of 14.33% by the 15th SW. According to Srinivas *et al.* (2019) described that Pod fly activity started on the 44th SMW and continued until the 8th SMW, when it peaked at the 4th SMW. Later, the population diminished, reaching its minimum at the 8th SMW in both conventional and organic farming systems. According to Jaisal *et al*. (2010) five plants were randomly chosen these plants were pooled. From this pool, 100 pods were randomly selected to assess pod and grain damage. The pod fly, *Melanagromyza obtusa*, was first detected in the 2nd standard week in all genotypes. The population of the pod fly reached its peak between the 8th and 12th standard weeks. The average pod fly population varied significantly among the genotypes with counts ranging from 1.19 pod flies. According to Harshita *et al*. (2024) the 52nd Standard Meteorological Week, the pod fly population reached its peak at 10.80 maggots per 10 pods, resulting in the highest levels of pod damage at 27.75% and seed damage at 17.51%. The current finding according to Soni *et al*. (2018) in October 2016, populace was recorded at 0.10 larvae per 4th week and 0.06 maggots per 10 pods per month. This number increased to a range of 0.10 to 0.67 maggots per 10 pods per SW of 0.36 maggots per 10 pods by November 2016. The population continued to rise steadily and by the 49th week (early December 2016), the larvae per 10 pods ranged from 0.03 to 1.2 per week, averaging 0.70 maggots per 10 pods in December 2016. According to Kumar and Soni, (2018) the incidence of the pod fly, *Melanagromyza obtusa* began in the first week of November and peaked at 1.20 maggots per 10 pods during the first week of December, when temperatures ranged from 9.90 to 22.90°C and relative humidity varied between 51.00% and 87.10%. According to Seni, (2021) the pests were first observed in the 48th Standard Week (Fourth week of November) and remained active until March. Their peak activity occurred during the 7th Standard Week (Second week of February) with an average of 2.4 pests per plant. Kumar *et al*. (2018) also observed that the first maggot incidence in the 48th Standard week with 0.67 maggots per 20 pods in both July and August sown crops. Pupal occurrence also began in the 48th SW with 0.33 pupae per 20 pods in the

July crop and 0.67 pupae in the August crop, continuing until harvest. Peak maggot populations were recorded in the 4th SW, reaching 8.00 and 8.67 maggots per 20 pods in the July and August crops, respectively, while peak pupal occurrences occurred in the 5th SW with 10.67 pupae in the July crop and 11.67 pupae in the August crop. The result according to Dadas *et al*. (2019) the incidence of the pod fly (*M. obtusa*) began in the 43rd Standard Meteorological Week (SMW) with 0.80 maggots per 10 pods and continued until the 49th SMW, reaching 3.05 maggots per 10 pods. The pest populace peaked at 6.20 maggots per 10 pods in the 46th SMW, when the max. temperature was 35.7°C, the minimum temperature was 11.4°C, morning relative humidity was 75.4%, evening relative was 23.1% and there was no rainfall.

4.1.2. Natural Parasitization of *M. obtusa*

During the *Kharif* season of 2022-23, to assess the incidence of larval and pupal parasitism of the pod fly, a random sample of 100 pods was collected between the 41st Standard Meteorological Week (SMW) of 2022 and the 2nd SMW of 2023. These collected pods were brought to the entomology laboratory for analysis. The data given blow in Table 4.3 shows that randomly collected 100 pods from Pigeonpea UPAS120 revealed the first appearance of *Euderus lividus* and *Ormyrus orientalis* during the 43rd and 44th SMW. Initially, larval parasitism was observed at 11.76 percent, while pupal parasitism at 9.37 percent. In the 43rd SMW, larval parasitization of the pod fly varied between 11.76 and 31.82 percent. It's peaked at 31.82 percent of 46th SMW with highest temp. of 28.00°C, lowest temp. of 13.00°C, maximum Rh% of 52.00% and minimum Rh% of 47.00%. while the lowest larval parasitization of pod fly was 10.53 per cent at 52nd SMW. In contrast, pupal parasitization of the pod fly increased from 9.37 to 25.64 percent during the 44th SMW, reaching its highest level of 25.64 percent at 47th SMW with maximum. and min. temp. of 28.00°C and 19.00°C, maximum and minimum relative humidity of 81.00% and 76.00%. while the lowest pupal parasitization of pod fly recorded of 3.22 per cent at 1st SMW (Table 4.3 and Fig. 4.3).

During *Kharif* season 2023-24, the incidence of larval and pupal parasitism of pod fly at 39th Standard Meteorological Weeks (SMW) of 2023 and 1st SMW of 2024 and randomly 100 pods were collected and transported to the laboratory of entomology.

The pods were opened under stereo-zoom binocular microscope to observe the incidence of infestation and parasitism. The emergence of the pest and parasitoids was recorded daily. pigeon pea variety UPAS 120, the parasitoids *Euderus lividus* and *Ormyrus orientalis* were first observed during the 41st and 42nd SMW. Initially, the larval parasitism rate was 4.17 percent, while the pupal parasitism rate was 11.53 percent. In the 43rd SMW, the larval parasitization of the pod fly ranged 4.17 - 29.72 %. The larval parasitization of pod fly reached its highest of 29.72 percent during the 45th SMW. This peak coincided with highest and lowest temp. of 29.05°C and 13.57°C, respectively, along maximum relative humidity of 93.23% and a minimum relative humidity of 47.22%. While the lowest larval parasitization of pod fly was 4.17 per cent at 41st SMW. Similarly, the pupal parasitization of the pod fly fluctuated between 11.53 and 24.32 percent from the 42nd to the 44th SMW. During the 44th SMW, it peaked at 24.32 percent, coinciding with max and min temperatures of 31.32°C and 13.30°C and maximum and minimum Rh% of 94.01% and 45.82%. Conversely, the lowest recorded pupal parasitization of the pod fly was 3.84 percent during the 51st SMW (Table 4.4 and Fig. 4.4). The present studied partially align with findings of Moudgal *et al.* (2005) noticed that the larval-pupal parasitoid *Euderus lividus* and the pupal-parasitoid *Eurytoma* sp. were found on *Melanagromyza obtusa*. The level of parasitism varies between from 5.45% to 10.00% for *Euderus lividus* and from 3.69% to 5.00% for *Eurytoma* sp. Both parasitoids became active in early October, peaking in activity during the second half of the month. Their parasitic activity coincided through the presence of juvenile stages of the host. The current results partially align with the findings of Yadav *et al.* (2011^{b}) observed thar the survey conducted in pigeonpea cultivation areas around Agra revealed the presence of three primary parasitoids: *Euderus lividus* (Eulophidae), *Ormyrus orientalis* (Ormyridae) and *Eurytoma* sp. (Eurytomidae). These parasitoids were found to be dominant, with parasitization rates ranging from 2.9% in November to 11.0% in January, particularly targeting late varieties of pigeonpea. The percentage of parasitization by *E. lividus* ranged from 9.1% to 72.7%, while *O. orientalis* showed rates between 8.0% and 18.8%. The distribution and incidence of parasitism were influenced by climatic variations, leading to the elimination of one parasitoid species from the pod fly populace. The current conclusions are agreement with the results of Chakravarty *et al.* (2016) observed that during the investigation, three parasitic wasps, namely *Euderus lividus, Euderus agromyzae* and *Ormyrus orientalis* were identified as natural enemies of the pod fly. The highest level of natural parasitization (17.3%) of *M. obtusa* occurred during the 51st Southwest monsoon. However, there was no significant correlation found between the percentage of parasitization of *M. obtusa* and abiotic factors. Multiple regression analysis revealed that various weather parameters contributed to 85.9% and 92.6% of the variation in the population of *M. obtusa* and its percentage of parasitization, individually. The present findings were partially agreement with finding of Chiranjeevi and Patange (2018[a]) during the 3rd Standard Meteorological Week, research indicated peak populations of larvae, pupae and total pod flies at 125 larvae, 67 pupae and 192 pod flies per 100 pods. The pods and grains damage due to pod fly varied from 09.00 to 93.00 and 03.00 to 52.13 percent throughout the same time period, maximum at 93.00 and 52.13 percent on the 3rd SW. The *Euderus* sp., *Ormyrus* sp., *Torymus* sp. and *Eurytoma* sp. were found on pod fly larvae and pupae during the study. The current result according to Patange *et al*. (2017) noticed that the study also identified parasitoids from six different families on the immature stages of the pod fly. The highest levels of natural parasitization for larvae, pupae and the combined population (larvae & pupae) were recorded during the 2nd standard meteorological week (SMW), with percentage of 60.00%. 51.61% and 55.81%, respectively. According to Badiger and Prabhu (2019) during the survey, few larval and pupal parasitoids of the pod fly were identified. Parasitized larvae and pupae collected from pigeonpea pods were kept for adult emergence. *Euderus* sp. (Eulophidae) was identified as larval parasitoid, while *Ormyrus orientalis* (Ormyridae) and *Pseudotorymus* sp. (Torymidae) were identified as pupal parasitoids.

4.1.3. Pod borer (*Helicoverpa armigera*)

During *Kharif* season of 2022-23, *Helicoverpa armigera* larva occurrence were recorded from the 41st and 52nd Standard Meteorological Week (2.67 and 0.67 larvae per 100 pods). Pod borer activity on pigeonpea was started from 41st week and increased gradually until the 47th week. The highest larval population of 40.00 larvae per 100 pods was observed in the 47th week, with highest temperature at 28.00°C, lowest temperature at 19.00°C and max. Rh% and minimum relative humidity (Rh%) at 81.00% and 76.00%, respectively. Conversely, the lowest larval population of 0.67 larvae/ 100 pods was observed in the 52nd SMW, with maximum temperature at 21.00°C, minimum temperature at 9.00°C and highest and lowest Rh% at 98.00% and 88.00%, respectively. The larval population varied between 0.67 and 40.00 larvae per 100 pods for the whole duration. (Table 4.1 and Fig. 4.1).

During *Kharif* season of 2023-24, *Helicoverpa armigera* larva occurrences were recorded from the 42nd and 51st Standard Meteorological Week. Larval activity on pigeonpea crop was started from 42nd week and increased gradually until the 46th SMW. After that the larval population declined at 51st SMW. The highest larval population of 36.67 larvae per 100 pods was observed in the 46th week, with a max. temperature of 27.06°C and a min. temp. of 10.20°C, with a maximum temperature of 10.20°C. relative humidity at 93.84% and 49.26%, respectively. While minimum larval population of 3.33 larvae per 100 pods was recorded in the 51st SMW with maximum and minimum temperature at 21.11°C and 6.66°C, max. and min. relative humidity at 97.00% and 57.00% (Table 4.2 and Fig. 4.2). The current results are aligned with those findings of Jakhar *et al.* (2016) revealed that data revealed that the average larval population of *Helicoverpa armigera* per plant during the period (from the 27th to 3rd standard weeks) was 0.97, 0.32, 0.30 and 0.38 larvae per plant in the years 2011, 12, 13 and 2014, respectively. The current results union with those of Charan *et al.* (2017) informed that the topmost damage caused by *Helicoverpa armigera* attack was recorded in the 47th monitoring week. The majority of *Helicoverpa armigera* population was observed during the 35th monitoring period. This was influenced by a minimum temperature of 31.66°C and a maximum temperature of 33.20°C, accompanied by morning Rh% of 96.86% and evening humidity of 81.71%, along with 4.00 mm of rainfall. The present findings according to Indrasen *et al.* (2017) found that the presence of *H. armigera* was documented in 4th week with an average of 2.33 larvae per plant. This number rose to its highest point in the 11th week, where the mean population reached 7.66 larvae per plant. Agreeing to Keval *et al*. (2017[a]) the study of *H. armigera* population grew in the 9th standard week with 8.00 and 7.75 maggots per plant. The current findings are in partially align with those of Rathore *et al.* (2017) who observed that the greatest pod damage caused by the pod borer occurred at a rate of 14.32% during the 42nd standard monitoring week, with the tur pod fly resulting in 8.47% damage during the 46th standard monitoring week. The current findings according to Soni *et al*. (2018) the first appearance of blue butterfly, *Lampides boeticus* larvae was noted in the 42nd standard week (SW) in 2010. The larval population was present was present from the 42nd to 50th standard week, peaking between the 47th and 49th weeks at 0.20 larvae per plant. After this peak, the population declined until the crop was harvested. The current result according to Kumar *et al.* (2022) the larval population first appeared in the 46th standard week, averaging 0.26 larvae per plant with temperature at 27.60°C, relative humidity at 84.30% and 44.40% and rainfall at 1.30 mm. pest activity increased from the third week of November, peaking in the 10th SW of March with 1.33 larvae per plant. At this peak, temperatures were 32.30°C and 14.50°C, relative humidity was 72.60% and 35.40 and there was no rainfall.

4.1.4. Blister beetle (*Mylabris pustulata*)

During the *Kharif* season of 2022-23, blister beetles were recorded feeding on flower buds of pigeonpea for the first time since the 39th SMW of 2022. The incidence was recorded at 39th SMW till 47th SMW of 2022. The larval population of blister beetles varied from 3.33 to 2.00 per 100 pods. The peak larval population (18.67 larvae per 100 pods) was recorded during the 43rd SMW, with a maximum temperature 29.00°C, minimum temperature 18.00°C, maximum Rh% 53.00% and minimum Rh% of 43.00%. Conversely, the lowest population (2.00 larvae/100pods) was noted during the 47th SMW with maximum temperature 28.00°C, minimum temperature 19.00°C, maximum relative humidity (Rh%) 81.00% and minimum relative humidity 76.00% (Table 4.1 and Fig. 4.1).

Blister beetles were seen feeding on pigeonpea flower buds during the *Kharif* season of 2023-24, recorded the first appearance at 38th Standard Meteorological Week (SMW) of 2023. Their presence was noted from the 38th to 48th SMW of 2023. The larval population of blister beetle varied from 6.67 to 3.67 per 100 pods. The peak population (20.33 larvae/100 Pods) occurred during the 44th SMW, coinciding with maximum temperature of 31.32°C, minimum temperature of 13.30°C, maximum Rh% of 94.01% and minimum relative humidity of 45.82%. Conversely, the lowest population (3.67/100 pods) was observed in the 48th SMW, where the maximum temperature was 22.70°C, lowest temp. was 10.10°C, highest Rh% 91.20% and lowest Rh% 59.70% (Table 4.2 and Fig. 4.2). The current findings according to Dhakla *et al.* (2010) subjected that the incidence of blister beetles, specifically *Mylabris pustulata* (Thunberg). The lowest mean beetle population during the crop season (2.7 beetles per plot of 4×2.25 m) was recorded on AL 1489, while H 2004-24 exhibited the highest incidence (5.9 beetles per plot). In laboratory experiments conducted in 2007, AL 1489 demonstrated the minimum flower damage (16.6%), whereas H 2004-24 showed the maximum damage (27.5%). The existing outcomes are those findings of Singh *et al*. (2021) exposed that adult blister beetles began to emerge in pigeonpea fields towards the latter part of the third week of August, initially with no beetles observed per 4-meter row length. Subsequently, there was a noticeable increase in blister beetle population, peaking during the fourth week of September at 21.04% beetles per 4-meter row length. The presence of *Mylabris pustulata* (Thunberg) continued until the fourth week of October, indicating the peak flowering phase of pigeonpea throughout the produce season. The current outcome is consistent plus those findings of Singh *et al.* (2022) the study realized that blister beetles greatly affected both pigeonpea and mung bean yields. A density of 200 *M. pustulata* Thunberg beetles per cage rendered optimum reductions of 54% under the net house conditions. In pod setting, it was 18% and in mobile teaming it was 20.15% for seed setting, 64.10% to 88% in grain yield for pigeonpea. In mung bean, 4 beetles per cage were effective in causing reduction of up to 67.14% in pod and26% of grains increase by 65%, while there was a 75% increase in pods 29% in grain yield.

4.1.5. Pod bug (*Clavigralla gibbosa*)

During the *Kharif* season 2022-23, Pod bug is the main pest of pigeonpea. They were observed sucking from leaves, flowers and growing pods, both as nymphs and adults. The 1st occurrence of *C. gibbosa* was observed in 41st SMW with the population of 9.67 nymph/ 100 pods. Which reached the peak during 46th SMW with population was 45.67 nymph/100 pods during 2022, at highest temp 28.00°C, lowest temp. 13.00°C, max. relative humidity 52.00 percent and min. relative humidity 47.00 percent. The lowest number of pod bug 15.67 nymph/100 pods was observed during 49th SMW at maximum temperature 26.00°C, minimum Temperatures of 9.00°C, maximum relative humidity 89.00 percent and min. relative humidity 61.00 percent. Pod bugs were observed in the field frequently up to crop harvest (Table 4.1 and Fig. 4.1).

During *Kharif*, 2023-24, first time occurrence of *C. gibbosa* was observed in the 40th SMW with population of 6.33 nymph/100 pods. Which population reach the peaked at 44th SMW with population was 34.67 nymph/100 pods at max. temp. 31.32°C, minimum temp. 13.30°C, maximum Rh% 94.01% and minimum Rh% 45.82%. The lowest population of 4.67 nymph/100 pods was observed at 49th SMW with maximum temperature 23.33°C, minimum temperature 9.44°C, maximum 94.00% and minimum relative humidity 47.00%. While, until harvest of crop, pod bugs were often seen in the fields (Table 4.2 and Fig. 4.2). The present studied are also in agreement with the findings of Vikram *et al.* (2015) in a study on pigeonpea crops, researchers noted the presence of various insect pests throughout different growth stages. The focus was on two pests: *M. obtusa* & *C. gibbosa*. Pod fly was initially spotted in 3rd week of 2012, with its larval population peaking by the 10th week. Similarly, *C. gibbosa* was first time shown in 1st week and 10th week. Despite a decrease in pest activity after reaching their peaks, they persisted in the field until harvest. The emergence of *M. obtusa* in the 3rd week of 2012 corresponded with the crop's late vegetative stage. The current result is also aligned with the conclusions of Pandey *et al.* (2016) reported that in a study on infestations in short period pigeon pea crops, researchers noted the presence of various insect & pests. They specifically investigated the occurrence patterns of the pod fly & the pod bug, *C. gibbosa*. *M. obtusa* was observed for the primary period in the 42nd standard week, with populace of 0.10 maggots per plant. Its population peaked during the 45th standard week, with 0.30 maggots per plant during the 2010-11 season. Similarly, pod bug was first sighted in the 40th standard week, with an average populace of 0.03 maggots per plant. Its population reached its peak during the 44th and 45th standard weeks with mean populations of 0.40 larvae per plant during together weeks. The current result according to Khamoriya *et al*. (2017) the study found that the occurrence of the pod bug began in the 2nd SW continued dynamic until the 14th SW in both years. The *Clavigralla gibbosa* population peaked at 2015-16, while in 2016-17, the highest populace was noted in the 10th SW with 5.50 bugs per plant.

4.1.6. Blue butterfly (*Lampides boeticus*)

During the 2022-23 *Kharif* season, the larvae of blue butterfly, *Lampides boeticus* consumed buds, flowers and tender pods. Blue butterfly was recorded (3.67 larvae per 100 pods) in the 42nd SMW on pigeon pea. The population of the pest fluctuated between 1.00 to 26.33 larvae per 100 pods. The highest larval population of the blue butterfly (26.33 larvae per 100 pods) was observed in the 44th SMW with maximum temperature of 34.00°C, minimum temperature of 19.00°C, maximum Rh% of 56.00% and minimum relative humidity (Rh%) of 42.00%. Conversely, the lowest population (1.00 larvae per 100 pods) was noted in the 48th SMW with maximum temperature of 25.00°C, minimum temperature of 11.00°C, maximum relative humidity of 89.00% and minimum relative humidity of 77.00% (Table 4.1 and Fig. 4.1).

During 2023-24, blue butterfly larvae were recorded from the 38th and 48th Standard Meteorological Week (SMW). Larval population activity was started from 38th SMW of (3.67 larvae per 100 pods) and increased gradually until the 44th SMW of (15.33 larvae per 100 pods). After that the lowest larval population at 48th SMW (1.00 larvae per 100 pods). The highest larval population of 15.33 larvae per 100 pods was recorded in the 44th week by maximum temperature of 31.32°C, minimum temperature of 13.30°C and maximum and minimum Rh% 94.01% and 45.82%, respectively. Larval population of 3.67 larvae per 100 pods was noted in the 38th week with maximum temperature at 34.61°C, minimum temperature at 24.83°C and maximum relative humidity at 92.99% and minimum relative humidity at 64.83%. While lowest larval population of 1.00 larvae per 100 pods were recorded in the 48th SMW with maximum temperature at 22.70°C, minimum temperature at 10.10°C, maximum relative humidity at 91.20%, minimum relative humidity at 59.70% and rainfall at 0.20 mm (Table 4.2 and Fig. 4.2). The present results are indicating that Kumar and Nath (2005) to examine from 1994-96 how meteorological factors impacted the insect pest population in pigeonpea UPAS 120. The study found that all meteorological parameters had non-significant effects on pigeonpea pests. Specifically, temperature, relative humidity and water evaporation negatively correlated with the population growth of the blue butterfly (*Lampides boeticus*) and the pod bug (*Clavigralla gibbosa*). The current results are partially agreement with the findings of Pandey *et al*. (2015) reported that the larvae of the blue butterfly, *Lampides boeticus*, first appeared in the 42nd standard week of 2010. The larvae were observed from the 42nd to 50th standard weeks. The larval population peaked between the 47th and 49th standard weeks, reaching 0.20 larvae per plant. After this peak, the population declined until the crop harvest. The present findings align partially with those of Sharma *et al*. (2022) in the 2018-19 crop reproductive phase, researchers examined the insect *L. boeticus* and observed the first blue butterfly in the fourth week. Significant variations in population were noted among different genotypes. For example, genotype AVT1-707 had a peak population of 0.14 larvae per plant, while AVT2-904 had a lower population of 0.04 larvae per plant in the initial week. The larval population of *L. boeticus* remained steady across all genotypes from the fourth to the twelfth week. The average population of the blue butterfly varied by genotype, ranging from 0.20 larvae per plant in AVT2- 903 to 0.27 larvae per plant in MAL-13 (AVT1) and AVT1-704. Furthermore, cereal yields in AVT1-704 varied from 617 kg/ha to 1434 kg/ha, with AVT1-708 showing remarkable performance.

Table 4.1: Population dynamics of main pests on pigeonpea crop during *Kharif*, 2022-23

SMW	*M. obtusa*	*H. armigera*	*M. pustulata*	*C. gibbosa*	*L. boeticus*	Temperature (°C)		Rh (%)		Rainfall (mm)
						Max.	Min.	Max.	Min.	
39	0.00	0.00	3.33	0.00	0.00	36.00	23.00	74.00	60.00	0.00
40	0.00	0.00	8.00	0.00	0.00	34.00	22.00	50.00	42.00	0.00
41	9.33	2.67	6.00	9.67	0.00	32.00	23.00	59.00	43.00	0.00
42	20.89	13.33	11.33	13.00	3.67	31.00	20.00	56.00	46.00	0.00
43	38.00	23.00	18.67	22.67	14.00	29.00	18.00	53.00	43.00	0.00
44	56.67	18.67	16.00	32.67	26.33	34.00	19.00	56.00	42.00	0.00
45	54.33	35.67	10.33	38.33	23.67	24.00	18.00	59.00	49.00	0.20
46	70.67	39.33	7.67	45.67	15.33	28.00	13.00	52.00	47.00	0.00
47	67.33	40.00	2.00	36.67	9.33	28.00	19.00	81.00	76.00	0.00
48	49.33	28.33	0.00	21.00	1.00	25.00	11.00	89.00	77.00	0.00
49	36.67	22.67	0.00	15.67	1.33	26.00	9.00	89.00	61.00	0.00
50	30.33	0.00	0.00	0.00	0.00	25.00	10.00	97.00	65.00	0.00
51	21.67	0.00	0.00	0.00	0.00	24.00	9.00	90.00	79.00	0.00
52	15.00	0.67	0.00	0.00	0.00	21.00	9.00	98.00	88.00	2.00
1	8.67	0.00	0.00	0.00	0.00	12.00	6.00	98.00	86.00	0.00
2	1.33	0.00	0.00	0.00	0.00	12.00	10.00	94.00	86.00	0.00

No incidence of pod fly on pigeonpea crop at 3rd Standard Meteorological Week of 2022-23

Fig. 4.1: The population dynamics of main pests on pigeonpea crop during *Kharif*, 2022-23

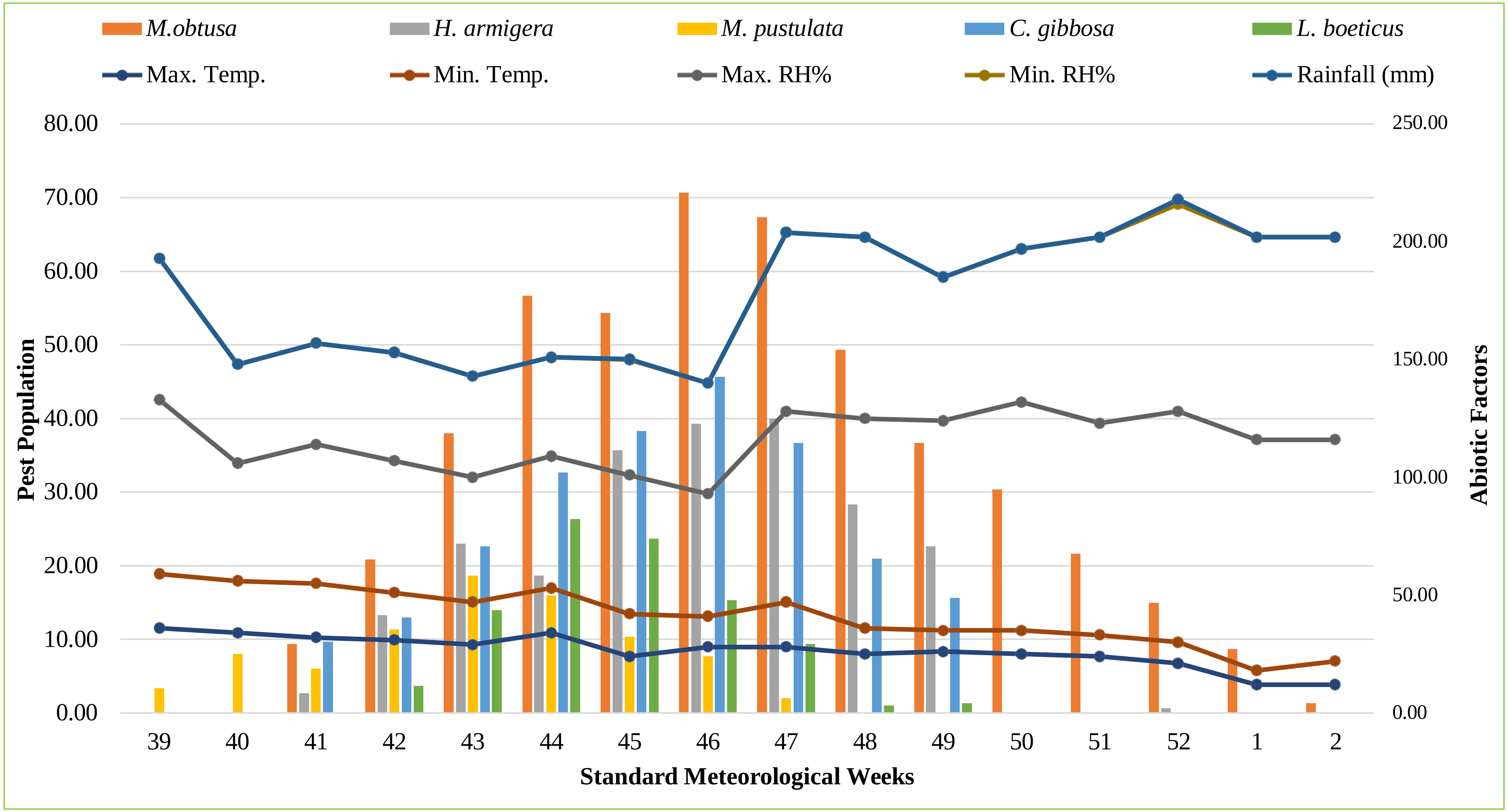


Plate 3. Tagging of Experimental field

Plate 4. Flowering stage of pigeonpea crop in experimental field

Plate 5. Pod formation in pigeonpea crop

Plate 6. Observations of insect-pest at flowering stage and maturity stage in pigeonpea

