Original Research Article

Evaluation of promising varieties of sunflower against major sucking insect pests and eco-safe pest management

Abstract:

Presently jassid, whitefly and aphid have emerged as the new serious sucking insect pest complex on sunflower. This study evaluated the effectiveness of three sunflower varieties (BARI Sunflower-2, BARI Sunflower-3, and the hybrid Mayabi) against them and assessed some pest control methods (yellow sticky traps with *Trichogramma spp.* and *Microbracon sp.* release, egg mass collection with Carbaryl spray and pheromone traps with chlorpyriphos spray) against these insects at Sher-e-Bangla Agricultural University, Bangladesh. A two-factorial randomized complete block design with three replications tested three pest management treatments over control. Mayabi was most susceptible, while BARI Sunflower-2 showed the highest resistance. Pheromone traps with chlorpyriphos (T_4) effectively reduced pest populations and increased yield. BARI sunflower- 2 (V_1) had the highest seed yield (1.72 Ton/hactare) from V_1T_4 treatment combination were recorded while the lowest seed yield were recorded from $V_3T_{1.}$ The overall results indicate that combined pest management strategies effectively reduced insect pest incidence on sunflower compared to the untreated control (T_1). Findings highlight the importance of integrated pest management combining resistant varieties with eco-friendly strategies to enhance sunflower yield and reduce environmental hazards.

1. Introduction

For oilseed crop production, sunflower is the third or fourth most important oil crop by volume with a global value of approximately 14 to 20 billion USD (USDA-FAS 2024). Among the oilseed crops sunflower ranked 4th for edible oil production in the world (Pilorge, 2020) after soybean, palm and rapeseed. Pilorge, E. (2020). Sunflower was grown on about 1599.27 ha in Bangladesh from which about 2006.20 metric ton are produced in the year 2021, with the average regional yield of 1.07 t ha-1(BBS, 2021). Numerous insect pests considerably diminish the productivity of sunflowers. Broadley (1982) reported 45 insect pests attacking in Australia whereas Sandhu *et al.* (1973) recorded 43 insects as pests of sunflower in India. Different insect pests cause various level of damage to the sunflower crop in different regions of Pakistan. For example, whitefly and jassid together can cause up to 44% loss of yield in Sindh, Pakistan (Lohar *et al.*, 1987). These insects also serve as vector of leaf curl virus on sunflower and many other oil seed crops. (Katti *et al.*, 2007). Whitefly, jassid and dusky bug are the key insect pests that are destructive to the sunflower crop, Bio-control agents not only control the insect pest but also solve the problem of environmental pollution and secondary pest outbreaks (Basit *et al.*, 2016).

In Bangladesh, according to the findings (Akhter T. *et al*., 2024) remarkably different sucking insect pest jassid, whitefly, aphid, mealybug and beneficial insects were observed in study. Recognizing the damage site and damaging behavior with ecological secrets of studied insect pests on sunflower are of great importance to find the most suitable management method to control the insect pests effectively aiming to increase the productivity of sunflower and improve the quality of production (Saleh A. H. *et al.,* 2025). Recent reviews emphasize the need for multi tactic IPM approaches combining biological, cultural, and chemical controls, along with regular monitoring and use of resistant varieties to sustainably manage pest populations, mitigate resistance development, and protect beneficial organisms [Reddy *et al*., 2024], [Kennedy and Lekshmi, 2022]. These reviews argue forcefully for the transition away from single strategy (chemical-dominant) management, recognizing the role of ecosystem services and environmental stewardship. Innovative IPM strategies incorporating pheromone traps, selective chemical sprays, and parasitoid releases are highlighted for their efficacy in sunflower as well as other crops, reducing the environmental load and long-term risks associated with broad- spectrum insecticides [Royer and Knodel, 2019]. For sunflower specifically, the importance of pollinator diversity for seed production and ecosystem resilience has been increasingly recognized [Shpak *et al.*, 2023]. Commercial cultivation of sunflower in Bangladesh started with the composite varieties namely BARI Surjamukhi-2 and Kironi developed by ORC (Oilseed Research Center), BARI, Gazipur. (Habib *et al*., 2021). Finally, hybrids of sunflower were assessed for their resistance to key pests in the semi-arid tropics, with the identification of those exhibiting a lower pest incidence and enhanced tolerance [Rana and Sheoran, 2004]. A detailed examination of agricultural insect pests and control strategies in tropical areas, emphasizing the effectiveness of various pest management based on local conditions have to ensure. Few research has been reported on sunflower flower insects in Bangladesh; however, no comprehensive research has been conducted on sunflower insects especially sucking insect pest. Therefore, this study aimed to survey sucking insect pests, investigate the abundance of the three major sucking insects (whitefly, Jassid and Aphid) in relation to plant age and yield parameters on sunflower in Bangladesh.

2. Materials and Methods

The experiment took place at the farm of Sher-e-Bangla Agricultural University, located in Sher- e-Bangla Nagar, Dhaka, Bangladesh, at coordinates 23074/N latitude and 90035/E longitude from November 2022 to April 2023; aimed to assess the effectiveness of promising sunflower varieties/genotypes against major insect pests and their eco-friendly management. Below are the details of the materials and methods used in this experiment:

For the experiment, three varieties of sunflower were chosen as: BARI Sunflower-2, BARI Sunflower-3, and the hybrid variety Mayabi as V_1,V_2 and V_3 respectively. Seeds were soaked in water for 12 hours before being sown in polyethylene bags to guarantee consistent and early germination. During final land preparation, an insecticidal treatment was applied using Sevin 85WP at the rate of 4 kg/ha to control soil dwelling pests such as cutworms and mole crickets, which could damage young sunflower seedlings. Urea, Triple Super Phosphate (TSP), and Muriate of Potash (MP) were used as sources of nitrogen, phosphorus, and potassium, respectively.

Four different pest management treatments were applied:

T_1: Control (no treatment)

T_2: Yellow sticky board combined with alternate releases of *Trichogramma* spp. & *Microbracon* sp.

T_3: Collection of egg masses & larvae followed by spraying Carbaryl 50WP @2gL^{-1}/10 days

T_4: Use of pheromone traps @ 12 No./ha (septa replaced every three weeks) combined with spraying Chlorpyriphos 20 EC at 1.5 g/L every 10 days

The experiment was a two-factorial Randomized Complete Block Design (RCBD) with three replications. The experimental field was divided into three blocks, each consisting of 12 subplots measuring 4.5 m × 4.0 m. A spacing of 1.0 m was maintained between plots, and rows were spaced at 0.5 m. Seeds were sown in the first week of December, maintaining a spacing of 0.5 m × 0.5 m. Standard procedures for intercultural operations were adhered to, which included gap filling, weeding, earthing up, irrigation, and pest control as necessary. Seedlings that were damaged were replaced with healthy seedlings that had intact soil balls on the same date, and they were watered for seven consecutive days after transplantation. Fruits were picked by hand when they were fully mature and ripening. Several parameters were measured, such as the count of insects per plant or plot, the count of beneficial insects per plot, and the count of infested versus healthy leaves, shoots, flowers, and heads. Moreover, data were gathered regarding the count of healthy seeds per head, the weight of healthy seeds per head, yield per plot, and overall yield. Natural enemies such as predatory ladybird beetles, spiders, ants, and other arthropods were monitored through direct visual observation. When required, tools for magnification were employed to ensure precise counting and identification of the arthropods found in the field.

