

Impact of flea beetle (*Phyllotreta Cruciferae*) on growth and development of mustard (*brassica juncea*) with reference to nanomaterial

Kuldeep Meena¹, Dr. Sumita Kachwaa²

¹Assistant Professor, Dyal Singh College, Lodhi Road, New Delhi

²Associate Professor, University of Rajasthan, Jaipur

Abstract—Flea beetle (*Phyllotreta cruciferae*) infestation severely limits the productivity of mustard (*Brassica juncea*), an essential oilseed crop, especially in the early stages of growth. **Objective:** The purpose of the study was to assess how natural flea beetle infestation affected mustard leaf damage, growth metrics, and seed yield in field settings. **Method:** The observational study was conducted in a field-based study during the rabi season with a sample of 75 mustard plants being selected in 5 fields. The incidence of flea beetles was obtained by means of sweep net sampling and ocular counts. Percentage Leaf Damage Index (PLDI) was employed to measure the amount of leaf damage and the plants with least and highest infestation compared to measure the level of growth reduction and yield loss. **Result:** PLDI increased to 26.67 percent in infested plants with the highest level of infestations to 6.67 percent in least infested plants. Under severe infestations the height of the plant, the number of leaves and leaf area index reduced by 25.4 percent, 34.4 percent and 35.7 percent respectively. The seed production was reduced by 38.2 in severely affected plants. **Conclusion:** Mustard growth and yield are significantly reduced by flea beetle infestation, highlighting the necessity for efficient and long-lasting pest management techniques.

I. INTRODUCTION

Mustard (*Brassica juncea*) is one of the most important oilseeds in the world, and India is the major producer in this region, as it produces a great deal of edible oil, biofuel, and industrial raw materials [1]. Its production guarantees food and nutritional security and plays a significant role in the agricultural economies [2]. Nevertheless, several types of biotic stressor often reduce the productivity of mustard, and insect pests have played a significant role in reducing yield and quality [3]. The flea beetle (*Phyllotreta cruciferae*) is

one of the worst pests of mustard among them [4]. The cotyledons, leaves, and young stems of mustard plants are the main food sources for flea beetles, which are tiny, hopping insects [5]. Their feeding habits cause distinctive "shot-hole" damage to the leaves, which seriously impairs nutrient transfer, photosynthesis, and the general health of the plant [6]. Early growth stage infestation can result in reduced leaf area, delayed germination, stunted growth, and in extreme situations, total crop failure [7]. Flea beetle attacks have an impact on mustard's qualitative characteristics, like oil content and seed quality, in addition to its quantitative yield losses. This has an impact on both market value and food security [8].

➤ Impact of Flea beetle (*Phyllotreta cruciferae*) on mustard

The flea beetle is one of the worst pests of mustard, that infests young stems, leaves and cotyledons [9]. It has unique shot-hole damage that retards growth, decreases photosynthetic ability, and can result in a loss of leaf area and a slowing of development [10]. Even in the situation of total crop loss, the severe cases of infestation in the initial growth can lead to the loss of crops [11]. The pest affects the quality of the seeds and their yields including oil level [12]. In order to enhance the sustainable production of mustard and come up with effective management practices, there is a need to study the interaction between the flea beetles and the mustard plants [13].

➤ Significance and cultivation of Mustard (*Brassica juncea*)

Mustard is a very important oil seed crop in its culinary oil and nutritional value as well as industrial use [14].

It is very crucial to agricultural economy and rural population. Nonetheless, the productivity of it is often threatened by insect pests, diseases, and environmental conditions that influence the growth and development of plants and the quality of their yield [15]. The production of mustard has significant economic value especially in such countries as China, India, and Canada where the production of mustard contributes to the livelihoods of rural area inhabitants and the GDP of agriculture [16]. The plant grows in cool and temperate climates and would normally be planted in regions of moderate precipitation as well as well drained soils [17]. Mustard is a common rabi crop that is grown in India, with variations in the time of sowing [18].

