OPEN ACCESS Plant Protection, 09 (02) 2025. 325-337 DOI:10.33804/pp.009.02.5638

Check for updates

Available Online at EScience Press
Plant Protection
ISSN: 2617-1287 (Online), 2617-1279 (Print)
http://esciencepress.net/journals/PP

Research Article

EFFECT OF PLANT GROWTH REGULATORS ON THE INFESTATION OF MAJOR INSECT PESTS IN OKRA

[ab]Jawad Hussain Arain, [a]Shakal Khan Korai, [c]Humera Amin, [b]Khalid Hussain Qureshi, [d]Amir Khan Korai, [b]Imtiaz Ahmed Nizamani, [b]Muhammad Ibrahim Kubar, [a]Xiaoshan Wang

[a] *Department of Grassland, College of Animal Science and Technology, Yangzhou University, Yangzhou 225009, P.R. China.*
[b] *Department of Plant Protection, Faculty of Crop Protection, Sindh Agriculture University, Tandojam, Sindh, Pakistan.*
[c] *Department of Agricultural Extension and Rural Studies, College of Agriculture, University of Sargodha, Pakistan.*
[d] *College of Plant Protection, Northwest Agricultural and Forestry University, Yangling 712100, Xi'an, Shaanxi, P.R. China.*

ARTICLE INFO

Article history
Received: 20th February, 2025
Revised: 8th May, 2025
Accepted: 20th May, 2025

Keywords
Plant growth regulators
Jassid
Whitefly
Thrips
Aphid
Shoot and fruit borer
Insect pest management

ABSTRACT

A field trial was conducted in 2022 using a randomized complete block design with three replicates to evaluate the effects of foliar-applied plant growth regulators, Isabion and Aegis, on major insect pests in okra. Populations of jassid, whitefly, thrips, aphid, and *Earias vitella* were monitored fortnightly from March 15 to August 30. Two foliar sprays were applied: the first on March 12 and the second a month later. Pest infestation levels in the PGR-treated plots were compared to untreated controls. Population ranges (per plant) observed for Isabion, Aegis, and the control were as follows: jassid (2.14-8.14, 2.61-9.93, 8.54-15.36), whitefly (0.51-1.95, 0.63-2.38, 2.18-3.68), thrips (0.68-1.12, 1.80-2.96, 2.79-4.57), aphid (1.50-5.02, 1.83-7.95, 10.24-18.43), and *E. vitella* (1.03-5.13, 1.16-8.12, 2.08-21.22), respectively. Compared to the control, Isabion and Aegis reduced the populations of jassid by 53.27% and 42.99%, whitefly by 53.18% and 43.95%, thrips by 75.53% and 35.40%, aphid by 74.96% and 64.04%, and *E. vitella* by 66.80% and 46.24%, respectively. Peak infestations occurred on May 15 for jassid (11.14/plant), whitefly (2.67/plant), and aphid (10.42/plant), and on May 30 for thrips (2.88/plant) and *E. vitella* (3.42/plant). Pest populations declined thereafter, reaching minimal levels by August. The results indicate that both PGRs enhanced plant vigor and conferred resistance to insect pests, with Isabion being more effective than Aegis. Therefore, okra growers are recommended to apply PGRs, preferably Isabion, to boost plant health, improve pod quality, and reduce pest pressure.

Corresponding Author: Xiaoshan Wang; Shakal Khan Korai
Email: xswang@yzu.edu.cn; khanshakal7@gmail.com

INTRODUCTION

Okra (*Abelmoschus esculentus* Moench) is a widely cultivated vegetable belonging to the Malvaceae family. It is enjoyed by people of all socioeconomic backgrounds and grown globally (Patil and Panchbhai, 2003). Due to its delicious taste and high nutritional value, okra is especially popular in South Asia. Per 100 g of the edible portion, okra contains 129 kilocalories of energy, 7.03 g of carbohydrates, 1.20 g of sugars, 3.2 g of dietary fiber, 1.10 g of fat, 2 g of protein, 90.17 g of water, and 81 mg of calcium (Gopalan et al., 1989).

Okra thrives best in tropical and subtropical climates but is highly susceptible to frost (Khayatnezhad et al., 2011). Although it can adapt to a wide range of soil types, it performs best in well-drained soils that are rich in organic matter and contain adequate essential nutrients (Sudhakar et al., 2000).

The rapid spread of insect pests, particularly sucking pests, poses a major threat to vegetable crops worldwide, including okra (Pettersson et al., 2017). Among these pests, aphids, whiteflies, and jassids are of significant economic importance and frequently infest okra crops. These phytophagous insects cause severe damage to okra foliage and fruit, often giving them a dark green tint. Moreover, these pests secrete saliva that contains enzymes such as pectinase, cellulase, phenol oxidase, and peroxidase upon contact with plant tissues. These enzymes contribute to metabolic disruptions by breaking down the cell walls of phloem tissues, thereby facilitating insect feeding and reproduction (Rasool et al., 2017).

Studies have shown that the enzymes and proteins present in aphid saliva can trigger host cell breakdown, increasing plant susceptibility to infections. Common symptoms of sucking insect infestations include leaf curling, wilting, defoliation, and premature fruiting. These insects are also major vectors of viral diseases and can transmit bacterial infections. Furthermore, the honeydew secreted by aphids promotes the growth of sooty mold fungi on the lower leaves, which obstructs photosynthesis and reduces both yield and quality (Agegnehu et al., 2014). In severe infestations, aphids can spread rapidly across fields, reducing crop yields by up to 80% (Kishore and Parihar, 2002). Similarly, whitefly infestations can cause yield losses ranging from 20% to 100%, depending on the severity (Rapisarda and Tropea Garzia, 2002).

Sucking insect infestations significantly reduce crop productivity by altering plant morphological traits and phytochemical composition. To evaluate plant resistance levels, factors such as infestation severity, morphological traits, and phytochemical profiles are considered. Insect infestations not only affect the quantity and quality of agricultural produce but also its visual appeal. The nutritional composition of plant tissues plays a critical role in host selection by phytophagous insects, greatly influencing plant susceptibility to pest attacks. Much like human nutrition, optimal plant nutrition has yet to reach its full potential in enhancing resistance to pests (Simpson et al., 2015).

Previous research has demonstrated that the foliar application of various plant growth regulators (PGRs) can enhance resistance to both biotic and abiotic stresses (El-Rare, 1999; Chatterjee et al., 2013; Camara et al., 2018). Kalsoom et al. (2019) reported a significant reduction in whitefly populations and disease severity in vegetables following nutrient application.