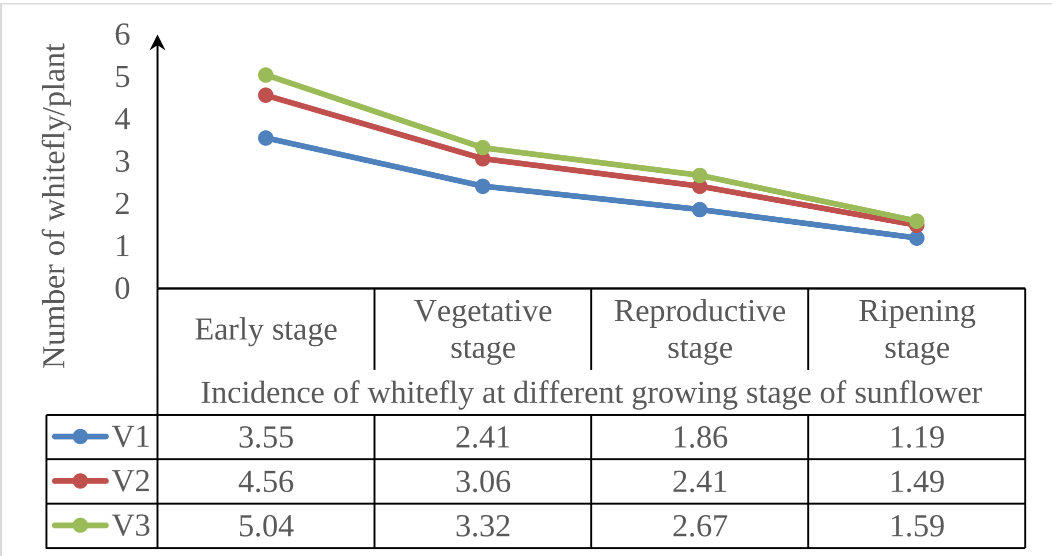
All data were statistically analyzed to determine significant differences in treatment effects. Analysis of variance (ANOVA) was conducted using the F-test, and mean differences were separated using Duncan's Multiple Range Test (DMRT) at a 5% level of significance.

3. Result & discuisson

3.1 Incidence of Whitefly on sunflower

3.1.1 Effect of variety on Whitefly incidence

Whitefly is one of the most important sucking insect pests of sunflower which attacks at the early stage. Ghante et al. (2020) observed the activity of whiteflies throughout the year in sunflower ecosystem with population ranging from 0.40 to 60.56 /6 leaves per plant. Starting with the early stage of growth, the Mayabi (V_3) variety exhibited the highest incidence of whitefly per plant at 5.04, which is significantly higher than both the BARI sunflower-2 (V_1) and BARI sunflower-3 (V_2) varieties, as evidenced by their respective incidences of 3.55 and 4.56. In the vegetative stage, similar trends were observed, with the Mayabi variety still showing a higher whitefly incidence per plant (3.32) than both BARI sunflower 2 (2.41) and BARI sunflower 3 (3.06). This continuation of susceptibility suggests that the Mayabi variety may inherently attract more whitefly pests, or perhaps its physiological traits are more conducive to whitefly survival and reproduction. In the reproductive and ripening stages, the incidences of whitefly decreased across all varieties. However, the Mayabi variety consistently maintained the highest incidence per plant in both stages, with 2.67 and 1.59 respectively, followed by BARI sunflower 3 and then BARI sunflower 2, with their incidences decreasing in the same sequence. In conclusion, the choice of sunflower variety significantly influences the incidence of whitefly across all growing stages, with the Mayabi variety exhibiting the highest incidence at each stage. (Fig: 1)



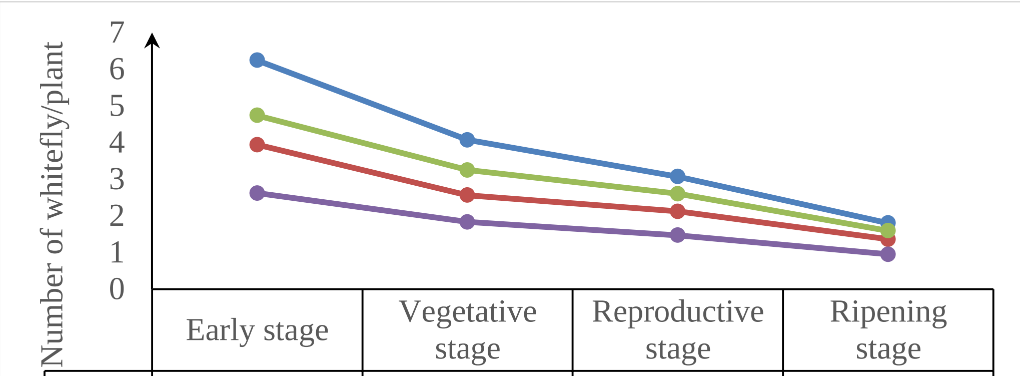
	Early stage	Vegetative stage	Reproductive stage	Ripening stage
V1	3.55	2.41	1.86	1.19
V2	4.56	3.06	2.41	1.49
V3	5.04	3.32	2.67	1.59

Fig 1: Effect of different varieties on incidence of whitefly at growing stage of sunflower.

3.1.2 Effect of various pest management strategies on Whitefly abundance

The data provided in the figure 02 indicates a statistically significant difference in the incidence of whitefly per plant at various stages of sunflower growth across the different pest management techniques applied (T_1, T_2, T_3, and T_4). For the early stage of growth, the control condition (T_1) showed the highest whitefly incidence per plant at 6.24, significantly higher than the incidences observed in the other treatments. This is followed by treatment T_3 (4.74), treatment T_2 (3.94), and finally, treatment T_4 exhibited the least incidence

(2.62). A similar pattern is observed in the vegetative, reproductive, and ripening stages. In all these stages, the control condition consistently had the highest whitefly incidence, followed by T_3, T_2, and T_4 in that order. The T_4 treatment, which involves the setup of pheromone traps and spraying of Chlorpyriphos, had the lowest whitefly incidence across all stages, indicative of its effectiveness in managing whitefly infestation. The pest management module (pheromone traps @ 4/acre) were evaluated for their efficacy against major insect pests, bee visitation, and natural enemy populations in sunflower, emerged as the most effective, reducing larval counts of *H. armigera and S. litura* by 81.05% and 82.98% over the control. (Mukhtar & Shankar, 2024). Notably, treatment T_4 proves to be the most effective in reducing whitefly incidence, highlighting its potential as a recommended practice for managing whitefly in sunflower cultivation. This could be due to the combined effect of pheromone traps attracting and removing whiteflies and the systematic application of Chlorpyriphos providing a deterrent effect on these pests.