II. LITERATURE REVIEW

Li et al., (2024) indicated that several species of flea beetles (Chrysomelidae: Alticini) damage Brassica vegetable and oilseed crops. Two *Phyllotreta* species that are significant oilseed rape pests in North America, *Phyllotreta striolata* and *Phyllotreta cruciferae*, have been the subject of the majority of research during the past few decades. “The cabbage stem flea beetle, *Psylliodes chrysocephala*”, has grown significantly in importance and is currently regarded as the main pest of winter oilseed rape in Europe, particularly since the European Union banned neonicotinoids. Predicting population dynamics in the field, varying pesticide susceptibility, and the absence of resistant plant cultivars and other commercially feasible alternative management techniques are the main obstacles to flea beetle control. However, there are still many basic facets of flea beetle biology and ecology that are little known and may be important for the creation of long-term management methods [19]. Woodland et al., (2024) reported that the striped flea beetle, “*Phyllotreta striolata* (Fabricius) (Coleoptera: Chrysomelidae), and the crucifer flea beetle, *Phyllotreta cruciferae* (Goeze) (Coleoptera: Chrysomelidae), are major economic pests to canola crops, *Brassica napus* (L.) (Brassicaceae), in the Canadian prairies”. Cause recurrent yield losses by defoliating canola seedlings. Chemical control through seed-coated and foliar spray treatments is a major component of current management practices in the Canadian prairies. There has been an emphasis on alternative flea beetle management techniques, such as

changing plant density and identifying potential natural enemies, in order to reduce the use of chemical pesticides due to possible negative environmental impacts. “The effects of temperature, plant density, and predators on cotyledon and stem feeding by both species of flea beetles in terms of damage intensity and prevalence” were investigated in laboratory experiments conducted in petri dishes and microcosms [20].

Roy (2024) observed that in India and around the world, mustard is an important oilseed crop that needs careful management to continue producing. In order to manage pests in mustard agriculture, integrated pest management, or IPM, is crucial. In order to direct prompt responses, this chapter emphasizes the significance of systematic field monitoring, scouting, and establishing Economic Threshold Levels (ETLs). Deep ploughing, clean cultivation, and early sowing are examples of cultural techniques that are emphasized for lowering pest pressure. It also includes biological control using natural enemies and biopesticides as environmentally benign substitutes, as well as mechanical and physical controls including sticky traps and human removal. Chemical management is taken into consideration, with a focus on applying insecticides based on ETLs to preserve ecological balance and safeguard pollinators. This all-encompassing strategy is essential for long-term pest control in mustard farming, guaranteeing output and environmental responsibility [21].

Verma et al., (2023) in the “Roorkee region of Uttarakhand's Haridwar district”, a field experiment was conducted in 2021 and 2022 during the rabi season to investigate the insect pests linked to rapeseed mustard. About eight different insect-pest species have been connected to rapeseed mustard in this area. It has been observed that the mustard aphid, *Lipaphis erysimi*, is continuously growing in number and harming mustard crops economically. While mustard sawflies, “*Athalia lugens proxima*, flea beetles, *Phyllotreta cruciferae*, and painted bugs, *Bagrada cruciferarum*”, caused minor pest damage to the crop from seedling to maturity, it happened from flowering to the crop's maturity stage. The rose aphid *Macrosiphum rosae*, the cabbage butterfly “*Pieris brassicae*, and the cabbage aphid *Brevicoryne brassicae* were all observed in isolated”, low-population instances during the vegetative stage. Benefit ratio of insecticide applications, and can lessen

the use of chemical insecticides by recognizing their natural foes [22].

Mason et al., (2020) indicated that although flea beetles are frequent pests of eggplant “(*Solanum melongena* L., Solanales: Solanaceae) and cabbage (*Brassica oleracea* L., Brassicales: Brassicaceae)”, little is known about flea beetle numbers in Virginia, their effects on yield, or the best ways to eradicate them. In order to identify the most effective control strategies, this study examines flea beetle numbers and the effects of their feeding harm on cabbage and eggplant in Southwest Virginia. Cabbage and eggplant harvests were vacuum sampled every week for two summers at Whitethorne, Virginia (2015, 2016). “*Phyllotreta cruciferae* (Goeze), a crucifer flea beetle (Coleoptera: Chrysomelidae), and *Phyllotreta striolata* Fabr, a striped flea beetle”. Flea beetle populations, defoliation, and individual plant yields were measured at harvest in order to determine the effects of flea beetle feeding on these plants. Significant yield losses of 1–20% and >60% defoliation were noted for cabbage [23].

