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Combined performance of okra cultivars and certain insecticides for management of *Earias vittella* (Fabricius) (Lepidoptera: Noctuidae) in Assam, India

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Abstract
The purpose of this study was to see the effectiveness of certain insecticides and three popular okra cultivars against *Earias vittella*, the major insect pest of okra. The experiment was carried out at the Experimental Farm, Dept. of Horticulture, Assam Agricultural University, Jorhat, Assam during the *kharif*, 2020 and the spring-summer, 2021. It was found that there was significant role of trichome present in adaxial and abaxial side of leaves in the okra varieties Arka Anamika, Pusa Sawani and S-51. In control plots, the population of insect pests and the percentage of fruit infestation increased over time. Treatment lambda cyhalothrin 5% EC @ 15 gm *a.i.*/ha + S-51 had the highest percentage of fruit infestation (12.33% in *kharif* and 10.33% in spring-summer). Treatment chlorantraniliprole 18.5% SC @ 25 gm *a.i.*/ha + Arka Anamika had the highest average yield (58.70q/ha) and benefit-cost ratio (3.08: 1). The study demonstrated that in terms of trichome density, there was no considerable difference among the varieties, except in the case of Arka Anamika. Whereas there was a significant difference in insecticidal treatments for the management of *Earias vittella*, the insecticide chlorantraniliprole 18.5% SC proved to be the most effective insecticide followed by emamectin benzoate 5% SG.

Keywords: *Abelmoschus esculentus*, Arka Anamika, chlorantraniliprole, *Earias vittella*, emamectin benzoate and split plot design

Introduction

As a relative of cotton (*Gossypium hirsutum* L.), okra [*Abelmoschus esculentus* (L.) Moench] belongs to the malvaceae family, popularly known as the mallow family. It is native to Ethiopia and may be found in tropical, subtropical, and warm temperate climates across the world. It's also high in carbs, protein, calcium, potassium, and a variety of enzymes. Furthermore, because its mucilage has several medical and industrial purposes, okra is commercially grown for young fruits (Benchasri 2012; Lamont 1999; Kumar *et al*. 2013a) [6, 25, 22]. It is a commercially grown vegetable crop known for its soft green pods. Okra pods are picked when they are tender, especially if they are to be eaten. Mucilage has been utilised as a spreading agent in the production of paper in Malaysia. Okra has a protein level that varies from 18% to 27%. (Kumar *et al*. 2013b; Singh *et al*. 2014; Gemede *et al*. 2015) [23, 40, 13].

India, Nigeria, Sudan, and Pakistan are all major producers of okra. In terms of area and output, India is the world's largest producer, followed by Nigeria. According to the 2nd advance estimation for 2020-21, okra is grown on roughly 532 thousand hectares in India, yielding 6513 thousand MT. Okra is grown on 12.45 thousand hectares in Assam, with a yield of 204.49 thousand MT. In Assam, the largest okra-growing locations are Darrang and Nagaon (Anon. 2017; Anon. 2020-21) [3-4].

From germination until harvest, the okra crop is attacked by a variety of insect pests and diseases. Sucking pests were found during the vegetative growth stage, red cotton bug (*Dysdercus cingulatus* Fabricius) from the flower initiation stage to the last picking, fruit borer (*Helicoverpa armigera*) and okra shoot and fruit borer (*Earias vittella*) during the reproductive stage, and were more active at the fruiting stage (Shabozo *et al*. 2011; Meenambigai *et al*. 2017; Nair *et al*. 2017; Bhatt *et al*. 2018a) [37, 29, 31, 7]. Das (2018) [12] observed a variety of natural enemies, including lady bird beetles (*Coccinella transversalis*, *Menochilus sexmaculata*, *Brumoides suturalis*, *Micraspis discolour*, and *Harmonia dimidiate*), chrysoperla larvae, hover fly, robber fly, dragonfly, damselfly ground beetle, assassian bug, rove beetle and praying mantid.

Farmers often turn to chemical pesticides for quick and effective insect pest control, but their overuse has led to widespread insect resistance (Ridley *et al*. 2017; Singh *et al*. 2019) [35, 41].