	Early stage	Vegetative stage	Reproductive stage	Ripening stage
T1	6.24	4.07	3.07	1.8
T2	3.94	2.56	2.12	1.36
T2	4.74	3.25	2.6	1.59
T4	2.62	1.83	1.47	0.95

Figure 02: Effect of different pest management strategies on the incidence of whitefly at different growing stage of sunflower

3.1.3 Interaction effect on Whitefly infestation in sunflower

From the provided table 1, it can be ascertained that there is a statistically significant interaction effect between sunflower variety and management strategy on the incidence of whitefly per plant at different growth stages of sunflower. During the early growth stage, the highest incidence of whitefly was observed in V_3T_1, followed by V_2T_1, V_1T_1, V_3T_2, V_2T_3, V_3T_3, V_2T_2, V_1T_3, V_3T_4, V_1T_2, V_2T_4, and V_1T_4 in descending order. A similar pattern of significance is observed during the vegetative, reproductive, and ripening stages. In each of these stages, the combination of variety V_3 and control treatment T_1 consistently showed the highest incidence of whitefly, while the combination of variety V_1 and treatment T_4 consistently recorded the lowest incidence. It can be inferred from these results that both the sunflower variety and the type of pest management treatment employed have significant impacts on the incidence of whitefly at all growth stages. Notably, the combination of BARI sunflower 2 (V_1) and the treatment involving the use of pheromone traps and Chlorpyriphos spraying (T_4) appears to be the most effective in controlling whitefly infestation across all stages. Conversely, the Mayabi hybrid (V_3) under control conditions (T_1) tends to have the highest whitefly infestation.

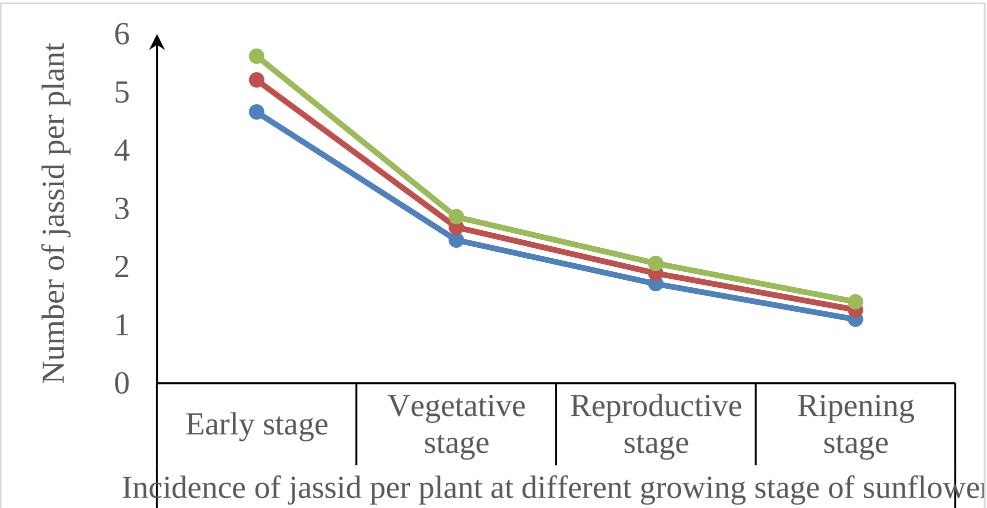
Table 1: Combined effect of variety and pest management strategies on the incidence of whitefly at different growing stage of sunflower

Treatment	Incidence of whitefly/plant			
	Early stage	**Vegetative stage**	**Reproductive stage**	**Ripening stage**
V_1T_1	5.88 c	3.99 b	2.97 b	1.80 a
V_1T_2	2.84 j	1.72 i	1.44 g	0.93 g
V_1T_2	3.34 h	2.36 g	1.87 f	1.31 e
V_1T_4	2.16 l	1.54 j	1.18 i	0.72 h
V_2T_1	6.17 b	4.08 a	3.10 a	1.82 a
V_2T_2	4.27 g	2.64 f	2.25 e	1.52 d
V_2T_2	5.22 e	3.81 c	2.90 c	1.73 b
V_2T_4	2.55 k	1.70 i	1.37 h	0.89 g
V_3T_1	6.67 a	4.13 a	3.13 a	1.76 ab
V_3T_2	4.71 f	3.32 e	2.67 d	1.64 c
V_3T_2	5.65 d	3.56 d	3.02 b	1.73 b
V_3T_4	3.15 i	2.25 h	1.87 f	1.23 f
$LSD_{(0.05)}$	0.02	0.09	0.05	0.06
CV (%)	1.48	3.73	2.85	4.81

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).]

3.2 Incidence of Jassid on sunflower

3.2.1 Effect of variety on Jassid infestation in sunflower



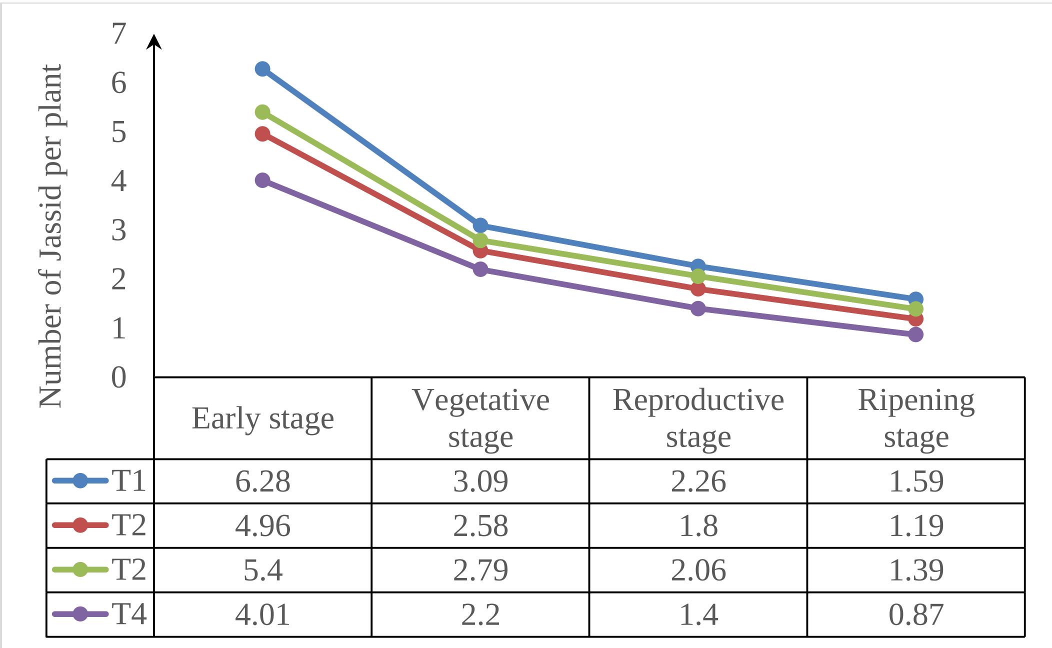
	Early stage	Vegetative stage	Reproductive stage	Ripening stage
V1	4.66	2.46	1.71	1.1
V2	5.21	2.68	1.89	1.26
V3	5.62	2.86	2.06	1.4