Yadav and Rathee (2020) reported that the rapeseed mustard crop basket is extremely susceptible to a wide range of insect pests at all stages of plant development, which have been shown to reduce oilseed crop yields by 15–30% in India and other areas of the world. More than thirty insect pest species are known to devastate India's main Rabi oilseed crops, rapeseed and mustard. The insect pests that consume these crops can be broadly categorized as putrefying (Diptera), “piercing and/or sucking” “(Heteroptera, Homoptera, Thysanoptera), and chewing (Coleoptera, Lepidoptera, Hymenoptera)”. The worldwide distribution, identification, life cycle, kind of damage, magnitude of losses, and integrated pest control of the main sucking pests of rapeseed mustard have all been discussed [24].

Neupane et al., (2018) reported that one of the most popular “vegetable crops in Nepal is broad leaf mustard (BLM) (*Brassica juncea* L. var. *rugosa*, Brassicaceae)”. Major pests like flea beetles and mustard aphids limit crop productivity in open fields. Analyze the impact of a pest exclusion net (PEN) on the yield and pest infestation of the BLM cultivar “Khumal Broad Leaf.” The study used four replications and five treatments in a randomized complete block design (RCBD). “Control (no mulch + no net + no pesticide spray), black plastic mulch alone,

reflective plastic mulch alone, black plastic mulch + no net + pesticide spray, and PEN + black plastic mulch + no pesticide spray were among the treatments”. The RSTAT software program was used to analyze the data, and Duncan's multiple range test (DMRT) was used to separate the means at the 5% significant level [25].

III. METHODOLOGY

- Study design: The study was aimed at determining the natural impacts of flea beetle (*Phyllotreta cruciferae*) infestation on the growth of mustard (*Brassica juncea*) and its development through field observation and analyses. No chemical control procedures were applied during the period of the study.
- Study area and duration: The study was conducted in a few of the study area's mustard-growing fields during the rabi cropping season. From the time seedlings emerged until the crop reached maturity, observations were made.
- Sample size: Five mustard fields were chosen at random. A total of 75 plants made up the sample size after fifteen plants were chosen at random from each field.
- Inclusion criteria
 - ✓ Mustard plants cultivated in farmer's fields
 - ✓ Fields with a natural flea beetle infestation
 - ✓ Plants chosen at consistent phases of growth
 - ✓ Fields kept according to standard agronomic procedures
- Exclusion criteria
 - ✓ Insecticide-treated fields throughout the observation period
 - ✓ Plants with viral or fungal infections
 - ✓ Water-stressed or nutrient-deficient plants
 - ✓ To reduce edge effects, use border plants.
- Technique for pest population estimation
Optical counting and sweep net sampling were used to calculate the population of the flea beetles. The fields were also swept 10 times and the number of insects was recorded. Observations were done weekly during the vegetative and early stages of development.

➤ Technique for damage assessment

A visual estimating method was used to calculate the percentage of damaged leaf area in order to measure leaf injury. Based on the degree of "shot-hole" symptoms, damage severity was divided into three categories: low, moderate, and high.

3.1. Percentage leaf damage index (PLDI) A Percent Leaf Damage Index was utilized to measure the amount of leaf damage produced by flea beetles. Five leaves were randomly selected from each plant, and the number of shot holes in each leaf was tallied.

$$PLDI = \frac{\text{number of damage leaves}}{\text{total number of observed leaves}} \times 100$$

3.2. Pest incidence per plant in the early morning, a direct visual count was used to determine the average number of flea beetles per plant. To enable numerical comparison between growth stages, the data were presented as the mean number of beetles per plant ± standard error.