Additionally, many conventional pesticides have been restricted due to their adverse effects on the environment and human health (Damalas 2009) [11]. Hence, there's a crucial need for next-generation pesticides to enhance insect pest management.

Chlorantraniliprole, part of the diamide group, is the most efficient insecticide against lepidopteran pests and is recommended for various crops like rice, sugarcane, cabbage, tomato, okra, and more. Unlike typical insecticides, chlorantraniliprole activates the muscular calcium channel (Malha *et al*. 2012; Vijayasree *et al*. 2015; Kar *et al*. 2013; Sharma *et al*. 2014) [26, 43, 19, 38]. Emamectin benzoate, a member of the avermitilis group, is derived from fermented soil microorganisms and excels in controlling sucking pests, leaf miners, lepidopteran pests, and mites in cotton, fruits like citrus and grapes, various vegetables, soybean, and more (Jansson *et al*. 1997; Shivalingaswamy *et al*. 2008; Govindan *et al*. 2013) [16, 39, 14]. Lambda cyhalothrin, a synthetic pyrethroid, acts as a sodium channel modulator in insects' nervous systems and effectively combats pests in crops like cotton, paddy, soybean, and vegetables (Anadon *et al*. 2006; He *et al*. 2008; Seenivasan and Muraleedharan 2009) [1, 15, 36].

These novel pesticides have mitigated pesticide resistance and residues, offering new avenues for pest control strategies (Kunz and Kemp 1994) [24]. Consequently, further research into innovative pesticides is essential for improved insect pest control.

Materials and Methods

The purpose of this study was to see the effectiveness of certain insecticides against major insect pests of different okra cultivars. The experiment took place in the Experimental Farm of the Assam Agricultural University's Department of Horticulture in Jorhat, Assam. The okra plants were cultivated in a 150m^2 plot during the *kharif* season (August to November) of 2020 and the spring-summer season (February to May) of 2021. For the growth of the plants, all agronomic measures were followed according to the package of practices for horticultural crops of Assam, 2019. Firstly, the okra seeds were soaked overnight and then tied in a towel and allowed to germinate. After the seeds germinated (2-3 days), the seeds were sown in the field (25th August during *kharif* season and 28th February during spring-summer season) with appropriate spacing (60 x 45cm for *kharif* season crop and 45 x 20cm for spring-summer crop).

Selection of variety

Based on the availability and adaptability in the given area, Arka Anamika, Pusa Sawani, and a local variety S-51 were chosen. Arka Anamika is a long light green fruit cultivar with a well-branched, tall plant height, erect type, two flushes of 120-135 days, and resistance to yellow vein mosaic virus. Pusa Sawani's leaves and stems are moderately hairy, top leaves are deeply lobed (3-5 lobes), both sides of yellow petal have purple patch, leaf base, stem, and petiole are slightly purple pigmented, fruits are dark green in color, five ridged, smooth, and suitable for both *kharif* and spring-summer seasons. S-51 is an Assamese fruit variety that is tall, green, and long (Anon. 2019) [3].

Layout and design

The experiment was carried out in a randomised block design with split plot layout of treatments replicated three times to evaluate the selected insecticides against major insect pests of okra (Ndiso *et al*. 2017) [30]. The insecticide treatments were allotted to the sub-plots, whereas the okra varieties were placed to the main plots. There was a total of 36 sub plots created.

Treatments and it's application

The treatments used in the experiment were *viz*., V1T1- Chlorantraniliprole 18.5% SC @ 25 gm *a.i*./ha + Arka Anamika; V1T2 - Emamectin benzoate 5% SG @ 8.5 gm *a.i*./ha + Arka Anamika; V1T3- Lambda cyhalothrin 5%EC @ 15 gm *a.i*./ha + Arka Anamika; V2T1 - Chlorantraniliprole 18.5% SC @ 25 gm *a.i*./ha + Pusa Sawani; V2T2 - Emamectin benzoate 5% SG @8.5 gm *a.i*./ha + Pusa Sawani; V2T3 - Lambda cyhalothrin 5% EC @15 gm *a.i*./ha + Pusa Sawani; V3T1 - Chlorantraniliprole 18.5% SC @ 25 gm *a.i*./ha + S-51; V3T2 - Emamectin benzoate 5% SG @8.5 gm *a.i*./ha +S-51; V3T3 - Lambda cyhalothrin 5% EC @15 gm *a.i*./ha +S-51 and Control. The chemicals were sprayed using hydraulic knapsack sprayer with hollow cone nozzle and applied at a pressure of 3-5kg/cm2 and at high volume 500lit water per ha.