Plate 7. Pod damage by maggot of pod fly

Plate 8. Pupal stage of pod fly with infested seeds

Male

Female

Plate 9. Dimorphism of pod fly (*Melanagromyza obtusa*)

MALE

FEMAE

Plate 10. Dimorphism of larval parasitoid *Euderus lividus* of pod fly

Plate 11. Larval parasitization of *Euderus lividus* on pod fly maggot

Male **Female**

Plate 12. Dimorphism of pupal parasitoid *Ormyrus orientalis* on pod fly

Plate 13. Larva of pod borer (*Helicoverpa armigera*)

Plate 14. Adult of Blister beetle (*Mylabris pustulata*)

Nymph stage of *C. gibbosa* **Adult of *C. gibbosa***

Plate 15. Dimorphism of Tur pod bug (*Clavigralla gibbosa*)

Larva of *L. boeticus* **Adult of *L. boeticus***

Plate 16. Dimorphism of blue butterfly (*Lampides boeticus*)

Table 4.2: Population dynamics of major pest on pigeonpea crop during *Kharif*., 2023-24

SMW	*M. obtusa*	*H. armigera*	*M. pustulata*	*C. gibbosa*	*L. boeticus*	Temperature (°C)		Rh (%)		Rainfall (mm)
						Max.	Min.	Max.	Min.	
38	0.00	0.00	6.67	0.00	3.67	34.61	24.83	92.99	64.83	0.20
39	0.00	0.00	13.33	0.00	4.33	34.30	19.96	92.65	65.50	0.00
40	18.67	0.00	9.67	6.33	7.33	34.03	17.42	92.38	51.33	0.20
41	38.33	0.00	17.33	14.67	12.67	32.51	16.32	92.81	45.53	0.00
42	35.67	4.33	10.67	11.33	10.33	28.31	13.12	92.79	51.68	0.80
43	52.67	11.67	18.33	25.00	13.33	31.16	12.36	92.95	35.87	0.00
44	72.67	23.33	20.33	34.67	15.33	31.32	13.30	94.01	45.82	0.00
45	61.33	19.00	15.67	28.67	9.67	29.05	13.57	93.23	47.22	0.60
46	57.33	36.67	11.00	23.33	7.33	27.06	10.20	93.84	49.26	0.00
47	45.67	34.33	7.67	13.33	5.67	26.70	7.38	92.48	40.96	0.20
48	34.33	28.67	3.67	8.00	1.00	22.70	10.10	91.20	59.70	0.20
49	26.67	15.00	0.00	4.67	0.00	23.33	9.44	94.00	47.00	0.00
50	19.33	7.33	0.00	0.00	0.00	20.55	7.77	94.00	52.00	0.00
51	11.67	3.33	0.00	0.00	0.00	21.11	6.66	97.00	57.00	0.00
52	7.33	0.00	0.00	0.00	0.00	16.66	10.55	95.00	74.00	0.00
1	2.67	0.00	0.00	0.00	0.00	10.00	7.22	94.00	87.00	0.00
2	0.00	0.00	0.00	0.00	0.00	11.11	5.55	94.60	80.00	0.00

No incidence of pod fly on pigeonpea crop at 2nd Standard Meteorological Week of 2023-24

Fig. 4.2: Population dynamics of major pests on pigeonpea crop during Kharif, 2023-24

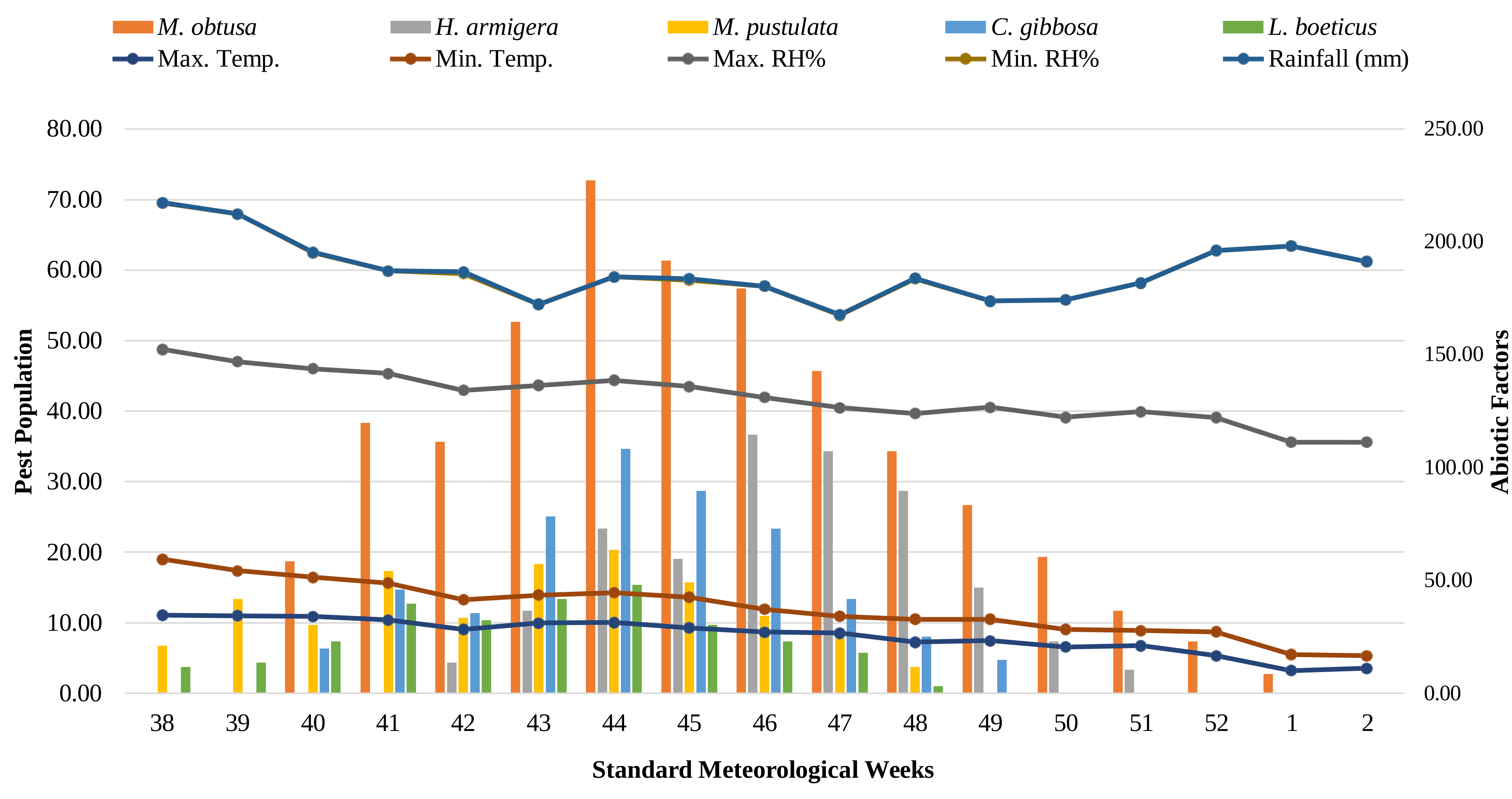


Table 4.3: Natural parasitoids associated with *Melanagromyza obtusa* (Malloch) during *Kharif*, 2022-23

SMW	Pod damage/ 100 pods	Larvae	Pupae	% of Emergence		Temperature (°C)		Rh (%)		Rainfall (mm)
				E. lividus	*O. orientalis*	Max.	Min.	Max.	Min.	
41	29	16	10	0.00	0.00	32.00	23.00	59.00	43.00	0.00
42	42	27	28	0.00	0.00	31.00	20.00	56.00	46.00	0.00
43	56	34	30	11.76	0.00	29.00	18.00	53.00	43.00	0.00
44	78	52	32	17.31	9.37	34.00	19.00	56.00	42.00	0.00
45	69	47	28	25.53	17.86	24.00	18.00	59.00	49.00	0.20
46	79	44	41	31.82	21.95	28.00	13.00	52.00	47.00	0.00
47	72	48	39	22.91	25.64	28.00	19.00	81.00	76.00	0.00
48	65	36	42	25.00	21.43	25.00	11.00	89.00	77.00	0.00
49	70	41	45	12.19	13.33	26.00	9.00	89.00	61.00	0.00
50	68	32	49	18.75	8.16	25.00	10.00	97.00	65.00	0.00
51	57	22	46	13.64	4.35	24.00	9.00	90.00	79.00	0.00
52	43	19	27	10.53	3.70	21.00	9.00	98.00	88.00	2.00
1	31	11	31	0.00	3.22	12.00	6.00	98.00	86.00	0.00
2	17	5	8	0.00	0.00	12.00	10.00	94.00	86.00	0.00

No incidence of pod fly on pigeonpea crop at 3rd Standard Meteorological Week of 2022-23

Fig. 4.3: Percentage of natural parasitization on pod fly 2022-23

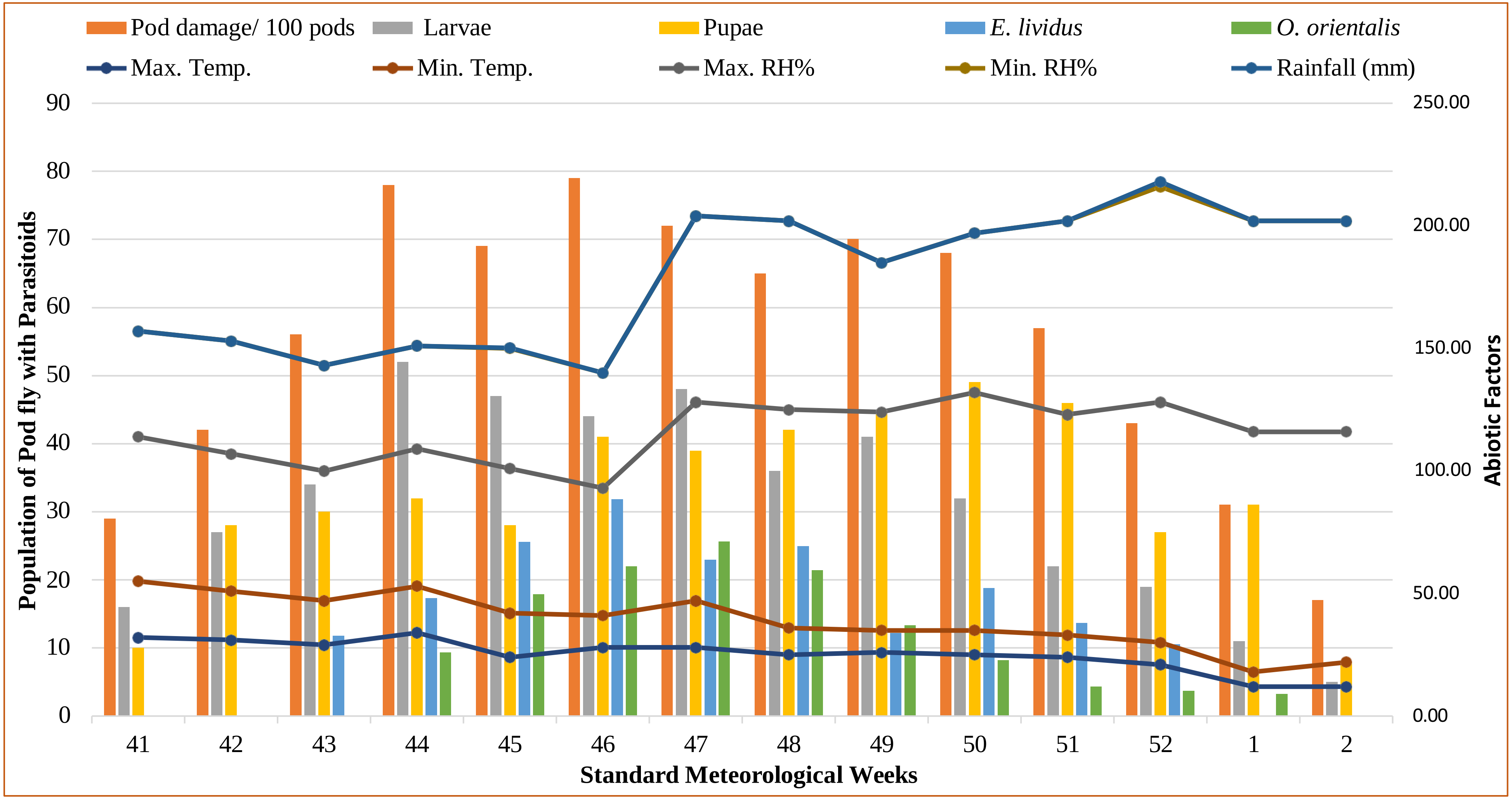
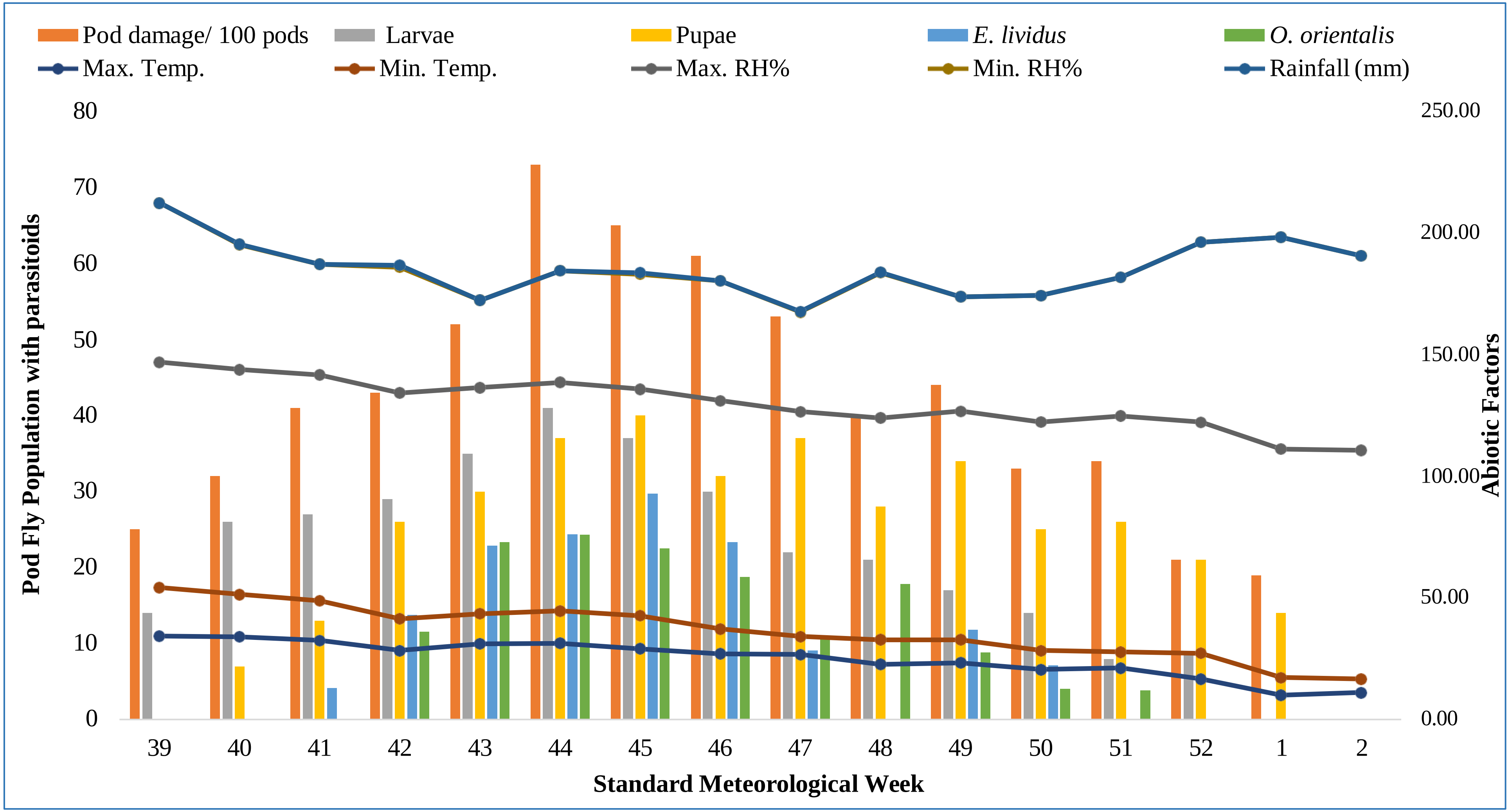


Table 4.4: Natural parasitoids associated with *Melanagromyza obtusa* (Malloch) during *Kharif*, 2023-24

SMW	Pod damage/ 100 pods	Larvae	Pupae	% of Emergence		Temperature (°C)		Rh (%)		Rainfall (mm)
				E. lividus	*O. orientalis*	Max.	Min.	Max.	Min.	
39	25	14	0	0.00	0.00	34.30	19.96	92.65	65.50	0.00
40	32	26	7	0.00	0.00	34.03	17.42	92.38	51.33	0.20
41	41	27	13	4.17	0.00	32.51	16.32	92.81	45.53	0.00
42	43	29	26	13.79	11.53	28.31	13.12	92.79	51.68	0.80
43	52	35	30	22.85	23.33	31.16	12.36	92.95	35.87	0.00
44	73	41	37	24.39	24.32	31.32	13.30	94.01	45.82	0.00
45	65	37	40	29.72	22.50	29.05	13.57	93.23	47.22	0.60
46	61	30	32	23.33	18.75	27.06	10.20	93.84	49.26	0.00
47	53	22	37	9.09	10.81	26.70	7.38	92.48	40.96	0.20
48	40	21	28	0.00	17.85	22.70	10.10	91.20	59.70	0.20
49	44	17	34	11.76	8.82	23.33	9.44	94.00	47.00	0.00
50	33	14	25	7.14	4.00	20.55	7.77	94.00	52.00	0.00
51	34	8	26	0.00	3.84	21.11	6.66	97.00	57.00	0.00
52	21	9	21	0.00	0.00	16.66	10.55	95.00	74.00	0.00
1	19	0	14	0.00	0.00	10.00	7.22	94.00	87.00	0.00
2	0	0	0	0.00	0.00	11.11	5.55	94.00	80.00	0.00

No incidence of pod fly on pigeonpea crop at 2nd Standard Meteorological Week of 2023-24

Fig. 4.4: Percentage of natural parasitization on pod fly 2023-24



4.1. Correlation of population dynamics of *M. obtusa* on *C. cajan* with weather parameters

The correlation between major insect pests observed during the *Kharif* seasons of 2022-23 and 2023-24 was studied in relation to abiotic factors. Changes in weather conditions were seen as the main cause for the fluctuating occurrence of these pests. The findings of this investigation are summarized below (Table 4.5 and 4.6).

4.1.1. Pod fly (*Melanagromyza obtusa*)

During the *Kharif* season of 2022-23, the relation among the occurrence of *M. obtusa* and climate parameters exhibited both positive and negative correlations, although these correlations were non-significant. The correlation determined between number of pod fly maggots and abiotic factors exhibited non-significant positive relationship with highest temperature (r= 0.161) and non-significant negative correlation with lowest temperature (r= -0.016), maximum Rh% (r= -0.238), minimum Rh% (r= -0.209) and rainfall (mm) (r= -0.139) (Table 4.5).

In the *Kharif* season of 2023-24, the correlation coefficients analysis between pod fly occurrence and abiotic factors revealed substantial negative correlation with minimum Rh% (r= -0.772**). The maximum temperature and rainfall observed positive correlations at no-significant (r= 0.402 and r= 0.253 respectively). Other abiotic factors such as minimum temperature and maximum Rh% had negative relationships at low levels (r= - 0.076 and r= -0.252, separately) (Table 4.6).

Throughout the *Kharif* season of 2022-23, correlations between pod fly larvae occurrence and weather parameters showed both positive and negative relationships, though mostly non-significant. Larvae of *M. obtusa* exhibited positive non-significant correlation (r= 0.380) with lowest temperature and a substantial positive association (r= 0.646*) with the highest temperature. However, they demonstrated non-significant negative effects on precipitation (r= -0.203), minimal Rh% (r= -0.515) and maximum Rh % (r= -0.472). Pupae of pod fly showed non-significant positive relationships to lowest relative humidity (r= 0.075), highest Rh% (r= 0.217) and the highest temperature (r= 0.198). They displayed however, non-significantly negative relationships with precipitation (r= -0.140) and the lowest temp. (r= -0.370) (Table 4.7).

In the *Kharif* season of 2023–2024, data showed that there was a highly significant negative relationship (r= -0.776**) with min. relative humidity and a highly significant positive relationship (r= 0.746**) with maximum temperature for pod fly larvae. Additionally, there were non-significant positive correlations between bare min. temp. (r= 0.420) and precipitation (r= 0.376) and a negative non relationship with maximum Rh% (r= -0.403). Pod fly pupae exhibited a significant negative correlation with lowest temperature (r= -0.541), along with non-significant negative correlations with highest temp. (r= -0.091) and minimum Rh% (r= -0.513). They also exhibited positive non-significant correlations by max Rh% (r= 0.127) and precipitation (r= 0.245) (Table 4.8). The current research aligns with Yadav *et al*. (2011[a]) findings, indicating that maggot presence was first noted in early October in a crop aged 90 to 100 days, peaking by the first week of November (100 to 125 days old crop). Afterward, the population gradually decreased, reaching zero levels by early December, with the pest's activity persisting for approximately two months. The maggot population began to increase as the max. temp. fell below 32°C, reaching its peak as temperatures further decline. The study suggests that a max. temp. below 30°C, min. temp. The pest's population growth is due to a range of 8.10 to 17.00°C and an usual relative humidity of 60-70 per cent. Stepwise multiple regression analysis showed an R2 value of 0.48, indicating the populace of the pod fly based on rainfall data from the current week and up to three weeks prior. The highest population of weekly percentage parasitization was found by Pillai and Agnihotri (2013) during 51st standard week, while the lowest level of weekly percentage parasitization was recorded during 47th SW at 6.52%. The population of *M. obtusa* and weather parameters positively and significantly correlated with minimum temperature (r = 0.769). The regression analysis revealed that the variations in abiotic factors were the most significant factors contributing to 88.50 and 86.30% of difference in the pod fly populace and per cent of pod fly parasitization, separately. The studies are accordance with the findings of Chandra and Singh (2017) the maggot population exhibited a negative correlation, while the pupal populace exhibited positive correlation with both max. & min. temp. in the Bahar and NDA-1 varieties. In contrast, relative humidity was positively corrected with the pupal population. Rainfall on the other hand caused a negative correlation between maggots and pupal population in both varieties. According to Keval *et al*. (2017[a]) the data from 2015-16 showed that the population of *M. obtusa* had a significant positive correlation with max. temp. (r= 0.796**), minimum temperature (r= 0.659*) and sunshine hours (r= 0.690**), while a significant negative correlation was found with average Rh% (r= -0.785**). Other abiotic factors did not significantly impact pest incidence. Similarly, in 2016-17, there was a significant positive correlation with maximum temperature (r= 0.883**) and sunshine hours (r= 0.587*) and a significant negative correlation with average Rh% (r= - 0.710**). Other abiotic factors showed no significant correlation. According to Patange *et al.* (2017[a]) an analysis of the relationship between larval population, grain damage and abiotic factors like maximum temperature and evaporation revealed positive correlations. Additionally, positive correlations were observed between larval and pupal populations of pod fly, pigeonpea pods, grain damage, larval, pupal and total parasitization**.**

4.1.2. Natural parasitization on pod fly

During the *Kharif* season of 2022-23, the relationship among the presence of pod fly and abiotic factors indicated both positive and negative correlation at non-significant. The analysis of correlation coefficients between the number of damaged pods and pod fly larvae with various abiotic factors revealed the following relationships: a positive significant relationship with highest temperature (r=0.550*) & (r= 0.646*), a non-significant positive relationship with lowest temperature (r= 0.116) and (r= 0.380), negative non-significant relationship with maximum Rh% (r=-0.276)and (r=- 0.472), minimum Rh% (r= -0.360) & (r= -0.515) and rainfall (r=-0.161) & (r= -0.203). The pupae of pod flies exhibit a positive relationship with the highest temp. (r= 0.198) and with both maximum and minimum Rh% (r= 0.17). However, there's a negative non- significant relationship with lowest temp. (r= -0.370) and rainfall (Rh%) (r= -0.140). The correlation analysis between *Euderus lividus* and abiotic factors revealed non- significant positive correlations with both maximum and minimum temperature (r= 0.313 and r= 0.018, respectively). Conversely, there were non-significant negative relationships with both relative humidity (Rh%) (r= -0.186 & r= -0.160) and rainfall (r= -0.049). Whereas the analysis of the correlation between the incidence of *Ormyrus orientalis* and abiotic factors displayed non-significant positive correlations with temperature (r= 0.194 and r= 0.021) and lowest relative humidity (r= 0.003). Conversely, non-significant negative relationships were observed with the highest Rh% (r= -0.051) and the rainfall (r= -0.146) (Table 4.7).