3.3. Growth reduction percentage: by comparing infested and least-infested plants, the growth loss caused by flea beetle infestation was computed using the following formula:

$$\text{Growth reduction (\%)} = \frac{C-T}{C} \times 100$$

- C = Mean value of growth parameter in least-infested plants
- T = Mean value of growth parameter in highly infested plants

3.4. Yield loss estimation (%) Yield loss due to flea beetle infestation was calculated using the formula:

$$\text{Yield loss (\%)} = \frac{Y_1 - Y_2}{Y_1} \times 100$$

Where:

- Y₁ = Mean yield of least-infested plants
- Y₂ = Mean yield of highly infested plants

IV. RESULT

4.1. Sample size: The impact of flea beetle (*Phyllotreta cruciferae*) infestation on mustard (*Brassica juncea*) was evaluated in this study using a multistage random sampling technique.

- Number of field selected :5 mustard-growing field

- Number of plants sample per field= 15 plants (randomly selected)

Total sample size = 5 field × 15 plants = 75 plants

4.2. Percentage leaf damage index (PLDI)

Table1: Percentage leaf damage index (PLDI)

Infestation level	Number of damage leaves	Total leaves observed	PLDI (%)
Least infested	375	25	$(25/375) \times 100 = 6.67\%$
Moderate infested	375	50-75	$(50-75/375) \times 100 = 13.33-20.00$
Highly infested	375	100	$(100/375) \times 100 = 26.67\%$
Overall	375	175-200	46.67-53.33%

Interpretation In the PLDI data, the mustard leaves are highly affected by the infestation of flea beetle. The PLDI of the least affected plants was 6.67, that of the moderately affected plants was 13.33- 20, and that of the severely affected plants was 26.67. All in all, the damages caused in the 375 leaves was 175-200 (46.67- 53.33% PLDI), which indicates that the more the infestation is, the more the foliar damage and potential loss of yield.

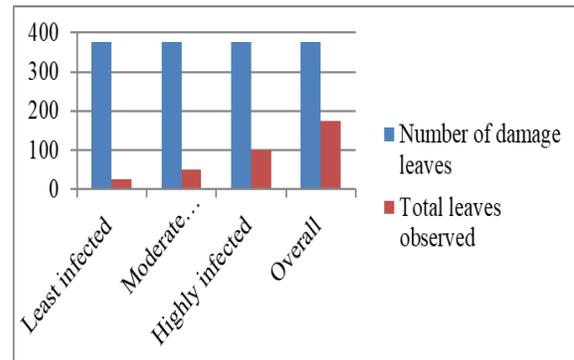


Fig 4.1: “Leaf Damage Caused by Flea Beetle (*Phyllotreta cruciferae*) Infestation in Mustard (*Brassica juncea*)”

Interpretation: The bar graph will show the percentage of damaged leaves to the total number of leaves observed at different levels of infection. The damaged leaves at various levels of infection levels- least, moderate, and highly infested are almost similar at approximately 375. However, in the very infested

plants, the total count of leaves rose to 100, making a total of 175. This indicates that the damage of leaves is widespread, but the proportion of the damaged leaves is larger in plants having fewer leaves in total.

4.3. Growth reduction percentage

Table2: Growth reduction percentage

➤ Formula used = Growth reduction (%) = $\frac{C-T}{C} \times 100$

Growth parameter	Least infested plants (C)	Highly infested plants (T)	Growth reduction (%)
Plant height (cm)	162.5	121.3	$\frac{(162.5-121.3)}{162.5} \times 100 = 25.4\%$
Number of leaves / plants	18.6	12.1	$\frac{(18.6-12.1)}{18.6} \times 100 = 34.4\%$
Leaf area index	4.2	2.7	$\frac{(4.2-2.7)}{4.2} \times 100 = 35.7\%$

Interpretation: The infestation of the flea beetle on the development of the mustard plant is presented in the table. The height of the plants dwarfed by 25.4 per cent, the highest height of 162.5 cm in the least diseased plants shrubs to 121.3 cm in the worst-diseased ones. The number of leaves per plant (18.6 to 12.1) dropped by 34.4 percent and the leaf area index dropped by 35.7 percent (4.2 to 2.7). Based on these results, the growth of plants as indicated by the flea beetle’s infestation is significantly less thus affecting the development of the leaves as well as plant size.