Observation

Trichome number

The number of trichomes in a 1cm^2 area was counted to determine the trichome density. Three leaves from each variety were chosen, one from the top, one from the middle, and one from the bottom. A 1cm^2 cut was made on the midrib, vein, and lamina region, and the number of trichomes was counted on both the adaxial and abaxial sides using a Magnus MS24 Binocular Microscope (4X). The data was collected from five plants at various stages of development, including vegetative, reproductive, and harvesting, and the average of the five plants was used in the analysis (Manju *et al*. 2021) [28].

Percent fruit infestation

Five randomly selected plants per plot were examined for percent fruit infestation. The number of damaged fruits, and total quantity of fruits were noted. The percentage of fruit infestations was estimated using the formulae below (Rahman *et al*. 2013) [34].

$$\text{Percent fruit infestation} = \frac{\text{Number of damaged fruits}}{\text{Total number of fruit}} \text{ x } 100$$

Yield and benefit-cost ratio

The total yield of each plot was calculated by adding the fruit yield of each picking from each plot. The cost of the treatments was also recorded in order to compute the benefit-cost ratio and determine the best treatment for maximum pest control and maximum yield at the lowest cost (Aziz *et al*. 2012) [5]. The benefit-cost ratio was computed using the formulae below

$$\text{Benefit: Cost } = \frac{\text{Value of yield over control}}{\text{Cost of expenditures}}$$

Statistical analysis

The data collected in the field was statistically evaluated using SPSS software. To examine the impact of variety and insecticidal treatment on insect pest population split plot design was used (Ndiso *et al*. 2017) [30]. Analysis of variance was used to compare the results at the P =0.05 level.

Results

Trichome density difference among different varieties (Table 1)

The total trichome density on leaf was found to be highest at vegetative stage (69.62 to 105.07 cm^2) and had decreasing trend to harvesting stage (21.11 to 26.35 per cm^2). The type of trichome observed was straight and three branched, unicellular, non-glandular in all the varieties (Figure 1 and 2). The insecticidal treatment was done at 60DAS, which coincides with the fruiting stage of the crop. So, this might be a reason for the less impact of individual effect of trichome on insect pest population.

Table 1: Trichome density difference among different varieties

Variety	Total trichome On adaxial side	Total trichome On abaxial side	Total trichome density on leaf
Vegetative stage			
Arka Anamika	96.17±0.80^a	113.98±2.88^a	105.07
Pusa Sawani	73.05±1.22^b	95.52±1.80^b	84.28
S-51	61.32±2.22^c	77.92±0.86^c	69.62
P value	0.0001	0.0001	
F value	664.705	396.635	
Fruiting/ Reproductive stage			
Arka Anamika	32.45±2.07^b	58.58±1.70^a	45.51
Pusa Sawani	25.65±1.12^a	50.05±1.45^b	37.85
S-51	23.52±1.38^a	36.38±2.30^c	29.95
P value	0.0001	0.0001	
F value	43.455	181.728	
Harvesting stage			
Arka Anamika	23.72±1.48^b	28.98±1.79^b	26.35
Pusa Sawani	20.12±1.19^a	24.51±0.93^a	22.31
S-51	19.38±1.45^a	22.85±1.07^a	21.11
P value	0.0001	0.0001	
F value	14.052	28.879	

Data are the mean of three replications

Fig 1: Unbranched, non-glandular, straight trichome on okra leaf

Fig 2: Three branched, non-glandular trichome on okra leaf

Effect of treatments one, three, five, ten and fifteen days after treatment on percent fruit infestation during kharif and spring-summer (Table 2)

At 1 DAT, the treatment V1T1 had the highest reduction in fruit infestation (16.66% during kharif and 14.33% during spring-summer), which was statistically similar to V1T2 (15.33%), V2T1 (14.66%), and V3T1 (16.00%) during spring-summer, and significantly different from other treatments in kharif. In contrast, V3T3 had the least reduction in fruit infestation (22.33% during kharif and 18.66% during spring-summer), statistically similar to V1T3 (20.66%) and V2T3 (21.66%) in kharif, and significantly different from other treatments in spring-summer.

