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EVALUATION OF OKRA (*ABELMOSCHUS ESCULENTUS* L.) PEST CONTROL STRATEGIES AND COST-BENEFIT ANALYSIS

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ABSTRACT

A field study on integrated pest management of okra insect pests was conducted at the Plant Pathology Research Institute, Ayub Agriculture Research Institute, in collaboration with the Department of Entomology, University of Agriculture Faisalabad, during the 2022 crop season. Rama Krishma, a variety of okra, was sown using the Randomized Complete Block Design with four replications and employing the drilling technique and agronomical practices. Significant differences ($P<0.05$) in insect pest populations, namely whitefly, jassid, thrips, aphids, *Helicoverpa*, and spotted bollworm, were observed across various treatments. The pest populations of all these insects progressively decreased with treatment applications, and post-treatment measurements were taken 48 hours after each spray. The minimum mean populations of aphids (2.01/leaf), thrips (0.15/leaf), jassids (1.86/leaf), and spotted bollworm (2.41/plant) were recorded with the application of the biosal treatment, followed by *Helicoverpa* (1.25/plant) and whitefly (0.13/leaf) populations, which were observed in plots treated with tobacco extract and *Chrysoperla* + *Trichogramma*, respectively. The maximum mean populations of *Formicomus antiqumus* (0.55), *Laius malleifer* (0.17), *Orius* bugs (0.56), *Trichogramma chilonis* (Ishii) (20.41), *Chrysoperla carnea* (0.31), ladybird beetles (0.69), ants (0.79), and spiders (0.89) were recorded in the *Chrysoperla* + *Trichogramma* treated plots, indicating the safety of this bio-pesticide for predatory populations. Analysis of yield attributing parameters revealed that biosal-treated plots exhibited the highest values for several factors, including the maximum number of fruits per plant (19.57), number of flowers (8.75), squares (18.34), plant height (42.36 cm), and number of branches per plant (3.73). Furthermore, the cost-benefit ratios for okra plants were highest for treatments involving tobacco extract and natural enemies, with ratios of 1:16.3 and 1:10.6, respectively. The application of biosal after treatment demonstrated superior efficacy as a control approach compared to alternative treatments.

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INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is one of the most cultivated vegetables in Pakistan. Several pests including *Nezara viridula*, *Dysdercus koengii*, *Haritalodes derogata*, *Sylepta derogata*, *Anomisflava*, *Podagrica*, *Aphis gossypii*, *Thrips tabaci*, *Acrocercops bifasciata*, *Helicoverpa armigera*, *Bemisia tabaci*, *Earias vittella*, and *Amrasca devastans* significantly reduced the okra production. Among all these pests, *B. tabaci*, *H. armigera*, *E. vittela*, and *Amrasca devastans* are the most common okra pests (Dubey et al., 1999; Wagan and Wagan, 2015). However, these pests also help in dispersal of several plant pathogens which restrict growth of plants (Dhaliwal et al., 1981). In this situation, entomologists must concentrate on integrated pest management (IPM) of okra and other crops (Kumawat et al., 2000; Aatif et al., 2023).

Predators, parasitoids, and natural enemies significantly reduced noxious insect pest populations (Civantos-Ruiz et al., 2022). Biocontrol agents and neem extracts are eco-friendly ways to manage the okra pests (Al-Eryan et al., 2001; Moarefi et al., 2023). Neem oil is considered non-toxic and acted as an oviposition deterrent, growth inhibitor, and antifeedant against okra and cotton bugs (Owais et al., 2018). Widespread insecticide use has killed natural enemies and polluted the ecosystem. Therefore, application of integrated pest management strategies protects the ecosystem. Biological pest and weed control by natural enemies is eco-friendly, so encouraging them is key to integrated pest management (Kapadia et al., 1991; Abubakar et al., 2022).

Various management measures are employed to manage insect pests in okra, including chemical insecticides, biological control methods, synthetic insecticides, and resistance mechanisms that modify insect growth, development, and population dynamics (Mukhtar et al., 2023; Shahbaz et al., 2023). However, previous studies have indicated that using entomopathogenic fungi, either independently or in conjunction with plant extracts, has the potential to mitigate insect pest populations effectively (Javed et al., 2019; Gulzar et al., 2020; Shehzad et al., 2021, 2022). According to Jan et al. (2022), synthetic insecticides have been extensively employed to manage insect infestations. Nevertheless, these substances pose a threat to human beings, animals, and beneficial insects. Agricultural workers are rendered susceptible due to their continuous exposure to pesticides. The incidence of mortality resulting from insecticide poisoning has been reported to be responsible for 40,000 individuals, with an additional two million individuals experiencing adverse effects (Ahmad, 2020). Over an extended period, the agricultural and horticultural industries have employed genetically engineered insecticides to decrease the widespread application of pesticides without discrimination. Biopesticides are effective in organic farming when used in reduced quantities. The application of improved alternatives for humans, animals, non-target organisms, plants, and microorganisms contributes to enhanced safety measures. The studies conducted by Ahmed (2020), and Iqbal et al. (2017) are relevant to the topic under discussion.