[Here, V_1 = BARI sunflower 2, V_2 = BARI sunflower 3, V_3 = Mayabi (Local hybride)]

Figure 03: Effect of different varieties on the incidence of jassid at different growing stage of sunflower

The data in the figure 03 indicates that the variety of sunflower significantly influences the incidence of jassid at each growth stage. At the early stage, the Mayabi variety (V_3) had the highest incidence of jassid, followed by the BARI sunflower 3 (V_2), and then BARI sunflower 2 (V_1) with the least. A similar trend is observed at the vegetative, reproductive, and ripening stages with Mayabi (V_3) consistently recording the highest incidence and BARI sunflower 2 (V_1) recording the lowest. Thus, it can be concluded that sunflower variety significantly influences the incidence of jassid at all stages of growth. The Mayabi variety, despite being a local hybrid, is more susceptible to jassid infestation across all growth stages. Conversely, the BARI sunflower 2 variety appears to be more resilient, recording the lowest incidence of jassid throughout the sunflower's lifecycle. This variety was developed by ORC (Oilseed Research Center), BARI, Gazipur. Lodging tendency due to tallness and lower yield are the major constrains for the expansion of this variety to the farmer‟s field. Farmer prefer hybrid sunflower variety as hybrids are stable, self fertile, high yielding as well as uniform at maturity (Habib *et al*., 2021). These findings highlight the importance of variety selection in managing jassid infestation in sunflower cultivation. The results also point to the need for targeted pest management strategies for different sunflower varieties.

3.2.2 Effect of various pest management strategies on Jassid infestation in sunflower



	Early stage	Vegetative stage	Reproductive stage	Ripening stage
T1	6.28	3.09	2.26	1.59
T2	4.96	2.58	1.8	1.19
T2	5.4	2.79	2.06	1.39
T4	4.01	2.2	1.4	0.87

Figure 04: Effect of different pest management strategies on the incidence of jassid at different growing stage of sunflower

The results (Figure 04) clearly indicate that the chosen treatment strategy has a significant influence on jassid incidence at all growth stages of the sunflower. This suggests that the differences observed among the treatments are statistically significant. In the early stage, the control (T_1) exhibited the highest incidence of jassid per plant, followed by T_3, T_2, and T_4. The same pattern persists through the vegetative, reproductive, and ripening stages. This trend suggests that the application of pest management strategies significantly reduces jassid incidence compared to the control treatment. The treatment T_4, which comprises setting up pheromone traps and spraying Chlorpyriphos, appears to be the most effective at reducing jassid incidence per plant across all growth stages. In contrast, T_1, where no active management strategies are applied, is associated with the highest incidence of jassid. In conclusion, the choice of pest management strategy significantly influences the incidence of jassid at all stages of sunflower growth. The most effective treatment appears to be T_4, highlighting the value of integrated pest management strategies such as the use of pheromone traps and insecticides. The population of jassid was reduced up to 93.00% by Curacron in sunflower; Curacron is also an organophosphate insecticide like Chlorpyriphos (Chang and Rajput, 2016).

3.2.3 Interaction effect varieties and pest management practices on Jassid infestation in sunflower

The data table 2 presented depicts the interaction effect of sunflower variety and pest management treatment on the incidence of jassid per plant at four distinct stages of sunflower growth: early, vegetative, reproductive, and ripening stages and it is clear that both the variety of sunflower and the type of pest management treatment applied have a statistically significant effect on the incidence of jassid per plant at each growth stage. In the early growth stage, the V_3T_1 combination of the Mayabi sunflower variety with the control treatment recorded the highest incidence of jassid, while the V_1T_4 combination of BARI sunflower 2 variety and the T_4 pest management strategy displayed the lowest. This pattern generally persists across all stages of growth, with some variations. Interestingly, it appears that the BARI sunflower 2 variety (V_1) when combined with the T_4 management strategy consistently results in the lowest jassid incidence across all growth stages. This could be due to the specific resistance of this sunflower variety towards jassid, or the particular effectiveness of the T_4 pest management strategy. In conclusion, the variety of sunflower and the pest management strategy employed significantly influence the incidence of jassid at all stages of sunflower growth. These findings underscore the importance of carefully selecting both the crop variety and the pest management strategy, with the BARI sunflower 2 variety and the T_4 pest management strategy showing the most promising results in reducing jassid incidence.

Table 2: Combined effect of variety and pest management strategies on the incidence of jassid at different growing stage of sunflower