At 3 and 5 DAT, a decreasing trend in fruit infestation was observed. At 3 DAT, V1T1 had the lowest infestation in both seasons (10.33% in kharif and 8.66% in spring-summer), similar to V2T1 (11.33% and 9.66%). In kharif, V1T2, V3T1, V2T2, V3T2, V1T3, and V2T3 had significantly higher infestation compared to V1T1 and V2T1. Similarly, in spring-summer, V1T2 (10.66%), V3T1 (12.00%), V2T2 (12.66%), V3T2 (13.66%), V1T3 (15.00%), and V2T3 (15.66%) had significantly higher infestation than V1T1 and V2T1. The treatment V3T3 had the highest infestation (19.66% in kharif and 16.66% in spring-summer) compared to other treatments.

At 5 DAT, V1T1 had the lowest infestation in both seasons (4.00% and 3.66%), statistically similar to V2T1 (9.66%) and V1T2 (10.66%) in spring-summer. In kharif, V2T3 and V3T3 had the highest infestation (11.33% and 12.33%). In spring-summer, V3T3 (10.33%) had the highest infestation, while V1T1 (4.33%) and V2T1 (4.66%) were significantly different and had the lowest infestation.

At 10 and 15 DAT, all treatments showed increasing fruit infestation, except for the control, which had a slight reduction. In the control plots during kharif, infestation decreased from 33.66% at 5 DAT to 31.66% at 15 DAT. V3T3 had the highest infestation (13.66% and 14.00%), followed by V2T3 (12.66% and 13.33%), V1T3 (11.66% and 12.33%), V3T2 (10.33% and 10.66%), V2T2 (9.33% and 9.66%), V3T1 (8.33% and 8.66%), V1T2 (7.33% and 7.66%), and V2T1 (6.33% and 6.66%). V1T1 had the lowest infestation at 10 and 15 DAT (5.00% and 5.66%), significantly different from other treatments.

During spring-summer, at 10 and 15 DAT, V1T1 had the lowest infestation (4.33% and 4.66%), significantly different from other treatments. V1T2 (6.33% and 6.66%), V1T3 (10.00% and 10.33%), V2T1 (5.33% and 5.66%), V2T2 (8.00% and 8.33%), V2T3 (10.66% and 11.00%), V3T1 (7.33% and 7.66%), and V3T2 (9.00% and 9.33%) had significantly lower infestation rates than the control. V3T3 had the highest infestation (11.33% and 11.66%).

In kharif, variety had a significant effect only at 10DAT, while insecticidal treatments played a significant role in reducing infestation. In spring-summer, both variety and insecticidal treatment had a significant impact on reducing infestation.

Table 2: Percent infestation of fruits by *Earias vittella* at different treatments during *kharif*, 2020 and spring-summer, 2021