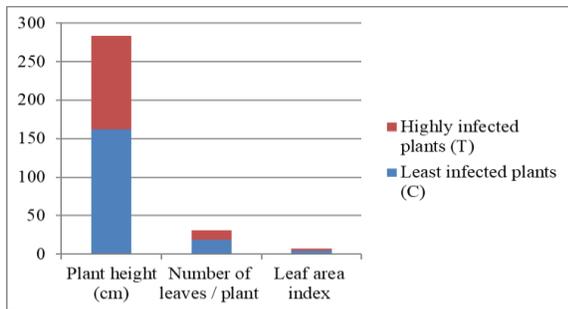


Fig 2:” Effect of Infection on Growth Parameters of Mustard Plants”

Interpretation: As shown in the bar graph, the effect of infection on the mustard plants was determined by comparing highly infested mustard plants (T) and least

infested mustard plants (C) on three growth parameters, including height of the plants, number of leaves per plant and the leaf area index. Plants that are highly infested have reduced growth in all measures, with the most significant change in the plant height. The leaves of infested plants are also far fewer with lesser leaf area index implying that infection has a serious inhibitory effect on overall plant development.

4.4. Yield loss estimation

➤ Formula used: Yield loss (%) = $\frac{Y1-Y2}{Y1} \times 100$

Were

Yi = mean yield of least – infested plants (15.2)

Y2 = mean yield of highly infested plants (9.4)

Table3: "Effect of Flea Beetle Infestation on Seed Yield of Mustard Plants"

Parameter	Least infested plants (Y1, g/plants)	Highly infested plants (Y2, g/ plants)	Yield loss (%)
Seed yield per plants	15.2	9.4	$\frac{(15.2-9.4)}{15.2} \times 100 = 38.2$

Interpretation: The influence of flea beetle infestation on mustard seed yield is shown in the table. Highly infested plants delivered only 9.4 g of seeds per plant, while least afflicted plants produced an average of 15.2 g. This indicates that a heavy flea beetle infestation significantly lowers mustard productivity, with a yield loss of 38.2%.

V. DISCUSSION

The study demonstrates that mustard leaf damage increases with flea beetle infestation, with PLDI increasing from 6.67% in least-infested plants to 26.67% in highly afflicted plants. The overall percentage of damaged leaves ranged from 46.67 to 53.33%, indicating that severe infestations pose a serious danger to plant health and productivity. Chen and Liu (2023). In crop pest control and ecology, estimating population density is an essential subject. Small-scale creatures, like insects, are difficult to estimate in terms of density because of their abundance and poor visibility. The main adversary of crops is a herbivorous insect, which frequently results in significant losses. “Based on these four physiological characteristics of BPH-damaged rice

leaves compared to those of healthy leaves, four ratio physiological indices were developed, and showed a strong correlation with BPH density in rice plants” [26].

The study confirms that flea beetle infestation dramatically slows mustard plant vegetative growth. In comparison to least-infested plants, heavily infested plants saw a 25.4% loss in plant height, a 34.4% decrease in the number of leaves per plant, and a 35.7% fall in the leaf area index. This shows that mustard growth and development are significantly hampered by increased pest infestation. Sharf et al., (2021) More than 500 plant species are afflicted by the soil-borne fungus *Sclerotium rolfsii*. Intended to evaluate the potential of two plant-growth-promoting rhizobacteria (PGPR) species, “*Bacillus megaterium* and *Pseudomonas fluorescense*, as well as an allelopathic weed, *Anagallis arvensis* L., for the management of chili southern blight disease [27]”. Plant survival was lower (73%) in the positive control treatment (*S. rolfsii* alone) than in the negative control (100%). Compared to the positive control, “OSR3, PF-097, OSR3 + 2% DBA, and PF-097 + 2% DBA” greatly increased plant survival.