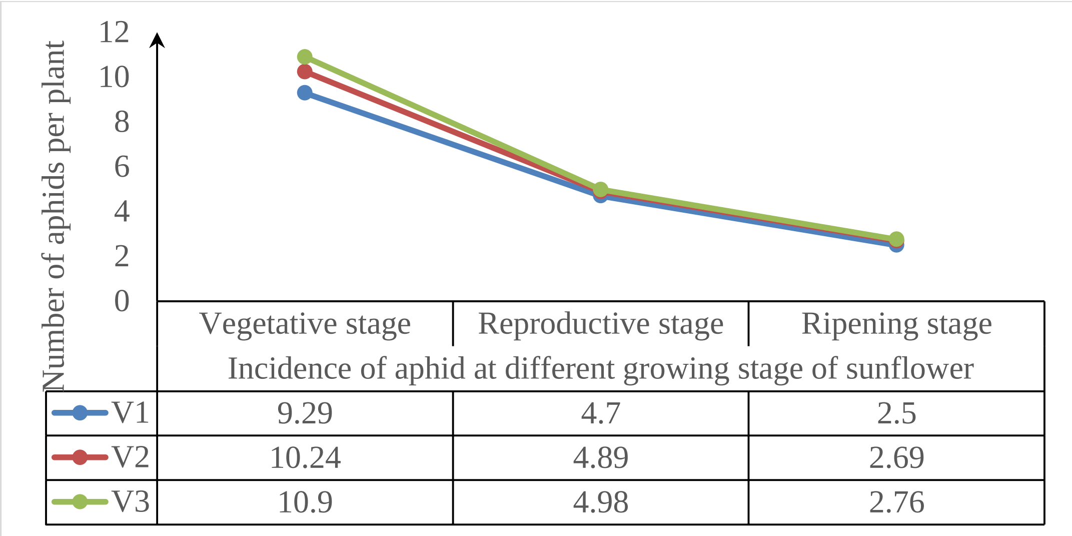
Treatment	Incidence of jassid per plant at different growing stage of sunflower			
	Early stage	**Vegetative stage**	**Reproductive stage**	**Ripening stage**
V_1T_1	5.95 c	2.96 b	2.37 a	1.65 a
V_1T_2	4.45 j	2.34 g	1.55 f	0.94 g
V_1T_2	4.91h	2.56 ef	1.75 de	1.18 ef
V_1T_4	3.34 l	1.97 i	1.15 h	0.62 h
V_2T_1	6.22 b	3.08 b	2.16 b	1.46 bc
V_2T_2	5.12 g	2.64 de	1.86 d	1.27 de
V_2T_2	5.56 e	2.83 c	2.14 b	1.44 bc
V_2T_4	3.93 k	2.17 h	1.37 g	0.88 g
V_3T_1	6.66 a	3.23 a	2.25 ab	1.56 ab
V_3T_2	5.32 f	2.76 cd	1.99 c	1.36 cd
V_3T_2	5.73 d	2.98 b	2.29 a	1.55 ab
V_3T_4	4.76 i	2.48 f	1.69 e	1.12 f
$LSD_{(0.05)}$	0.12	0.12	0.12	0.12
CV (%)	0.92	1.88	2.18	3.59

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

3.3 Incidence of Aphid on sunflower

3.3.1 Effect of variety on Aphid infestation in sunflower

From the figure 05, it is clear that the sunflower variety has a statistically significant impact on aphid incidence at each of the measured growth stages. In each of the growth stages, the Mayabi variety (V_3) had the highest incidence of aphids, followed by BARI sunflower 3 (V_2), and BARI sunflower 2 (V_1) having the least incidence. This pattern suggests that the Mayabi variety might be more susceptible to aphid infestation or less capable of fending off the pest, while BARI sunflower 2 has the highest resistance or deterrent effect.



	Vegetative stage	Reproductive stage	Ripening stage
V1	9.29	4.7	2.5
V2	10.24	4.89	2.69
V3	10.9	4.98	2.76

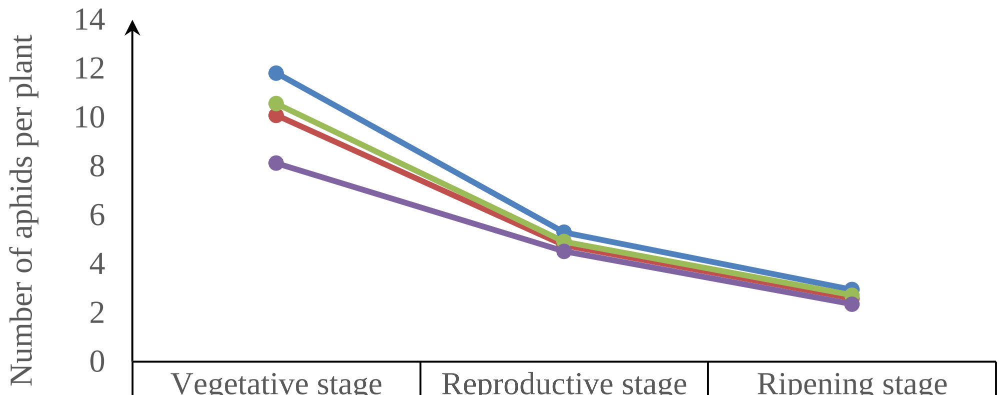
[Here, V_1 = BARI sunflower 2, V_2 = BARI sunflower 3, V_3 = Mayabi (Local hybride)]

Figure 05: Effect of different varieties on the incidence of aphid at different growing stage of sunflower

In conclusion, these findings strongly suggest that the sunflower variety has a profound influence on the incidence of aphids at all measured growth stages. As such, choosing a variety resistant to aphid infestation, like BARI sunflower 2, can be an effective strategy for mitigating crop damage and maximizing yield.

3.3.2 Effect of various pest management strategies on Aphid infestation in sunflower

Statistical analysis of the data revealed that the different treatments significantly influenced the incidence of aphid per plant at all stages of sunflower growth (Figure 6). For all stages of growth, the untreated control (T_1) had the highest incidence of aphids, while the method employing pheromone traps and Chlorpyriphos spraying (T_4) resulted in the lowest incidence. This suggests that T_4 was the most effective strategy in controlling the aphid population. The strategies involving yellow sticky board, *Trichogramma* spp., *Microbracon* sp., and carbaryl 50 WP (T_2 and T_3) showed intermediate levels of effectiveness. In summary, the data suggests that the type of pest management strategy employed can have a significant impact on the incidence of aphids in sunflower crops, with strategy T_4 appearing to be the most effective across all growth stages. It is also indicated and reaveled that E-β-F is the main effective component of the alarm pheromone from onion aphid (*N. formosana)* , but the blend (E β F and +-limonene) plays a critical role in the repellent behavior for aphid management (Huang, Y *et al.*, 2025).



	Vegetative stage	Reproductive stage	Ripening stage
T1	11.81	5.29	2.95
T2	10.08	4.76	2.59
T2	10.56	4.91	2.72
T4	8.124	4.51	2.35

Figure 6: Effect of different pest management strategies on the incidence of aphid at different growing stage of sunflower