Biosal, *Bacillus thuringiensis*, neex extracts, and other biological control agents including *Trichogramma*, *Chrysoperla*, *Laius*, myrid bug, *Orius*, lady bird beetle, ant, and spider should be used in combination for cost-effective insect pest management (Abro et al., 2004; Jafir et al., 2018). Since long, industrial agriculture and horticulture have been used as natural bio-pesticides to avoid pesticide problems (Dahal et al., 2020). Bio-pesticides from animals, plants, microbes, and minerals are good alternatives. Bio-pesticides target only the pest and are less toxic to non-targeted natural enemies (Toundou et al., 2020). Bio pesticides work in small amounts and decompose rapidly, reducing exposure and pollution. Neem tree seeds (*Azadirachta indica* A. Juss.) have many pest-controlling impacts and little toxicity to non-target organisms (Halder et al., 2022). Tobacco extract, neem oil, and extract are inexpensive and easily collected in rural areas, making them hopeful pest control measures (Baig et al., 2021).

Farm employees are endangered when pesticides are stored and used. Insecticide toxicity killed 40,000 people and affected two million others (Ashraf et al., 2018; Lalruatsangi, 2022). Thus, there is a dire need to manage the insect pests' populations through biological control agents. Hence, the main objective of present study was to compare the effects of various management strategies, such as the use of botanicals (tobacco extract and biosal), synthetic insecticides, and natural enemies (*Chrysoperla carnea* and *Trichogramma chilonis*), on the insect pest population of the okra crop and to analyze the cost benefits ratio.

MATERIALS AND METHODS

The present study was conducted at the research area of

Plant Pathology Research Institute (PPRI), Ayub Agriculture Research Institute in collaboration with the Department of Entomology, University of Agriculture Faisalabad during 2022 crop season.

Cultivation of crop

The okra cultivar such as Rama Krishna was cultivated in the well prepared soil on ridges in research area of PPRI following Randomized Complete Block Design with four replications on 17-02-2022 on one acre land. The row to row and plant to plant distance was kept 60 cm and 30 cm respectively. The seed rate was applied @ 8kg/acre and treatment size was maintained 1500 square feet.

Application of treatments

Five treatments were applied including a control. The detail of treatment is illustrated in Table 1.

Table 1. Details of treatments used during the investigation.

Sr. No.	Treatments	Description
1	T_1 = Biosal	Biosal was obtained from the University of Agriculture Faisalabad. Biosal was applied with a concentration of 1% spray solution on weekly basis
2	T_2 = tobaccostems/leaves	The stems and leaves of a Desi genotype of tobacco were ground in a blender and left for 24 hours. To obtain tobacco extract, the pulp was sieved through a muslin cloth. Every seven days, the extract was sprayed at a rate of 2% (2 g of stems or leaves in 100 ml of water).
3	T_3 = cards of *T. chilonis and C. carnea*	The cards of natural enemies, including *T. chilonis* and *C. carnea* obtained from the University of Agriculture Faisalabad, were released on a weekly basis as pest management measures.
4	T_4 = Thiodan	The chemical insecticide "Thiodan" was applied with various rates and intervals as a crop protection strategy.
5	T_5 = Control	Untreated control was used to compare the results with other pest management tactics.

Data recording

The data of treatments were observed after every seven days intervals. The observations on insect pests and predators were recorded early in the morning because of moving and flying of these species. The data were collected by tagging the five plants randomly selected in each treatment. The sucking insect complex populations were reported per leaf from five leaves: one from the top, two from the middle, and two from the bottom of the plant. Predator and chewing insect pests were recorded per plant. To count *Trichogramma*, ten *Sitotroga cerealella* cards with 100 fresh eggs were put into each of the five treatments at a rate of ten cards per acre. *S. cerealella* egg cards were collected from the field after 24 hours and stored in Petri dish at 27±2°C in the lab. *S. cerealella* egg cards were examined under a microscope after four days. The percentage of black eggs parasitized by *Trichogramma* was calculated.

Both pre-treatment and post-treatment observations were made before and after the application of plant protection measures.