PGRs serve multiple functions in protecting crops from insect pests. While primarily responsible for regulating plant growth and development, PGRs also influence insect behavior, development, and physiology (Finkelstein, 2013; Hedden and Sponsel, 2015). These changes can disrupt the interaction between insect pests and host plants. For instance, PGRs may alter plant physiology in ways that make plants less favorable or accessible to pests (Vriet et al., 2012; Bleecker and Kende, 2000). Abscisic acid (ABA), for example, regulates plant water status, which can negatively affect insects that feed on plant sap or tissues by limiting water availability (Agrawal, 2004). PGRs may also interfere with insect feeding behavior, thereby hindering their development and reproduction (Howe and Jander, 2008).

The use of PGRs to reduce insect pest infestations in okra has been widely investigated. Although PGRs are mainly used to control plant growth and development, they have been shown to enhance plant resistance to insect pests through various mechanisms. For example, treatment of okra with gibberellic acid (GA_3) has been shown to reduce aphid populations and inhibit the development of viral infections. GA_3 treatments modify plant structure and leaf morphology, thereby disrupting aphid feeding and reproduction (Meldau et al., 2009; Ghorai et al., 2014). Similarly, salicylic acid (SA) treatment has been found to enhance plant defense mechanisms and significantly reduce whitefly populations. This effect is attributed to the upregulation of defense-related genes and the accumulation of secondary metabolites (Khanal et al., 2020). Jasmonic acid (JA) also plays a vital role in mediating plant responses to insect attacks. JA-treated okra plants exhibit reduced aphid infestations and feeding damage, likely due to increased synthesis of defensive compounds (Fatima et al., 2022).

Furthermore, Mandal et al. (2018) reported that PGR treatments increased okra's resistance to aphids by activating defense-related genes and inducing morphological and nutritional changes in the plants. Therefore, the present study was conducted to investigate the effect of plant growth regulators on the infestation levels of various insect pests in okra.

MATERIALS AND METHODS

In 2022, the study was conducted at the Institute of Plant Protection, Agriculture Research Center, Tandojam, to investigate the effect of PGRs on the infestation of major insect pests in okra. The objective was to determine how PGRs influence crop growth and efficacy in relation to insect pest populations.

Experimental design and procedure

For the experimental layout, the land was initially ploughed deeply using a disc plow to break the hardpan, followed by a disc harrow for further soil refinement. Clod crushing and leveling were carried out to eliminate weeds and create a uniform soil surface, facilitating even distribution of irrigation water. After a soaking irrigation, once the soil reached proper condition, a cultivator was used, and ridges were prepared.

Plots were arranged according to a Randomized Complete Block Design (RCBD), with each sub-plot separated by a wide strip to prevent the movement of insect pests between plots. Feeding channels were also prepared across treatments. The plots were separated in such a manner as to minimize cross-treatment effects.

The okra variety "Sabzpari" was sown on March 1, 2022, in a total experimental area of half an acre. The aim was to assess populations of major insect pests of okra, including the sucking complex and shoot/fruit borer. The area consisted of three main plots, each measuring 25 × 25 m (625 m²), and each main plot was further subdivided into three replicated plots based on the RCBD layout.

All recommended agronomic practices were followed, including land preparation, timely sowing, weeding, irrigation, and fertilization, as per the guidelines provided by the Horticulture Research Institute, Mirpurkhas. Row spacing was maintained at 75 cm, and plant spacing within rows was 25 cm.

No insecticidal control measures were applied, to allow for assessment of the sole effect of PGRs. A control plot was included in each replication. Two commercially available PGRs, as per the treatment plan, were procured from the local agricultural market. Detailed usage information was obtained from the respective product dealers.

The following are the details of the PGR products used, as mentioned on their labels:

Table 1. Description of plant growth regulators.

Sr. No.	PGR	Company	Formulation	Dose	Mode of Action	Composition	Packing size
1	Isabion	Syngenta	SC (Suspension Concentrate)	2ml/L	Systemic	Amino Acids 100g/L	250 ml
2	Aegis	Greenlet Suncrop PGPR	PGPR	2ml/L	-	Bio Stimulant Sodium Nitrogen Organic Acids	400 ml
3	Control (Untreated)	-	-	-	-	-	-

The commercial NPK fertilizers were applied at the rate of 150-100-80 kg ha^{-1} in the form of urea, single superphosphate (SSP), and sulfate of potash (SOP), respectively. All of the phosphorus (P), potassium (K), and half of the nitrogen (N) were incorporated into the soil before ridge preparation. The remaining nitrogen was applied in two equal splits at monthly intervals following the first application.

Application of PGRs

Two weeks after okra seed emergence, the first foliar spray of PGRs was applied. The second spray was administered one month after the first application. Control plots were not treated with PGRs. However, all other agronomic practices, including fertilizer application, weeding, and irrigation, were carried out uniformly across all plots, including the control. The total quantity of spray solution required for uniform coverage per plot was calculated separately for each treatment. A knapsack hand sprayer was used for the application of PGRs. Separate solutions were prepared for each plot by mixing the prescribed quantity of plant growth regulators with water.

Monitoring insect pest populations

To record seasonal populations of major insect pests of okra, namely aphids, whiteflies, jassids, thrips, and shoot and fruit borers, a total of 50 plants were randomly selected from each sub-plot/treatment within each replication. The population trends of sucking insect pests were monitored by counting all individuals of each pest species on the selected plants. Pest population buildup was assessed weekly throughout the okra growing season. For borer assessment, okra fruits showing signs of infestation were dissected with a knife, and the borers present were recorded.

Statistical analysis

Data related to the population dynamics of sucking insect pests were recorded on data sheets and entered into Microsoft Excel to calculate average pest populations. To evaluate the effectiveness of treatments, the collected data were subjected to statistical analysis using Statistix 8.1 software. The significance of treatment effects on insect pest populations was determined through analysis of variance (ANOVA), and treatment means were compared using the Least Significant Difference (LSD) test.

RESULTS

Effect of foliar-applied PGPRs on insect pest population in okra

The study was conducted during the summer season of 2022 to evaluate the effect of foliar-applied PGRs, Isabion and Aegis, on insect pest populations in okra. The populations of *Amrasca devastans* (jassid), *Bemisia tabaci* (whitefly), *Thrips tabaci* (thrips), *Aphis gossypii* (aphid), and *Earias vitella* (shoot and fruit borer) were monitored from March 15 to August 30, 2022.

Effectiveness of PGRs on Jassid

The Table 2 compares the weekly jassid populations under Isabion, Aegis, and an untreated control from March 15 to August 30, 2022. Isabion-treated plants recorded jassid populations ranging from 6.03 to 8.14/plant, while Aegis ranged from 7.36 to 9.93/plant. The control group showed higher populations, ranging from 11.38 to 15.36/plant. Average populations were 6.11 for Isabion, 7.45 for Aegis, and 12.75 for the control. Both PGRs effectively reduced jassid populations compared to the control, with Isabion being more effective.