Treatments	***Kharif*, 2020**						**Spring-summer, 2021**					
	Pre-count	**Post treatment count**					**Pre-count**	**Post treatment count**				
		1 DAT	**3 DAT**	**5 DAT**	**10 DAT**	**15 DAT**		**1 DAT**	**3 DAT**	**5 DAT**	**10 DAT**	**15 DAT**
V_1T_1	20.33 (26.71)	16.66 (23.99)^{d}	10.33 (18.52)^{e}	4.00 (11.27)^{f}	5.00 (12.74)^{f}	5.66 (13.62)^{e}	17.33 (24.45)	14.33 (22.19)^{c}	8.66 (16.99)^{de}	3.66 (10.86)^{e}	4.33 (11.89)^{f}	4.66 (12.35)^{g}
V_1T_2	21.00 (27.20)	17.66 (24.76)^{cd}	12.33 (20.82)^{de}	6.00 (14.04)^{e}	7.33 (15.56)^{e}	7.66 (15.92)^{de}	18.33 (25.29)	15.33 (23.00)^{c}	10.66 (19.02)^{d}	4.66 (12.35)^{e}	6.33 (14.50)^{d}	6.66 (14.89)^{e}
V_1T_3	23.66 (29.08)	20.66 (26.92)^{bc}	17.66 (24.76)^{cd}	10.66 (19.02)^{c}	11.66 (19.89)^{c}	12.33 (20.45)^{bc}	19.66 (26.26)	17.33 (24.45)^{bc}	15.00 (22.71)^{bc}	8.66 (17.04)^{c}	10.00 (18.41)^{bc}	10.33 (18.68)^{c}
V_2T_1	20.66 (26.92)	17.33 (24.45)^{cd}	11.33 (19.52)^{e}	5.33 (13.26)^{e}	6.33 (14.38)^{ef}	6.66 (14.77)^{e}	17.66 (24.76)	14.66 (22.46)^{c}	9.66 (17.97)^{de}	4.33 (11.89)^{e}	5.33 (13.26)^{e}	5.66 (13.68)^{f}
V_2T_2	22.33 (28.17)	19.33 (29.38)^{b}	15.00 (22.71)^{d}	8.33 (16.65)^{d}	9.33 (17.68)^{d}	9.66 (18.01)^{cd}	19.00 (25.79)	16.33 (23.77)^{bc}	12.66 (20.78)^{cd}	7.00 (15.23)^{d}	8.00 (16.34)^{cd}	8.33 (16.65)^{d}
V_2T_3	24.33 (29.51)	21.66 (27.70)^{bc}	18.66 (25.56)^{c}	11.33 (19.59)^{bc}	12.66 (20.78)^{bc}	13.33 (21.39)^{b}	20.33 (26.75)	18.00 (25.02)bc	15.66 (23.25)^{bc}	9.66 (18.01)^{bc}	10.66 (19.00)^{b}	11.00 (19.35)^{bc}
V_3T_1	21.66 (27.70)	18.33 (25.28)^{cd}	13.66 (21.63)^{d}	7.33 (15.56)^{d}	8.33 (16.65)^{de}	8.66 (16.99)^{d}	18.66 (25.56)	16.00 (23.51)^{c}	12.00 (20.22)^{cd}	6.33 (14.43)^{d}	7.33 (15.56)^{d}	7.66 (15.92)^{de}
V_3T_2	22.66 (28.39)	19.66 (26.26)^{cd}	16.00 (23.51)^{cd}	9.33 (17.68)^{cd}	10.33 (18.71)^{cd}	10.66 (19.00)^{c}	19.33 (26.05)	17.00 (24.30)^{bc}	13.66 (21.63)^{c}	8.00 (16.34)^{cd}	9.00 (17.38)^{c}	9.33 (17.68)^{cd}
V_3T_3	24.66 (29.71)	22.33 (28.15)^{bc}	19.66 (29.61)^{b}	12.33 (20.71)^{b}	13.66 (21.67)^{b}	14.00 (21.93)^{b}	20.66 (26.92)	18.66 (25.53)^{b}	16.66 (23.99)^{b}	10.33 (18.71)^{b}	11.33 (19.55)^{b}	11.66 (19.92)^{b}
Control	23.33 (28.83)	28.66 (32.35)^{a}	30.33 (33.40)^{a}	33.66 (35.45)^{a}	32.33 (34.64)^{a}	31.66 (34.21)^{a}	18.00 (25.02)	22.66 (28.37)^{a}	24.33 (29.47)^{a}	27.66 (31.66)^{a}	26.33 (30.80)^{a}	26.66 (31.08)^{a}
Var.												
P value	0.190	0.387	0.273	0.085	0.047	0.080	0.622	0.021	0.091	0.030	0.066	0.040
F value	2.590	1.214	1.826	4.877	7.190	5.058	0.537	11.942	4.643	9.514	5.799	7.944
Treatment												
P value	0.397	0.002	0.0001	0.0001	0.0001	0.0001	0.524	0.001	0.0001	0.0001	0.0001	0.0001
F value	1.043	7.465	46.607	269.923	134.916	137.895	0.772	8.563	40.072	146.251	155.291	148.545
Var. X Treatment												
P value	0.729	0.842	0.352	0.099	0.797	0.567	0.473	0.559	0.533	0.633	0.385	0.947
F value	0.597	0.440	1.197	2.135	0.505	0.822	0.970	0.834	0.874	0.728	1.129	0.263

Data are mean of three replications. Figures in parenthesis indicate angular transformed values of percentage data.