Yield parameters record

From seed germination to harvest, several variables affecting okra yield were recorded. The number of fruits each plant produced in each treatment was recorded at harvest. Before and after the treatment was applied, the yield parameters were recorded every week.

Cost: benefit analysis

The total population density per acre was maintained 22000 as per recommendation (Khoso, 1992). The overall okra crop yield per acre was determined by multiplying the yield per plant in different treatments by the number of plants per acre.

For cost benefit ratio calculations, the average price per kilogram of produce was set at Rs.90.00 due to seasonal price fluctuations. Okra yield and per-kilogram price were multiplied to calculate per-acre income. Crop protection costs were calculated by recording recommended doses per acre and cost per spray. The overall seasonal crop protection expenses were estimated by multiplying per-spray costs by the number of sprays. Plant protection expenses were subtracted from per-acre total income to compute benefit per acre. Lastly, the cost: benefit ratio was computed by deducting control plot income from total income. Per-acre expenses divided the products. The rest of the values were presented as a cost-benefit ratio.

Analysis of data

During one week, observations were recorded before and after treatment with each application of IPM strategies lasting for a period of 48 hours. The observed data were analyzed using Minitab version 17 with a significance threshold of 5%. ANOVA and LSD tests were employed to determine the means of each treatment. In order to determine how predators affected pest populations, a correlation was determined between pest and predator population growth rates.

RESULTS

The data analysis revealed a statistically significant difference (P<0.05) in the population dynamics of many pests, such as whiteflies, jassid, thrips, aphids, *Helicoverpa*, and spotted bollworms. The occurrence of whitefly was observed from the third week of March until the third week of April. The lowest numbers of whiteflies were found on leaves treated with *Chrysoperla* + *Trichogramma* (0.13%). This was compared to leaves treated with Thiodan (0.14%), biosal (0.15%), and tobacco extracts (0.18%). In contrast, the untreated control exhibited the highest whitefly population (0.21/leaf). The application of biosal treatment resulted in the observation of the lowest mean population densities for jassid (1.86/leaf), thrips (0.15/leaf), and aphid (2.01/leaf). The untreated control group exhibited the highest mean population densities of jassid (2.56/leaf), thrips (0.31/leaf), and aphid (3.36/leaf).

Helicoverpa started to damage the crop in the second week of March and maximum mean population was observed (3.57/plant) in the second fortnight of May. The minimum mean population was recorded with the application of tobacco extract (1.25/plant), followed by *Chrysoperla* + *Trichogramma* (1.27/plant), biosal (1.32/plant) and Thiodan (2.21/plant), respectively.

Seasonal mean population of spotted bollworm exhibited that pest population greatly influenced with the application of various treatments. The lower pest population was recorded in the biosal plot (2.41/plant), followed by tobacco extract plot (2.51/plant), *Chrysoperla* + *Trichogramma* plot (2.73/plant) and Thiodan (2.99); while the maximum pest population was recorded in the untreated control plot (3.39/plant) (Table 2).

Table 2. Overall mean population of pests in different treatments on okra crop under field conditions.

Treatments	Population Per leaf				Population Per plant	
	Whitefly	Jassid	Thrips	Aphid	*Helicoverpa*	Spotted bollworm
T1	0.15bc	1.86d	0.15c	2.01c	1.32c	2.41d
T2	0.18ab	2.21b	0.25b	2.52bc	1.25c	2.51cd
T3	0.13c	1.99c	0.18c	2.94ab	1.27c	2.73c
T4	0.14c	2.21b	0.19c	2.3bc	2.21b	2.99b
T5	0.21a	2.56a	0.31a	3.36a	3.57a	3.39a

Means that do not share a letter are significantly different; T_1 = Biosal, T_2 = Tobacco Extract, T_3 = *Chrysoperla* + *Trichogramma*, T_4 = Thiodan, T_5 = Control

Development of predators' populations

A significant (P<0.05) difference was observed in the population development of predators viz. myrid bug, *Laius* sp., *Formicomus* sp., *Orius* bug, *Trichogramma, C. carnea,* lady bird beetles, ants and spiders with the application of treatments. In the okra crop, myrid bugs appeared as late predators. It appeared on the okra crop in the second and third weeks of April and remained until harvest. The maximum mean population of myrid bugs was found in biosal plots (0.85), indicating that treatment could not reduce the predator population. The minimum (0.34) myrid bugs per plant were recorded in Thiodan-treated farmer-practiced plots (Table 3).