Early May data showed moderate jassid populations: 6.03/plant (Isabion), 7.36/plant (Aegis), and 11.38/plant (control). Populations peaked in mid-May, 8.14/plant (Isabion) and 9.93/plant (Aegis), followed by a gradual decline. By July, a significant reduction was observed: 2.14/plant (Isabion), 2.61/plant (Aegis), and 8.54/plant (control). This indicates a seasonal trend, with populations increasing from April to May and declining from June onward. Overall, both PGRs were effective in reducing jassid populations, with Isabion showing greater efficacy throughout the study period (Table 2).

Table 2. Jassid population on okra as affected by foliar application of different PGRs.

Observation dates (OD)	Plant Growth Regularos		
	Isabion	Aeg	Control
15-03-2022	6.03	7.3	11.38
30-03-2022	6.69	8.1	12.63
15-04-2022	7.36	8.9	13.88
30-04-2022	7.96	9.7	15.02
15-05-2022	8.14	9.9	15.36
30-05-2022	7.78	9.4	14.68
15-06-2022	7.18	8.7	14.56
30-06-2022	6.15	7.5	13.88
15-07-2022	6.16	7.5	14.14
30-07-2022	4.56	5.5	9.89
15-08-2022	3.13	3.8	9.10
30-08-2022	2.14	2.6	8.54
Average seasonal population	6.11c	7.4 5b	12.75a
	Treatments (T)	OD	T × OD
S.E.±	0.0424	0.08	0.1469
LSD 0.05	0.0846	0.16	0.2930
CV%	2.05	-	-

Note: Mean values for jassid populations with the same alphabetical letters indicate no significant difference at the 0.05 probability level.

Reduction (%) in Population of Jassid

Table 3 presents a comparative analysis of the impact of two PGRs, Isabion and Aegis, on the reduction of jassid population compared to the untreated control. The data reveal a significant difference in jassid population reduction between the two treatments, aimed at determining which PGR was more effective. According to the Table, a noticeable decline in jassid population was observed. On March 15, 2022, the reduction was 47.01% with Isabion and 35.33% with Aegis, compared to the control plot where no treatment was applied. The effectiveness of both treatments increased over time, with Isabion consistently demonstrating a higher reduction percentage than Aegis throughout the observation period.

From June 15, 2022 onward, Isabion consistently showed greater reductions in jassid populations compared to Aegis. The percentage reductions for both PGRs continued to increase significantly beyond this date, indicating a progressive improvement in pest control efficacy over time.

By the end of the observation period on August 30, 2022, the jassid population in plots treated with Isabion and Aegis had decreased by an average of 74.94% and

69.44%, respectively. This indicates that foliar sprays containing Isabion and Aegis were highly effective in reducing jassid infestation in okra plants. Among the two treatments, Isabion proved to be more effective than Aegis in suppressing the jassid population, suggesting its greater potential for managing jassid infestations in okra cultivation.

Table 3. Percent reduction in jassid population on okra treated with different PGRs.

Observation dates	Population reduction (per plant) over control		% reduction in pest population over control	
	Isabion	Aegis	Isabion	Aegis
15-03-2022	5.35	4.02	47.01	35.33
30-03-2022	5.94	4.46	47.03	35.31
15-04-2022	6.52	4.9	46.97	35.30
30-04-2022	7.06	5.31	47.00	35.35
15-05-2022	7.22	5.43	47.01	35.35
30-05-2022	6.9	5.19	47.00	35.35
15-06-2022	7.38	5.8	50.69	39.84
30-06-2022	7.73	6.38	55.69	45.97
15-07-2022	7.98	6.63	56.44	46.89
30-07-2022	5.33	4.32	53.89	43.68
15-08-2022	5.97	5.28	65.60	58.02
30-08-2022	6.4	5.93	74.94	69.44
Seasonal average	6.65	5.30	53.27	42.99

Effectiveness of PGRs against whitefly

Table 4 presents data on whitefly populations in okra plots treated with two PGRs, Isabion and Aegis, compared to untreated controls. Insect populations were recorded at fortnightly intervals from March 15 to August 30, 2022. Whitefly populations in Isabion-treated plots ranged from 0.51 to 1.95 per plant, while Aegis-treated plots showed populations between 0.63 and 2.38 per plant. In contrast, control plots recorded higher populations, ranging from 2.18 to 3.68 per plant. The average whitefly population was 1.47/plant for Isabion, 1.76/plant for Aegis, and 3.08/plant for the control.

These results indicate that both PGRs effectively suppressed whitefly populations, with Isabion performing better than Aegis. On March 15, 2022, whitefly populations were moderate but varied by treatment: 1.67/plant for Isabion, 1.76/plant for Aegis, and 2.73/plant in the control. Populations peaked on May 15, 2022, reaching 1.95/plant in Isabion and 2.38/plant in Aegis-treated plots, then steadily declined through August. By August 30, whitefly levels were negligible across all treatments.

The seasonal trend showed population increases from April to June and declines thereafter, suggesting environmental influence. The reduced whitefly populations in treated plots may be attributed to enhanced plant vigor induced by PGRs, which likely contributed to increased resistance against pest infestation.

Table 4. Effect of foliar application of different PGRs on whitefly population in okra.

Observation dates	Plant growth regulators		
	Isabion	Aegis	Control
15-03-2022	1.67	1.76	2.73
30-03-2022	1.61	1.96	3.03
15-04-2022	1.76	2.15	3.33
30-04-2022	1.91	2.33	3.60
15-05-2022	1.95	2.38	3.68
30-05-2022	1.86	2.28	3.52
15-06-2022	1.72	2.10	3.49
30-06-2022	1.48	1.80	3.33
15-07-2022	1.36	1.56	3.39
30-07-2022	1.09	1.33	2.37
15-08-2022	0.75	0.91	2.18
30-08-2022	0.51	0.63	2.37
Average seasonal population	1.47c	1.76b	3.08a
	Treatments (T)	OD	T × OD
S.E.±	0.0285	0.0	0.0989
LSD 0.05	0.0569	0.1	0.1972
CV%	5.72	-	-

Note: Mean values for whitefly populations with the same alphabetical letters indicate no significant difference at the 0.05 probability level.

Reduction (%) in Population of Whitefly

Table 5 presents data on the comparative effects of two PGRs, Isabion and Aegis, on whitefly population reduction in okra. The results showed a significant decrease in whitefly populations in plots treated with either PGR compared to the control.

On March 15, 2022, whitefly reduction was recorded at 38.83% in Isabion-treated plots and 35.53% in Aegis-treated plots. The effectiveness of both treatments increased over time, with Isabion consistently showing a higher reduction than Aegis throughout the experiment. Whitefly suppression ranged from 38.83% to 78.48% in Isabion-treated plots and from 35.53% to 73.42% in those treated with Aegis. The lowest reductions were observed at the beginning of the study, while the highest occurred at the final observation.