The study demonstrates that mustard seed yield is considerably decreased by flea beetle infestation. A yield loss of 38.2% resulted from highly infested plants producing 9.4 g per plant, whereas least-affected plants produced 15.2 g. This proves that a serious flea beetle infestation can significantly reduce crop yields. Singels et al., (2019) A significant amount of the world's sugarcane is grown under irrigation, which frequently takes place in regions with unreliable or scarce water supplies. For several fields on a farm, the model determines crop output and “survival for the current (Y1) and upcoming (Y2)” seasons under specific irrigation strategies, water supply, and climate conditions [28]. A slightly and severely restricted allocation (about 50% and 25% of the total allocation) during a 24-month and 12-month timeframe were the four scenarios of restricted water allocation that were examined.

VI. CONCLUSION

The study indicates that the infestation of the flea beetles (*Phyllotreta cruciferae*) seriously affects the growth and development and yield of mustard “(*Brassica juncea*)”. Percentage Leaf Damage Index (PLDI) was found to increase by 6.67 per cent in plants

that were least infested to 26.67 per cent in the highly infested plants. The extent of the damage to the leaves was 46.67-53.33 percent in total with the severity of the infestation increasing. The height of the plants, the number of leaves per plant and the leaf area index declined by 25.4, 34.4 and 35.7, respectively, at extreme infestation. Plants that were highly infested experienced a 38.2 percent reduction in the seed productions. These findings highlight the importance of the application of effective methods of integrated pest management to ensure the protection of mustard crops and maintain productivity.

REFERENCE

- [1] Jat RS, Singh VV, Sharma P, Rai PK. Oilseed brassica in India: Demand, supply, policy perspective and future potential. OCL. 2019;26:8.
- [2] Pawlak K, Kołodziejczak M. The role of agriculture in ensuring food security in developing countries: Considerations in the context of the problem of sustainable food production. Sustainability. 2020 Jul 7;12(13):5488.
- [3] Choudhary V, Kumar KK, Sahu BH, Muthappa SK, Das AD. Agronomic innovations in biotic stress management and its combined effect with abiotic stresses in crop production. Indian J Agron. 2021;66(5):237-57.
- [4] Metspalu L, Kruus E, Ploomi A, Williams IH, Hiiesaar K, Jõgar K, Veromann E, Mänd M. Flea beetle (*Chrysomelidae: Alticinae*) species composition and abundance in different cruciferous oilseed crops and the potential for a trap crop system. Acta Agriculturae Scandinavica, Section B—Soil & Plant Science. 2014 Oct 3;64(7):572-82.
- [5] SARWAR M. 14 Integrated Control of Insect Pests. Integrated Management of Insect Pests on Canola and Other Brassica Oilseed Crops. 2017 Apr 26:193.
- [6] Egie M, Sherif M, Dejene T. Fundamentals Crop Health.
- [7] Mduma HS, Mkindi M, Karani A, Ngiha K, Kalonga J, Mohamed Y, Mbega ER. Major signs and symptoms caused by biotic and abiotic agents on plants in the tropical Africa. Int J Sci Res. 2015;6:750-9.