During the *Kharif* season of 2023-24, when examining the correlation between damaged pods and various environmental factors, substantial negative relationships were found with least relative humidity (r= -0.744**), while maximum relative humidity showed a non-significant negative relationship (r = -0.149). Conversely, both maximum and minimum temperatures exhibited positive non-significant relationships (r= 0.482 and r= 0.027, separately), as did rainfall (r= 0.246). Pod fly larvae showed a significant positive relationship with highest temperature (r= 0.746**) and a significant negative relationship with lowest relative humidity (r= -0.776**). Larvae also demonstrated positive correlations with the minimum temperature (r= 0.420) and rainfall (r= 0.376) and a negative correlation with the maximum Rh% (r= -0.403). Pupae of pod flies displayed a positive significant correlation with minimum temp. (r= - 0.541) and a non-significant negative correlation with max. temp. and min. Rh% (r= - 0.091 and r= -0.513), separately. Conversely, non-significant negative correlations were observed with the highest Rh% and rainfall (r= 0.127 and r= 0.245). The correlation analysis regarding the occurrence of *Euderus lividus* showed a significant negative correlation with minimum relative humidity (r= -0.612*) and non-significant positive correlations with temperature (r= 0.360 and r= 0.035) and rainfall (r= 0.303) with a non-significant negative relationship with maximum relative humidity (r= - 0.055). Similarly, the correlation analysis for the incidence of *Ormyrus orientalis* exhibited a significant negative relationship with min. Rh% (r= -0.564*) and non-significant negative correlations with min. temperature (r= -0.084) and max. Rh% (r= - 0.219). On the contrary, non-significant positive relationships were discovered through maximum temperature (r= 0.287) and rainfall (r= 0.276) (Table 4.8). These findings partially align with the results of Pillai and Agnihotri (2013) observed that the correlation showed a significant positive correlation between the *M. obtusa* population and minimum temperature (r= 0.769). The correlation between parasitization and percentage were the most influential, accounting for 88.5% (R^2= 0.863) of the variation in *M. obtusa* population and parasitization percentage, respectively. These findings are in line with those by Chakravarty *et al*. (2016), which stated that the population growth of *M. obtusa* was highly negatively correlated with evening Rh% (r= -0.743*) and highly significantly positively correlated with maximum (r= 0.746*) and minimum temperatures (r= 0.812*). Non-significant relationship was found amongst percent parasitization of *M. obtusa* and weather parameters. Patange *et al*. (2017[a]) reported that there was no significant relationship between the parasitoid population and both afternoon humidity and wind speed. Rainfall (r=-3040), maximum and minimum temperatures (r=-0.4505), morning humidity (r=-0.1106) and evaporation (r=-0.3507) were all found to be in negative correlation. This indicates that the populations of the parasitoid *M. obtusa* are adversely affected by higher temperatures and lower relative humidity. The results according to Chiranjeevi and Patange (2018[a]) reported the presence of four parasitoids on larvae and pupae on pod fly species. A strong negative correlation was found with temperature and the number of maggots, pupa and population. Correlation coefficient for maggots, pupae and total population were -0.8045, -0.7578 and -0.6585, -0.8988, -0.8490 and -0.6652, -0.8647, -0.7513 and -0.7473, respectively.

4.1.3. Pod borer (*Helicoverpa armigera*)

During *Kharif* season 2022-23, the correlation determined between for the occurrence of *H. armigera* and abiotic factors showed a both of positive and negative correlations. The data clearly indicates that the larval population shown non-significant positive correlations with max. temp. (r= 0.175) and min. temp. (r= 0.132), whereas both relative humidity (Rh%) (r= -0.358 and r= -0.270) & precipitation (r= -0.191) exhibited non-significant negative correlations during *Kharif*, 2022-23 (Table 4.5).

During the 2023-24 *Kharif* season, an analysis of correlation coefficients showed that pod fly occurrence and abiotic factors had a negative significant association with minimal Rh% (r= -0.515*). There were non-significant positive correlations observed between max. temperature and rainfall showed at (r= 0.128 and r= 0.076 respectively). Other abiotic factors like min. temperature and maximum Rh% exhibited non-significant negative correlations of (r= -0.293 and r= -0.271), respectively (Table 4.6). The findings of the study by Pawar *et al*. (2007) are supported in the correlation and regression coefficients between max and min temp. and relative humidity as well as those between the larval populace of *Helicoverpa armigera* on pigeonpea crop and these variables, which have been statistically insignificant. According to Rathore *et al*. (2017), a statistically positive relationship was observed amongst the mean temp. and maggot's populace of pod borer while there was negative though not statistically significant correlation with relative humidity.

4.1.4. Blister beetle (*Mylabris pustulata*)

The analysis of correlation between occurrence of *M. pustulata* and abiotic factor revealed both positive and negative correlations. The data clearly shows that larval population indicated significant positive relationships through both max. and min. temp. (r= 0.532* and r= 0.618* respectively). Conversely, there were noteworthy negative relationships with both maximum and minimum Rh% (r= -0.864** and r= -0.814** separately), as well as with rainfall (r= -0.202), although the harmful relationship with rainfall was non-significant during 2022-23 (Table 4.5).

During the *Kharif* season of 2023-24, the analysis of correlation coefficients between *M. pustulata* occurrence and weather parameters exhibited revealed significant positive correlation with both maximum and minimum temperature (r=0.772** & r=0.516* respectively) then a negative significant relationship with minimum Rh% (r= -0.608**). In contrast, a non-significant negative correlation was observed with the maximum relative humidity (r= -0.429), while there was a non-significant positive correlation with rainfall (r= 0.222) (Table 4.6). Kumar and Nath (2005) observed that the temperature, sunshine and water evaporation had no negative impact on the population of blister beetles (*Mylabris pustulata*). Conversely, maximum, minimum and average relative humidity, wind velocity and rainfall had a positive impact on the population of blister beetles infesting pigeonpea crops. Pawar *et al*. (2014) revealed that the significant negative correlations with maximum temperature (r= -0.389) and minimum temperature (r= -0.386) at r= 0.01. A similar negative trend was observed for minimum temperature (r= -0.625 at p= 0.01) during the kharif 2012-13 season under regular sown conditions.

In the late sown condition of *Kharif* 2012-13, there was a negative correlation with bright sunshine hours (r= -0.456**). Conversely, morning relative humidity (r= 0.505**) and evening relative humidity (r= 0.426*) showed statistically significant positive correlations with blister beetle abundance. Additionally, there was a strong negative association with evaporation. These outcomes are results of Sandal, (2007) found that there was a significant positive correlation between blister beetle activity on pigeonpea and maximum temperature as well as sunshine hours, whereas relative humidity showed a negative correlation.

4.1.5. Pod bug (*Clavigralla gibbosa*)

During the *Kharif* season of 2022-23, the correlation coefficients calculated to analysis the relationship between the occurrence of *C. gibbosa* and various abiotic factors such as (temperature, humidity and rainfall etc.) showed both positive and negative correlations. During the analysis of the pod bug population, the findings revealed a negative significant of correlation with maximum Rh% (r=-0.512*), indicating that as the relative humidity increased, the pod bug population decreased. However, the correlations with temperature (both minimum and maximum temp.) were positive but non-significant, with values of r=0.264 & r=0.244, separately. Although there was non-significant negative relationship observed between the pod bug populace and minimum Rh% (r= -0.420) as well as with rainfall (r= -0.203) (Table 4.5).

During the analysis of pod bug populations, a significant negative correlation was observed with min. relative humidity (r= -0.669**), indicating that as minimum relative humidity decreased, the pod bug population increased. However, the correlations with max. and min. temp. They were positive but not significant with values of (r= 0.450) and (r= 0.064). Additionally, there was a non-significant negative relationship (r= -0.230) observed between the pod bug population and abiotic factor. In contrast, the relationship among the pod bug population and rainfall was positive, but not significant (r= 0.226) during 2023-24 (Table 4.6). The present studies are accordance with the findings of Keval *et al*. (2018) found that the highest infestation by the pod borer complex occurred during the second half of Oct. with 44^{th} and 45^{th} SW in both years. The relationship analysis revealed a significant positive between the population of these insect & pest maximum and minimum temperature. Conversely, a significant negative correlation was observed with relative humidity and rainfall (mm). According to Jakhar *et al.* (2017) the population of *C. gibbosa* showed a significant negative correlation with maximum temperature (r= -0.73), rainfall (r= -0.29) and relative humidity (r= -0.79) in the morning and r= -0.58 in the evening). The present study aligns with those of Pandey *et al.* (2024) the correlation studies over two years showed that morning Rh% had a negative association (r= -0.568) with pod bug populace, while evening Rh% had a stronger negative relationship (r= -0.665). Regression analysis identified maximum temperature morning and evening relative humidity and wind velocity as the most influential factors, affecting pod bug population by 16.3%, 32.2%, 44.2% and 20.7%, respectively.

4.1.6. Blue butterfly (*Lampides boeticus*)

During the *Kharif* season of 2022-23, the correlation coefficients determined to analysis the relationship between the occurrence of blue butterfly and various abiotic factors as temperature, humidity and rainfall etc., exhibited both positive and negative correlations. The analysis of the blue butterfly population revealed a negative significant relationship with both maximum and minimum Rh% (r= -0.578* and r= -0.512*), indicating that as Rh% increased, the butterfly population decreased. Conversely, the larval population shown a significant positive relationship with max. and min. temp. (r=0.256 & r=0.300, separately), maximum temperature was associated with increased larval numbers. However, the relationship between larval population and precipitation was negative, but not significant (r= -0.122) (Table 4.5).

In the *Kharif* season of 2023-24, the analysis of the blue butterfly populace exhibited a positive significant connection with max. temp. (r= 0.694**), indicating that the maximum temperatures were associated with an increase in the blue butterfly population. On the other hand, the larval populace showed a major negative relationship with lowest relative humidity (r= -0.657**). However, the relationships with min. temp. and rainfall were non-significant positive relationship with values of r= 0.397 and r= 0.292, separately. Additionally, the correlation between the blue butterfly population and highest Rh% was non-significant negative relationship (r= -0.358) (Table 4.6).

The current results align with those of Rathore *et al*. (2017), who reported that for the blue butterfly and all abiotic factors were not statistically significant @ 5% level. According to Jalondhara and Patel (2018) the blue butterfly population showed a significant positive correlation with maximum temperature (r= 0.591) and average temperature (r= 0.450). the multiple regression equation for predicting the blue butterfly population was Y= -2.9113 + 0.0791 maximum temperature + 0.0233 average temp. (R^2= 0.3072).

Table 4.5: Correlation coefficients of major pests population with abiotic factors on pigeonpea during *Kharif*, 2022-23

Pest population / Abiotic factors	Temperature (°C)		Rh (%)		Rainfall (mm)
	Max. Temp.	Min. Temp.	Max. Rh%	Min. Rh%	
M. obtusa	0.161	-0.016	-0.238	-0.209	-0.139
H. armigera	0.175	0.132	-0.358	-0.270	-0.191
M. pustulata	0.532*	0.618*	-0.864**	-0.814**	-0.202
C. gibbosa	0.262	0.244	-0.512*	-0.420	-0.203
L. boeticus	0.256	0.300	-0.578*	-0.512*	-0.122

*Significant and ** Highly significant

Table 4.6: Correlation coefficients of major pests population with abiotic factors on pigeonpea during *Kharif*, 2023-24

Pest population / Abiotic factors	Temperature (°C)		Rh (%)		Rainfall (mm)
	Max. Temp.	. Min. Temp.	Max. Rh%	Min. Rh%	
M. obtusa	0.402	-0.076	-0.252	-0.772**	0.253
H. armigera	0.128	-0.293	-0.271	-0.515*	0.076
M. pustulata	0.772**	0.516*	-0.429	-0.608**	0.222
C. gibbosa	0.450	0.064	-0.230	-0.669**	0.226
L. boeticus	0.694**	0.397	-0.358	-0.657**	0.292

*Significant and ** Highly significant

Table 4.7: Correlations between damage pods and parasitoids of pod fly larvae and pupae collectively with abiotic factors in 2022-23

Pest population / Abiotic factors	Temperature (°C)		Rh (%)		Rainfall (mm)
	Max. Temp.	Min. Temp.	Max. Rh%	Min. Rh%	
Damage Pods	0.550*	0.116	-0.276	-0.360	-0.161
Larvae	0.646*	0.380	-0.472	-0.515	-0.203
Pupae	0.198	-0.370	0.217	0.075	-0.140
E. lividus	0.313	0.018	-0.186	-0.160	-0.049
O. orientalis	0.194	0.021	-0.051	0.003	-0.146

Table 4.8: Correlations between damage pods and parasitoids of pod fly larvae and pupae collectively with abiotic factors in 2023-24

Pest population / Abiotic factors	Temperature (°C)		Rh (%)		Rainfall (mm)
	Max. Temp.	Min. Temp.	Max. Rh%	Min. Rh%	
Damage Pods	0.482	0.027	-0.149	-0.744**	0.246
Larvae	0.746**	0.420	-0.403	-0.776**	0.376
Pupae	-0.091	-0.541*	0.127	-0.513	0.245
E. lividus	0.360	0.035	-0.055	-0.612*	0.303
O. orientalis	0.287	-0.084	-0.219	-0.564*	0.276

4.2. Estimate extent of damage cause by pod fly, *M. obtusa*

During the *Kharif* season of 2022-23, five plants were covered with mosquito nets 45 to 50 days after flowering in pigeon pea, especially during the mid-mature pod stage. Ten pairs of adult pod flies were released in covered 5 plants. Then observation was after a week. The incidence of maggot and pupae was observed on 5 covered plants (P_1, P_2, P_3, P_4 and P_5) at 41^{st} Standard Meteorological Week (SMW) with peaked population of 31 maggots/Pupae per 100 pods on Plant no. 2 (P_2). The initial observation noted infestations of maggots and pupae in Plant1 (27 per 100 pods), Plant2 (31 per 100 pods), Plant3 (24 per 100 pods), Plant4 (26 per 100 pods), Plant5 (25 per 100 pods) and Uncontrol (36 per 100 pods). The highest population of maggot and pupae (31 maggots/larvae per 100 pods) was recorded at 41^{st} as maximum temperature 31.00°C, minimum temperature 20.00°C, maximum Rh% of 56.00% and minimum Rh% of 46.00%, respectively. In second observation, 20 pairs of adult pod flies were introduced into five covered plants without use of pesticides. The second observation, the number of maggots and pupae infestation in Plant1 (51 per 100 pods), Plant2 (49 per 100 pods), Plant3 (57 per 100 pods), Plant4 (52 per 100 pods), Plant5 (48 per 100 pods) and Uncontrol (44 per 100 pods). The highest population of maggot and pupae (57 maggots/larvae per 100 pods) was observation occurred at the 42nd week, with maximum temperature recorded at 29.00°C, minimum temperature at 18.00°C, maximum relative humidity at 53.00% and minimum relative humidity at 43.00%. During the third assessment, released 30 pairs mated pod fly adult in covered five plants without use of pesticides. The infestation of pod fly (maggots and pupae) observed per 100 pods was as follows: 76 for Plant1, 82 for Plant2, 78 for Plant3, 69 for Plant4, 70 for Plant5 and 59 for uncontrol or uncovered plant. The peaked population of maggot and pupae (82 maggots/larvae per 100 pods) was observation during the 43^{rd} week of the study with highest temp. of 34.00°C, lowest temp. of 19.00°C, maximum Rh% of 56.00% and minimum relative humidity of 42.00%. In the fourth observations, 40 pairs of adult pod flies were released into covered five plants (P_1, P_2, P_3, P_4 and P_5) without the use of pesticides. The number of pod fly infestations including both maggots and pupae per 100 pods were recorded as follows: 54 for Plant1, 50 for Plant2, 61 for Plant3, 57 for Plant4, 66 for Plant5 and 41 for uncontrolled plants. The highest population of maggots and pupae, reaching 66/ 100 pods was observed at 44th SMW. This observation with highest temp. of 24.00°C, lowest temp. of 18.00°C, maximum Rh% of 59.00%, minimum relative humidity of 49.00% and Rainfall of 0.20 mm (Table 4.9 and Fig. 4.5).

During the 2023-24 *Kharif* season, five pigeon pea plants were covered mosquito nets placed over them around 45 to 50 days after flowering, particularly when they reached the mid-mature pod stage. In these covered plants, ten pairs of pod flies were released. Subsequently, observation was one week later. During the 39th Standard Meteorological Week (SMW), the maggots and pupae infestation was recorded on five cover plants (P1, P2, P3, P4 and P5). Among them, the highest infestation was observed in plant4 (P4) with 33 maggots/pupae per 100 pods. Initial observations revealed that plant1 (29 per 100 pods), Plant2 (28 per 100 pods), Plant3 (26 per 100 pods), Plant4 (33 per 100 pods), Plant5 (30 per 100 pods) and uncontrolled plant (36 per 100 pods) was infested pods. The maximum population of maggots and pupae (33 maggots/larvae per 100 pods) was recorded at 39th at maximum temperature 32.51°C, minimum temperature 16.32°C, maximum Rh% 92.81% and minimum Rh% 45.53%. In the second time observation, 20 pairs of adult pod flies were released to five covered plants and no pesticides were applied. during the infestation of maggots and pupae was observed in Plant1 (49 per 100 pods), Plant2 (53 per 100 pods), Plant3 (58 per 100 pods), Plant4 (52 per 100 pods), Plant5 (51 per 100 pods) and the uncontrolled (46 per 100 pods). The highest population of maggot and pupae (58 maggots/larvae per 100 pods) was observation occurred at the 40th week with maximum temperature recorded at 28.31°C, minimum temperature at 13.12°C, extreme relative humidity at 92.79.00%, least relative humidity at 51.68% and rainfall 0.80 mm. In the third evaluation, 30 pairs of mated adult pod flies were released into the five covered plants at 41st SMW. The incidence of pod fly infestation (maggots and pupae) per 100 pods was noted as follows: 67 for Plant1, 70 for Plant2, 62 for Plant3, 60 for Plant4, 68 for Plant5 and 50 for the uncontrolled plant. The maximum population of larvae and pupae (70/ 100 pods) was noted between the 41st week of the study, indicating the maximum. temp. of 31.16°C, min. temp. of 12.36°C, maximum Rh% of 92.95% and minimum relative humidity of

35.87%. In the fourth observations, the number of 40 pairs of adult pod flies were released into the five covered plants (P1, P2, P3, P4 and P5) without use pesticides. The number of pod fly infestations, both maggots and pupae per 100 pods were recorded as: 49 for Plant1, 47 for Plant2, 56 for Plant3, 48 for Plant4, 46 for Plant5 and 41 for the uncontrolled plants. In the 44th Standard Meteorological Week (SMW), the peaked population of pod fly maggots and pupae reached 66/ 100 pods. Observations with the highest temp. of 31.32°C, the lowest temp. of 13.30°C, the maximum Rh% of 94.01% and the maximum relative humidity of 45.82% (Table 4.10 and Fig.4.6). These findings partially align with the results of Kumar *et al*. (2015) found that during the *Kharif* seasons of 2013-14 and 2014-15, pod fly infestation was highest in the IPA 7-10 genotype, with 1.50 and 1.41 maggots per plant, respectively, while the KA 12-2 genotype had the lowest infestation, with 0.58 and 0.56 maggots per plant. IPA 7-10 also showed the highest pod and grain damage percentages, whereas KA 12-2 had the lowest damage percentages and achieved the highest grain yields, indicating its resistance to *M. obtusa* infestation. The results align with the findings of Revathi *et al*. (2015) conducted research on twenty medium-duration pigeonpea genotypes to assess their tolerance to pod fly infestation. They found variation in the quantity of larvae (0-4 per pod) and pupae (0-6 per pod) among the genotypes, with the highest numbers recorded being 1.5 larvae per pod and 1.7 pupae per pod. The average grain weight loss due to pod fly infestation was 60.0%, ranging from 47.8% to 86.6% across different pigeonpea genotypes. The result is accordance with the findings of Chakravarty *et al*. (2016[b]) damaged pods against pod fly varied significantly across differ pigeonpea genotype, ranging from 6.97% to 15.42% compared to 13.29% and 11.74% on the checks, Manak and UPAS 120, respectively. According to Priyadarshini *et al*. (2013) considerable loss in grain yield is caused by their presence on fruiting bodies. Pod borers can result in a 60 to 90 percent reduction in pigeonpea yields of grain under favorable condition, although seed damage from *M. obtusa* typically ranges since 14.3 to 46.6 percent.

Table 4.9: Infestation capability of pod fly, *M. obtusa* (Malloch) in pigeonpea 2022-23

SMW	Treatment	Damage pods					Control (385)	Temperature °C		Rh (%)		Rainfall (mm)
		P_1 (379)	P_2 (364)	P3 (398)	P_4 (403)	P_5 (368)		Max.	Min.	Max.	Min.	
41	**10 Pairs**	27	31	24	26	25	36	31.00	20.00	56.00	46.00	0.00
42	**20 Pairs**	51	49	57	52	48	44	29.00	18.00	53.00	43.00	0.00
43	**30 Pairs**	76	82	78	69	70	59	34.00	19.00	56.00	42.00	0.00
44	**40 Pairs**	54	50	61	57	66	41	24.00	18.00	59.00	49.00	0.20
SE		2.78	2.91	3.05	2.54	2.84	1.48	0.77	0.22	0.33	0.47	0.45
SD		20.05	21.21	22.58	18.13	20.53	9.90	4.20	0.96	2.45	3.16	0.10

SMW: Standard Meteorological Week, SE: Standard Error, SD: Standard Deviation, Max.: Maximum, Min.: Minimum, Rh%: Relative humidity and mm: millimeter

Fig. 4.5: Infestation capability of pod fly, *M. obtusa* (Malloch) in pigeonpea 2022-23

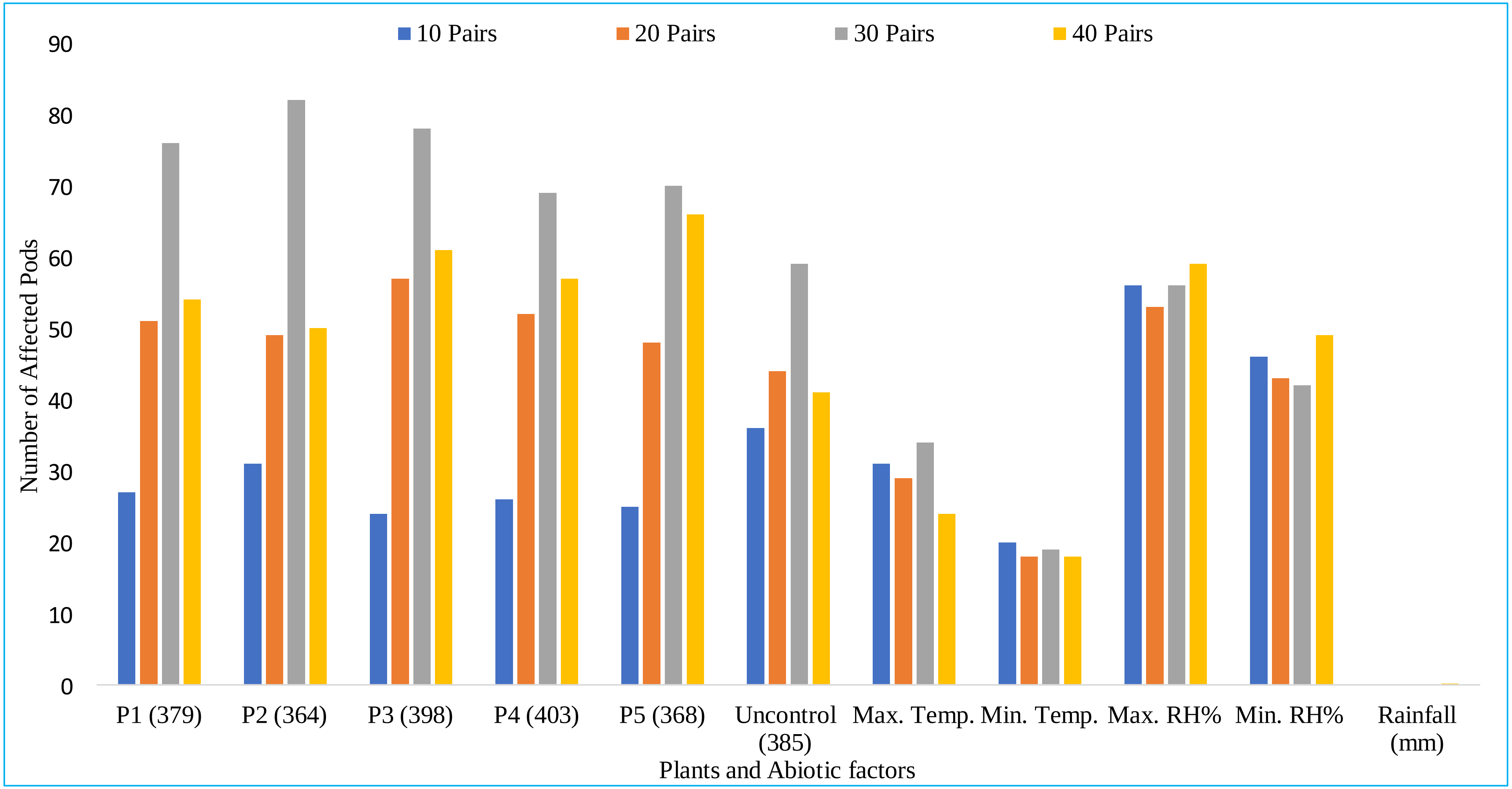
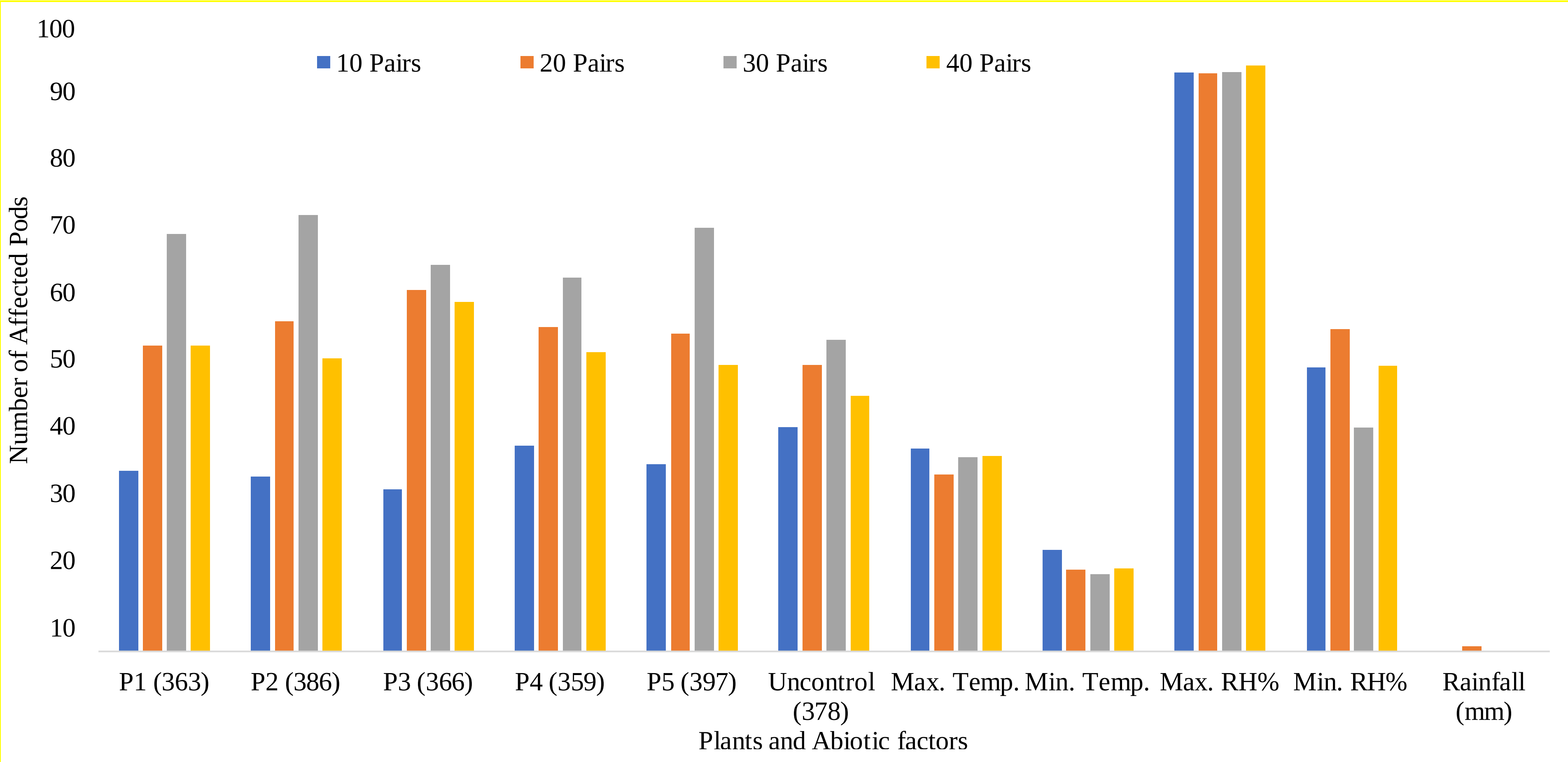