On average, Isabion treatment resulted in a 53.18% reduction in whitefly population, while Aegis achieved a 43.95% reduction compared to the control. These findings indicate that foliar application of Isabion was more effective in reducing whitefly infestation in okra than Aegis.

Table 5. Effect of different PGRs on the percentage reduction of whitefly population in okra.

Observation dates	Population reduction (per plant) over control		% reduction in pest population over control	
	Isabion	Aegis	Isabion	Aegis
15-03-2022	1.06	0.97	38.83	35.53
30-03-2022	1.42	1.07	46.86	35.31
15-04-2022	1.57	1.18	47.15	35.44
30-04-2022	1.69	1.27	46.94	35.28
15-05-2022	1.73	1.30	47.01	35.33
30-05-2022	1.66	1.24	47.16	35.23
15-06-2022	1.77	1.39	50.72	39.83
30-06-2022	1.85	1.53	55.56	45.95
15-07-2022	2.03	1.83	59.88	53.98
30-07-2022	1.28	1.04	54.01	43.88
15-08-2022	1.43	1.27	65.60	58.26
30-08-2022	1.86	1.74	78.48	73.42
Seasonal average	1.61	1.32	53.18	43.95

Effectiveness of PGRs against thrips on okra

Table 6 presents the weekly infestation data of *Thrips tabaci* on okra from March 15 to August 30, 2022, to evaluate the effect of foliar sprays of two PGRs, Isabion and Aegis. Control plots (no PGR spray) were included for comparison.

Results showed that okra plots treated with Isabion (two foliar sprays during early growth) had a thrips population ranging from 0.33 to 1.12 per plant. In Aegis-treated plots, the population ranged from 0.88 to 2.96 per plant. In control plots, thrips population ranged from 1.37 to 3.89 per plant. The average thrips population per treatment was 0.72/plant for Isabion, 1.90/plant for Aegis, and 2.94/plant for the control. Both PGRs enhanced okra plant vigor and reduced thrips infestation, with Isabion proving more effective than Aegis.

Initially (March 15), infestation was low, but it increased steadily, peaking on May 30 at 1.12, 2.96, and 4.57 thrips/plant in Isabion, Aegis, and control plots, respectively. Thereafter, infestation gradually declined, reaching 0.68, 1.80, and 2.79 thrips/plant in the respective plots by August 30.

Seasonal infestation trends showed an initial population of 0.86/plant on March 15, rising to 1.21 (March 30), 1.35 (April 15), 1.69 (April 30), and 2.02/plant (May 15), peaking at 2.88/plant on May 30. A subsequent decline followed, with population levels decreasing to 2.45 (June 15), 2.28 (June 30), 2.10 (July 15), 1.85 (July 30), 1.79 (August 15), and 1.76/plant on the final observation (August 30). Although all plots followed a similar infestation trend, thrips populations were consistently higher in control plots than in PGR-treated plots.

Table 6. Thrips population on okra as influenced by foliar application of different PGRs.

Observation dates	Plant growth regulators			
	Isabi	Aegis		Control
15-03-2022	0.33	0.88		1.37
30-03-2022	0.47	1.24		1.93
15-04-2022	0.52	1.38		2.14
30-04-2022	0.66	1.74		2.68
15-05-2022	0.79	2.07		3.20
30-05-2022	1.12	2.96		4.57
15-06-2022	0.95	2.52		3.89
30-06-2022	0.89	2.34		3.61
15-07-2022	0.82	2.16		3.34
30-07-2022	0.72	1.89		2.93
15-08-2022	0.70	1.84		2.85
30-08-2022	0.68	1.80		2.79
Average seasonal population	0.72c	1.90b		2.94a
	Treatments (T)		OD	T × OD
S.E. ±	0.0444		0.0	0.1539
LSD 0.05	0.0886		0.1	0.3070
CV%	10.15		-	-

Note: Mean values for thrips populations with the same alphabetical letters indicate no significant difference at the 0.05 probability level.

Reduction (%) in thrips population

Table 7 presents data on the effect of foliar application of Isabion and Aegis (commercially marketed PGRs) on okra and their influence on reducing thrips infestation compared to control plots. A significant difference in thrips population reduction was observed between the two treatments, highlighting the superior efficacy of one product over the other.

At the start of the observation period (March 15, 2022), thrips population was reduced by 75.91% in plots treated with Isabion and by 35.77% in plots treated with Aegis, compared to the control. Both PGRs showed sustained effectiveness throughout the study; however, Isabion consistently achieved more than double the reduction compared to Aegis.

Throughout the experiment, the percentage reduction in thrips population in Isabion-treated plots ranged from 75.31% to 75.91%, whereas in Aegis-treated plots, it ranged from 35.07% to 35.77%. These values remained relatively stable from March 15 to August 30, 2022.

On average, Isabion application resulted in a 75.53% reduction in thrips population, while Aegis achieved a 35.4% reduction. These findings indicate that Isabion was highly effective in suppressing thrips infestation in okra, while Aegis provided moderate control.

Table 7. Percentage reduction in thrips population on okra treated with different PGRs.

Observation dates	Population reduction (per plant) over		% reduction in pest population over control	
	Isabion	Aegis	Isabion	Aegis
15-03-2022	1.04	0.49	75.91	35.77
30-03-2022	1.46	0.69	75.65	35.75
15-04-2022	1.62	0.76	75.70	35.51
30-04-2022	2.02	0.94	75.37	35.07
15-05-2022	2.41	1.13	75.31	35.31
30-05-2022	3.45	1.61	75.49	35.23
15-06-2022	2.94	1.37	75.58	35.22
30-06-2022	2.72	1.27	75.35	35.18
15-07-2022	2.52	1.18	75.45	35.33
30-07-2022	2.21	1.04	75.43	35.49
15-08-2022	2.15	1.01	75.44	35.44
30-08-2022	2.11	0.99	75.63	35.48
Seasonal average	2.22	1.04	75.53	35.40

Effectiveness of PGRs against aphid infestation on okra

Weekly observations of aphid populations on okra, treated with PGRs Isabion and Aegis, were recorded from March 15 to August 30, 2022 (Table 8). The aphid population ranged from 1.50 to 5.02/plant in plots treated with Isabion and from 1.83 to 7.95/plant in those treated with Aegis. In untreated control plots, the population ranged from 10.24 to 18.43/plant. The average aphid population per plant was 3.91 for Isabion, 5.66 for Aegis, and 15.31 for the control. Both PGRs effectively reduced aphid infestation, with Isabion showing greater efficacy than Aegis.

Seasonal trends showed an initial rise in aphid populations, peaking on May 15 and June 15, 2022, at 18.43 (control), 7.95 (Aegis), and 5.02/plant (Isabion). Populations then gradually declined, reaching their lowest on August 30 at 10.24 (control), 1.83 (Aegis), and 1.50/plant (Isabion), with an overall average of 4.52/plant. The infestation began at an average of 7.72/plant on March 15, peaked at 10.42 on May 15, and steadily decreased to 5.26/plant by August 15 and 4.52/plant by the final observation.