The population of *Laius malleifer* appeared late in field compared with the other predator population. From the third week of April until the last week of May, the *Laius* was active. The highest mean population of predator (0.17) was observed in those plots which were treated with the *Chrysoperla + Trichogramma* and the minimum population was observed in case of Thiodan (0.06) application.

Table 3. Overall mean population of predators (per plant) in different treatments on Okra crop under field conditions.

Treatments	Myridbug	*Laius* sp.	*Formicomus* sp.	*Orius* bug	*Trichogramma*	*C. carnea*	Lady bird beetles	Ants	Spiders
T_1	0.85 a	0.15 a	0.20 bc	0.51 b	15.71 b	0.24 b	0.64 b	0.62 b	0.67 d
T_2	0.67 c	0.04 b	0.17 bc	0.52 b	14.12 c	0.25 b	0.68 b	0.78 a	0.78 c
T_3	0.51 d	0.17 a	0.55 b	0.56 d	20.41 a	0.31 a	0.69 b	0.79 a	0.89 b
T_4	0.34 e	0.06 c	0.13 c	0.26 c	6.58 e	0.08 c	0.49 c	0.65 b	0.53 e
T_5	0.75 b	0.30 a	0.34 a	0.71 a	10.78 d	0.21 b	0.87 a	0.74 a	0.99 a

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Similarly, maximum mean population of *F. antiqumus* (0.55), *Orius* bug (0.56), *T. chilonis (Ishii)* (20.41), *C. carnea* (0.31), lady birdbeetles (0.69), ants (0.79), and spiders (0.89) was recorded with the *Chrysoperla + Trichogramma* treated plots as compared to the control. It exhibited that the bio-pesticide "*Chrysoperla + Trichogramma*" was safe for these predators populations (Table 3).

Crop yield attributes

Data analysis showed that there was a significant (P<0.05) difference in the yield attributing parameters of crop such as in the number of fruits, number of flowers, squares, plant height, number of branches and number of leaves with the application of various treatments. The maximum number of fruits per plants (19.57), number of flowers (8.75), squares (18.34), plant height (42.36 cm) and number of branches per plant (3.73) were recorded in those plots which were treated with biosal. The minimum populations of these attributes were observed in the plots which were kept untreated as control (Table 3). However, maximum mean population of number of leaves (21.23) was observed in the *Chrysoperla + Trichogramma* treatment plots as compared to the control (18.82) (Table 4).

The significant variations were observed in the yield of okra plants with the application of different treatments. The maximum crop yield (326.14 g/ plant) was observed in plots treated with biosal as compared by tobacco extract (316.56), Thiodan (310.44), *Chrysoperla + Trichogramma* (309.74) over control (303.14 g/plant) (Table 5).

Cost benefits analysis

The plots treated with biosal produced maximum okra yield and the minimum yield was observed in the untreated fields. Farmers paid Rs. 700 per spray, whereas natural enemy treatment cost Rs.93.00 per release. Plant protection expenses per acre in biosal-treated plots were Rs. 3700.00, while predators cost was recorded Rs. 790.00. The benefits of okra crop per acre varied from Rs. 642057 in Biosal to Rs. 613521 in Thiodan. Okra had the greatest cost-benefit ratios for tobacco extract and natural enemies treatments, with ratios of 1:16.3 and 1:10.6 respectively (Table 5).

Table 4. Overall mean (per plant) of okra plant parameters in different treatments under field conditions.

Treatments	Leaves	Branches	Height	Squares	Flowers	Fruits
T_1	19.63 d	3.73 b	42.36 a	18.34 a	8.75 a	19.57 a
T_2	20.89 b	3.54 c	40.32 b	17.37 b	8.38 c	19.45 b
T_3	21.23 a	3.66 bc	37.62 c	15.37 d	8.38 c	19.43 c
T_4	20.65 c	3.54 c	34.11 d	16.30 c	8.46 b	18.97 d
T_5	18.82 e	3.21 d	33.93 e	11.20 e	7.45 d	18.75 e

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Table 5. Impact of treatments on the yield, and cost benefits ratio on the okra plants.