3.3.3 Interaction effect varieties and pest management practices on Aphid infestation in sunflower

Statistical analysis of the data (Table 3) indicates that the combination of variety and pest management strategy significantly influenced the incidence of aphid per plant at all stages of sunflower growth. The highest incidence of aphids across all growth stages was observed in V_3T_1 (V_3 variety with T_1 management), with incidences of 12.39, 5.32, and 3.02 aphids per plant during the vegetative, reproductive, and ripening stages respectively. This was expected since T_1 is the control condition where no active pest management strategy was employed, and it suggests that the V_3 variety might be highly susceptible to aphid infestations. On the other hand, the V_1 variety managed with T_4 management (V_1T_4) demonstrated the lowest incidence of aphids, with values of 6.18, 4.33, and 2.20 for the vegetative, reproductive, and ripening stages respectively. This suggests that the V_1 variety combined with T_4 management (consisting of pheromone traps and periodic Chlorpyriphos sprays) is highly effective in minimizing aphid infestations across all growth stages. Other combinations also showed varying levels of aphid incidence. For instance, the V_2 variety with T_2 management (V_2T_2) showed moderate incidences of aphids per plant, with 10.69 during the vegetative stage, 4.94 during the reproductive stage, and 2.88 during the ripening stage. Meanwhile, V_3T_2 showed higher aphid incidence of 10.91, 5.10, and 2.74 in the vegetative, reproductive, and ripening stages respectively. In summary, these results suggest a significant interaction effect between sunflower variety and pest management strategy on the incidence of aphids at different growth stages. The V_1 variety combined with T_4 management showed the lowest incidence, suggesting its effectiveness in controlling aphids, whereas the V_3 variety, particularly when not paired with an active pest management strategy (T_1), showed the highest aphid incidence. A Field experiments were carried out at Entomology Farm, SKUAST-J, Chatha for two consecutive years (2018 and 2019) to evaluate the bio-efficacy of selective insecticides against aphids on strawberry. Chlorpyriphos 20 EC @2.0 ml/L offered moderate control of aphids (8.70 aphids/3leaves/3 plants) on strawberry[1] (Raina, S *et al.*, 2022). This analysis underlines the importance of carefully selecting both the sunflower variety and the pest management strategy to control aphid infestation effectively.

Table 3: Combined effect of variety and pest management strategies on the incidence of aphid at different growing stage of sunflower

Treatment	Incidence of aphid at different growing stage of sunflower		
	Vegetative stage	Reproductive stage	Ripening stage
V_1T_1	11.33 c	5.20 c	2.89 c
V_1T_2	9.58 j	4.59 h	2.40 g
V_1T_2	10.08 h	4.69 g	2.53 f
V_1T_4	6.18 l	4.33 i	2.20 i
V_2T_1	11.71 b	5.26 b	2.93 b
V_2T_2	10.23 g	4.77 f	2.64 e
V_2T_2	10.69 e	4.94 e	2.88 c
V_2T_4	8.33 k	4.60 h	2.31 h
V_3T_1	12.39 a	5.32 a	3.02 a
V_3T_2	10.43 f	4.93 e	2.73 d
V_3T_2	10.91 d	5.10 d	2.74 d
V_3T_4	9.87 i	4.59 h	2.56 f
LSD $_{(0.05)}$	**0.04**	**0.04**	**0.04**
CV (%)	**0.56**	**0.91**	**1.54**

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

3.4 Leaf infestation by insect pests

Table 4: Combined effect of variety and pest management strategies on Leaf infestation

Treatment	Number of leaves	Number of healthy leaves	Number of infested leaves	% leaf infestation
V_1T_1	15.11 h	8.71 h	6.40 b	42.44 c
V_1T_2	23.11 c	19.33 c	3.78 f	16.32 i
V_1T_2	21.89 d	16.93 e	4.96 d	22.72 g
V_1T_4	27.99 a	24.22 a	3.77 f	13.50 j
V_2T_1	14.56 h	6.26 i	8.30 a	56.95 b
V_2T_2	19.89 e	14.68 f	5.21 cd	26.29 f
V_2T_2	17.18 f	11.54 g	5.64 c	32.88 e
V_2T_4	25.08 b	22.26 b	2.81 g	11.25 j
V_3T_1	12.11 i	3.67 j	8.45 a	69.77 a
V_3T_2	17.56 f	12.24 g	5.31 cd	30.25 e
V_3T_2	15 .89 g	9.60 h	6.29 b	39.61 d
V_3T_4	22.62 cd	18.21 d	4.42 e	19.57 h
LSD $_{(0.05)}$	**0.78**	**0.91**	**0.45**	**2.79**
CV (%)	**4.71**	**7.66**	**9.82**	**10.34**

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Interaction effect of different varieties and pest management practices showed a significant variation on leaf infestation of sunflower (Table 4).The first observation to note is the significantly improved leaf health and reduced infestation rates when pest management strategies are applied, as compared to the control group (T_1) across all varieties. The combination of BARI Sunflower 2 and the pheromone trap and chlorpyriphos spray strategy (V_1T_4) proved most effective, with the highest total number of leaves (27.99), the highest number of healthy leaves (24.22), and the lowest number of infested leaves (3.77), translating to the lowest leaf infestation rate (13.5%). BARI Sunflower 3 (V_2) also showed improved results when paired with the T_4 strategy, coming second in terms of total leaves (25.08), healthy leaves (22.26), and having a relatively low number of infested leaves (2.81), resulting in one of the lowest infestation rates (11.25%). However, the local hybrid Mayabi (V_3) had a higher vulnerability to leaf infestation across all treatments. Even when combined with the T_4 strategy, the results were less optimal compared to the other varieties, although it still significantly outperformed the control condition (V_3T_1).When comparing the same variety across different treatments, it is clear that the T_4 strategy consistently performs best in terms of total leaf count, healthy leaf count, and leaf infestation rates, irrespective of the sunflower variety.

3.5 Interaction effect of different varieties and pest management practices on Plant height

The plant heights of sunflower were significantly affected by the interactions of the varieties with the pest management treatments (Figure 7). The combination of V_1T_4 (BARI sunflower 2 with pheromone traps and Chlorpyriphos spray) resulted in the highest plant height (181.3 cm), closely followed by the V_2T_4 combination (180.2 cm). These findings suggest that the T_4 management strategy was particularly effective across different sunflower varieties, likely due to its comprehensive approach to pest control. The least effective combination was V_3T_1, with the lowest plant height of 144.5 cm. It appears that the V_3 variety (Mayabi) was more susceptible to pest damage, and without any pest management strategy (T_1), its growth was significantly hampered. The results underline the importance of the choice of both sunflower variety and pest management strategy for optimal plant growth. It could be inferred that while the pest-resistant BARI varieties fared better, the use of comprehensive pest management strategies, particularly T_4, significantly contributed to plant height across all varieties. These findings are in agreement with previous studies emphasizing the interaction effects of crop variety and pest management strategies on crop growth (Yan *et al.*, 2019). In case of V2 (Mayabi Hybrid) variety, the higher plant height were 26.43, 66.17, 113.91, 120.02 and 114.24 cm at 25, 45, 65, 85 DAS and at harvest, respectively while the V1 (BARI Surjumukhi-2) variety showed plant height 24.03, 57.62, 95.51, 103.15 and 99.21 cm at 25, 45, 65, 85 and at harvest, respectively (Afrose T., 2021)