Table 8. Effect of foliar application of different PGRs on aphid population in okra.

Observation dates	Plant growth regulators		
	Isabion	Aegis	Control
15-03-2022	3.62	5.89	13.65
30-03-2022	4.02	6.54	15.16
15-04-2022	4.41	7.18	16.66
30-04-2022	4.77	7.77	18.02
15-05-2022	4.88	7.95	18.43
30-05-2022	4.67	7.59	17.62
15-06-2022	5.02	6.13	17.48
30-06-2022	4.30	5.25	16.66
15-07-2022	4.31	5.26	16.97
30-07-2022	3.19	3.89	11.87
15-08-2022	2.19	2.68	10.93
30-08-2022	1.50	1.83	10.24
Average seasonal population	3.91c	5.66b	15.31a
	Treatments (T)	OD	T × OD
S.E. ±	0.0654	0.1	0.2266
LSD 0.05	0.1305	0.2	0.4520
CV%	3.35	-	-

Note: Mean values for aphid populations with the same alphabetical letters indicate no significant difference at the 0.05 probability level.

Reduction (%) in aphid population

Table 9 presents a comparative analysis of the reduction in aphid populations on okra plants treated with the PGRs Isabion and Aegis, compared to an untreated control. A significant difference was observed between the two treatments, indicating that one PGR was more effective in inducing resistance against aphid infestation.

On March 15, 2022, the reduction in aphid population was 73.48% in plots treated with Isabion and 56.85% in those treated with Aegis, compared to the control. Both treatments consistently reduced aphid infestation throughout the growing season, with Isabion showing a higher and more consistent effect.

The aphid reduction in Isabion-treated plots ranged from 71.28% to 85.35%, while Aegis-treated plots showed a reduction range of 56.85% to 82.13%. On average, Isabion achieved a 74.96% reduction, compared to 64.04% with Aegis. These results suggest that foliar application of Isabion is more effective than Aegis in enhancing resistance of okra plants to aphid.

Table 9. Effect of various PGRs on the reduction (%) of aphid population in okra.

Observation dates	Population reduction (per plant) over control		% reduction in pest population over control	
	Isabion	Aegis	Isabion	Aegis
15-03-2022	10.03	7.76	73.48	56.85
30-03-2022	11.14	8.62	73.48	56.86
15-04-2022	12.25	9.48	73.53	56.90
30-04-2022	13.25	10.25	73.53	56.88
15-05-2022	13.55	10.48	73.52	56.86
30-05-2022	12.95	10.03	73.50	56.92
15-06-2022	12.46	11.35	71.28	64.93
30-06-2022	12.36	11.41	74.19	68.49
15-07-2022	12.66	11.71	74.60	69.00
30-07-2022	8.68	7.98	73.13	67.23
15-08-2022	8.74	8.25	79.96	75.48
30-08-2022	8.74	8.41	85.35	82.13
Seasonal average	11.40	9.64	74.96	64.04

Effectiveness of PGRs against shoot and fruit borer in okra

Table 10 presents weekly infestation data of shoot and fruit borer on okra treated with the PGRs Isabion and Aegis from March 15 to August 30, 2022. Plants sprayed with Isabion showed *E. vitella* populations ranging from 1.03 to 5.13 insects per plant, while Aegis-treated plots recorded 1.16 to 8.12 insects per plant. In contrast, control plots had significantly higher infestations, ranging from 2.08 to 21.22 insects per plant. Average *E. vitella* populations were 3.34/plant for Isabion, 5.64/plant for Aegis, and 11.40/plant in the control, indicating that both PGRs enhanced plant resistance, with Isabion being more effective.

Seasonal variation showed an increasing trend in infestation, peaking on May 30, 2022, with 5.13, 8.12, and 21.22 insects/plant in Isabion, Aegis, and control plots, respectively. Infestation declined steadily thereafter, reaching the lowest levels on August 30, 2022: 1.03 (Isabion), 1.16 (Aegis), 2.08 (control), with an overall average of 1.42 insects/plant.

Initially, the average infestation was 2.29/plant (March 15), rising to 8.03 (April 15), 9.67 (April 30), 11.07 (May 15), and peaking at 11.49/plant on May 30. A consistent decline followed: 10.88 (June 15), 7.11 (June 30), 6.66 (July 15), 5.87 (July 30), 3.35 (August 15), and 1.42 (August 30).

Table 10. Effect of foliar application of different PGRs on the population of shoot and fruit borer in okra

Observation dates	Plant growth regulators		
	Isabion	Aegis	Control
15-03-2022	1.36	2.01	3.49
30-03-2022	2.85	3.08	5.12
15-04-2022	4.12	6.66	13.32
30-04-2022	4.85	7.31	16.85
15-05-2022	5.06	7.81	20.35
30-05-2022	5.13	8.12	21.22
15-06-2022	4.98	8.02	19.65
30-06-2022	3.77	7.24	10.33
15-07-2022	3.21	7.12	9.65
30-07-2022	2.16	6.89	8.55
15-08-2022	1.56	2.26	6.22
30-08-2022	1.03	1.16	2.08
Average seasonal population	3.34c	5.64b	11.40a
	Treatments(T)	OD	T×OD
S.E. ±	0.1320	0.17	0.2619
LSD 0.05	0.2928	0.41	0.6972
CV%	6.70	-	-

Note: Mean values for shoot and fruit borer populations with the same alphabetical letters indicate no significant difference at the 0.05 probability level.

Percent reduction in *E. vitella* population

Table 11 presents the impact of foliar application of PGRs, Isabion and Aegis, on reducing *E. vitella* infestation in okra compared to the untreated control. The results revealed a highly significant reduction in *E. vitella* population in plots treated with either PGR, indicating both contributed to inducing plant resistance against the pest.

On March 15, 2022, infestation was reduced by 61.03% in Isabion-treated plots and by 42.41% in Aegis-treated plots compared to the control. This trend continued throughout the season, with Isabion consistently showing higher efficacy than Aegis. *E. vitella* reduction ranged from 44.34% to 75.82% in Isabion-treated plots, and from 26.22% to 61.73% in those treated with Aegis. On average, Isabion reduced *E. vitella* infestation by 66.80%, while Aegis achieved a 46.24% reduction. These findings suggest that foliar application of Isabion is more effective in enhancing okra resistance to *E. vitella*, whereas Aegis provides moderate protection.

Table 11. Effect of PGRs on the reduction (%) of *E. vitella* infestation in okra.