Table 4.10: Infestation capability of pod fly, *M. obtusa* (Malloch) in pigeonpea 2023-24

SMW	Treatment	Damage pods					Uncontrol (378)	Temperature °C		Rh (%)		Rainfall (mm)
		P_1 (363)	P_2 (386)	P3 (366)	P4 (359)	P_5 (397)		Max.	Min.	Max.	Min.	
39	**10 Pairs**	29	28	26	33	30	36	32.51	16.32	92.81	45.53	0.00
40	**20 Pairs**	49	53	58	52	51	46	28.31	13.12	92.79	51.68	0.80
41	**30 Pairs**	67	70	62	60	68	50	31.16	12.36	92.95	35.87	0.00
42	**40 Pairs**	49	47	56	48	46	41	31.32	13.30	94.01	45.82	0.00
SE		2.23	2.46	2.33	1.63	2.24	0.92	0.32	0.47	0.06	0.98	0.89
SD		15.52	17.33	16.52	11.33	15.65	6.08	1.78	1.75	0.58	6.55	0.40

SMW: Standard Meteorological Week, SE: Standard Error, SD: Standard Deviation, Max.: Maximum, Min.: Minimum, Rh%: Relative humidity and mm: millimeter

Fig. 4.6: Infestation capability of *M. obtusa* (Malloch) in pigeonpea 2023-24



4.2.1. Correlation of estimate extent of damage due to pod fly, *M. obtusa* 2022-23

During *Kharif* crop 2022-23, The correlation between maggot population and abiotic factors such as temperature, Rh% and precipitation for 2022 and 2023 was analyzed (Table 4.11). The correlation coefficient max. Temp. and maximum relative humidity was non-significant positive relationship of covered plants P1 (r= 0.237, r= 0.061 & rainfall value r= 0.067), P2 (r= 0.434 & r= 0.019), P3 (r= 0.081, r= 0.072 & rainfall r= 0.177) and P4 (r= 0.044, r= 0.113 & rainfall r= 0.221) and P5 with maximum Rh% & precipitation (r= 0.358 & r= 0.446). Whereas relationship of utmost temperature with P5 (r= -0.133) showed non-significant destructive relationship. Whereas least temperature and smallest relative humidity with non-significant negative relationship in P1 (r= -0.451 & r= -0.457), P2 (r= -0.246, r= -0.562 & rainfall data r= -0.094), P3 (r= -0.601 & r= -0.373), P4 (r= -0.615 & r= -0.331) and P5 (r= -0.623 & r= -0.087).

During 2023-24, the correlation coefficient of minimum temperature with P3 and P4 showed an extremely significant relationship (r= -0.996 and r= -0.975, respectively). The correlation of maximum and minimum temp. and minimum Rh% exhibited a non-significant negative correlation for covered plant P1 (r= -0.333, r= -0.940 and r= -0.575, respectively), P2 (r= -0.425, r= -0.935, max. Rh% data r= -0.007 & r= -0.521), P3 (r= -0.607 minimum Rh% data r= -0.195; P4 (r= -0.517 and min. Rh% data r= -0.407) and P5 (r= -0.385, r= -0.917, max. and min. Rh% data was -0.024 and r= -0.562. While the correlation of maximum Rh% and rainfall (mm) exhibited a positive non-significant affiliation for P1 (r= 0.117 & r= 0.021, separately), P2 (only rainfall r= 0.135), P3 (r= 0.278 and r= 0.303), P4 (r= 0.064 and r= 0.221) and P5 (precipitation r= 0.096).

Table 4.11: Correlation of estimate extent of damage against pod fly with abiotic factors on pigeonpea during *Kharif*, 2022-23

Pest population / Abiotic factors	Temperature °C		Rh (%)		Rainfall (mm)
	Max. Temp.	Min. Temp.	Max. Rh%	Min. Rh%	
P1	0.237	-0.451	0.061	-0.457	0.067
P2	0.434	-0.246	0.019	-0.562	-0.094
P3	0.081	-0.601	0.072	-0.373	0.177
P4	0.044	-0.615	0.113	-0.331	0.221
P5	-0.133	-0.623	0.358	-0.087	0.446
Control	0.577	-0.141	-0.124	-0.692	-0.269

* Significant at 5% level of significance, ** Highly significant and P: Plant

Table 4.12: Correlation of estimate extent of damage against pod fly with abiotic factors on pigeonpea during *Kharif*, 2023-24

Pest population / Abiotic factors	Temperature °C		Rh (%)		Rainfall (mm)
	Max. Temp.	Min. Temp.	Max. Rh%	Min. Rh%	
P1	-0.333	-0.940	0.117	-0.575	0.021
P2	-0.425	-0.935	-0.007	-0.521	0.135
P3	-0.607	-0.996**	0.278	-0.195	0.303
P4	-0.517	-0.975*	0.064	-0.407	0.221
P5	-0.385	-0.917	-0.024	-0.562	0.096
Control	-0.554	-0.903	-0.170	-0.410	0.302

*Significant and ** Highly significant and P: Plant

4.2.2. Extent of yield loss through release pairs of pod fly

According to the present studies 2022-23, after releasing pod fly, *Melanagromyza obtusa* pairs inflicts varying of damage to pigeonpea crops. In the current study, pairs of pod flies were released onto five different covered plant by muslin cloth in each replication: Plant1 (P1), Plant2 (P2), Plant3 (P3), Plant4 (P4) and Plant5 (P5). Observations recorded at weekly intervals to assess extent of damage caused by pod fly. The findings indicated that the percentage of pod damage from 50.62% to 58.24%, the percentage of grain damage ranged from 25.31% to 29.12% and the percentage of weight loss ranged from 67.06% to 75.78% across the five plant species infested with the pod flies. In contrast, an uninfected control plant, which had no pod fly pairs released onto it, exhibited 46.75% pod damage, 23.37% grain damage and 79.26% weight loss.

During the Kharif crop season of 2023-24, a study was conducted to assess the damage caused by the *M. obtusa* on five different covered plant by muslin cloth. 100 pairs of pod flies were intentionally released as per treatment on Plant1 (P1), Plant2 (P2), Plant3 (P3), Plant4 (P4) and Plant5 (P5). Weekly observations were made to evaluate the extent of the damage inflicted by *M. obtusa*. The findings revealed that ratio of pod destruction across infested plants from a low of 5.19% to a high of 49.12%. The proportion of grain damage varied between 24.56% and 27.60%, while the percentage of weight loss ranged from 70.90% to 77.19% among the five plant species exposed to the pod fly infestation. In contrast, an uninfected control plant, which was covered to prevent any pod fly pairs from entering, exhibited 45.77% pod damage, 23.37% grain damage and 79.26% weight loss.

Table 4.13: Extent of yield loss through release pair of Pod fly 2022-23

Parameters	P1	P2	P3	P4	P5	Control
Total damage pods	208	212	220	204	213	180
Total number of seeds	1516	1456	1592	1612	1472	1540
Total number of damage seeds (Weight)	416 (18.80gm)	424 (19.16gm)	440 (19.88gm)	408 (18.44gm)	426 (19.25gm)	360 (16.27gm)
Fresh pods	171	152	178	199	155	205
Total healthy seeds (Weight)	684 (65.43gm)	608 (58.16gm)	712 (68.10gm)	796 (76.14gm)	620 (59.31gm	820 (78.44gm)
Percentage of pod damage	54.88%	58.24%	55.27%	50.62%	57.88%	46.75%
Percentage of grain damage	27.44%	29.12%	27.64%	25.31%	28.94%	23.37%
percent of weight loss	71.26%	67.06%	70.81%	75.78%	67.54%	79.26%

P: Plant, gm: gram

Table 4.14: Extent of yield loss through release pair of Pod fly 2023-24

Parameters	P1	P2	P3	P4	P5	Control
Total damage pods	194	198	202	193	195	173
Total number of seeds	1452	1544	1464	1436	1588	1512
Total number of damages seeds (Weight)	388 (17.54gm)	396 (17.90gm)	404 (18.26gm)	386 (17.45gm)	390 (17.63gm)	346 (15.64gm)
Fresh pods	169	188	164	166	202	205
Total healthy seeds (Weight)	676 (64.67gm)	752 (71.94gm)	656 (62.75gm)	664 (63.52gm)	808 (77.30gm	820 (78.44gm)
Percentage of pod damage	53.44%	51.29%	55.19%	53.76%	49.12%	45.77%
Percentage of grain damage	26.72%	25.65%	27.60%	26.88%	24.56%	22.88%
percent of weight loss	72.88%	75.12%	70.90%	72.53%	77.19%	80.06%

P: Plant, gm: gram

4.1. Effect of early and late sowing on the intensity of *M. obtusa*

In the Kharif season crop2022-23, research on the effect of the different sowing date on insect pest prevalence and the resulting damage from pod fly has demonstrated significant findings. The occurrence of pod fly was 0.47 % on first date of sowing (1st DOS) at 42nd SMW. The peaked incidence of pod fly was recorded at 51st SMW against 1st DOS 44.93%, 2nd DOS 45.13 and 3rd DOS 45.33% increasing then from 4th DOS 46.87%, on 5th DOS 42.20% reduction in incidence of pod fly recorded suddenly incidence get increase 48.20% and 51.80% in 6th and 7th DOS respectively with having max. and min. temperature 24.00℃ and 9.00℃ with maximum and minimum relative humidity (Rh%) 90.00 and 79.00% respectively. The pigeonpea crop yield was diminished under late sowing conditions. The data revealed that early sowing (1st DOS) resulted in a significantly higher yield of 15.70 q/ha, while the latest sowing (7th DOS) produced the minimal yield of 10.14 q/ha.

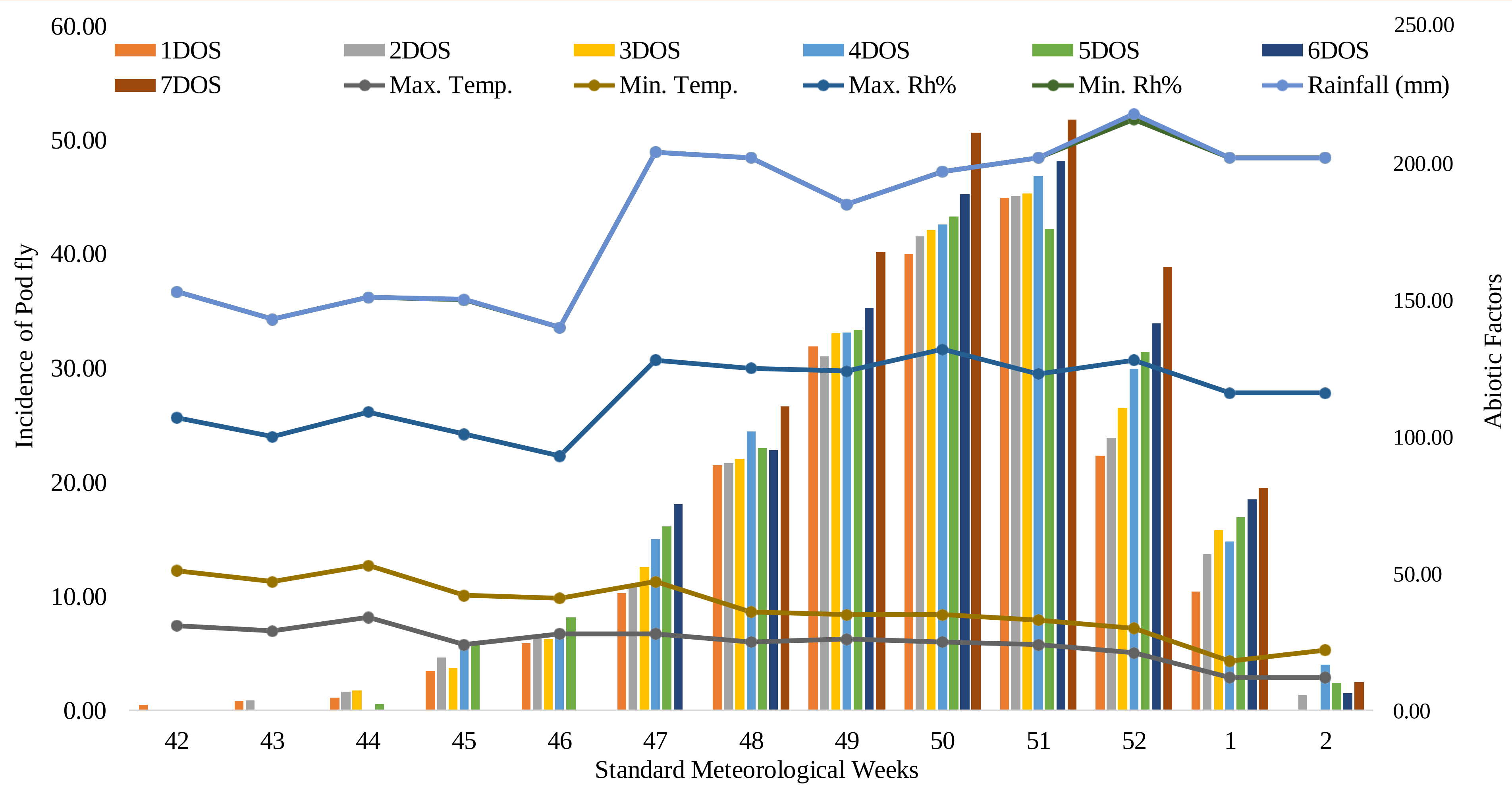
In the 2023-24 period, the occurrence of pod fly was recorded at 0.20% on the first sowing date (1st DOS) at the 41st SW. The maximum occurrence of pod fly was detected during the 51st SMW, with infestation reaching 41.80% for the first sowing date (1st DOS), 41.93% for the second sowing date (2nd DOS) and 45.67% for the third sowing date (3rd DOS). Subsequently, there was a gradual increase in incidence, reaching 46.73% on the fourth sowing date (4th DOS), 47.27% on the fifth sowing date (5th DOS) and 46.80% on the sixth sowing date (6th DOS). A suddenly increased of pod fly incidence was observed on the seventh sowing date (7th DOS) at 52.33%. At this time, the max. and min. temperature registered were 21.11℃ and 6.66℃ respectively, with corresponding maximum and minimum relative humidity levels of 97.00% and 57.00% respectively. The late sowing conditions also resulted in a reduced in the yield of the pigeonpea crop. The observation showed that the pigeonpea crop sown on the 1st DOS (early sowing) achieved a noted utmost yield of 14.29 q/ha related to last date of sowing (7th DOS). Conversely, the pigeonpea crop sown on the 7th DOS exhibited the lowest yield of 10.07 q/ha among the late-sown crops. The present studies are accordance with the findings of Keval *et al.* (2017[b]) observed significant differences in the resistance of various cultivars to major insect pests over a prolonged period. The

KA-12-2 cultivar experienced the highest grain damage due to insects, whereas the BAHAR cultivar had the least grain damage. Grain yields also varied significantly among the genotypes/varieties, ranging from 658 kg/ha in KA-12-2 to 1200 kg/ha in BAHAR. Dialoke *et al*. (2014) found that damaged seeds caused by the pod fly varied between years. Over two years, ICPL 87 had the highest seed damage, followed by ICPL 84023 and ICPL 151. Planting timing significantly influenced seed damage, with the highest damage occurring in April and decreasing as planting was delayed until August. The current results align with those findings of Hadiya *et al*. (2020) found variations in grain damage caused by pod fly across different sowing periods (24^{th}, 26^{th}, 28^{th}, 31^{st} and 33^{rd} SMW) and pigeonpea varieties over multiple years. In the 2014-15 season, the lowest damage occurred when sown on the 24^{th} SMW, with the Vaishali variety experiencing the least damage. However, in 2015-16, neither sowing periods nor varieties significantly affected grain damage. Significant variations were observed in the 2016-17 season, with the 24^{th} SMW and Vaishali variety showing the lowest damage. Similar trends were seen in 2017-18, with the 24^{th} SMW and Vaishali variety exhibiting the lowest damage. Overall, consistent with previous studies, the lowest damage occurred with the 24^{th} SMW sowing period and Vaishali variety. The current finding according to Srinivas *et al*. (2019) the seasonal incidence of *M. obtusa* on pigeonpea in both biological and conformist farming systems was observed at 14^{th} Weeks After Sowing (WAS) (44^{th} Standard Meteorology Week) and continued until 31 WAS (8^{th} SMW). The population peaked at 27 WAS (4^{th} SMW) with 36.00 and 30.96 larvae per 50 pods in the respective farming systems. The population then declined, reaching its lowest levels of 0.94 and 0.70 maggots per 50 pods at 31 WAS (8^{th} SMW). Damage of seeds caused by *M. obtusa* began at 15 WAS (44^{th} SW) & continuous until 31 WAS (8^{th} SW) with the maximum damaged of seeds of 78.50% and 77.18% occurring at 31 WAS (8^{th} SMW) and the lowest damage of 7.02% and 5.21% at 15 WAS (44^{th} SMW).

Table 4.15: Effect of different sowing dates on the incidence of pod fly of pigeonpea during 2022-23

Weekly Observation /Date of sowing	13-Jun-22	20-Jun-22	27-Jun-22	03-Jul-22	10- Jul-22	17- Jul-22	24- Jul-22	Temperature °C)		Rh (%)		Rainfall (mm)
								Max.	Min.	Max.	Min.	
42	0.47 (1.18)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	31.00	20.00	56.00	46.00	0.00
43	0.80 (1.39)	0.87 (1.43)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	29.00	18.00	53.00	43.00	0.00
44	1.07 (1.53)	1.60 (1.76)	1.73 (1.81)	0.07 (0.76)	0.53 (1.23)	0.00 (0.5)	0.00 (0.5)	34.00	19.00	56.00	42.00	0.00
45	3.47 (2.36)	4.60 (2.64)	3.73 (2.43)	5.60 (2.87)	6.00 (2.94)	0.00 (0.5)	0.00 (0.5)	24.00	18.00	59.00	49.00	0.20
46	5.87 (2.92)	6.60 (3.07)	6.20 (2.99)	6.67 (3.08)	8.13 (3.35)	0.00 (0.5)	0.00 (0.5)	28.00	13.00	52.00	47.00	0.00
47	10.27 (3.70)	11.07 (3.83)	12.53 (4.04)	15.00 (4.37)	16.13 (4.52)	18.07 (4.75)	0.00 (0.5)	28.00	19.00	81.00	76.00	0.00
48	21.47 (5.47)	21.67 (5.15)	22.07 (5.19)	24.47 (5.45)	23.00 (5.29)	22.80 (5.27)	26.67 (5.66)	25.00	11.00	89.00	77.00	0.00
49	31.93 (6.15)	31.03 (6.07)	33.07 (6.25)	33.13 (6.25)	33.40 (6.28)	35.27 (6.44)	40.20 (6.84)	26.00	9.00	89.00	61.00	0.00
50	40.00 (6.82)	41.53 (6.94)	42.13 (6.99)	42.60 (7.03)	43.27 (7.07)	45.27 (7.22)	50.67 (7.62)	25.00	10.00	97.00	65.00	0.00
51	44.93 (7.20)	45.13 (7.21)	45.33 (7.23)	46.87 (7.35)	42.20 (6.99)	48.20 (7.44)	51.80 (7.69)	24.00	9.00	90.00	79.00	0.00
52	22.33 (5.22)	23.87 (5.38)	26.53 (5.65)	29.93 (5.97)	31.43 (6.11)	33.93 (6.32)	38.87 (6.73)	21.00	9.00	98.00	88.00	2.00
1	10.40 (3.72)	13.67 (4.19)	15.80 (4.47)	14.80 (4.35)	16.93 (4.61)	18.47 (4.79)	19.53 (4.92)	12.00	6.00	98.00	86.00	0.00
2	0.00 (0.5)	1.33 (1.65)	0.00 (0.5)	4.00 (2.5)	2.40 (2.05)	1.47 (1.71)	2.47 (2.07)	12.00	10.00	94.00	86.00	0.00
SE	4.10	3.98	4.08	4.01	3.88	4.47	5.04	1.31	1.36	2.18	2.22	1.34
SD	15.80	15.74	16.36	16.61	16.08	18.52	21.21	6.49	4.91	19.24	17.89	0.55

Fig. 4.7: Effect of different sowing dates on the incidence of pod fly of pigeonpea during 2022-23

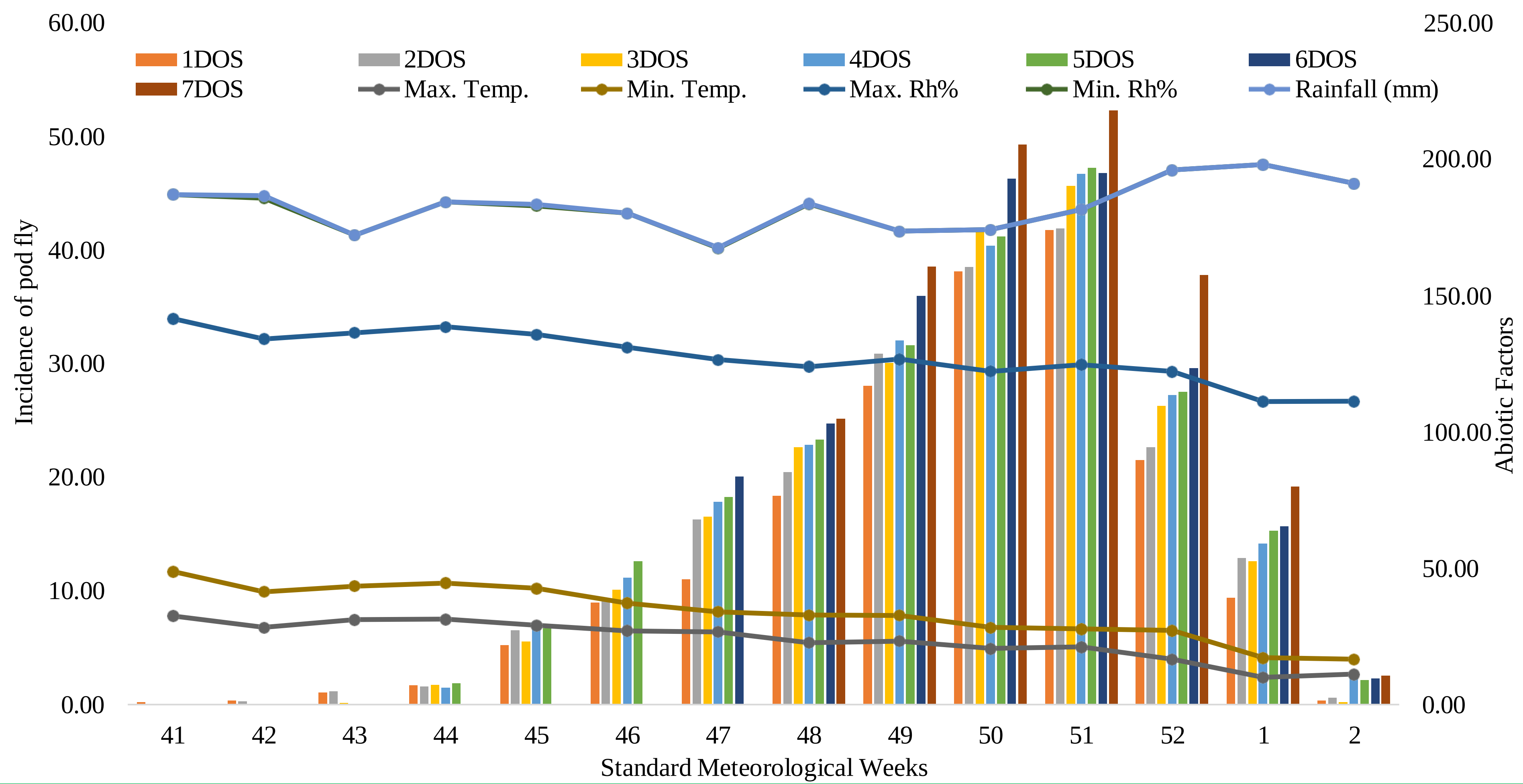


* DOS = Date of Sowing, Temp.= Temperature, Rh%= Relative humidity, Max.= Maximum and Min.= Minimum

Table 4.16: Effect of different sowing dates on the incidence of pod fly of pigeonpea during 2023-24