Effect of insecticidal treatments on yield and benefit-cost ratio over control (Table 3)

In the 2020 kharif season, V1T1 had the highest yield at 59.14 q/ha, followed by V2T1 (53.41q/ha), V1T2, V3T1 (53.04, 52.56 q/ha), and V2T2 (52.12q/ha). V1T3, V3T2, and V2T3 (50.65, 50.61, 50.37 q/ha) had similar yields. V3T3 had the lowest yield at 48.28 q/ha, but it was significantly higher than the control (33.51 q/ha). In the 2021 spring-summer season, V1T1 had the highest yield at 58.26 q/ha, followed by V2T1 (52.85 q/ha), V2T1 (52.80 q/ha), V3T1 (51.60 q/ha), and V2T2 (50.52 q/ha). V1T3, V3T2, and V2T3 had similar yields (49.75, 49.73, 49.63 q/ha). V3T3 had the lowest yield at 46.34 q/ha, but all treatments were significantly higher than the control (32.40 q/ha). On average across both seasons, V1T1 had the highest yield at 58.70 q/ha, significantly outperforming other treatments. The lowest yield was from V3T3 (47.31 q/ha), which was also significantly higher than the control (32.95 q/ha).

Insecticide, fertilizer, seeds, hiring fees, and labor costs all contributed to the total cost of okra cultivation, which ranged from Rs. 35,250 to Rs. 38,000 per hectare. The insecticidal treatments made a net profit of Rs. 59,370 to Rs. 79,400 per acre above the control. Treatment V1T1 (Rs. 79,400) had the highest return in terms of money, with a benefit-cost ratio of 3.08: 1, followed by treatments V1T2, V1T3, V2T3, V2T2, V2T1, V3T1, V3T2 and V3T2 with benefit-cost ratios of 2.90: 1, 2.84: 1, 2.83: 1, 2.81: 1, 2.79: 1, 2.74: 1 and 2.75: 1 respectively. The treatment V3T3 provided the least benefit, with a benefit-to-cost ratio of 2.68:1. The insecticidal treatments can be classified as follows based on their benefit-to-cost ratio V1T1 > V1T2 > V1T3 > V2T3 > V2T2 > V2T1 > V3T2 > V3T1 > V3T3.

From the above study, it was found that the highest efficacy, lowest fruit infestation and highest benefit cost ratio was observed in variety Arka Anamika treated with chlorantraniliprole 18.5% SC.

Table 3: Effect of insecticides on yield and economics of okra

Treatment	Yield (q/ha)		Mean yield (q/ha)	Total cost of cultivation (Rs/ha)	Value of increased yield (Rs/ha)	Percent increased yield over control (%)	Net profit over control (Rs/ha)	Benefit-cost ratio
	kharif, 2020	spring-summer, 2021						
V_1T_1	59.14^a	58.26^a	58.70	38,000	1,17,400	78.14	79,400	3.08: 1
V_1T_2	53.04^b	52.80^b	52.92	36,400	1,05,840	60.60	69,440	2.90: 1
V_1T_3	50.65^c	49.75^c	50.20	35,250	1,00,400	52.35	65,150	2.84: 1
V_2T_1	53.41^b	52.85^b	53.13	38,000	1,06,260	61.24	68,260	2.79: 1
V_2T_2	52.12^{bc}	50.52^c	51.32	36,400	1,02,640	5.75	66,240	2.81: 1
V_2T_3	50.37^c	49.63^c	50.00	35,250	1,00,000	51.74	64,750	2.83: 1
V_3T_1	52.56^b	51.60^{bc}	52.08	38,000	1,04,160	58.05	66,160	2.74: 1
V_3T_2	50.61^c	49.73^c	50.17	36,400	1,00,340	52.26	63,940	2.75: 1
$V3T_3$	48.28^d	46.34^d	47.31	35,250	94,620	43.58	59,370	2.68: 1
Control	33.51^e	32.40^e	32.95	35,000	65,900	-	-	-
Variety								
P value	0.317	0.105						
F value	1.549	4.170						
Treatment								
P value	0.0001	0.0001						
F value	32.067	160.118						
Variety * Treatment								
P value	0.960	0.070						
F value	0.234	2.403						