Observation dates	Population reduction (per plant) over control		% reduction in pest population over control	
	Isabion	Aegis	Isabion	Aegis
15-03-2022	2.13	1.48	61.03	42.41
30-03-2022	2.27	2.04	44.34	39.84
15-04-2022	9.2	6.66	69.07	50.00
30-04-2022	12	9.54	71.22	56.62
15-05-2022	15.29	12.54	75.14	61.62
30-05-2022	16.09	13.1	75.82	61.73
15-06-2022	14.67	11.63	74.66	59.19
30-06-2022	6.56	3.09	63.50	29.91
15-07-2022	6.44	2.53	66.74	26.22
30-07-2022	6.39	1.66	74.74	19.42
15-08-2022	4.66	3.96	74.92	63.67
30-08-2022	1.05	0.92	50.48	44.23
Seasonal average	8.06	5.76	66.80	46.24

DISCUSSION

Pakistan lies in an acute water-scarce zone, with the situation being particularly severe in the Sindh province due to intense summer heat and prolonged sunshine. These harsh environmental conditions directly impact crop foliage, ultimately reducing productivity. Moreover, the agricultural soils in Sindh are significantly deficient in organic matter, resulting in weak and less vigorous crops that are more susceptible to both biotic and abiotic stressors. The foliar application of PGRs has been shown to enhance plant vigor, leading to improved resistance against biotic stresses, including insect pest infestations.

The present study primarily aimed to evaluate the effects of PGRs on the infestation levels of major insect pests of okra. The results revealed that foliar applications of Isabion and Aegis significantly reduced insect pest populations compared to the untreated control. Specifically, Isabion and Aegis led to substantial reductions in the populations of jassid (53.27% and 42.99%), whitefly (53.18% and 43.95%), thrips (75.53% and 35.40%), aphid (74.96% and 64.04%), and *E. vitella* (66.80% and 46.24%), respectively. Following peak infestation, pest populations gradually declined and reached minimum levels during the final two weeks of observation. Both PGRs contributed to enhanced plant vigor and resistance, with Isabion-treated plants exhibiting comparatively higher levels of resistance.

Isabion, a Syngenta product, demonstrated superior efficacy over Aegis, likely due to its high amino acid content (100 g/L), which plays a critical role in promoting plant growth and metabolism. Amino acids serve as precursors and activators of phytohormones, enzymes, and secondary metabolites vital for plant development and stress tolerance (Trovato et al., 2021; Kaya, 2023). Isabion's systemic mode of action enables efficient absorption and translocation within the plant, thereby improving nutrient uptake and stress mitigation, which results in vigorous growth and higher yield potential (Jahanbani et al., 2024). In contrast, Aegis contains PGPRs and biostimulant compounds such as sodium nitrogen and organic acids. Although PGPRs positively influence root development and microbial activity in the rhizosphere, their effects are often less direct and more dependent on environmental conditions (Santoyo et al., 2021).

Moreover, the direct provision of amino acids through Isabion may more effectively activate stress-responsive genes and defense pathways compared to Aegis, enhancing the plant's innate immunity to biotic and abiotic stress (Hasanuzzaman and Fujita, 2022). Exogenous amino acid application has been shown to improve photosynthesis, root development, and antioxidative defense systems under stress, benefits that microbial-based biostimulants may not provide to the same extent (Johnson et al., 2024; Sun et al., 2024). Given these advantages, Isabion not only delivers faster and more consistent results but also contributes to overall plant health, making it a more effective growth enhancer under diverse conditions.

Similar findings were reported by Alyousuf and Nikpay (2020), who assessed the efficacy of various insect growth regulators (IGRs) against okra insect pests. Among these, Hi-Catch showed the highest control efficiency (82.01%), not significantly different from Match and other treatments (81.11%, 78.36%, and 73.1%) as reported by Shaaban et al. (2011). Post-treatment infestation rates were substantially reduced (10.18-12.23%) compared to the control (31.11%), with improved efficacy observed after the second spray.

Since PGRs stimulate physiological processes in plants, they may also reduce insect herbivory by activating defense mechanisms. A growing body of literature supports the role of PGRs in inducing protective responses against insect pests (Ali et al., 2024). For example, Kumar et al. (2020) noted that sucking insect pests, including whiteflies, aphids, jassids, and thrips, cause considerable yield losses in okra. Praveen and Regupathy (2003) also highlighted that infestation levels and subsequent crop damage vary depending on geographical and seasonal factors, with environmental conditions (temperature, humidity, rainfall) significantly influencing pest dynamics. Moreover, natural enemies present in okra agro-ecosystems help control soft-bodied insect pests, contributing to eco-friendly pest management.

Fahad et al. (2016) evaluated 13 PGRs for their effects on crop morphology, phenology, yield, and pest resistance. Application of naphthalene acetic acid (NAA) at 20 ppm improved morphological traits and reduced pest infestation. Similarly, Gadade et al. (2017) reported that gibberellic acid (GA_3 and NAA significantly enhanced plant height, branching, and yield in okra while reducing the incidence of sucking pests and fruit borers compared to control plots.

Seasonal pest population trends showed that jassid, whitefly, and aphid populations peaked on May 15, 2022, while thrips and *E. vitella* peaked on May 30, 2022. After these peaks, pest populations declined significantly. The application of Isabion and Aegis improved plant resilience to pest attacks, with Isabion proving more effective. Other studies have indicated that GA_3-treated okra plants suffered less damage from bollworms due to increased expression of defense-related genes. Similarly, indole-3-acetic acid (IAA) enhanced resistance to aphids by boosting defensive enzymes such as peroxidase and polyphenol oxidase.

Although the use of PGRs shows promise in reducing insect pest infestations in okra, several areas remain underexplored, including optimal application rates, timing, long-term ecological impacts, and the effectiveness of hormone combinations. Nevertheless, PGRs represent a viable strategy for integrating pest resistance into crop management systems. For example, Uttam (2024) reported that the PGR Novaluron inhibited bollworm larval molting, significantly reducing their survival. The IGR Lufenuron also selectively targeted pests without harming non-target organisms. Dilruba et al. (2009) found that PGRs such as Alga Gold, Crop Care, and Ripen-15 significantly improved fruit yield and reduced pest infestations when applied at appropriate growth stages.

Previous studies have extensively documented the role of PGRs in enhancing plant defense against biotic stress. Among these, salicylic acid (SA) has been identified as a central molecule in plant immunity, particularly through its involvement in systemic acquired resistance (SAR), which provides long-lasting protection against biotrophic pathogens via upregulation of pathogenesis-related (PR) genes and accumulation of reactive oxygen species (ROS) (Roychowdhury et al., 2024).

Likewise, jasmonic acid (JA) and ethylene (ET) activate induced systemic resistance (ISR), which is particularly effective against necrotrophic pathogens and herbivorous insects. The JA/ET signaling cascade regulates the expression of defense-related genes such as *PDF1.2*, crucial in the plant's response to insect herbivory and fungal invasion (Raad, 2016). These hormonal pathways are finely tuned and interact based on the type of biotic stress encountered.