Treatments	Yield/ plant (g)	Yield/ acre (kg)	Total income/ acre	Total cost	Benefit	Cost: benefit ratio
T_1	326.14	7175.08	645757	3700	642057	1:16.3
T_2	316.56	6964.32	626788	2500	624288	1:10.6
T_3	309.74	6814.28	613285	790	612495	1:12.5
T_4	310.44	6829.68	614671	1150	613521	1:12.5
T_5	303.14	6669.08	600217	-	-	-

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DISCUSSION

Integrated Pest Management (IPM) methods exhibited a greater efficacy in decreasing insect pest populations compared to conventional chemical approaches. In comparison to farmers, the implementation of neem-based therapy resulted in a reduction in pest populations. According to a study by Mudathir and Basedow (2004), the use of neem formulations significantly reduced the infestation of okra bugs, a common pest. The presence of predators was notably more pronounced in the okra plants treated with biosal as compared to those treated with thiodan, indicating that the neem insecticide exhibited a lesser degree of toxicity towards the predators. In their study, Gowri et al. (2022) observed that all neem formulations showed a higher level of safety compared to thiodan when tested against two coccinelid predators, namely *Micraspis vincta* and *Kibakoganae sexmaculta*, on okra plants. According to the study conducted by Fan et al. (2022), the regions treated with neem, exhibited the presence of predatory coccinelids. According to Gowri et al. (2002), neem preparations exhibited a comparable level of safety as chemical pesticides when tested against *T. chilonis* and *C. carnea*. Furthermore, the use of neem preparations could potentially contribute to the preservation of biodiversity within crop ecosystems. In their study, Praveen and Dhandapani (2001) observed that the use of *C. carnea* and Econeem resulted in a significant reduction in sucking pests and crop borer infestation in okra plants. In another study, Rajaram et al. (2006) conducted an investigation on integrated pest management in cotton crops. The researchers observed that the frequency of leaf hopper (*Amrasca* spp.) occurrence was 1.4 per plant in the IPM plots, but it was 2.2 per plant in the non-IPM plots. The incidence of bollworm (*Helicoverpa* spp.) damage in IPM plots was found to be lower (11-14%) compared to non-IPM plots (25-29%). According to Rajaram et al. (2006), the use of integrated pest management resulted in a yield of 1450 kg per hectare in the respective plots. Conversely, non-IPM fields yielded 1000 kg per hectare.

Applications of natural predators significantly control the phytophagous insect populations. In this trial investigation, farmer-applied insecticide Thiodan reduced predator activity in okra plots compared to untreated control plots. Sardana et al. (2005) used IPM modules to reduce okra pest infestation. Bio-intensive, cultural, and chemical therapies optimized pest control. Tanwar et al. (2007) found that IPM reduced *H. armigera* populations.

In Pakistan,s agriculture context, it is essential to note that a simple increase in pesticide applications does not necessarily result in a proportional rise in crop yields and subsequent financial gains. In order to save on expenses associated with insecticides, it may be advisable to increase the threshold for pest density marginally. As a result, rather than relying solely on time considerations, the selection of spray treatments should consider factors like bug density, benefit-to-cost ratio, net revenue, and cost. The adoption of integrated pest management, focusing on the conservation of natural enemies, has supplanted the previous approach of complete pest eradication, which entailed heightened pesticide application. This study aligns with the findings of Shabozoi et al. (2011), who also recommended the utilization of selective insecticides as opposed to broad-spectrum alternatives for preserving natural enemies. Ensuring the protection of an adequate population of target pests is of utmost importance in order to sustain the populations of natural enemies. According to Ghosal et al. (2013), quantifying private advantages fails to capture the scientific and social ramifications of pesticide utilization accurately. These ramifications include impacts on natural enemies, the development of resistance, public health implications, and environmental degradation. As mentioned earlier, the implications increase the expenses associated with insecticides, reducing the ratio of benefits to costs. Therefore, it is necessary to establish a pest population threshold that exceeds the estimated theoretical value.

In the current investigation, biosal insecticide had the best cost-benefit ratio (1:16.3). Praveen and Dhandapani (2001) found a cost-benefit ratio of 1:2.60 when *C. Carnea* + Econeem were applied to okra to control main insect pests. According to Das et al. (2021) Acephate had the largest cost-benefit ratio (1:58) in okra, followed by imidacloprid (1:4.63). The *C. carnea* at a predator: aphid ratio of 1:50 in okra areas reduced *A. gossypii* population by 100% after 12 days (Zaki et al., 1999). Kumar and Singh (2022) documented that neem seed kernel extract (3%) had the best cost: benefit ratio (1:10.7), followed by endosulfan. (1:10.1).

CONCLUSION

Bio-insecticides and natural enemies dramatically increases production. Tobacco extract and biosal were predator-safe. Bio-insecticides saved money, reduced pests, and helped agroecosystems compared to chemical insecticides.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

SN and AM conceived and designed the experiments; JAS, SA, SN and MJY performed the experiments; MAZ, SMA analyzed the data; SS, KK and YA contributed materials, analysis, and tools; SN and YA wrote the paper.

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