Data are mean of three replications

Discussion

Impact of trichome of different varieties on insect pest population and percent fruit infestation of okra.

Recent data showed significant differences in trichome density among various plant varieties. Kassi *et al*. (2019) [21] found that while leaf area and thickness were similar, the density of trichomes on okra leaves midribs and lamina varied noticeably. Total trichome density at the fruiting stage was 45.51, 37.85, and 29.51 per cm^2 in Arka Anamika, Pusa Sawani, and S-51, respectively. Trichome numbers and forms differed among plant species and within the same species (Kang *et al*. 2010) [18]. In this study, all cultivars had fewer trichomes at the fruiting stage when treatments began. Non-glandular trichomes offer morphological protection in early crop development due to their surface structure (Karabourniotis *et al*. 2020) [20]. They can store toxic chemicals and protect plants from stress, while glandular trichomes produce various secondary metabolites. Glandular trichomes' acyl sugars make plants resistant to aphids, whiteflies, army worms, leaf miners, spider mites, and other pests (Tanveer and Yousaf 2020) [42].

Efficacy of different insecticidal treatments against major insect pest of okra

In control plots, insect pest populations and fruit infestation increased. The most effective insecticide was chlorantraniliprole 18.5% SC @ 25 gm *a.i.*/ha, with Arka Anamika as the best variety. P percent fruit infestation decreased up to 5 DAT in both seasons but then increased in all insecticidal treatments. The V1T1 treatment (chlorantraniliprole 18.5% SC + Arka Anamika) had the highest yield (58.70q/ha) and benefit-cost ratio (3.08:1). Emamectin benzoate 5% SG @ 8.5 gm *a.i.*/ha and lambda cyhalothrin 5% EC @ 15 gm *a.i.*/ha were more effective than the control. Chowdary *et al*. (2010) [10] found the highest fruit output with chlorantraniliprole (rynaxypyr) 20 SC @ 30 gm *a.i.*/ha. Mahata *et al*. (2014) [27] reported the highest yield with chlorantraniliprole 18.5 SC @ 27.75 gm *a.i.*/ha. Chlorantraniliprole treatment had the lowest population loss due to its impact on insect protein synthesis. The findings aligned with Rahman *et al*. (2015) [33], who also found Arka Anamika to be the best variety with the least pest infestation. Pandya (2017) reported that Arka Anamika had the lowest larvae, fruit damage, and highest yield. Bhatt *et al*. 2018b recorded the highest fruit production in chlorantraniliprole 18.5% SC treated plots.

Emamectin benzoate was the second most effective insecticide, followed by lambda cyhalothrin. Shivalingaswamy *et al*. (2008) [39] found emamectin benzoate effective against lepidopteron pests in vegetables. Javed *et al*. (2018) [17] observed that emamectin benzoate, indoxacarb, and lambda cyhalothrin effectively suppressed *E. vittella*, increasing fruit yield by 45%, 44%, and 18%, respectively.

Conclusion

The treatment Arka Anamika + chlorantraniliprole 18.5% SC @ 25 gm *a.i.*/ha was found to be the most effective in terms of lower percent fruit infestation, higher yield, and a high benefit-cost ratio, and the reason for this could be due to the variety's higher trichome density and the different mode of action of chlorantraniliprole, which acts as a muscle calcium channel stimulator. Though the interaction effect of variety and treatment was not significant in all cases, the effects of the treatments were significant individually, indicating that insecticides were more effective than controls.

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