Abscisic acid (ABA), though primarily associated with abiotic stress tolerance, also plays a context-specific role in plant-pathogen interactions. Whereas it may suppress defenses against biotrophs, it can enhance tolerance to necrotrophs under certain conditions (Ghozlan et al., 2020). Other hormones like cytokinins and auxins, generally known for their developmental roles, are also involved in defense signaling. Cytokinins reinforce SA-dependent pathways, while auxin plays a dual role, potentially exploited by pathogens for infection but also capable of triggering enhanced resistance when its signaling is modified (Fu and Wang, 2011).

Finally, brassinosteroids (BRs), best known for promoting plant growth, also enhance immune responses and stimulate oxidative bursts, thus reinforcing plant defense mechanisms (De Bruyne et al., 2014). Collectively, these understandings emphasize the multifaceted role of PGRs in integrated pest management, offering a sustainable alternative to conventional pesticides while promoting crop resilience and productivity.

CONCLUSION

The experiment was conducted during the summer of 2022 to evaluate the impact of foliar-applied plant growth regulators, Isabion and Aegis, on insect pest populations in okra. The first spray was applied two weeks after seed emergence, followed by a second spray one month later. Control plots were left unsprayed. Pest populations, including jassid, whitefly, thrips, and aphid, were monitored from March 15 to August 30, 2022. Both PGRs effectively reduced pest populations, with Isabion proving more effective than Aegis. Infestations followed a seasonal pattern, rising from April to June and peaking in mid to late May, then declining through July and August. Peak populations were recorded on May 15 for jassid (11.14/plant), whitefly (2.67/plant), and aphid (10.42/plant), and on May 30 for thrips (2.88/plant) and borers (11.49/plant). Compared to the control, Isabion and Aegis reduced populations respectively as follows: jassid by 53.27% and 42.99%, whitefly by 53.18% and 43.95%, thrips by 75.53% and 35.40%, aphid by 74.96% and 64.04%, and borers by 66.80% and 46.24%. These results demonstrate the effectiveness of PGRs, particularly Isabion, in reducing insect pests and highlight their potential role in integrated pest management strategies for okra cultivation.

AUTHORS' CONTRIBUTIONS

KHQ and XW designed the study; KHQ and JHA prepared the materials, collected and analyzed the data; SKK and AKK helped in disease scoring; KHQ, XW, and IAN supervised the studies; JHA, HA, MIK, and SKK wrote the manuscript; All the authors proofread and approved the final manuscript.

RESEARCH FUNDING

This work was supported by the National Key Research and Development Program of China (No. 2022YFE0113400).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUSTAINABLE DEVELOPMENT GOALS TARGETED

SDG 2: Zero Hunger
SDG 12: Responsible Consumption and Production
SDG 15: Life on Land

REFERENCES

Agegnehu, E., Ousma, Y., Ayalew, A., 2014. Screening of some foliar chemical insecticides against white fly (*Bemisia tabaci*) on tomato at Metema district, North Gondar, Ethiopia. Open Access Library Journal 1(2), 1-7.

Agrawal, A.A., 2004. Plant defense and density dependence in the population growth of herbivores. The American Naturalist 164(1), 113-120.

Ali, J., Tonğa, A., Islam, T., Mir, S., Mukarram, M., Konôpková, A.S., Chen, R., 2024. Defense strategies and associated phytohormonal regulation in Brassica plants in response to chewing and sap-sucking insects. Frontiers in Plant Science 15, 1376917.

Alyousuf, A., Nikpay, A., 2020. Economic importance insects of the plantations in Basrah Province, Iraq. Annals of Agricultural and Crop Sciences 5(2), 1061.

Bleecker, A.B., Kende, H., 2000. Ethylene: a gaseous signal molecule in plants. Annual Review of Cell and Developmental Biology 16(1), 1-18.

Camara, J., Logah, V., Osekre, E.A., Kwoseh, C., 2018. Leaf nutrients content of tomato and incidence of insect pests and diseases following two foliar applications. Journal of Plant Nutrition 41(2), 159-167.

Chatterjee, R., Choudhuri, P., Laskar, N., Pundibari, C.B., 2013. Influence of nutrient management practices for minimizing whitefly (*Bemisia tabaci* Genn.) population in tomato (*Lycopersicon esculentum* Mill.). International Journal of Science, Environment and Technology 2(5), 956-962.

De Bruyne, L., Höfte, M., De Vleesschauwer, D., 2014. Connecting growth and defense: the emerging roles of brassinosteroids and gibberellins in plant innate immunity. Molecular Plant 7(6), 943-959.

Dilruba, S., Hasanuzzaman, M., Karim, R., Nahar, K., 2009. Yield response of okra to different sowing time and application of growth hormones. Journal of Horticultural Science & Ornamental Plants 1, 10-14.

El-Rare, K.K., 1999. Effect of different rates of (N, P, K) fertilizers on *Bemisia tabaci* (Genn.) infestation on tomato and its effect on the yield. Egyptian Journal of Agricultural Research 77(3), 1067-1073.

Fahad, S., Hussain, S., Saud, S., Hassan, S., Ihsan, Z., Shah, A.N., Wu, C., Yousaf, M., Nasim, W., Alharby, H., 2016. Exogenously applied plant growth regulators enhance the morpho-physiological growth and yield of rice under high temperature. Frontiers in Plant Science 7, 1250.

Fatima, A., Husain, T., Suhel, M., Prasad, S.M., Singh, V.P., 2022. Implication of nitric oxide under salinity stress: the possible interaction with other signaling molecules. Journal of Plant Growth Regulation 41, 1-15.

Finkelstein, R., 2013. Abscisic acid synthesis and response. The Arabidopsis Book/American Society of Plant Biologists 11.

Fu, J., Wang, S., 2011. Insights into auxin signaling in plant-pathogen interactions. Frontiers in Plant Science 2, 74.

Gadade, S.B., Shinde, V.S., Deosarkar, D.B., Shinde, S.S., 2017. Effect of plant growth regulators on growth and yield of okra (Abelmoschus esculentus L.). Plant Archives 17(1), 177-180.

Ghorai, S., Wang, B., Tivanski, A., Laskin, A., 2014. Hygroscopic properties of internally mixed particles composed of NaCl and water-soluble organic acids. Environmental Science & Technology 48(4), 2234-2241.

Ghozlan, M.H., Eman, E.-A., Tokgöz, S., Lakshman, D.K., Mitra, A., 2020. Plant defense against necrotrophic pathogens. American Journal of Plant Sciences 11(12), 2122-2138.

Gopalan, C., Rama Sastri, B.V., Balasubramanian, S.C., 1989. Nutritive value of Indian foods.