Weekly Observation /Date of sowing	13-Jun-23	20-Jun-23	27-Jun-23	03-Jul-23	10-Jul-23	17-Jul-23	24-Jul-23	Temperature °C)		Rh (%)		Rainfall (mm)
								Max.	Min.	Max.	Min.	
41	0.20 (0.95)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	32.51	16.32	92.81	45.53	0.00
42	0.33 (1.07)	0.27 (1.02)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	28.31	13.12	92.79	51.68	0.80
43	1.07 (1.53)	1.13 (1.56)	0.13 (0.86)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	0.00 (0.5)	31.16	12.36	92.95	35.87	0.00
44	1.67 (1.79)	1.60 (1.76)	1.73 (1.81)	1.47 (1.71)	1.87 (1.87)	0.00 (0.5)	0.00 (0.5)	31.32	13.30	94.01	45.82	0.00
45	5.20 (2.78)	6.53 (3.05)	5.53 (2.85)	6.67 (3.08)	6.73 (3.09)	0.00 (0.5)	0.00 (0.5)	29.05	13.57	93.23	47.22	0.60
46	9.00 (3.50)	9.33 (3.55)	10.13 (3.68)	11.13 (3.84)	12.60 (4.05)	0.00 (0.5)	0.00 (0.5)	27.06	10.20	93.84	49.26	0.00
47	11.00 (3.82)	16.33 (4.54)	16.53 (4.56)	17.87 (3.95)	18.27 (4.77)	20.07 (4.98)	0.00 (0.5)	26.70	7.38	92.48	40.96	0.20
48	18.40 (4.79)	20.47 (5.02)	22.67 (5.26)	22.87 (5.28)	23.33 (5.33)	24.73 (5.47)	25.17 (5.52)	22.70	10.10	91.20	59.70	0.20
49	28.07 (5.79)	30.87 (6.06)	30.07 (5.98)	32.07 (6.16)	31.67 (6.13)	36.00 (6.50)	38.60 (6.71)	23.33	9.44	94.00	47.00	0.00
50	38.13 (6.67)	38.53 (6.71)	41.60 (6.95)	40.40 (6.86)	41.20 (6.92)	46.33 (7.31)	49.33 (7.52)	20.55	7.77	94.00	52.00	0.00
51	41.80 (6.96)	41.93 (6.97)	45.67 (7.26)	46.73 (7.33)	47.27 (7.37)	46.80 (7.34)	52.33 (7.73)	21.11	6.66	97.00	57.00	0.00
52	21.53 (5.14)	22.67 (5.26)	26.33 (5.63)	27.27 (5.72)	27.53 (5.75)	29.60 (5.94)	37.80 (6.65)	16.66	10.55	95.00	74.00	0.00
1	9.40 (3.56)	12.93 (4.09)	12.60 (4.05)	14.20 (4.27)	15.33 (4.41)	15.67 (4.46)	19.20 (4.88)	10.00	7.22	94.00	87.00	0.00
2	0.33 (1.07)	0.60 (1.27)	0.20 (0.95)	2.40 (2.05)	2.13 (1.96)	2.27 (2.00)	2.53 (2.09)	11.11	5.55	94.60	80.00	0.00
SE	3.91	3.82	4.05	3.96	3.95	4.56	5.12	1.48	0.98	0.14	2.03	0.71
SD	14.25	14.54	15.81	15.82	15.95	18.12	20.54	7.21	3.15	1.36	15.06	0.26

Fig. 4.8: Effect of different sowing dates on the incidence of pod fly of pigeonpea during 2023-24



* DOS = Date of Sowing, Temp.= Temperature, Rh%= Relative humidity, Max.= Maximum and Min.= Minimum

4.3.1. Correlation of different dates of sowing on the incidence of pod fly on pigeonpea crop

In the *Kharif* season of 2022-23, the relationship coefficient amongst the occurrence of Pod fly and various abiotic factors was comparable to both positive and negative. At the first and second dates of sowing (1DOS and 2DOS), larval population showed important positive relationship by max. Rh% (r= 0.639* & r= 0.669*) & meaningful negative relationship with lowest temp. (r= -0.611* & r= -0.642*). There were non-significant positive associations with bare lowest possible Rh% (r= 0.410 & r= 0.445) and precipitation (r= 0.121 & r= 0.137). For 3rd to 7th Dates of Sowing (3DOS, 4DOS, 5DOS, 6DOS and 7DOS), pod fly incidence had a significant positive relationship with max. relative humidity (r= 0.688**, r= 0.720**, r= 0.728**, r= 0.757** & r= 0.728**) and significant negative correlations with min. temperature (r= -0.652*, r= - 0.662*, r= -0.651* and r=-0.726**). In contrast, 3DOS, 4DOS, 5DOS and 7DOS showed positive non-significant relationship by the lowest Rh% (r= 0.466, r= 0.520, r= 0.517) and rainfall (mm) (r= 0.170, r= 0.211, r= 0.46, r= 0.276). However, 6DOS showed a significant positive relationship with min. relative humidity (r= 0.555*) and a non- significant positive connection with rainfall (r= 0.245mm). Non-significant negative relationships were observed between extreme temperature and all DOS (1st DOS, 2nd DOS, 3rd DOS, 4th DOS, 5th DOS, 6th DOS and 7th DOS) with values of r= -0.071, r= - 0.118, r= -0.125, r= -0.166, r= -0.169, r= -0.174 and r= -0.210, respectively.

During the *Kharif* season of 2023-24, the incidence of pod fly showed a significant negative connection with lowest temperature in the 2nd, 3rd, 4th, 5th and 6th Date of Sowing (DOS) (r= -0.550*, r= -0.541*, r= -0.570*, r= -0.574* & r= -0.570*), while showing a non-significant negative correlation in the 1st and 7th DOS (r= -0.513 and r= -0.481). Additionally, there was a positive no significant correlation between both maximum and minimum humidity (Rh%) across all DOS: maximum relative humidity (r= 0 .502, r= 0.460, r= 0.470, r= 0.487, r= 0.487, r= 0.427 and r= 0.529) and minimum relative humidity (r= 0.080, r= 0.092, r= 0.111, r= 0.138, r= 0.143, r= 0.162 and r= 0.277). Furthermore, a non-important negative correlation was recorded with highest temperature (r= -0.317, r= -0.342, r= -0.346, r= -0.377, r= -0.379, r= -0.408 and r= -0.461) and rainfall (r= -0.310, r= -0.303, r= -0.309, r= -0.315, r= -0.320, r= -0.324 and r= -0.350 mm) across all DOS.

Table 4.17: Correlation of different dates of sowing on the incidence of pod fly on pigeonpea crop 2022-23

Date of Sowing / Abiotic factors	Temperature °C)		Rh (%)		Rainfall (mm)
	Max. Temp.	Min. Temp.	Max. Rh%	Min. Rh%	
1DOS	-0.071	-0.611*	0.639*	0.410	0.121
2DOS	-0.118	-0.642*	0.669*	0.445	0.137
3DOS	-0.125	-0.652*	0.688**	0.466	0.170
4DOS	-0.166	-0.662*	0.720**	0.520	0.211
5DOS	-0.169	-0.669*	0.728**	0.517	0.246
6DOS	-0.174	-0.651*	0.757**	0.555*	0.245
7DOS	-0.210	-0.726**	0.728**	0.492	0.276

Table 4.18: Correlation of different dates of sowing on the incidence of pod fly on pigeonpea crop 2023-24

Date of Sowing / Abiotic factors	Temperature °C)		Rh (%)		Rainfall (mm)
	Max. Temp.	Min. Temp.	Max. Rh%	Min. Rh%	
1DOS	-0.317	-0.513	0.502	0.080	-0.310
2DOS	-0.342	-0.550*	0.460	0.092	-0.303
3DOS	-0.346	-0.541*	0.470	0.111	-0.309
4DOS	-0.377	-0.570*	0.487	0.138	-0.315
5DOS	-0.379	-0.574*	0.487	0.143	-0.320
6DOS	-0.408	-0.570*	0.427	0.162	-0.324
7DOS	-0.461	-0.481	0.529	0.277	-0.350

***** Significant at 5% level of significance and ** Highly significant

4.3.2. Effect of dates of sowing yield loss against incidence of pod fly

The current research concludes that the pod fly plays a significant role in reducing pigeonpea yield. The yield of the crop decreased under late sowing conditions. The data showed that early sowing on June 13th, 2022 (1st DOS) resulted in a significantly higher yield of 15.70 q/ha compared to the yields from late sowing dates. The crop sown on July 24th, 2022 (7th DOS) produced 10.14 q/ha, with the lowest yield. While the data of pooled mean highest yield (14.99 q/ha) and lowest yield in pooled yield (10.10q/ha) during 2022-23. In results, the yield of pigeonpea was significantly reduced due to the late sowing time. The current findings were confirmed by research, which similarly highlighted those sowing dates significantly. The highest yield of pigeonpea was documented when planted early, while the minimal yield was examined in crops sown late. The highest infestation of *M. obtusa* was noted on crops sown late (24th July) in comparison to those sown early. The data from the study indicated that among the seven treatments, which included sowing dates of June 13th, June 20th, June 27th, July 3rd, July 10th, July 17th and July 24th, 2022. The initial pigeonpea crop was weakened from insect pest as compared to the crop sown on alternative dates of sowing. The crop's yield was also observed to be correlated with various sowing dates. The crop sown early yielded more compared to the other seven treatments.

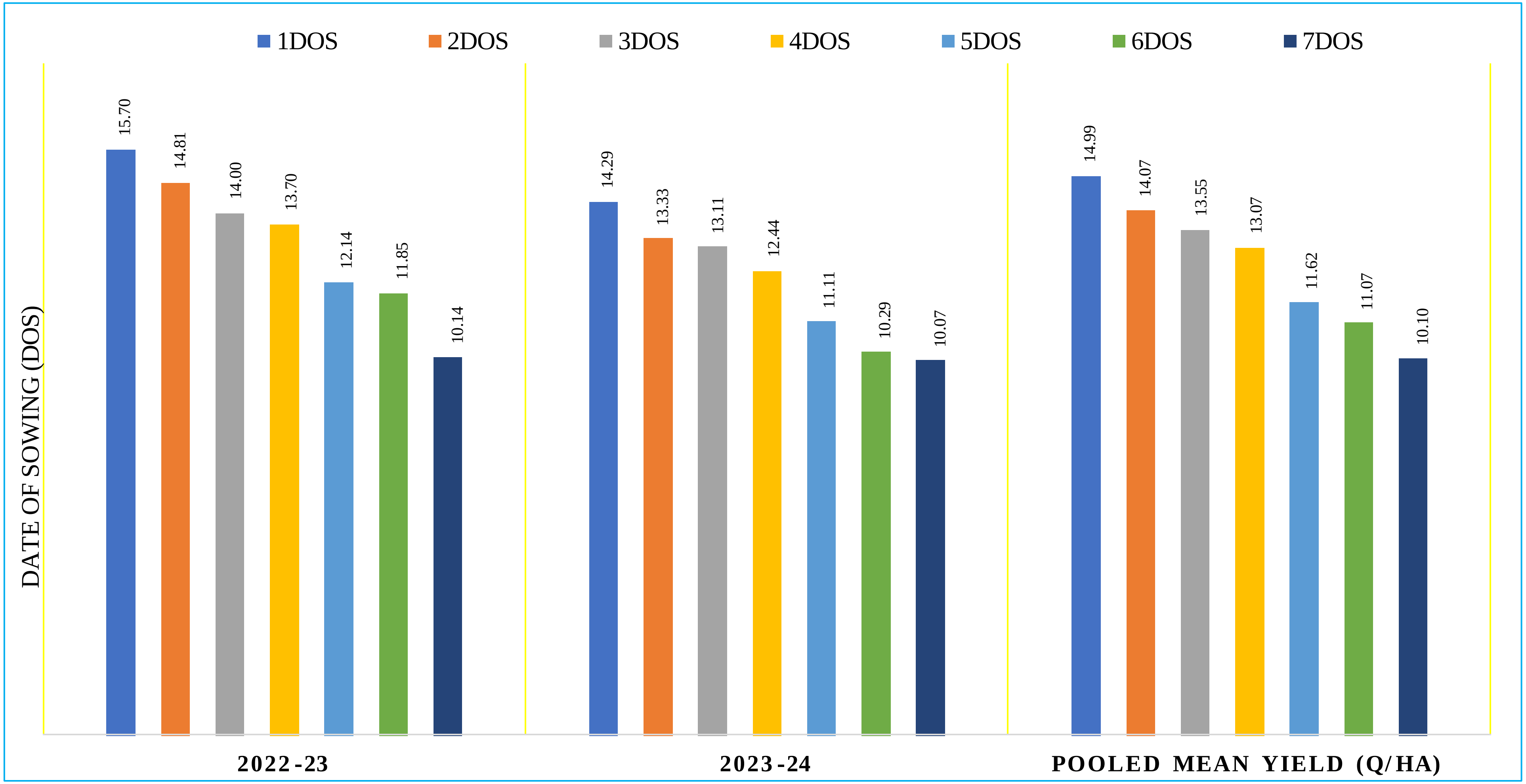
During the 2023-24 season, crop yields decreased with late sowing. Early sowing on June 13th, 2023 (1st DOS) resulted in a significantly higher yield of 14.29 q/ha evaluated to later sowing dates. The lowermost possible yield was observed in the crop sown on July 24th, 2022 (7th DOS), producing 10.07 q/ha. The pooled mean highest yield was 14.99 q/ha, while the lowest yield in pooled yield was 10.10 q/ha during 2022-23. Pigeonpea exhibited its highest yield when sown early. Whereas the lowest yield was observed in crops sown later due to a higher incidence of pod fly infestation during late sowing, resulting in significantly reduced yields.

Table 4.19: Effect of sowing dates of yield loss against incidence of pod fly 2022-23 and 2023-24

Date of Sowing	2022-23	2023-24	Pooled Mean Yield (q/ha)
1DOS	15.70	14.29	14.99
2DOS	14.81	13.33	14.07
3DOS	14.00	13.11	13.55
4DOS	13.70	12.44	13.07
5DOS	12.14	11.11	11.62
6DOS	11.85	10.29	11.07
7DOS	10.14	10.07	10.10

DOS= Date of Sowing, q= quintal and ha=hectare

Fig. 4.9: Effect of sowing dates of yield loss against incidence of pod fly 2022-23 and 2023-24



4.4. Ecofriendly management practices by using biorational pesticides against pod fly in pigeonpea

The information regarding the impact of different treatments on pod damage has been detailed in (Tables 4.20 and 4.21). The data clearly indicates that pod damage was consistent across treatments prior to their application and significantly exceeded the economic threshold level of 5% pod damage.

In the *Kharif* season of 2022-23, each treatment was significantly more effective than the control, as observed by the percentage of pod damage per plot at 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS after the initial spraying. A few days before the initial sprayer, the population of *M. obtusa* was evenly distributed across entirely treatments, showing no significant differences. The treatment with Dimethoate 30% EC @ 5ml/Lit. The recommended amount per hectare showed the highest reduction in the pigeonpea pod fly population. At 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after the first spray application the population counts were 46.67, 37.33, 31.67, 23.00 and 24.33 *M. obtusa* per 100 pods and Neem Seed Kernel Extract (NSKE) @ 5% concentration. The population counts after applying NSKE were 42.00, 38.00, 32.00, 24.33 and 27.67 pod flies per 100 pods at 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after the first spray, indicate that were more effective in overpowering the populace of the pigeonpea pod fly. The application of Eucalyptus leaf extract @ 2 ml/ Lit. per ha (with pod fly counts of 47.67, 41.33, 35.67, 27.33 and 32.67 per 100 pods), Datura leaf extract @ 2 ml/ Lit. per ha (with pod fly counts of 50.33, 44.67, 39.33, 31.67 and 35.33 per 100 pods), *HaNPV* @ $3x10^{12}$ POB per ha (with pod fly counts of 50.00, 46.00, 42.00, 34.67 and 38.67 per 100 pods) and *Bt.* 5% WP @ 5 gm/ Lit. (with pod fly counts of 54.67, 49.33, 43.67, 38.33 and 40.33 per 100 pods) showcase moderate reduction in the *M. obtusa* population. These treatments demonstrated similar effectiveness in suppressing the pod flies. While treatment was highly effective in conquering the populace of the pest, pod fly, it still proved to be superior to the controller. The greatest populace of pod fly was monitored without treatment control i.e. 59.33, 61.33, 63.00, 65.33 and 70.33 pod flies per 100 pods on 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after first spray indicating that biorational was necessary to prevent the pest, *M. obtusa* population. According to the previous spray description the changes have been noticed the population of *M. obtusa* one day prior to 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS after days 2nd spray. The populace of pod fly showed non-significant difference all treatments at one day before the 2nd spray, representing an evenly distributed presence of the pest. The application of Dimethoate 30% @ of 2ml/Lit. a.i. per ha was determined to among the most active in dropping the pod fly populace (maggots and pupae). This treatment resulted in counts of 27.67, 23.33, 17.67, 10.33 and 7.67 pod flies per 100 pods on days 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS after the second spray followed by NSKE @ 5ml/Lit. i.e. 30.67, 22.00, 15.00, 12.33 and 9.33 pod flies per 100 pods on 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after the second spray. These findings indicate that these molecules were particularly effective in reducing the populace of pod fly. The application of *Eucalyptus* leaf extract @ 2 ml/ Lit. per ha (with pod fly counts of 34.33, 30.33, 23.67, 14.00 and 10.33 per 100 pods), *Datura* leaf extract @ 2 ml/ Lit. per ha (38.67, 34.67, 26.67, 19.67 and 14.33 pod flies per 100 pods), *HaNPV* @ $3x10^{12}$ POB per ha (with pod fly counts of 40.33, 37.00, 29.67, 21.67 and 17.67 per 100 pods). The treatment *Bt*. 5% WP @ 5 gm/ Lit. The treatment was not successful in controlling the population of the pest, as *M. obtusa*, it still showed significant superiority over the control. The highest number of pod fly was noted in the untouched control i.e. 69.33, 70.67, 71.67, 66.33 and 61.67 pod flies per 100 pods on 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after second spray. This suggests that the use of biorational methods is essential for controlling the population of *M. obtusa*.

In the *Kharif* season of 2023-24, every treatment showed significant superior over the control when observation. The amount of pod damage per plot at One, Three, Five, Seven and Fourteen days after the initial spraying. One day before the initial spraying, the population of was spread out *M. obtusa* showed non-significant differences across all treatments, indicating an equal spread of the pest. The recommended dosage of Dimethoate 30% EC @ 5ml/Lit. It was discovered that *Melanagromyza obtusa*, the pigeonpea pod fly, was the most effective method for eliminating the population of *M. obtusa*. The number of pod flies (larvae and pupae) per 100 pods was recorded at different intervals after the first spray application: 41.33

After spraying (DAS), 33.33 at 3 DAS, 28.33 at 5 DAS, 20.33 at 7 DAS & 23.33 at 14 DAS, at 1 day after spraying (DAS). Neem seed kernel extract (NSKE) @ 5% concentration was the most effective solution after Dimethoate 30% EC. The population counts after applying NSKE were 41.67, 34.33, 30.33, 22.67 and 25.33 pod flies per 100 pods at 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after the first spray, indicate that were more effective in suppressing the populace of the pigeonpea pod fly. The application of Eucalyptus leaf extract @ 2 ml/ Lit. per ha (with pod fly counts of 43.33, 38.67, 35.67, 28.00 and 33.67 per 100 pods), *Datura* leaf extract @ 2 ml/ Lit. per ha (with pod fly counts of 46.00, 42.33, 36.33, 32.67 and 36.33 per 100 pods), *HaNPV* @ $3x10^{12}$ POB per ha (with pod fly counts of 51.33, 48.33, 44.00, 38.33 and 41.33 per 100 pods) and *Bt*. 5% WP @ 5 gm/ Lit. (with pod fly counts of 52.33, 49.67, 45.33, 39.67 and 43.67 per 100 pods) that these molecules were more effective in reduce of pod fly population. These treatments showed comparable effectiveness in controlling the pod flies. Although the treatment was less effective in reducing the populace of the pest, pod fly, it still demonstrated significant superiority over the control group. The highest populace of pod fly was noted in uncontrol i.e. 63.00, 70.33, 71.00, 72.00 and 71.33 pod flies per 100 pods on 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after the initial spray, the need to apply biorational solutions to suppress the populace of the pod fly. According to the previous spray the populace of pod fly (larvae & pupae) was noted one day before and then at 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after the second spray to observe any changes. The total population of *M. obtusa* showed non-significant differences observed among all treatment one day before the second spray, suggesting an evenly distributed presence of the pest. Dimethoate 30% applied at a rate of 2ml per liter of water per hectare was the was the maximum effective in eliminating the populace of *M. obtusa* larvae and pupae. This treatment resulted in counts of 32.00, 27.67, 18.33, 10.67 and 7.67 pod flies per 100 pods on days 1DAS, 3DAS, 5DAS, 7DAS and 14DAS after the second spray followed by NSKE @ 5ml/Lit. i.e. 30.67, 30.67, 23.67, 12.67 and 11.33 pod flies /100 pods on 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after the second spray. The results find out, these molecules were particularly highly efficient in destroying the population of pod fly. The application of Eucalyptus leaf extract @ 2 ml/Lit per hectare (resulting in pod fly counts of 39.33, 33.33, 29.33, 20.33 and 17.67 per 100 pods), Datura leaf extract @ 2 ml/Lit. per hectare (with counts of 41.33, 36.00, 33.33, 24.00 and 21.67 pod flies per 100 pods) and *HaNPV* @ 3x10^12 POB per hectare (with counts of 43.33, 40.33, 38.67, 34.67 and 29.00 per 100 pods) showed varying levels of effectiveness. The treatment with *Bt*. 5% WP @ 5 g/Lit. The pest population of *M. obtusa* was reduced by 47.00, 44.67, 41.00, 33.67 and 30.00 per 100 pods. *M. obtusa* but still significantly better than the control. The greatest inhabitants of *M. obtusa* was recorded in the untreated control group with counts of 72.33, 70.00, 69.33, 63.67 and 62.33 pod flies per 100 pods on 1 DAS, 3 DAS, 5 DAS, 7 DAS and 14 DAS days after the second spray. These findings indicate the necessity of using biorational methods to control the population of *M. obtusa*. The current research aligns with the conclusions of Bantewad *et al*. (2018) found that Chlorantraniliprole, Flubendiamide and Dimethoate exhibited the lowest pod fly population counts at 3rd, 7th and 14th days after spraying. This result was statistically similar to using Chlorantraniliprole followed by Indoxacarb and Acetamiprid in succession, as they effectively reduced the pod fly population, minimized pod damage and resulted in higher grain yields. Chiranjeevi and Patange (2018[d]) conducted a study that demonstrated that Chlorantraniliprole 18.5 SC @ 30 g a.i. per hectare was the most effective method for controlling the maggot, pupal and overall populations of *Melanagromyza obtusa*. Neem oil @ 3% also performed well, coming in second. In contrast, eucalyptus oil at 5% was the least effective in suppressing *M. obtusa*. The other treatments had moderate success in reducing the pest population, while the untreated control plots saw the highest levels of maggot, pupal and total *M. obtusa* populations. The current research aligns with the conclusions of Sharma *et al*. (2011) conducted a two-year experiment and demonstrated that combining resulted in lower pod fly grain damage (13.30% and 11.95%, respectively) and higher grain yields (1399 kg/ha and 1392 kg/ha, respectively). Similarly, among the treatments involving crude NSKE 5%, Neem oil and Pongamia oil, the application of crude NSKE 5% was found to be superior in increasing yield by 31.28% compared to the others. These results partially correspond with findings of Sreekanth *et al*. (2020) found that among a range of insecticides, Thiacloprid 21.7 SC emerged as the most efficient in reducing pod fly damage, leading to increased grain yields and achieving the highest incremental cost-benefit ratio (ICBR). Diafenthiuron 50 WP, Flubendiamide 480 SC and Dimethoate 30% EC closely followed in effectiveness against pod fly damage and economic advantages. The current results accordance to Kumar *et al.* (2016) Neem seed kernel extract @ 5% (23.29%) was the second most effective treatment, followed by chilli + garlic + kerosene @1% (27.06%). Both treatments were highest significantly to the untreated cack, which recorded the highest seed damage (43.13%). According to Chiranjeevi and Sarnaik (2017[b]) that the neem oil at 3% was more effective in suppressing *M. obtusa* populations, with pod fly counts of 50.67, 33.33, 22.67, 18.00 and 24.00; and 43.67, 44.67, 22.00, 17.67 and 31.33 per 100 pods. In contrast, Eucalyptus oil @ 5% was less effective with pod fly counts of 60.67, 63.67, 54.33, 55.00 & 71.67 & 54.67, 58.33, 54.33, 53.00 & 66.00/ 100 pods on days one, three, seven, ten and fourteen after the first and second spray.