- [8] FARUK M. EFFECT OF INSECTICIDES APPLICATION TIMING ON INSECT PEST ATTACK, GROWTH, YIELD AND NUTRIENTS CONTENT OF MUSTARD.
- [9] Cranshaw W, Al-Doghairi MA. Flea beetles. Colorado State University Cooperative Extension; 2006.
- [10] Shyam Prasad G, Babu KS, Subbarayudu B, Bhagwat VR, Patil JV. Identification of sweet Sorghum accessions possessing multiple resistance to shoot fly (*Atherigona soccata* Rondani) and spotted stem borer (*Chilo partellus* Swinhoe). *Sugar Tech*. 2015 Jun;17(2):173-80.
- [11] Oerke EC. Crop losses to pests. *The Journal of agricultural science*. 2006 Feb;144(1):31-43.
- [12] Gagic V, Riggi LG, Ekbom B, Malsher G, Rusch A, Bommarco R. Interactive effects of pests increase seed yield. *Ecology and Evolution*. 2016 Apr;6(7):2149-57.
- [13] Akhatar J, Upadhyay P, Kumar H. Crop Cultivation and Hybrid Seed Production Strategies in Rapeseed-Mustard. In *Hybrid Seed Production for Boosting Crop Yields: Applications, Challenges and Opportunities* 2025 Mar 1 (pp. 177-224). Singapore: Springer Nature Singapore.
- [14] Kaur R, Sharma AK, Rani R, Mawlong I, Rai PK. Medicinal Qualities of Mustard Oil and Its Role in Human Health against Chronic Diseases: A Review. *Asian Journal of Dairy & Food Research*. 2019 Apr 1;38(2).
- [15] Liliane TN, Charles MS. Factors affecting yield of crops. *Agronomy-climate change & food security*. 2020 Jul 15;9:9-24.
- [16] Sharma P, Sharma HO, Rai PK. Strategies and technologies for enhancing rapeseed-mustard production and farmer income. *Indian Farming*. 2018;68(1).
- [17] Hilgard EW. Soils: their formation, properties, composition, and relations to climate and plant growth in the humid and arid regions. Good Press; 2025 Mar 2.
- [18] Jiotode DJ, Parlawar ND, Patil SR, Kuchanwar OD, Khawle VS, Dhanwate AG. Effect of weather parameter on rabi mustard varieties under different sowing dates. *International Journal of Researches in Biosciences, Agriculture & Technology*. 2017;5(2):72-8.
- [19] Li Z, Costamagna AC, Beran F, You M. Biology, ecology, and management of flea beetles in Brassica crops. *Annual review of entomology*. 2024 Jan 25;69(1):199-217.
- [20] Woodland S. Effects of ground predators, abiotic factors and plant density on the flea beetles, *Phyllotreta cruciferae* (Goeze) and *Phyllotreta striolata* (F.)(Coleoptera: Chrysomelidae).
- [21] Roy SD. Integrated Pest Management in Mustards.
- [22] Verma PK, Varma A, Aggarwal G. Studies on insect-pests complex of rapeseed mustard and their natural species in Roorkee Region, Uttarakhand, India. In *Biological Forum-An International Journal* 2023 (Vol. 15, No. 5, pp. 529-533).
- [23] Mason J, Michael Alford A, Patrick Kuhar T. Flea beetle (Coleoptera: Chrysomelidae) populations, effects of feeding injury, and efficacy of insecticide treatments on eggplant and cabbage in southwest Virginia. *Journal of Economic Entomology*. 2020 Apr 6;113(2):887-95.
- [24] Yadav S, Rathee M. Sucking pests of rapeseed-mustard. In *Sucking pests of crops* 2020 Oct 13 (pp. 187-232). Singapore: Springer Singapore.
- [25] Neupane RC, Shrestha AK, Regmi R, Fooyontphanich K, Devkota AR. Effect of pest exclusion net (PEN) on the sustainable production of late season broad leaf mustard (BLM) in Chitwan, Nepal. *Journal of Agricultural Science and Technology A*. 2018;8:315-22.
- [26] Chen M, Liu XD. Estimating insect pest density using the physiological index of crop leaf. *Frontiers in Plant Science*. 2023 Aug 10;14:1152698.
- [27] Sharf W, Javaid A, Shoaib A, Khan IH. Induction of resistance in chili against *Sclerotium rolfsii* by plant-growth-promoting rhizobacteria and *Anagallis arvensis*. *Egyptian Journal of Biological Pest Control*. 2021 Jan 15;31(1):16.
- [28] Singel KL, Emmons TR, Khan AN, Mayor PC, Shen S, Wong JT, Morrell K, Eng KH, Mark J, Bankert RB, Matsuzaki J. Mature neutrophils suppress T cell immunity in ovarian cancer microenvironment. *JCI insight*. 2019 Mar 7;4(5):e122311.