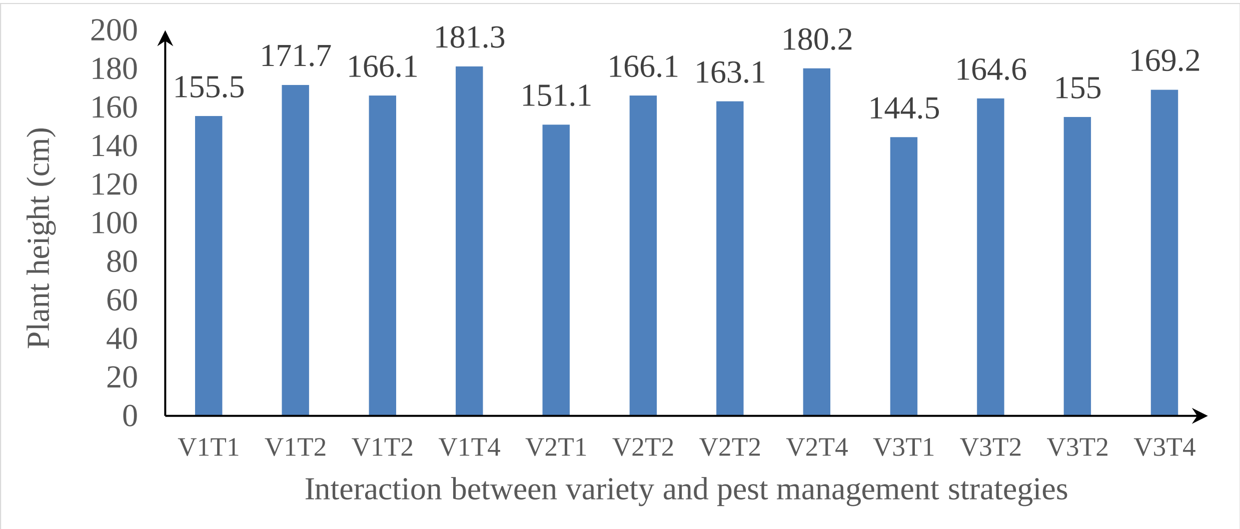


Figure 7: Combined effect of variety and pest management strategies on plant height of sunflower

3.6 Interaction effect of varieties and pest management practices Capitulum diameter (cm)

The findings demonstrate that there are significant differences in the inflorescence diameter among different sunflower varieties when subjected to different management practices (Table 5). Notably, the V_1T_4 combination yielded the largest diameter (22.33 cm), indicating the highest response to this management practice, followed closely by the V_1T_2 and V_2T_4 combinations, at 21.42 cm and 21.70 cm, respectively. The sunflower var. BARI Surjomukhi-2 was tested and it was revealed that the maximum head diameter 18.33 were obtained (Ahmed, B. et al., 2015). The V_3T_4 combination resulted in a moderate diameter (20.53 cm), demonstrating the local hybrid's potential when combined with management practice T_4. The smallest diameter was observed with V_3T_1 (15.33 cm), suggesting that the control management strategy is less beneficial for the Mayabi sunflower variant. In literature, Mayabi Hybrid (V2) variety gave the highest head diameter 16.69 cm (Afrose T., 2021).

3.7 Interaction effect of varieties and pest management practices on Number of heads/plot

Table 5: Combine effect of variety and pest management strategies on capitulum diameter (cm), diameter of inflorescence with petals (cm) and number of total heads per plot

Treatment	Capitulum diameter (cm)	Diameter of inflorescence with petals (cm)	Number of total head/plot
V_1T_1	7.40 h	17.22 g	37.67 i
V_1T_2	11.64 b	21.42 b	43.67 c
V_1T_2	10.05 cd	19.30 d	41.33 e
V_1T_4	12.16 a	22.33 a	45.33 a
V_2T_1	6.43 i	16.66 h	36.67 j
V_2T_2	9.73 de	19.07 d	40.67 f
V_2T_2	8.36 f	18.51 e	38.67 h
V_2T_4	12.04 a	21.70 b	44.67 b
V_3T_1	5.22 j	15.33 i	34.33 k
V_3T_2	9.59 e	18.60 e	39.33 g
V_3T_2	7.96g	17.52 f	38.33 h
V_3T_4	10.25 c	20.53 c	42.67 d
LSD $_{(0.05)}$	**0.33**	**0.30**	**0.57**
CV (%)	**4.22**	**1.85**	**1.67**

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan’s Multiple Range Test (DMRT).

The data table (Table 5) provided demonstrates the interaction effect between different sunflower varieties and management strategies on the total number of sunflower heads per plot. Clearly, the treatments exhibit a significant influence on the number of heads per plot, with varying mean values that show statistical significance based on a Least Significant Difference (LSD) value of 0.57 at a 5% level of probability. Among the variety-management combinations, the highest number of heads per plot was recorded for the combination of V_1T_4 (BARI sunflower 2with pheromone traps and Chlorpyriphos), averaging 45.33. This combination was closely followed by V_2T_4, V_1T_2, and V_3T_4, with averages of 44.67, 43.67, and 42.67 respectively. The least number of heads per plot were recorded for V_3T_1 (34.33), a combination of Mayabi sunflower with the control treatment, showing that this variety under a non-intervention approach yielded the least. This pattern suggests that among the varieties, BARI sunflower 2 (V_1) and BARI sunflower 3 (V_2) tend to perform better under more integrated pest management practices (T_2 and T_4). Additionally, the use of Chlorpyriphos, a broad-spectrum organophosphate pesticide and pheromone traps (T_4), seems to have a significant impact on the increase in the number of heads per plot across all the varieties. In conclusion, these findings underscore the importance of the interaction between sunflower variety and pest management strategy.

3.8 Interaction effect of varieties and pest management practices Seed infestation by number

In assessing the implications of variety and pest management strategies on the infestation rates in sunflower seeds by number, the study reveals noteworthy interactions that significantly influence the outcome of seed infestation (Table 6). The study illuminates the particularly high vulnerability of the Mayabi variety (V_3) in the absence of any management interventions (T_1), as evidenced by the highest seed infestation percentage of 36.65% observed for the V_3T_1 combination. This may be attributed to inherent susceptibilities of the Mayabi variety to pests or its comparably lower natural resistance. Conversely, the combination of BARI sunflower 2 variety (V_1) with the fourth management strategy (T_4), which involved the deployment of pheromone traps and Chlorpyriphos spraying, resulted in the lowest seed infestation by number of 8.85% (V_1T_4). The significant reduction of seed infestation by number under this combination underscores the efficacy of the T_4 management strategy and the robustness of the BARI sunflower 2 varieties in mitigating pest threats.