Table 4.20: Efficacy of biorational pesticides against pod fly during 2022-23

Treatments	DBS	First Spray					Mean	% Reduction over control	DBS	Second Spray					Mean	% Reduction over control	Yield (kg)	Yield % Reduction over control
		1 DAS	3 DAS	5 DAS	7 DAS	14 DAS				1 DAS	3 DAS	5 DAS	7 DAS	14 DAS				
NSKE @5ml/ Lit.	46.67 ±7.64^{a}	42.00 ±5.29^{c}	38.00 ±3.61^{cd}	32.00 ±4.36^{d}	24.33 ±4.51^{d}	27.67 ±3.79^{b}	32.80	48.64	35.33 ±13.80^{b}	30.67 ±8.96^{b}	22.00 ±5.29^{c}	15.00 ±5.29^{d}	12.33 ±5.86^{cd}	9.33 ±3.06^{cd}	19.20	71.71	2.19	19.67
Eucalyptus leaf extract @2ml/ Lit.	50.33 ±6.51^{a}	47.67 ±2.52^{bc}	41.33 ±4.16^{bcd}	35.67 ±2.52^{cd}	27.33 ±6.11^{cd}	32.67 ±12.86^{b}	36.93	42.17	41.67 ±14.57^{b}	34.33 ±10.12^{b}	30.33 ±7.57^{bc}	23.67 ±8.14^{bcd}	14.00 ±3.61^{cd}	10.33 ±5.13^{cd}	21.73	67.98	2.07	13.11
Datura leaf extract @2ml/ Lit.	53.33 ±6.81^{a}	50.33 ±3.79^{abc}	44.67 ±6.81^{bcd}	39.33 ±1.53^{bc}	31.67 ±4.73^{bcd}	35.33 ±13.87^{b}	40.27	36.94	44.00 ±16.52^{ab}	38.67 ±13.61^{b}	34.67 ±9.87^{bc}	26.67 ±3.06^{bcd}	19.67 ±9.87^{bcd}	14.33 ±5.86^{bcd}	26.80	60.51	1.87	2.18
Bt. 5%WP @5gm/ Lit.	58.00 ±7.94^{a}	54.67 ±5.86^{ab}	49.33 ±3.06^{b}	43.67 ±4.73^{b}	38.33 ±7.37^{b}	40.33 ±9.61^{b}	45.27	29.14	47.33 ±15.01^{ab}	44.67 ±8.50 ^{b}	40.33 ±6.66^{b}	33.33 ±5.86^{b}	25.67 ±6.43^{b}	21.67 ±6.43^{b}	33.13	51.19	1.48	-19.12
HaNPV @3x10^{12} POB/ha	54.33 ±4.73^{a}	50.00 ±2.65^{abc}	46.00 ±4.36^{bc}	42.00 ±5.29^{bc}	34.67 ±4.16^{bc}	38.67 ±6.43b^{b}	42.27	33.81	43.67 ±15.50^{ab}	40.33 ±9.61^{b}	37.00 ±7.00^{b}	29.67 ±9.87^{bc}	21.67 ±4.73^{bc}	17.67 ±4.73^{bc}	29.27	56.87	1.58	-13.66
Dimethoate 30EC@ 2ml/ha	57.67 ±2.52^{a}	46.67 ±8.96^{bc}	37.33 ±4.93^{d}	31.67 ±2.08^{d}	23.00 ±4.36^{d}	24.33 ±9.29^{b}	32.60	48.95	33.33 ±12.86^{b}	27.67 ±10.69^{b}	23.33 ±6.81^{c}	17.67 ±8.14^{cd}	10.33 ±4.16^{d}	7.67 ±3.06^{d}	17.33	74.46	2.45	33.87
Control	57.33 ±5.03^{a}	59.33 ±3.21^{a}	61.33 ±1.53^{a}	63.00 ±2.65^{a}	65.33 ±3.21^{a}	70.33 ±1.53^{a}	63.86	-	68.67 ±2.08^{a}	69.33 ±3.79^{a}	70.67 ±2.08^{a}	71.33 ±1.15^{a}	66.33 ±2.52^{a}	61.67 ±2.52^{a}	67.87	-	1.83	-
P Value	0.269^{NS}	0.021	0.000	0.000	0.000	0.001	-	-	0.110^{NS}	0.003	0.000	0.000	0.000	0.000	-	-	-	-
F Value	1.436	3.671	10.808	27.090	24.345	8.120	-	-	2.159	6.091	17.209	24.723	33.815	50.033	-	-	-	-

NSKE= Neem Seed Kernal Extract, *Bt.*= *Bacillus thuringiensis*, *HaNPV*= *Helicoverpa armigera* Nuclear Polyhedrosis Virus, DBS= Date Before Spray, DAS= Date After Spray, ha= hectare, gm= gram ml= milliliter, lit.= Liter WP= Wettable Powder and EC=Emulsifiable Concentrate Pre-treatment: 1 Day before spray (DBS) Post treatment: Day after spray (DAS)

Fig. 4.10: Efficacy of biorational pesticides against pod fly during 2022-23

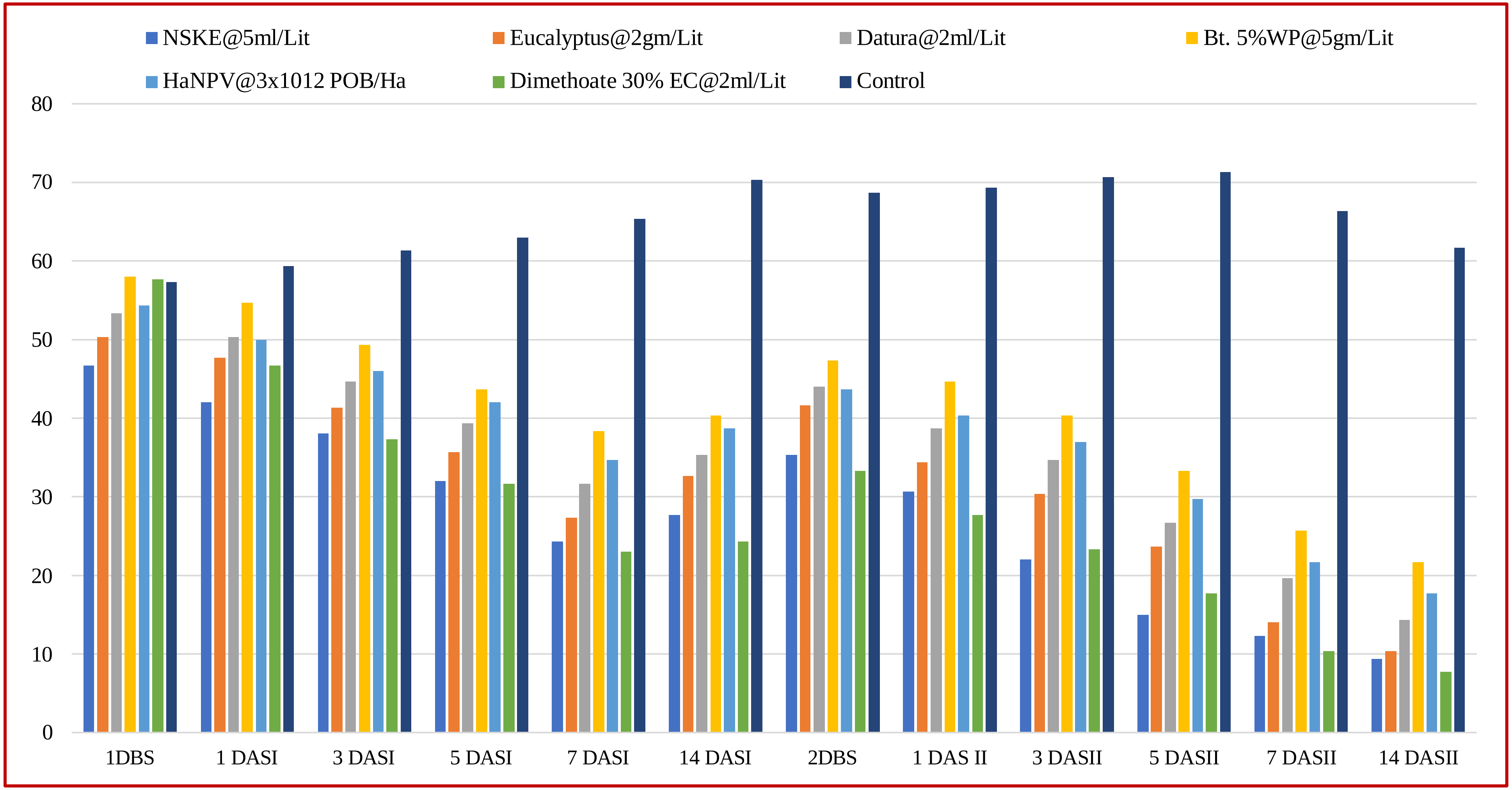
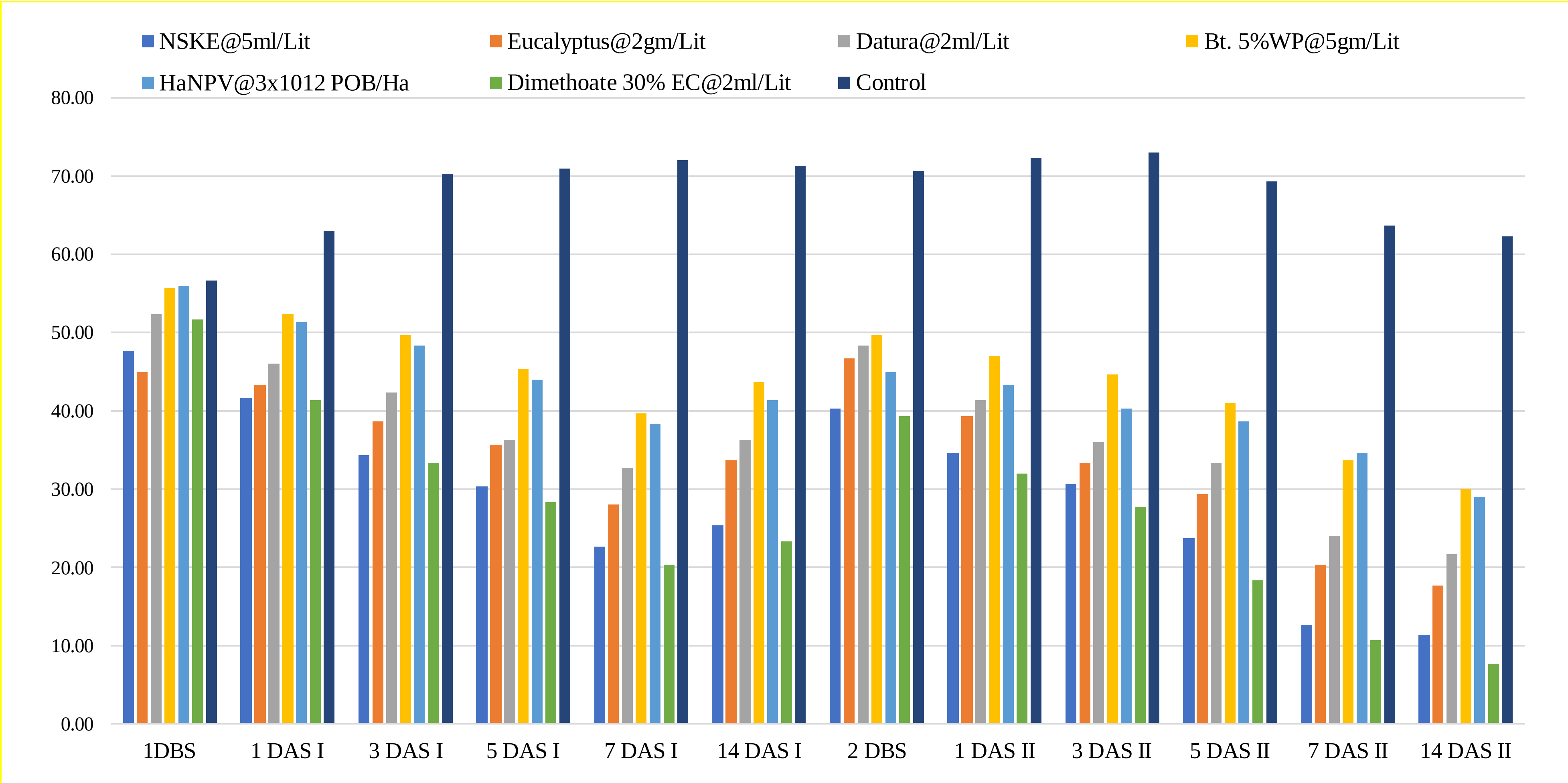


Table 4.21: Efficacy of biorational pesticides against pod fly during 2023-24

Treatments	DBS	First Spray					Mean	% Reduction over control	DBS	Second Spray					Mean	% Reduction over control	Yield (kg)	Yield % Reduction over control
		1 DAS	3 DAS	5 DAS	7 DAS	14 DAS				1 DAS	3 DAS	5 DAS	7 DAS	14 DAS				
NSKE @5ml/Lit	47.67 ±5.51^{a}	41.67 ±3.79^{c}	34.33 ±6.66^{cd}	30.33 ±3.21^{c}	22.67 ±2.08^{d}	25.33 ±4.93^{d}	30.87	55.60	40.33 ±14.47^{b}	34.67 ±4.73^{cd}	30.67 ±8.14^{d}	23.67 ±4.73^{ef}	12.67 ±3.79^{d}	11.33 ±1.53^{e}	22.60	68.83	2.09	16.75
Eucalyptus leaf extract @2ml/Lit.	45.00 ±2.65^{a}	43.33 ±7.37^{bc}	38.67 ±6.81^{cd}	35.67 ±8.14^{bc}	28.00 ±5.00^{cd}	33.67 ±4.51^{c}	35.87	48.41	46.67 ±14.15^{bc}	39.33 ±5.51^{bcd}	33.33 ±3.51^{cd}	29.33 ±2.31^{de}	20.33 ±3.51^{c}	17.67 ±7.51^{d}	28.00	58.90	1.97	10.05
Datura leaf extract @2ml/Lit.	52.33 ±9.07^{a}	46.00 ±4.36^{bc}	42.33 ±2.08^{bc}	36.33 ±5.51^{bc}	32.67 ±5.51^{bc}	36.33 ±4.16^{bc}	38.73	44.29	48.33 ±13.58 ^{bc}	41.33 ±5.77^{bcd}	36.00 ±5.29^{cd}	33.33 ±7.09^{cd}	24.00 ±5.57^{c}	21.67 ±3.51^{cd}	31.27	54.10	1.83	2.23
Bt. 5%WP @5gm/Lit.	55.67 ±7.37^{a}	52.33 ±2.89^{b}	49.67 ±1.53^{b}	45.33 ±8.50^{b}	39.67 ±7.51^{b}	43.67 ±2.08^{b}	46.13	33.65	49.67 ±14.15 ^{bc}	47.00 ±6.08^{b}	44.67 ±3.06^{b}	41.00 ±3.61^{b}	33.67 ±4.04^{b}	30.00 ±2.00^{b}	39.27	42.36	1.26	-29.60
HaNPV @3x10^{12} POB/Ha	56.00 ±4.36^{a}	51.33 ±8.14^{bc}	48.33 ±5.03^{b}	44.00 ±4.36^{b}	38.33 ±4.16^{b}	41.33 ±5.86^{bc}	44.67	35.75	45.00 ±18.19 ^{bc}	43.33 ±2.08^{bc}	40.33 ±1.53^{bc}	38.67 ±2.52^{bc}	34.67 ±3.51^{bc}	29.00 ±2.00^{bc}	37.20	45.40	1.53	-14.52
Dimethoate @1237 ml/Ha	51.67 ±6.03^{a}	41.33 ±5.51^{c}	33.33 ±3.06^{d}	28.33 ±8.50^{c}	20.33 ±4.93^{d}	23.33 ±3.06^{d}	29.33	57.82	39.33 ±14.47^{b}	32.00 ±2.65^{d}	27.67 ±3.79^{d}	18.33 ±2.08^{f}	10.67 ±1.53^{d}	7.67 ±1.53^{e}	19.27	71.72	2.16	20.67
Control	56.67 ± 4.73^{a}	63.00 ±3.61^{a}	70.33 ±4.73^{a}	71.00 ±4.36^{a}	72.00 ±3.46^{a}	71.33 ±3.51^{a}	69.53	-	70.67 ±7.23^{a}	72.33 ±7.64^{a}	73.00 ±4.58^{a}	69.33 ±2.52^{a}	63.67 ±5.13^{a}	62.33 ±3.21^{a}	68.13	-	1.79	-
P Value	0.204^{NS}	0.002*	0.000*	0.000*	0.000*	0.000*	-	-	0.203^{NS}	0.000*	0.000*	0.000*	0.000*	0.000*	-	-	-	-
F Value	1.656	6.193	22.025	15.103	37.396	44.056	-	-	1.663	19.468	32.023	53.751	60.348	75.744	-	-	-	-

NSKE= Neem Seed Kernal Extract, *Bt.= Bacillus thuringiensis*, *HaNPV= Helicoverpa armigera* Nuclear Polyhedrosis Virus, DBS= Date Before Spray, DAS= Date After Spray, ha= hectare, gm= gram ml= milliliter, lit.= Liter WP= Wettable Powder and EC=Emulsifiable Concentrate Pre-treatment: 1 Day before spray (DBS) Post treatment: Day after spray (DAS)

Fig. 4.11: Efficacy of biorational pesticides against pod fly during 20223-24



4.4.1. Effect of biorational pesticides on the production pigeonpea crop

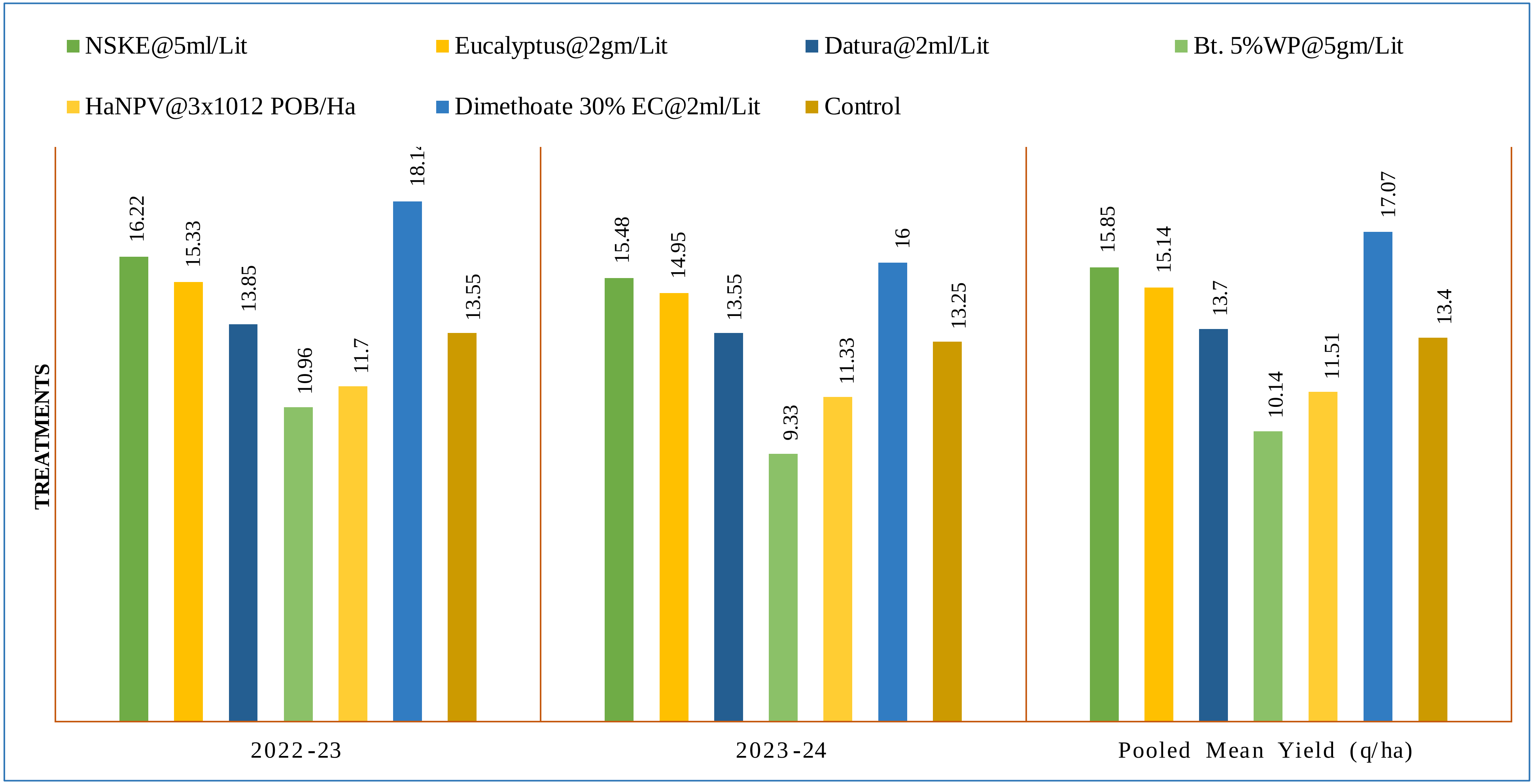
During the 2022–23 season, pigeonpea crop loss data was presented in Table 4.22 and graphed in Figure 4.11. It was noted that the pods damage caused by *M. obtusa* was significant. Pigeon pea crop was treated with dimethoate, applied twice (Spray 1 and Spray 2) and observed one week after each spray. The best result was seen in treatment 6 (T6), which gave a yield of 18.14 quintals per hectare. While treatment1 (T1) NSKE @ 5ml./Lit. yielded 16.22 q/ ha. Eucalyptus leaf extract @ 2 ml/Lit. When sprayed on pigeon pea crop, the yield was 15.33 q/ha less as compared to treatment 1 (T1) NSKE @ 5 ml/litre. In treatment 3 (T3), where Datura leaf extract @ 2 ml/Lit. were used, the yield was 13.85 quintals/ha. Although *Datura* leaf extract reduced the number of pod flies, the yield of T3 was lower than that of T1, T2 and T6. Thereafter the yield of treatment 5 (T5) *HaNPV* @ $3x10^{12}$ POB/Ha was lower than that of T3 and the lowest yield was recorded for treatment 4 (T4) *Bt.* 5%WP @ 5 gm/Litre. Whereas the data from the pooled table is similar with the previously given data. The highest yield being 17.07 q/ha in T6 and lowest yield as per T4 is 10.14 q/ha.

During the 2023-24 season, the crop loss data of pigeon pea is displayed in Tab 4.22 and graphed in Fig 4.11. The observed data of pod destruction by pod fly. The seven-treatment applied in experimental plots. The pigeon pea crop was treated with dimethoate, applied twice (Spray 1 and Spray 2), with observations made one week after each spray. The best result was obtained with treatment 6 (T6) Dimethoate 30%EC @ 2ml/Lit. yielded 16.00 q/ha. Treatment 1 (T1) NSKE @ 5 ml/L yielded 15.48 q/ha. When Eucalyptus leaf extract @ 2 ml/L was sprayed, the yield was 14.95 q/ha, which was much lower compared to treatment 1 (NSKE). Treatment 3 (T3) Datura leaf extract @ 2ml/ha. where Datura leaf extract @ 2 ml/Lit. was used, yielded 13.55 q/ha. Although Datura extract reduced the number of pod flies, the yield for T3 was lower than T1, T2 and T6. Treatment 5 (T5) with *HaNPV* @ 3x10^12 POB/Ha had a lower yield than T3 and the lowest yield was recorded for treatment 4 (T4) with *Bt.* 5% WP @ 5 g/L. The data from the pooled table is consistent with the above results. The highest yield was 17.07 q/ha of T6 and the lowest yield was 10.14 q/ha of treatment 4.

Table 4.22: Effect of biorational pesticides on the production pigeonpea crop 2022-23 and 2023-24

Treatments/ Years	Dose	2022-23	2023-24	Pooled Mean Yield (q/ha)
NSKE (Neem Seed Kernal Extract) (*Azadirachta indica*)	**5ml/Lit**	**16.22**	**15.48**	**15.85**
Eucalyptus leaf extract (*Eucalyptus gunnii*)	**2ml/Lit**	**15.33**	**14.95**	**15.14**
Datura leaf extract (*Datura stramonium*)	**2ml/Lit**	**13.85**	**13.55**	**13.70**
***Bt.* 5%WP** (*Bacillus thuringiensis*)	**5gm/Lit**	**10.96**	**9.33**	**10.14**
HaNPV *(Helicoverpa armigera Nuclear Polyhedrosis Virus)*	**$3x10^{12}$ POB/Ha**	**11.70**	**11.33**	**11.51**
Dimethoate 30% EC	**2ml/Lit**	**18.14**	**16.00**	**17.07**
Control	**-**	**13.55**	**13.25**	**13.40**

Fig. 4.12: Effect of biorational pesticides on the production pigeonpea crop 2022-23 and 2023-24



Chapter-V

SUMMARY AND CONCLUSION

The present analysis on the **"Population Dynamics and Ecofriendly Management of *Melanagromyza obtusa* (Malloch) infesting *Cajanus cajan* (L.)"** were conducted on students Agriculture Research Farm of the Department of Entomology, School of Agriculture, Lovely Professional University, Phagwara, Phagwara, Punjab, India during 2022-23 and 2023-24. The findings are summarized as follows:

During *Kharif* season 2022-23, pod fly on pigeonpea crop was first time seen in 41st Standard Meteorological Week (SMW), it gradually increased until the 46th SMW, with population ranging 9.33 to 70.67 per 100 pods. The maximum population of 70.67/100 pods occurred in 46th SMW at 28°C maximum and 13°C minimum temperature, 52% maximum and 47% minimum relative humidity (Rh%). The minimum population of 1.33/100 pods were observed in 2nd SMW. During *Kharif*, 2023-24 the maximum population of pod fly (72.67/100 pods) was observed in 44th SMW at 31.32°C max., 13.3°C minimum temperature, 94.01% maximum and 45.82% minimum Rh%. Whereas it was minimum (2.67/100 pods) occurred in 1st SMW at 10°C maximum, 7.22°C minimum temperature, 94.00% max. and 87.00% min. Rh%.

During *Kharif*, 2022-23 the peaked period of incidence of pod fly maggot and pupae was noted in 44th and 50th SMW with the population recorded as 52.0 maggot and 49.0 pupae per 100 pods with 34°C max. temp., 56.00% max. Rh% and 25°C max., 65.00% max. Rh%, respectively. The minimum infestation 5.0 maggots & 8.0 pupae per 100 pods was recorded at 2nd SMW with 12°C maximum temperature & 94.00% max. Rh%. During *Kharif*, 2023-2024, the occurrence of maggot (14 maggot per 100 pods) and pupae (41 pupae per 100 pods) was active from 39th to 44th SMW with 31.32°C max. temp., 94.01% maximum Rh%. The lowest population (7.0 pupae per 100 pods) & highest population (40.0 pupae per 100 pods) was observed in 40th to 45th SMW with 29.05 maximum temperature, 93.23% maximum Rh% & 0.60 mm rainfall.

During 2022-23 *Kharif*, the larval parasitism of pod fly by *Euderus lividus* commenced from 43rd to 46th SMW (11.76% to 31.82%) with 28°C maximum temp. &

52.00 % maximum Rh% and *Ormyrus orientalis* ranged from 44th & 47th SMW at 28°C maximum temperature & 81.00% maximum Rh%. In 2023-24 *Kharif*, initial occurrence larval/pupal parasitism was 4.17% & 11.53%. *E. lividus* population peaked at 29.72% in 45th SMW with 29.05°C max., temp. & 93.23% max. Rh%). The peaked population of *O. orientalis* was 24.32% in 44th SMW at 31.32°C maximum temperature & 94.01% max. Rh% dropping to 3.84% by 51st SMW.

During 2022-23 *Kharif*, *Helicoverpa armigera* larvae were present from 41st to 52nd SMW, with 2.67 to 0.67 larvae/100 pods. The maximum larvae of *H. armigera* (40.00 larvae per 100 pods) was observed in 47th SMW with 28°C max. temperature and 81% maximum Rh%. While lowest population (0.67 larvae per 100 pods) was observed in 52nd SMW. In 2023-24 *Kharif*, the occupation of *H. armigera* on pigeonpea crop was between 42nd and 51st SMW with 4.33 to 3.33 larvae per 100 pods. The highest larval population of *H. armigera* (36.67 larvae per 100 pods) was observed in 46th with 27.06°C max. temp. and 93.84% max. Rh% and lowest population (3.33 larvae per 100 pods) was observed in 51st SMW.