Hasanuzzaman, M., Fujita, M., 2022. Plant responses and tolerance to salt stress: physiological and molecular interventions. International Journal of Molecular Sciences 23(9), 4810.

Hedden, P., Sponsel, V., 2015. A century of gibberellin research. Journal of Plant Growth Regulation 34, 740-760.

Howe, G.A., Jander, G., 2008. Plant immunity to insect herbivores. Annual Review of Plant Biology 59(1), 41-66.

Jahanbani, S., Mumivand, H., Zahedi, B., Argento, S., 2024. Foliar application of urea and amino acids regulates growth, photosynthesis, pigments, antioxidant activity, and the essential oil content and composition of basil (*Ocimum basilicum* L.). Agronomy 14(12), 2950.

Johnson, R., Joel, J.M., Puthur, J.T., 2024. Biostimulants: The futuristic sustainable approach for alleviating crop productivity and abiotic stress tolerance. Journal of Plant Growth Regulation 43(3), 659-674.

Kalsoom, H., Ali, S., Sahi, G.M., Habib, A., Zeshan, M.A., Anjum, R., Yousaf, M., Abdullah, A., 2019. Differential response of micronutrients and novel insecticides to reduce cotton leaf curl virus disease and its vector in *Gossypium hirsutum* varieties. International Journal of Agriculture and Biology 22, 1507-1512.

Kaya, G., 2023. Plant-and animal-derived biostimulants for overcoming salinity stress by regulating the physiological parameters of broccoli. Polish Journal of Environmental Studies 32(6), 5129-5136.

Khanal, D., Maharjan, S., Lamichhane, J., Neupane, P., Sharma, S., Pandey, P., 2020. Efficacy of biorational compounds against mustard aphid (*Lipaphis erysimi* Kalt.) and English grain aphid (*Sitobion avenae* Fab.) under laboratory conditions in Nepal. Advances in Agriculture 2020(1), 9817612.

Khayatnezhad, M., Gholamin, R., Jamaati-e-Somarin, S., Zabihi-e-Mahmoodabad, R., 2011. The leaf chlorophyll content and stress resistance relationship considering in corn cultivars (*Zea mays*). Advances in Environmental Biology 5(1), 118-122.

Kishore, R., Parihar, S.B.S., 2002. Aphid species infesting tomato and brinjal crops. Insect Environment 8(1), 8-9.

Kumar, R., Singh, R.S., Yadav, N., Kumar, S., 2020. Impact of nutrient application on aphid incidence on different varieties of Indian mustard, *Brassica juncea* L. Journal of Entomology and Zoology Studies 8(5), 1026-1029.

Mandal, D., Pachuau, L., Hazarika, T.K., Shukla, A.C., 2018. Post-harvest application of salicylic acid enhanced shelf life and maintained quality of local mango cv Rangkuai of Mizoram at ambient storage condition. Environment and Ecology 36(4), 1057-1062.

Meldau, S., Wu, J., Baldwin, I.T., 2009. Silencing two herbivory-activated MAP kinases, SIPK and WIPK, does not increase Nicotiana attenuata's susceptibility to herbivores in the glasshouse and in nature. New Phytologist 181(1), 161-173.

Patil, G.B., Panchbhai, D.M., 2003. Response of okra varieties for different nitrogen levels. Annals of Plant Physiology 17(2), 146-149.

Pettersson, J., Tjallingii, W.F., Hardie, J., 2017. Host-plant selection and feeding. In: Van Emden, H.F., Harrington, R. (Eds.), Aphids as Crop Pests. CABI, Wallingford, UK, pp. 173-195.

Praveen, P.M., Regupathy, A., 2003. Insecticide resistance in field populations of cotton thrips (*Thrips tabaci* Lindeman) in major cotton growing regions of Tamil Nadu. Pesticide Research Journal 15(2), 197-200.

Raad, M., 2016. Plant-mediated interactions between the entomopathogenic fungus *Beauveria bassiana*, insect herbivores and a plant pathogen. Ph.D. Thesis, Lincoln University.

Rapisarda, C., Tropea Garzia, G., 2002. Tomato yellow leaf curl Sardinia virus and its vector *Bemisia tabaci* in Sicilia (Italy): present status and control possibilities. EPPO Bulletin 32(1), 25-29.

Rasool, B., McGowan, J., Pastok, D., Marcus, S.E., Morris, J.A., Verrall, S.R., Hedley, P.E., Hancock, R.D., Foyer, C.H., 2017. Redox control of aphid resistance through altered cell wall composition and nutritional quality. Plant Physiology 175(1), 259-271.

Roychowdhury, R., Mishra, S., Anand, G., Dalal, D., Gupta, R., Kumar, A., Gupta, R., 2024. Decoding the molecular mechanism underlying salicylic acid (SA)-mediated plant immunity: an integrated overview from its biosynthesis to the mode of action. Physiologia Plantarum 176(3), e14399.

Santoyo, G., Urtis-Flores, C.A., Loeza-Lara, P.D., Orozco-Mosqueda, M.C., Glick, B.R., 2021. Rhizosphere colonization determinants by plant growth-promoting rhizobacteria (PGPR). Biology 10(6), 475.

Shaaban, A.D., Alyousuf, A., Al-Kureashy, M.T., 2011. Comparative the Effect of some insect growth regulators in infestation of larvae spring bollworm Eaerias insulana (Boisd.) on Okra Hibiscus trionum L. Al-Mustansiriyah Journal of Science 22(3), 69-78.

Simpson, S.J., Clissold, F.J., Lihoreau, M., Ponton, F., Wilder, S.M., Raubenheimer, D., 2015. Recent advances in the integrative nutrition of arthropods. Annual Review of Entomology 60(1), 293-311.

Sudhakar, P., Chattopadhyay, G.N., Gangwar, S.K., Ghosh, J.K., 2000. Effect of foliar application of *Azotobacter*, *Azospirillum* and *Beijerinckia* on leaf yield and quality of mulberry (*Morus alba*). The Journal of Agricultural Science 134(2), 227-234.

Sun, W., Shahrajabian, M.H., Kuang, Y., Wang, N., 2024. Amino acids biostimulants and protein hydrolysates in agricultural sciences. Plants 13(2), 210.

Trovato, M., Funck, D., Forlani, G., Okumoto, S., Amir, R., 2021. Amino acids in plants: regulation and functions in development and stress defense. Frontiers in Plant Science 12, 772810.

Uttam, M.W.S., 2024. Bioefficacy of different biopesticides against sucking pest complex of okra (*Abelmoschus esculentus* L. Moench). M.Sc. Thesis, Mahatma Phule Krishi Vidyapeeth.

Vriet, C., Russinova, E., Reuzeau, C., 2012. Boosting crop yields with plant steroids. The Plant Cell 24(3), 842-857.