Table 6: Combined effect of variety and pest management strategies on percent seed infestation by number of sunflower

Treatment	Number of seeds/head	Number of healthy seeds/head	Number of infested seeds/head	% Seed infestation by number
V_1T_1	482.6 j	362.5 j	120.1 c	24.87 c
V_1T_2	618.2 c	538.1 c	80.14 h	12.96 h
V_1T_2	597.1 e	512.1 e	84.98 g	14.23 g
V_1T_4	646.0 a	588.9 a	57.17 j	8.85 j
V_2T_1	442.3 k	311.1 k	131.2 b	29.68 b
V_2T_2	555.5 f	458.1 f	97.42 f	17.54 f
V_2T_2	518.7 h	416.0 h	102.6 e	19.78 e
V_2T_4	629.3 b	567.0 b	62.38 i	9.91 i
V_3T_1	374.5 l	237.3 l	137.2 a	36.65 a
V_3T_2	545.1 g	443.0 g	102.2 e	18.76 e
V_3T_2	493.7 i	388.6 i	105.1 d	21.28 d
V_3T_4	609.7 d	530.4 d	79.39 h	13.02 h
LSD $_{(0.05)}$	**1.01**	**1.00**	**1.47**	**1.52**
CV (%)	**0.22**	**0.26**	**1.80**	**2.01**

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Furthermore, the study observed that any management strategy (T2, T3, and T4) generally achieved lower seed infestation rates compared to the control treatment (T1), across all sunflower varieties. This observation serves to underscore the critical role and effectiveness of active management interventions in controlling pest infestations. Additionally, when it comes to the seed count, combinations with the T4 management strategy consistently achieved a higher total number of seeds per head and healthier seeds, indicating the potential for this strategy to enhance overall plant health and productivity.

In conclusion, the study findings demonstrate the substantial impacts of sunflower variety and pest management strategy on seed infestation rates. The effective control of pest infestations and, consequently, the maximization of crop yield and quality necessitate the careful selection and implementation of appropriate pest management practices, particularly in sunflower varieties that are more prone to infestation.

3.9 Single seed weight (gm)

3.9.1 Interaction effect of different varieties and pest management practices

The data suggests a statistically significant interaction effect of sunflower variety and management strategy on the single seed weight of sunflower (Table 7). Breaking down the individual treatments, the combination of BARI sunflower 2 (V_1) and the pest management approach involving the use of pheromone traps and Chlorpyriphos spraying (T_4) yielded the highest single seed weight (0.13 gm), denoted as V_1T_4. This superior performance can be attributed to the unique properties of the BARI sunflower 2 that could have been more receptive to the applied management strategy, thereby resulting in a heavier seed. On the opposite end of the spectrum, the treatment combination involving the Mayabi sunflower variety (V_3) with no specific pest management (control, T_1), denoted as V_3T_1, and yielded the lowest single seed weight (0.06 gm). The significant decrease in weight in comparison to the V_1T_4 treatment indicates the potential susceptibility of the Mayabi variety to pest infestation, especially without the application of any pest management measures. The rest of the treatment combinations registered intermediate single seed weights, which reinforces the notion that the seed weight of sunflower is significantly influenced by the variety of sunflower as well as the pest management strategy employed.

In conclusion, the data strongly supports the hypothesis that the single seed weight of sunflower is significantly affected by the interaction of the sunflower variety and the applied management strategy. As such, optimal sunflower cultivation and pest management practices should consider both these aspects to effectively enhance the seed weight and overall yield of the crop. The sunflower var. BARI Surjomukhi-2 was tested and it was revealed that the maximum 1000- seed weight was 68 g were obtained (Ahmed, B. *et al.*, 2015)..

3.10 Yield (Kg/plot)

The table elucidates that the interaction effects of different sunflower varieties and management treatments significantly influenced the yield of sunflowers per plot (Table 7). This finding indicates that the yield differences between the treatments are statistically significant and are not attributed to random chance. Examining the specific outcomes, the treatment V_1T_4, a combination of the s (BARI sunflower 2 variety (V_1) and pest management involving pheromone traps and ChlorpyriphoT_4), yielded the highest output of 1.72 kg per plot. The sunflower var. BARI Surjomukhi-2 was tested and it was revealed that the maximum yield 2.5 t ha−1 were obtained (Ahmed, B. *et al.*, 2015). This result demonstrates the efficacy of this particular combination of sunflower variety and pest management treatment, suggesting that BARI sunflower 2 exhibits strong adaptability to this form of pest control, resulting in an optimized yield. The V_2T_4 treatment, incorporating BARI sunflower 3 and the same pest management strategy (T_4), resulted in the second highest yield of 1.65 kg per plot, a result not significantly different from V_1T_4. This outcome underscores the effectiveness of T_4 across multiple sunflower varieties. Meanwhile, the lowest yield was observed in the V_3T_1 treatment, using the Mayabi variety and the control management strategy, yielding 0.83 kg per plot. This combination appears to be least effective, suggesting that the Mayabi sunflower variety may require more intensive or specific pest management techniques to optimize yield.

Table 7: Effect of variety and pest management strategies on single seed weight and yield

Treatment	Single seed weight (gm)	Yield (kg/plot Or ton/ha)
V_1T_1	0.07 def	1.22 gh
V_1T_2	0.11 abc	1.58 c
V_1T_2	0.10 abcd	1.48 d
V_1T_4	0.13 a	1.72 a
V_2T_1	0.07 ef	1.19 h
V_2T_2	0.10 abcde	1.39 e
V_2T_2	0.09 bcde	1.34 f
V_2T_4	0.12 ab	1.65 b
V_3T_1	0.06 f	0.83 i
V_3T_2	0.09 bcde	1.35 ef
V_3T_2	0.08 cdef	1.24 g
V_3T_4	0.11 abc	1.56 c
LSD $_{(0.05)}$	**0.03**	**0.03**
CV (%)	**17.46**	**3.46**

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

In conclusion, the interaction of the different sunflower varieties and management treatments had a significant influence on the sunflower yield. Notably, the combination of BARI sunflower varieties 2 and 3 with the T_4 pest management strategy appears to be the most effective, supporting the idea that the choice of sunflower variety and corresponding pest management strategy should be carefully considered to optimize yield. However, the country grain yield is far less than the attainable yield (2.5 to 3.5 t ha-1) under good management conditions at farmers field (MOANR, 2017).

4. Conclusion

Considering the objectives of the research, overall result indicates that the combination of different managements decreased the incidence of insect pests of sunflower compared to T_1 treatment (control). Insect populations for plants/plot in the experimental plot whiteflies, aphid, Jassid were observed and the highest number of the insect pests was recorded from V_3T_1 (Variety Mayabi + untreated control) combination whereas the lowest number of insect pests was observed from V_1T_4 (BARI surjamukhi 2 + pheromone traps + Spraying Chlorpyriphos 20 EC @ 1.5gm/ L of water at the 10 days interval) combination at the different growing stage of sunflower. In conclusion, these findings strongly suggest that the sunflower variety has a profound influence on the incidence of whitefly, jassid, aphids and others insect pest at all measured growth stages. Incase yield contributing characters of sunflower, the highest in V_2 (BARI sunflower 2), T_4 treatment which was statistically different from among all other treatments. Regarding yield-contributing traits, the highest measurements recorded in V2T4, all statistically superior to other treatments. These findings emphasize the importance of integrated pest management and variety selection for sustainable sunflower production.

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