During *Kharif*, 2022-23 *Mylabris pustulata* was observed on pigeonpea crop from 39th to 47th SMW with population ranging 3.33 to 2.00 per 100 pods. Peak population of *M. pustulata* (18.67 per 100 pods) recorded in 43rd SMW with maximum temperature 29°C and 53% maximum Rh% and lowest population of *M. pustulata* (2.00 per 100 pods) was recorded in 47th SMW. During *Kharif*, 2023-24 the highest population of *M. pustulata* (20.33 per 100 pods) was observed in 44th SMW with 31.32°C max. temperature and 94.01% maximum relative humidity. Whereas it was lowest population (3.67 per 100 pods) was observed in 48th SMW.

During *Kharif*, 2022-23, *Clavigralla gibbosa* infestation by nymphs started in 41st SMW (9.67 nymph per 100 pods), peaked in 46th SMW (45.67 nymph per100 pods), decreased to 15.67 per100 pods at 49th SMW with 28.00°C max. temp. and 52.00% max. Rh%. But persisted till harvest with fluctuations linked to temperature and humidity. In 2023-24 *Kharif, C. gibbosa* appeared in 40th SMW (6.33 nymph per 100 pods), peaked at 44th SMW (34.67 nymph per 100 pods) corresponding to 31.32°C maximum temperature and 94.01% maximum Rh%. Population dropped to 4.67 nymphs per 100 pods at 49th SMW but continued till harvest.

During 2022-23 *Kharif*, *Lampides boeticus* larvae infestation started in 42nd SMW (3.67 larvae/100 pods), ranged 1.00 larvae/100 pods at 48th SMW. The peak larval population of *L. boeticus* (26.33 larvae per 100 pods) was recorded in 44th SMW at 34°C max. temperature and 56% max. Rh%. The lowest larval population of *L. boeticus* (1.00 larvae per 100 pods) was recorded in 48th SMW. In 2023-24 *Kharif*, the *L. boeticus* was incidence on pigeonpea crop up to 38th to 48th SMW. The peak larval population of *L. boeticus* (15.33 larvae per 100 pods) was recorded in 44th SMW with 31.32°C maximum temperature and 94.01% maximum relative humidity. The lowest population (1.00 larvae per 100 pods) was observed in 48th SMW.

The correlation coefficient of the incidence of pod fly, *M. obtusa* and abiotic factors revealed non-significant positive correlation with maximum temperature (r= 0.161) while minimum temperature (r= -0.016), maximum relative humidity (r= -0.238), minimum Rh% (r= -0.209) and rainfall (r= -0.139) showed non-significant with negative correlation during *Kharif*, 2022-23. In *Kharif*, 2023-24, the study found pod fly distribution associated with the abiotic factors of environment by demonstrating a highly significant negative correlation between pod fly incidence with minimum relative humidity (Rh%) (r= -0.772**) while non-significant positive correlation with maximum temperature (r= 0.402) and rainfall (r= 0.253), whereas non-significant negative correlation with the min. temp. (r= -0.076) and the max. Rh% (r= -0.252).

During the 2022-23 season, there was a significant correlation between damaged pods (r= 0.550*) and pod fly larvae (r= 0.646*) with extreme temperatures. The larvae and pupae showed non-significant fluctuations in response to minimum temperatures and relative humidity they had non-significant negative correlation with rainfall. Two parasitoids, *Euderus lividus* and *Ormyrus orientalis*, were also studied. Both were influenced by both temperatures, exhibiting positive but non-significant correlation. However, they were negatively non-significant relationship influenced by max. Rh% and rainfall (mm), again showed non-significant correlations fluctuations in response with minimum relative humidity. *E. lividus* population had a positive correlation with both maximum and minimum temperature (r= 0.313 and r= 0.018, respectively). In contrast, they showed non-significant negative correlations with max. relative humidity (r= -0.186), min. relative humidity (r= -0.160) and rainfall (mm) (r= -0.049). Similarly, *O. orientalis* exhibited non-significant positive correlation with maximum (r= 0.194), minimum temperature (r= 0.021) and minimum Rh% (r= 0.003). However, it had non-significant negative correlation with maximum Rh% (r= -0.051) and rainfall (r= -0.146). During *Kharif*, 2023-24 observed a highly significant negative correlation between damaged pods (r= -0.744**) and pod fly larvae (r= -0.776**) with minimum relative humidity, as well as between pod fly pupae (r= -0.541*) with minimum temperature. The pod fly larvae showed a highly significant positive correlation with maximum temperature (r= 0.746**). Both parasitoids, *Euderus lividus* and *Ormyrus orientalis*, exhibited significant negative correlation with min. The Rh% (r= -0.612* and r= -0.564*, respectively). The *E. lividus* populace had a positive non-significant correlation with max. Temperature (r= 0.360), min. temp. (r= 0.035) and rainfall (r= 0.303), while indicating a non-significant negative correlation with Rh% (r= -0.055). similarly, *O. orientalis* had no significant positive relationships with the maximum temperature (r= 0.287) and rainfall (r= 0.276) but had no significant negative correlation with the minimum temperature (r= -0.084) and the Rh% (r= -0.219).

During the 2022-23 *Kharif* season, correlation analysis revealed that the *Helicoverpa armigera* larval population had non-significant positive correlation with both maximum temperature (r= 0.175) and minimum temperature (r= 0.132), while exhibiting negative correlations with maximum Rh% (r= -0.358), minimum Rh% (r=-0.270) and rainfall (r= -0.191). During the 2023-24 *Kharif*, *Helicoverpa armigera* had a significant negative correlation with minimum relative humidity (r = -0.515). Additionally, it exhibited non-significant positive correlations with maximum temperature (r= 0.128) and rainfall (r= 0.076), while showing non-significant negative correlations with the minimum temperature (r= -0.293) and extreme relative humidity (r= -0.271).

During *Kharif* season of 2022-23, the occurrence of the blister beetle, *Mylabris pustulata* revealed intriguing patterns in relation to abiotic factors. The population *M. pustulata* showed significant positive correlations with both maximum and minimum temperatures (r= 0.532* and r= 0.618*). However, it exhibited highly significant negative correlations with maximum and minimum Rh% (r= -0.864** & r= -0.814**) & a negative non-significant relationship with rainfall (r= -0.202). During *Kharif*, 2023-24, the *M. pustulata*, thrived in warmer conditions, showed significant positive correlations with both maximum and minimum temperatures (r= 0.772** & r= 0.516*). However, it struggled with the minimum humidity levels, as indicated by a significant negative correlation with the minimum relative humidity (r = -0.608**). Additionally, the blister beetle occurrence had non-significant negative correlations with maximum Rh% (r= -0.429) and a non-significant positive correlation with rainfall (r= 0.222).

During *Kharif* season 2022-23, the *Clavigralla gibbosa* population had a significant negative correlation with the maximum Rh% (r= -0.512*), indicating that the population decreased as humidity increased. Additionally, there were no significant negative correlations with maximum and minimum temperatures (r= 0.262 & r= 0.244) & a negative non-significant relationship with rainfall (mm) (r= -0.203). In the *Kharif* season of 2023-24, the *C. gibbosa* population demonstrated a negative significant relationship with minimum Rh% (r= -0.669**) indicating that the population increased as humidity decreased. Additionally, there were non-significant positive correlation with maximum temperature (r= 0.450), minimum temperatures (r= 0.064) and rainfall (r= 0.226), while showed a non- significant negative correlation with maximum relative humidity (r= -0.230).

During the *Kharif* season of 2022-23, the *Lampides boeticus* population presented significant negative correlations with both extreme and lowest Rh% (r= -0.578* and r= -0.512*), while the larval populace had significant positive correlations with maximum and minimum temperatures (r= 0.256 and r= 0.300) and non-significant negative correlation with rainfall (r= -0.122). In the *Kharif*, 2023-24, the *L. boeticus* population demonstrated a positive correlation with the maximum temperature (r= 0.694**), while exhibiting a negative correlation with the relative humidity (r= -0.657**). Correlations with other factors, including rainfall were mostly non-significant.

During the *Kharif* seasons of 2022-23 and 2023-24, experiments were conducted on pigeonpea plants covered with mosquito nets. Where adult pod flies were released to observe maggot and pupae infestations. In 2022-23, peak infestations were recorded at 31 maggots/pupae per 100 pods in the first observation rising to 82 in subsequent observations, influenced by varying temperatures and humidity levels. Similarly, in 2023-24, infestations peaked at 33 per 100 pods initially, increasing to 70 in later observations. Throughout both seasons, the highest infestations correlated with specific meteorological conditions, such as temp and Rh%.

During 2022-23 study, after releasing pairs of pod flies onto pigeonpea plants covered with muslin cloth damage inflicted by *Melanagromyza obtusa* ranged from 50.62% to 58.24% for pod damage, 25.31% to 29.12% for grain damage and 67.06% to 75.78% for weight loss. Similarly, in the 2023-24 season, with intentional release of 100 pairs of pod flies onto covered plants, pod damage ranged from 5.19% to 49.12%, grain damage varied between 24.56% and 27.60% and weight loss ranged from 70.90% to 77.19%. Control plants, shielded from pod flies exhibited lower damage percentages. In the *Kharif* crop season of 2022-23, the analysis showed a non-significant positive correlation between maximum temperature, maximum relative humidity and maggot population for covered plants P1 to P5 with varying rainfall values. However, the minimum temperature and relative humidity demonstrated a non-significant negative correlation between these plants. During 2023-24, the minimum temperature observed a significant negative correlation with P3 and P4. The correlation between the maximum and minimum temperature and the Rh% was not significant for P1 to P5. Greatest relative humidity and rainfall demonstrated a non-significant positive relationship for most plants, except for P4, where it was negative.

In the 2022-23 *Kharif* season, studies on various sowing dates revealed that the incidence of pod fly peaked at the 51st SMW, with percentages ranging from 44.93% to 51.80%, indicating higher infestation in later sowings. Early sowing (1st DOS) showed significantly higher yields (15.70 q/ha) compared to late sowings, with the crop sown on the 7th DOS yielding the lowest (10.14 q/ha). Similarly, in 2023-24, pod fly incidence peaked during the 51st SMW, ranging from 41.80% to 52.33%, with early sowings (1st DOS) again higher yield (14.29 q/ha) than late sowings (7th DOS) at 10.07 q/ha. Late sowing conditions consistently resulted in reduced yields.

During the 2022-23 *Kharif* season, correlations between *M. obtusa* incidence and abiotic factors varied across sowing dates. Larval population correlated positively with extreme Rh% and negatively with lowest temperature on early sowing dates (1st DOS and 2nd DOS), while pod fly incidence correlated positively with maximum relative humidity and negatively with least temperature on later sowing dates (3rd DOS to 7th DOS). In 2023-24, similar correlations were observed with pod fly incidence negatively correlating with bare minimum temperature across most sowing dates and showing non-significant associations with humidity, extreme temperature and rainfall.

Recent studies have emphasized the significant role of pod fly, *Melanagromyza obtusa*, in reducing pigeonpea yields, particularly evident with late sowing. Early sowing, notably on June 13th, consistently yielded higher at 15.70 q/ha, compared to later sowing dates, with July 24th yielding the lowest at 10.14 q/ha. This trend persisted across multiple seasons, underscoring the correlation between early sowing, reduced pest damage and higher yields, reinforcing the importance of timely planting for optimal pigeonpea production.

During the 2022-23 *Kharif* season, all treatments significantly decreased the control in reducing pod damage and the population of the pod fly. Dimethoate 30% EC @ 5ml/Lit. was the most effective treatment, followed by Neem Seed Kernel Extract (NSKE) @ 5% concentration. Other treatments like *Eucalyptus*, *Datura*, *HaNPV* and *Bt*. 5% WP showed moderate effectiveness, albeit still superior to the control. The necessity of using biorational methods to control *M. obtusa* was evident. Similarly, during the 2023-24 season, treatments remained highly effective, with *Dimethoate* and

NSKE leading in suppressing the pest population, underscoring the importance of biorational solutions in managing *M. obtusa*.

During the *Kharif* season of 2023-24, all treatments significantly outperformed the control in reducing pod damage and the populace of *Melanagromyza obtusa* (pigeonpea pod fly). Prior to spraying, the pest distribution was uniform across treatments. Dimethoate 30% EC @ 5ml/Lit. was the most effective, reducing pod fly counts to 41.33 at 1 DAS and 23.33 at 14 DAS. Neem Seed Kernel Extract @ 5% was the most efficient. Other treatments like *Eucalyptus*, *Datura*, *HaNPV* and *Bt*. 5% WP also reduced pod fly populations but to a lesser extent. The untreated control had the highest pest counts, highlighting the necessity of these treatments. After the second spray, Dimethoate 30% @ 2ml/Lit. was again the most effective, reducing counts to 7.67 at 14 DAS. NSKE, *Eucalyptus*, *Datura*, *HaNPV* and *Bt*. also showed varying degrees of effectiveness, but all treatments were superior to the control. These results emphasize the importance of biorational methods in managing *M. obtusa* populations.

During the 2022–23 season, significant pod damage from *M. obtusa* was noted in pigeonpea crops. Treatment 6 (T6) with dimethoate applied twice yielded the highest at 18.14 quintals per hectare. Treatment 1 (T1) with NSKE @ 5ml/Lit. yielded 16.22 q/ha, while *Eucalyptus* leaf Extract @ 2 ml/Lit. resulted in 15.33 q/ha. *Datura* extract @ 2 ml/Lit. in Treatment 3 (T3) yielded 13.85 q/ha. Treatment 5 (T5) with *HaNPV* yielded less than T3 and Treatment 4 (T4) with *Bt*. 5% WP yielded the lowest at 10.14 q/ha. Pooled data confirmed T6 as the highest yield and T4 as the lowest.

During the 2023-24 season, pigeonpea crop loss data showed significant pod damage from pod fly. Seven treatments were tested with observations made one week after each of two dimethoate applications. The best yield was from treatment 6 (T6) with Dimethoate 30% EC @ 2ml/Lit., producing 16.00 q/ha. Treatment 1 (T1) with NSKE @ 5 ml/L yielded 15.48 q/ha, while *Eucalyptus* leaf extract @ 2 ml/L yielded 14.95 q/ha. Treatment 3 (T3) with *Datura* @ 2 ml/L yielded 13.55 q/ha. *HaNPV* treatment (T5) yielded less than T3 and the lowest yield was from treatment 4 (T4) with *Bt.* 5% WP @ 5 g/L. The pooled data confirmed T6 as the highest yield at 17.07 q/ha and T4 as the lowest at 10.14 q/ha.

Based on the findings, it can be concluded that:

- During the entire crop season over the two years of study, five major insect pests were observed. These pests included *Melanagromyza obtusa*, *Helicoverpa armigera*, *Mylabris pustulata*, *Clavigralla gibbosa* and *Lampides boeticus*.
- Two species of parasitoids *Euderus lividus* and *Ormyrus orientalis* were observed as natural enemies of pod fly, *M. obtusa*.
- The highest larval population of *M. obtusa* was observed in 46th and 44th Standard Meteorological Week (SMW) whereas it was lowest population in 2nd and 1st SMW during 2022-23 and 2023-24, respectively.
- *Helicoverpa armigera* population reached the peak in the 47th and 46th SW and min. population was recorded during 52nd and 51st SMW in 2022-23 and 2023-24, respectively.
- Maximum population of *Mylabris pustulata* was observed during 43rd and 41st SMW and minimum population was observed in 47th and 48th SMW during both the year.
- Highest population of *Clavigralla gibbosa* was recorded in 46th and 44th SMW during both the years. The minimum population was noted in 41st and 49th SMW during 2022-23 and 2023-24, respectively.
- Maximum population of *Lampides boeticus* attained peak at 44th SMW in both years and minimum population was observed at 48th SMW of both years.
- The high occurrence of pod fly maggots and pupae was noted in 47th & 50th SW and 44th & 45th SW during both the years (2022-23 and 2023-24), respectively.
- The correlation coefficients between the incidence of *Melanagromyza obtusa*, *Helicoverpa armigera*, *Mylabris pustulata*, *Clavigralla gibbosa* and *Lampides boeticus* with abiotic factors exhibited both positive and negative relationships with significant and non-significant during 2022-23 and 2023-24 of the study.
- The relationship coefficients between the maggot of *M. obtusa* (pod fly) and abiotic factors showed positive significant correlation with maximum temperature in 2022-23. However, maggot of *M. obtusa* and abiotic factors had highly significant positive and negative correlation with maximum temperature

and minimum relative humidity while pupae showed significant negative correlation with minimum temperature in 2023-24.

- The peak occurrence of *Euderus lividus* and *Ormyrus orientalis* was observed in 46^{th} and 47^{th} SW and 45^{th} and 44^{th} SW during 2022-23 and 2023-24, respectively.
- Treatments P4 and P5 showed the lowest pod and grain damage percentages in 2022-23 and 2023-24 respectively but had relatively high weight loss. Conversely, the control treatment had the lowest grain damage percentage across both years. However, it exhibited the maximum weight loss.
- The yield decreases progressively as the sowing date is late from 1DOS to 7DOS, indicating earlier sowing leads to higher yields. The yields in 2022-23 were consistently higher than in 2023-24 across all sowing dates, suggesting more favorable growing conditions in 2022-23. The trend of declining yield with late sowing is consistent in both years and the pooled mean, enhancing the importance of timely sowing for maximum yields.
- Dimethoate 30% EC @ 2ml/Lit treatment resulted in the highest pooled mean yield (17.07 q/ha), followed by NSKE @ 5ml/Lit (15.85 q/ha). The control treatment had the lowest pooled mean yield (13.40 q/ha). The yield differences among treatments highlight the effectiveness of various pest management strategies in improving crop productivity.

REFERENCES

Ahmad, M. A. (2020). Evaluation of eco-friendly approaches for the management of pod borer complex of pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Evaluation*, 21, 22p.

Ambarish, S., & Kalleshwaraswmy, S. C. M. (2021). Pod fly, *Melanagromyza obtusa*- A silent pod killer in pigeonpea. Krishi science – *eMagazine for Agricultural Sciences*, *02*(02), KS 1694.

Anonymous, (2024). Package of practices for crops of Punjab *Kharif* 2023. Additional Director of Communication, Punjab University, Ludhiana, *41*(1), 64-67.

Badiger, M., & Prabhu, S. T. (2019). Status of pigeonpea pod fly, *Melanagromyza obtusa* (Malloch) in major pigeonpea growing areas of Vaveri, Gadag and Dharwad districts. *Journal of Farm Sciences, 32*(3), 355-357.

Bantewad, S.D., Chavan, R.A., & Jahagirdar, J. E. (2018). Evaluation of sequential application of insecticides against pigeonpea pod fly *Melanagromyza obtusa* (Mall). *International Journal of Plant Protection*, *11*(1), 18-22.

Bhadani, D. J., & Patel, J. J. (2019). Seasonal Incidence of Pod Fly, *M. obtusa* Infesting Pigeonpea. *International Journal of Pure and Applied Bioscience*, *7*(2), 44-50.

Bhandari, P., & Ujagir, R. (2002). Bio-efficacy of certain insecticides against pod borer complex of early pigeonpea, *Cajanus cajan* (L.) Millsp. *Annals of Plant Protection Sciences*, *10*(2), 225-229.

Bhattacharjee, S., & Sharma, G. D. (2015). Effect of Arbuscular mycorrhizal fungi (AM fungi) and Rhizobium on the nutrient uptake of pigeon pea plant. *International Journal of Advanced Research*, *3*(8), 833-836.

Bhosale, B., Nishantha, K., Patinge, N., & Kadam, D. (2009). E2Y45 PIGEONPEA. Comparative efficacy of microbial insecticides with new insecticide molecule E2Y45 against pod borer complex of pigeonpea. *Pestology*, 33, 38-42.

Bijewar, A. K., Das, S. B., & Saxena, A. K. (2019). Succession of Insect Pest Complex and their Natural Enemies in Pigeonpea [*Cajanus cajan* (L) Millsp.]. *International Journal of Current Microbiology and Applied Sciences*, *8*(7), 619-628.

Bopape, F. L., Beukes, C. W., Katlego, K., Hassen, A. I., Steenkamp, E. T., & Gwata, E. T. (2022). Symbiotic performance and characterization of Pigeonpea (*Cajanus cajan* L. Millsp.) Rhizobia occurring in South African soils. *Agriculture*, *13*(1), 30.

Borah, S. R. (2002). Seasonal population trend of eggs of *Helicoverpa armigera* Hubner in pigeonpea. *Journal of the Agricultural Science Society of North-East India*, *15*(2), 203-206.

Chakravarty, S., Agnihotri, M., & Kumar, R. (2016[a]). Impact of weather parameters on population build up and natural parasitization of pod fly, *Melanagromyza obtusa* (Malloch) on Pigeonpea. *Annals of Plant Protection Sciences*, *24*(2), 290-294.

Chakravarty, S., Bera, T., Agnihotri, M., & Jaba, J. (2016[b]). Screening of short duration pigeonpea [*Cajanus cajan* (L.) Millsp.] genotypes against major insect pests. *Journal of Pure and Applied Microbiology*, *10*(4), 3009-3016.

Chandra, N., & Singh, D. C. (2017). Role of abiotic factors on the population dynamics of pigeonpea pod fly, *Melanagromyza obtusa* Malloch. *Progressive Agriculture*, *17*(1), 155-157.

Charan, Y. D., Wankhade, S. R., & Karale, G.V. (2017). Incidence study of major pests and their natural enemies on pigeonpea (*Cajanus cajan* [L.] MILL SP.). *Journal of Research in Science and Technology*,*7*(6), 2277-1174.

Chiranjeevi, B., & Patange, N. R. (2017). Appraisal of economic threshold level for the management of pigeonpea pod fly, *Melanagromyza obtusa* (Malloch). *Journal of Entomology and Zoology Studies*, *5*(5), 438-441.

Chiranjeevi, B., & Patange, N. R. (2018[a]). Population dynamics of pod fly *Melanagromyza obtusa* in long duration pigeonpea. *Indian Journal of Entomology*, *80*(4), 1488-1494.

Chiranjeevi, B., & Patange, N. R. (2018[b]). Field biology of pigeonpea pod fly, *Melanagromyza obtusa* (Malloch). *Journal of Entomology and Zoology Studies*, *6*(1), 717-719.

Chiranjeevi, B., & Patange, N. R. (2018[c]). Weight loss in seeds of different pigeonpea genotypes due to *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae) damage. *Journal of Entomology and Zoology Studies, 6*(4), 1156-1160.

Chiranjeevi, B., & Patange, N. R. (2018[d]). Bioefficacy of newer insecticides and botanicals against population of pigeonpea pod fly, *Melanagromyza obtusa* (Malloch). *Journal of Entomological Research*, *42*(3), 377-382.

Chiranjeevi, B., & Sarnaik, S. V. (2017[a]). Bio-efficacy of promising insecticides against maggot population of pigeonpea pod fly, *Melanagromyza obtusa* (Malloch). *Journal of Entomology and Zoology Studies, 5*(3), 159-162.

Chiranjeevi, B., & Sarnaik, S. V. (2017[b]). Efficacy of different insecticidal treatments on population of pod fly, *Melanagromyza obtusa* (Malloch). *Journal of Entomology and Zoology Studies, 5*(4), 1812-1815.

Chiranjeevi, B., Patange, N. R., & Manickavasagam, S. (2019). Parasitization of pigeonpea pod fly *Melanagromyza obtusa* and its population dynamics as influenced by genotypes. *Indian Journal of Entomology*, *81*(3), 521-525.

Dadas, S. M., Gosalwad, S. S., & Patil, S. K. (2019). Seasonal abundance of pod borers on pigeon pea and their natural enemies in relation with weather parameters. *Journal of Entomology and Zoology*, *7*(5), 702-705.

Dar, M. H., Rizvi, P. Q., & Gupta, A. (2005[a]). Development of integrated management module for pod fly, *Melanagromyza obtusa* Malloch in late pigeonpea. *Annals of Plant Protection Sciences*, *13*(2), 298-301.

Dar, M. H., Rizvi, R. Q., Saxena, H., & Naqvi, N. A. (2005[b]). Influence of resistant and susceptible pigeonpea cultivars on the parasitization efficiency of some parasitoids on Pod fly, *Melanagromyza obtusa* (Malloch). *Journal of Biological Control*, *19*(2), 87-92.

Das, B. C., Patra, S., Samanta, A., & Dhar, P. P. (2022). Evaluation of bio-rational insecticides and bio-pesticides against pod borer complex in pigeonpea. *International Journal of Bio-resource and Stress Management*, *13*(3), 261-267.

Dhakla, K., Yadav, G. S., & Rohilla, H. R. (2010). Incidence and flower damage of pigeonpea genotypes by blister beetle, *Mylabris pustulata* Thunberg. *Journal of Insect Science (Ludhiana)*, *23*(3), 348-350.

Dialoke, S. A., Ngwuta, A. A., Kabuo, N. O., Ofor, M. O., & Tom, C. T. (2014). Effect of time of planting on major insect pests and yield performance of three short duration pigeonpea (*Cajanus cajan* (L.) Millsp.) cultivars in Nsukka agro-ecological zone, Nigeria. *Journal of SAT Agricultural Research*, *12*, 1-6.

Dialoke, S., Ogbedeh, K., Nwokeji, E., Chigbundu, I., Nnebue, M., & Cookey, C. (2018). Impact of Plant Density and Planting Dates on the Population of Major Pod Sucking Bugs in Relation to Damage and Yield of Improved Pigeonpea Cultivar in Owerri Rainforest Zone, Nigeria. *Journal of Experimental Agriculture International*, *20*(1), 1-20.

Dobhal, P., Maurya, R. P., Bhatnagar, V. R., & Brijwal, L. (2018). Effect of different dates of sowing on dynamics of insect pests of pigeonpea in Tarai region of Uttarakhand. *Journal of Entomology and Zoology Studies*, *6*(6), 513-518.

Durairaj, C. (2005). Seasonal incidence of pupal parasitoids of pigeonpea pod fly (*Melanagromyza obtusa* Malloch) in Tamil Nadu. *Indian Journal of Pulses Research*, *18*(2), 260-265.

Ganguly, S., Srivastava, C. P., & Sitanshu (2017). Screening of some long duration genotypes of pigeonpea [*Cajanus cajan* (L.) Millisp.] against the infestation of pod fly (*Melanagromyza obtusa)*. *The Bioscan*, *13*(1), 153-157.

Gurusamy, S., Vidhya, C. S., Khasherao, B. Y., & Shanmugam, A. (2022). Pulses for health and their varied ways of processing and consumption in India-A review. *Applied Food Research, 2*(2), 100171.

Hadiya, G. D., Patel, S. D., Damor, C. B., Machhar, R. G., & Chavadhari, R. L. (2020). Impact of sowing period and variety on pod fly, *Melanagromyza obtusa* in Pigeonpea. *Journal of Entomology and Zoology Studies, 8*(3), 753-757.

Harshita, H. S., Gundannavar, K. P., Kambrekar, D. N., & Yenagi, B. S. (2024). Population dynamics of pod pest complex of pigeonpea. *Journal of farm sciences*, *37*(01), 32-35.

Indrasen, I., Ram Keval, R. K., Mishra, V. K., & Rahul Kumar, R. K. (2017). Efficacy of some newer insecticide against major insect pests in pigeonpea agro-ecosystem. *Journal of Experimental Zoology, 20*(1), 245-248.

Islam, S., Nanda, M. K., & Mukherjee, A. K. (2008). Effect of date of sowing and spacing on growth and yield of rabi pigeonpea (*Cajanus cajan* (L.) Millsp.). *Journal of Crop and Weed*, *4*(1), 7-9.

Jaisal, J. K., Srivastava, C. P., & Sharma, R. P. (2010). Resistance in long duration pigeon pea against major insect pests. *Annals of Plant Protection Sciences*, *18*(2), 501-502.

Jakhar, B. L., Singh, N., Venilla, S., Patel, M. H., Vekaria, M. V., Patel, B. D., & Panickar, B. (2016). Influence of climate change on *Helicoverpa armigera* (Hubner) in pigeonpea. *Journal of Agriculture and Ecology*, *2*, 25-31.

Jakhar, B. L., Singh, N., Tapre, P. V., Ravindrababu, Y., & Venilla, S. (2017). Study the influence of climate change on *Clavigralla gibbosa* (Spinola) in pigeonpea. *Journal of Agriculture and Ecology*, *4*, 37-43.

Jalondhara, R. M., & Patel, D. R. (2018). Population dynamics of insect pests of pigeonpea in south Gujarat. *Indian Journal of Entomology*, *80*(2), 207-210.

Jha, A. (2003). Population dynamics, life tables and management of pigeonpea pod borers (Doctoral dissertation, AAU, Anand). http://krishikosh.egranth.ac.in/handle/1/5810055669

Jeevarathinam, G., & Chelladurai, V. (2020). Pigeon pea. *Pulses: Processing and Product Development*, 275-296.

Jeyarani, S., & Karuppuchamy, P. (2010). Investigations on the enhancing efficacy of *granulovirus* on *nucleopolyhedrovirus* of *Helicoverpa armigera* (Hübner). *Journal of biopesticides*, *3*(1), 172.

Kar, A. (2017). Seasonal incidence on population dynamics of pigeonpea pod bug, *Clavigralla gibbosa* (Spinola). *Journal of Entomological Research*, *41*(4), 409-412.

Keval, R., & Srivastava, S. C. (2011). Seasonal incidence and pod infestation by Tur pod fly *Melanagromyza obtusa* (Malloch) on pigeonpea. *Indian Journal of Entomology*, *73*(1), 95-96.

Keval, R., Ganguly, H., & Chakravarty, S. (2018). Seasonal incidence of major insect pests on early maturing pigeonpea [*Cajanus cajan* (L.) Millsp.] In relation to abiotic factors of Varanasi region of Indo-Gangetic plain. *Advances in Research*, *17*(5), 1-13.

Keval, R., Kerketta, D., Nath, P., & Singh, P. S. (2010). Population fluctuations of pod fly on some varieties of pigeonpea. *Journal of Food Legumes*, *23*(2), 164-165.

Keval, R., Khamoriya, J., Chakravarty, S., & Ganguly, S. (2017[a]). Seasonal Incidence of Gram Pod Borer, *Helicoverpa armigera* (Hübner) and Tur Pod Fly, *Melanagromyza obtusa* (Malloch) on Late Maturing Pigeonpea in Varanasi Region of Indo-Gangetic Plain. *Journal of Experimental Agriculture International*, *19*(1), 1-8.

Keval, R., Kumar, R., Chakravarty, S., & Mishra, V. K. (2017[b]). Extent of damage caused by major insect pests on long duration pigeonpea [*Cajanus cajan* (L.) Millsp.] under natural conditions. *Plant Archives*, *17*(1), 643-646.

Keval, R., Srivastava, C. P., & Joshi, N. (2006). Integration of some pest management components against major insect pest of short duration pigeonpea. *Indian Journal of Pulses Research*, *19*(1), 140-142.

Khamoriya, J., Keval, R., Chakravarty, S., & Mishra, V. K. (2017). Seasonal incidence of tur pod bug, *Clavigralla gibbosa* (Spinola) (Hemiptera: Coreidae) on long duration pigeonpea. *Journal of Entomology and Zoology Studies*, *5*(4), 433-437.

Kumar, S. (2019). Population dynamics of pigeonpea pod fly (*Melanagromyza obtusa*) and their correlation with abiotic factors in pigeonpea. *Journal of Entomology and Zoology Studies*, *7*(6), 784-786.

Kumar, R., Keval, R., Yadav, A., & Srivastava, C. P. (2015). Field screening and evaluation of long duration pigeonpea genotypes against the infestation of pod fly (*Melanagromyza obtusa* Malloch). *The Ecoscan*, *7*, 291-295.

Kumar, G. S., Krishna, T. M., & Devaki, K. (2018). Biology and morphometrics of pod fly, *Melanagromyza obtusa* Malloch on pigeonpea *Cajanus cajan* (L.) Millsp. *Trends in Biosciences*, *11*(10), 2061-2063.

Kumar, G. S., Prasad, P. R., Krishna, T. M., Prasanthi, L., & Devaki, K. (2015). Effect of Abiotic Factors on The Incidence of Pod Fly, *Melanagromyza obtusa* (Malloch) in Early and Late Sown Pigeonpea Cultivars. *The Andhra Agricultural Journal*, *62*(1), 132-137.

Kumar, A., Lall, P. V., & Lal, D. (2011). Abiotic factors and pigeonpea pod fly, *Melanagromyza obtusa* (Malloch). *Indian Journal of Entomology*, *73*(1), 59-62.

Kumar, P., Mishra, D. N., Singh, D. V., Singh, R., & Mishra, P. (2022). Population fluctuation of pod borer, *Helicoverpa armigera* (Hübner) in relation with abiotic factors. *The Pharma Innovation Journal*, *11*(6), 1471-1474.

Kumar, A., & Nath, P. (2005). Study of the effect of meteorological factors on the population of insect pests infesting UPAS 120 cultivar of pigeonpea. *Journal of Maharashtra Agricultural Universities*, *30*(2), 190-192.

Kumar, A., & Soni, K. (2018). Population dynamics of *Helicoverpa armigera* and *Melanagromyza obtusa* on pigeonpea. *Indian Journal of Entomology*, *80*(4), 1642-1646.

Kumar, N. S., Yelshetty, S. D., Rathod, P. S., & Sreenivas, A. G. (2016). Bio-efficacy of insecticides for the management of pod fly, *Melanagromyza obtusa* Malloch (Diptera: Agromyzidae) in pigeonpea. *Journal of Experimental Zoology, India*, *19*(1), 591-595.

Lal, P. V., & Kumar, A. (2011). Influence of abiotic factors on seed infestation caused by *Melanagromyza obtusa* in pigeonpea. *Annals of Plant Protection Science, 19*(2), 485-486.

Mallikarjuna, N., Saxena, K. B., & Jadhav, D. R. (2011). *Cajanus*. In: Chittaranjan, K. (Eds). Wild crop relatives: genomic and breeding resources - legume crops and forages. Springer-Verlag Berlin Heidelberg.

Meena, B. M., Srivastava, C. P., & Sharma, R. P. (2010). Seasonal incidence of Pod fly, *Melanagromyza obtusa* (Malloch) on long duration Pigeonpea, (*Cajanus cajan* L.). *Annals of Plant Protection Sciences*, *18*(2), 394-399.

Minja, E. M., Shanower, T. G., Silim, S. N., & Karuru, O. (2000). Efficacy of different insecticides for pigeonpea pest management in Kenya. *International Chickpea and Pigeonpea Newsletter*, *7*, 53-55.

Moudgal, R. K.; Lakra, R. K., & Dahiya, B. (2005). Level of natural parasitization of *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae) on pigeonpea at Hisar. Association for Advancement of Entomology, Trivandrum, India. *Entomon*, *30*(3), 273-274.

Nagaraju, D., Kharbade, S. B., Jadhav, J. D., Balasubramanian, R., Shaikh, A. A., & Sthool, V. A. (2022). Assessment of correlation and forewarning models between weather parameters and population of *Melanagromyza obtusa* in pigeonpea varieties under different sowing windows. *The Pharma Innovation Journal*, *11*(3), 2404-2409.

Nair, N., Shah, S. K., Thangjam, B., Debnath, M. R., Das, P., Dey, B., Awasthi, D., & Hazari, S. (2017). Insect pest complex of Pigeon pea (*Cajanus cajan*) in agro ecosystem of Tripura, NE India. *Journal of Entomology and Zoology Studies*, *5*(4), 765-771.

Neharkar, P. S., Pravina, S. B., Kamdi, S. R., Lavhe, N. V., Gawande, R. W., & Masal, R. G. (2018). Efficacy of some newer insecticides in comparison with botanicals against Pod Borer complex in Pigeonpea. *International Journal of Current Microbiology and Applied Sciences*, 6, 911-919.

Padhi, A. K. (1995) "Effect of sowing date and planting geometry on yield of red-gram (*Cajanus cajan*) genotypes. *Indian Journal of Agronomy*, *40*(1), 72-76

Pandey, A. K., Keval, R., & Yadav, A. (2015). Population dynamics of legume pod borer *Maruca vitrata* (Geyer) and blue butterfly *Lampides boeticus* L. on short duration pigeonpea. *Research in environment and life sciences*, *8*(4) 777-778.

Pandey, A. K., Keval, R., Yadav, A., & Srivastava, C. P. (2016). Seasonal incidence of pod fly (*Melanagromyza obtusa* Malloch) and pod bug (*Clavigralla gibbosa* Spinola) in short duration pigeonpea. *Journal of Applied and Natural Science*, *8*(1), 28-30.

Pandey, A., Singh, S. K., Pandey, R., Mishra, M. K., Kumar, D., Shukla, G., & Kumar, J. (2024). Population build-up and seasonal occurrence of Pod Bug *Clavigralla Gibbosa* (Spinola) in long duration pigeonpea ecosystem in Bundelkhand Region of Uttar Pradesh. *Journal of Experimental Zoology*, *27*(1), 1145-1149.

Pandey, V., Srivastava, C. P., Nath, T., & Raha, P. (2011). Chemical traits of pigeonpea (*Cajanus cajan*) pod wall affecting pod fly (*Melanagromyza obtusa*) damage. *Indian Journal of Agricultural Sciences*, *81*(11), 1059.

Patange, N. R., & Chiranjeevi, B. (2017). Bioefficacy of newer insecticides against pigeonpea (*Cajanus cajan* L. Millsp.) pod borers. *Journal of Entomology and Zoology Studies*, *5*(3), 28-31.

Patange, N. R., Sharma, O. P., & Chiranjeevi, B. (2017[a]). Population dynamics of *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae) and its natural parasitization in pigeonpea. *Entomon*, *42*(3), 201-206.

Patange, N. R., Chiranjeevi, B., & Manickavasagam, S. (2017[b]). Impact of Weather Parameters on Parasitoids of Pigeonpea Pod Fly, *Melanagromyza obtusa* (Malloch). *The Bioscan*, *12*(1), 29-31.

Patel, H. P., Gurjar, R., Patel, K. P. N., & Patel, N. K. (2019). Impact of sowing periods on incidence of insect pest complex in Pigeonpea. *Journal of Entomology and Zoology Studies, 7*(2), 1363-1370.

Patel, J. D., & Patel, D. R. (2018). Avoidable losses due to pod borers in pigeonpea *Cajanus cajan* (L.) Millsp. *Trends in Biosciences*, *11*(13), 2390-2393.

Pawar, K. S., Dhavan, S. P., & Wadaskar, R. M. (2014). Temporal and intraday abundance variations of blister beetle *(Mylabris phalerata*) on green gram. *The Bioscan*, *9*(1), 65-69.

Pawar, R. B., Madandure, A. N., Jayewar, N. E., & Jangwad, N. P. (2007). Population dynamics and key mortality factors of *Helicoverpa armigera* on pigeonpea. *Crop Protection and Production Science*, *4*(1), 14-20.

Pillai, A. K., & Agnihotri, M. (2013). Seasonal incidence of pod fly, *Melanagromyza obtusa* (Malloch) and its hymenopteran parasitoids on pigeonpea. *Journal of Biological Control*, *27*(3), 190-193.

Priyadarshini, G., Reddy, C. N., & Reddy, D. J. (2013). Bio-efficacy of selective insecticides against lepidopteran pod borers in pigeonpea. *Indian journal of plant protection*, *41*(1), 6-10.

Rahman, S. M. A. S., Kumar, K. P., Naik, S. O., & Chakravarthy, A. K. (2017). Bio-Efficacy of Select Insecticides and Plant Products against the Pigeonpea Pod fly, *Melanagromyza obtusa* (Diptera: Agromyzidae) Malloch. *International Journal Pure Applied Bioscience, 5*(2), 826-835.

Rao, M. S., Reddy, K. D., Singh, T. V. K., & Reddy, G. S. (2003). Effect of Duration of Pigeonpea Cultivars and Intercropping on Pod Borders. *Annals of Plant Protection Sciences*, *11*(2), 232-236.

Rathore, H. K., Vyas, A. K., Ahir, K. C., Saini, A., & Kumar, P. (2017). Population dynamics of major insect pests and their correlation with weather parameters in pigeonpea (*Cajanus cajan* [L.] Mill sp.). *The Bio scan, 12*(1), 01-04.

Reddy, C. N., Singh, Y., & Singh, V. S. (2001). Effect of sowing time and plant type on pod borer incidence and grain yield in some pigeonpea genotypes. *Indian Journal of Entomology*, *63*(3), 215-220.

Reddy, D. V. C., Sreekanth, M., Sandhya, R. C., Adinarayana, M., & Rao, G.R. (2018). Time of application of insecticide in the management of Pod fly, *Melanagromyza obtusa* (Malloch) on Pigeonpea. *International Journal of Chemical Studies*, *6*(3), 316-319.

Revathi, K., Sreekanth, M., Krishnayya, P. V., & Rao, V. S. (2015). Incidence of pod fly, *Melanagromyza obtusa* (Malloch) and its influence on weight loss in different pigeonpea genotypes. *International Journal of Innovative Science, Engineering & Technology*, *2*(5), 460-464.

Revathi, K., Sreekanth, M., Krishnayya, P. V., & Rao, V. S. (2015a). Efficacy and Economics of Certain Newer Insecticides Against Pod Fly, *Melanagromyza obtusa* (Malloch) on Pigeonpea. *The Andhra Agriculture Journal*, *62*(4), 885-889.

Rubaihayo, P. R., Osiru, D. S. O., & Okware, P. (2000). Performance of pigeonpea and its finger millet and sorghum intercrops. *African Crop Science Journal*, *8*(1), 49-62.

Sandal, R. (2007). Management of blister beetles, *mylabris* species on pigeonpea (Doctoral dissertation, CSKHPKV, Palampur).

Sarkar, S., Panda, S., Yadav, K. K., & Kandasamy, P. (2020). Pigeon pea (*Cajanus cajan*) an important food legume in Indian scenario-A review. *Legume research-an international journal*, *43*(5), 601-610.

Saxena, H., Bandi, S., & Devindrappa, M. (2018). Pests of pulses. *Pests and Their Management*, 99-136.

Saxena, K., Choudhary, A. K., Dalvi, V. A., Saxena, R. K., Ghosh, J., Singh, S., Verma, P., & Kumar, S. (2021). Pigeonpea is significantly more than just a delicious pulse: Pigeonpea: Alternate uses. *Journal of Agri Search*, *8*(3), 177-187.

Sebastian, P. C. (1993). A study on the parasitoids of pigeon pea Pod fly, *Melanagromyza obtusa* (Malloch), in Kerala. *Indian Journal of Entomology*, *55*(2), 158-161.

Seni, A. (2021). Role of abiotic factors on the incidence of major insect pests of pigeonpea, *Cajanus cajan* (L.) Millsp. *Journal of Entomological Research*, *45*(suppl), 886-890.

Shanker, R., Singh, R. B., Patel, S., Patel, P. K., & Kumar, S. (2021[a]). Field evaluation of newer insecticides against pod fly (*Melanagromyza obtusa* Malloch) on pigeonpea (*Cajanus cajan*). *Journal of Entomological Research*, *45*(4), 724-727.

Shanker, R., Singh, R. B., Singh, S. P., Kumar, S., Patel, P. K., & Singh, A. K. (2021[b]). Seasonal activity of tur pod fly, *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae) and its relation with agro-climatic conditions of eastern Uttar Pradesh. *The Pharma Innovation Journal*, *10*(5), 716-718.

Sharma, O. P., Bhosle, B. B., Kamble, K. R., Bhede, B. V., & Seeras, N. R. (2011). Management of pigeonpea pod borers with special reference to pod fly (*Melanagromyza obtusa*). *Indian Journal of Agricultural Sciences, 81*(6), 539-543.

Sharma, H. C., Jaba, J., & Vashisth, S. (2017). Distinguishing proof and utilization of resistance of insect pests in grain legumes: progress and limitations. *Breeding insect resistant crops for sustainable agriculture*, 131-170.

Sharma, R., & Keval, R. (2021). Screening of pigeonpea [*Cajanus cajan* (L.) Millsp.] Against Tur Pod fly, *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae) in long duration pigeonpea genotypes. *Journal of Entomology and Zoology Studies*, *9*(3), 198-202.

Sharma, R., Keval, R., Yadav, S. P. S., & Yadav, B. (2022). Screening of pigeonpea [*Cajanus cajan* (L.) Millsp.] against blue butterfly, *L. boeticus* (L.) (Lepidoptera: Lycaenidae) in long duration pigeonpea genotypes. *The Pharma Innovation Journal*, *11*(9),1511-1514.

Singh, D. (1991). Three hymenopterous parasitoids of *Melanagromyza obtusa* (Malloch), a pest of tur, *Cajanus cajan* (L.) Millsp. *Journal of Entomological Research*, *15*(4), 282-286.

Singh, M. K., Keval, R., Chakravarty, S., & Mishra, V. K. (2017). Screening of pigeonpea genotypes against tur pod fly, *Melanagromyza obtusa* (Malloch) in agroecosystem. *International Journal of Current Microbiology and Applied Sciences*, *6*(3), 1911-1917.

Singh, G., Singh, R., & Singla, A. (2021). Seasonal abundance of Blister Beetle, *Mylabris pustulata* Thunberg on Pigeonpea and Mung bean. *MAUSAM*, *72*(3), 645-648.

Singh, G., Singh, R., & Singla, A. (2022). Estimation of crop losses in *Cajanus cajan* (L.) Millsp. and Vigna radiata (L.) Wilczek caused by blister beetle, *Mylabris pustulata* Thunberg (Coleoptera: Meloidae). *International Journal of Tropical Insect Science*, *42*(4), 3143-3150.

Singh, K., Singh, B. K., Singh, A. K., Pandey, R., Singh, A. K., Singh, S., & Singh, H. (2024). Damage of *Melanagromyza obtusa* (Malloch) and Management Potential of Newer Insecticides in Pigeon Pea. *Legume Research-An International Journal*, *47*(5), 866-871.

Somasundaram, J., Singh, R. K., Kumar, A., Sinha, N. K., & Patra, A. K. (2017). Ratoon Pigeon Pea An alternate source of income for rainfed farmers. *Indian Farming*, *67*(6), 04-05.

Soni, K. K., Kumar, A., Srivastava, P., Sahu, P. S., & Khan, H. H. (2018). Studies on population dynamics of *Helicoverpa armigera* and *Melanagromyza obtusa* in pigeonpea. *Journal of Entomology and Zoology Studies*, *6*(6), 61-64.

Sreekanth, M., Seshamahalakshmi, M., & Ramana, M. V. (2020). Management of Pod fly, *Melanagromyza obtusa* on Pigeonpea (Cajanus cajan L.). *Agricultural Science Digest-A Research Journal*, *40*(4), 382-386.

Srivastava, C. P., & Joshi, N. (2011). Insect pest management in pigeon pea in Indian scenario: a critical review. *Indian Journal of Entomology*, *73*(1), 63-75.

Srinivas, G., Kumar, S., & Patel, N. M. (2019). Seasonal abundance of pod fly, *M. obtusa* and seed damage on pigeonpea pea in relation to weather factors and cropping systems. *Journal of Entomology and Zoology Studies*, *7*(1), 1404-1408.

Srujana, Y., & Keval, R. (2014). Periodic occurrence and association of pod fly and pod bug on long duration pigeon pea (Bahar) with weather parameters. *Journal of Experimental Zoology*, *17*(2), 595-597.

Steck, G. J. (2003). Pigeonpea Pod Fly *Melanagromyza obtusa* (Malloch) (Agromyzidae). *Pest Alert*, 1703.

Subharani, S., & Singh, T. K. (2007). Influence of meteorological factors on population dynamics of pod fly, *Melanagromyza obtusa* Malloch (Diptera: Agromyzidae) in pigeonpea under agro-climatic conditions of Manipur. *Indian Journal of Entomology*, *69*(1), 78-80.

Subharani, S., & Singh, T. K. (2009). Biology of pod fly, *Melanagromyza obtusa* Malloch on *Cajanus cajan* (L.) Millsp. in Manipur, India. *Journal of Ecology and The Natural Environment*, *1*(9), 206-208.

Taveras, R., & Hansson, C. (2015). Pediobius *cajanus* sp. n. (Hymenoptera, Eulophidae), an important natural enemy of the Asian fly (*Melanagromyza obtusa* (Malloch) (Diptera, Agromyzidae) in the Dominican Republic. *Journal of Hymenoptera Research*, *45*, 41-54.

Tyagi, S., Keval, R., & Verma, S. (2022). Screening of Some Long Duration Pigonpea (*Cajanus cajan* (L.) Millsp.) Genotypes against Major Insect Pests in Varanasi. *Annals of Plant and Soil Research*, *24*(3), 491-495.

Upadhyaya, H. D., Reddy, K. N., Ramachandran, S., Kumar, V., Singh, S., Reddy, M. T., & Ahmed, M. I. (2015). Status and genetic diversity in pigeonpea germplasm from Caribbean and Central American regions at ICRISAT gene bank. *Plant Genetic Resources*, *13*(3), 247-255.

Vidya, Keshavareddy, G., & Lohithaswa, H. C. (2022). The incidence of pod fly, *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae) in major pigeonpea growing areas of southern Karnataka and its biology on pigeonpea, *Cajanus* *cajan* (L.) Millsp. *Mysore Journal of Agricultural Sciences*, *56*(4), 432-438.

Vikram, A., Keval, R., Srivastava, C. P., & Yadav, A. (2015). Seasonal incidence of pod fly, *Melanagromyza obtusa* (Malloch) and pod bug, *Clavigralla gibbosa* (Spinola) in long duration pigeonpea. *Journal of Experimental Zoology, India*, *18*(2), 795-797.

Yadav, S. K., Ahuja, D. B., & Dhandapani, A. (2011[a]). Seasonal activity of pod fly, *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae) and effect of abiotic factors on its incidence in pigeonpea. *Indian Journal of Entomology*, *73*(2), 162-165.

Yadav, A. K., Yadav, S., & Singh, M. K. (2011[b]). Impact of climatic variation on the parasitoid complex of *Melanagromyza obtusa* (Diptera: Agromyzidae). *Journal of Ecobiology*, *29*(3), 161-172.

Yadav, A. K., Yadav, S., & Singh, M. K. (2012). Effect of temperature on the population of parasitoids and their impact on the pest, *Melanagromyza obtusa* (Diptera: Agromyzidae). *The Ecoscan*, 1, 45-50.

Yadav, A. K., & Yadav, S. (2013). Studies on the biological characteristics of *Ormyrus orientalis* (Ormyridae: Hymenoptera), a major parasite of pigeonpea pod fly *Melanagromyza obtusa* (Diptera: Agromyzidae). *Journal of Experimental Zoology, India*, *16*(1), 169-172.

Yadav, D. K., Sachan, S. K., Singh, G., & Singh, D. V. (2016). Insect pests associated with pigeonpea variety UPAS 120 in Western Uttar Pradesh, India. *Plant Archives*, *16*(1), 140-142.

Yadav, S. K., Kumar, P., Singh, G., Gautam, C. P. N., Sharma, S., Kumar, S., & Nishad, R. N. (2020). Study the natural enemies associated with pigeonpea pod fly. *International Journal of Chemical Studies, 8*(5), 97-99.

LIST OF PUBLICATIONS

1. **Singh, M. K., Dwivedi, S. K. and H. M. Singh, 2024.** Population dynamics of pod fly, *Melanagromyza obtusa* (Malloch) and its natural enemies on pigeonpea. *Entomon*, 49(4): 519-526.
2. **Singh, M. K., Dwivedi, S. K. and J. Singh, 2024.** Studies on natural enemies associated with pod fly, *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae) on pigeonpea and their correlation with weather parameters. *Journal of Biological Control*, 38(2): 191-196.
3. **Singh, M. K., Dwivedi, S. K., Upadhyay, M., Dhiman, R., Sharma, A., Kumari, S. and J. A. Ashok, 2024.** Natural hymenopteran parasitoids of pod fly, *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae) on pigeonpea UPAS 120 in relation to weather parameters. *African Journal of Biological Sciences*, 6(5): 1056-1069.

CONFERENCES

1. International Seminar on Current Trends in Life Sciences (Int-SCTLS-2023) held at Amity Institute of Biotechnology & Department of Environmental Sciences, Amity University, Gwalior (M.P.) ***1st March 2023***
2. National Conference on Depletion of Biodiversity & Conservation Strategies held at Department of Zoology & Department of Biotechnology, Agra College, Agra ***21st March 2023***
3. Recent Advances in Smart and Sustainable Agriculture for Food and Nutritional Security-2023 ***22-23rd November 2023***
4. International Conference on Multidisciplinary Research & Practice held at Dr. Bhim Rao Ambedkar University, Agra ***16-18th December, 2023***
5. International Conference "Recent Advances in Smart and Sustainable Agriculture for Food and Nutritional Security-2023" held at Lovely Professional University, Punjab ***22-23rd November 2024***

PATENTS

1. The Solar-Driven System for Efficient Grain ad Chaff Separation ***20th October 2024***
2. Novel Organic Formulation for Sustainable Pest Management ***23rd October 2024***