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Evaluation of combination insecticides for managing the insect pest complex in okra (*Abelmoschus esculentus*)

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ABSTRACT: A field investigation was undertaken to determine the efficacy of certain combination insecticides against insect pests of okra. Among the combination insecticides tested, the imidacloprid 40% + fipronil40%WG @ 500g/ha was observed to be the most effective against whitefly (*Bemisia tabaci*) with mean population of whitefly (2.24±0.06 per 3leaves; 1.61±0.12 per 3 leaves, 77.51% & 82.48% PROC, after first and second spray, respectively), jassid (*Amrasca biguttula biguttula*)with mean population of jassid (1.87±0.29 per 3 leaves; 1.21±0.22 per 3 leaves, 77.17% & 84.89% PROC after first and second spray, respectively) and shoot and fruit borer damage (*Earias vittella*) with lowest mean damage (3.40±0.13 per cent shoot damage and 2.61±0.07 per cent fruit damage, 71.36% & 78.87% PROC after first and second spray, respectively) and least effective treatments was profenofos 40% + Cypermethrin 4% EC 1250 ml/ha against whitefly and jassid, deltamethrin0.72%+ buprofezin5.65% EC500ml/ha against shoot and fruit borer. The maximum yield of 95.27 q/ha was found in imidacloprid 40% + fipronil 40% WG 500 g/ha, while the minimum yield of 85.83 q/ha was recorded in deltamethrin 1% + triazophos 35% EC 1000 ml/ha. Untreated plot recorded the yield 60.13 q/ha. The highest incremental cost-benefit ratio of 1:21.21 was recorded in thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC125ml/ha, while the lowest ratio was observed in imidacloprid 40%+ ethiprole40% WG 500 g/ha (1:3.33).

Keywords: Efficacy, whitefly, jassid, shoot & fruit borer, yield, incremental cost- benefit ratio.

INTRODUCTION

Okra, *Abelmoschus esculentus* (L.) Moench, is a vital vegetable crop widely cultivated in tropical and subtropical regions across the globe. The okra is attacked by roughly 72 different insect pest species from germination to harvest (Rao and Rajendran, 2002). The major causes of the high pest occurrence in okra are either polyphagous or oligophagous pests, which have many alternate hosts throughout the year. The major insect pests attack the crop, including the shoot and fruit borer, *Earias vittella* (Fabricius) & *Earias insulana* (Boisd.), fruit borer, *Helicoverpa armigera* (Hübner), whitefly, *Bemisia tabaci* (Gennadius), jassid, *Amrasca bigutulla bigutulla* (Ishida), aphid, *Aphis gossypii* Glover, leaf roller, *Sylepta derogata* (Fabricius), blister beetle *Mylabris pustulatus* Thunberg, dusky cotton bug, *Oxycarenus hyalinipennis* Costa, red cotton bug, *Dysdercus cingulatus* (Fabricius) and red spider mite, *Tetranychus urticae* Koch (Bhatt and Karnatak, 2018; Meena *et al*., 2020; Chauhan *et al*., 2023).

The borer complex of okra comprises of shoot and fruit borers *viz*., *E. vittella* and *E. insulana* is also a very destructive pest. The attack of shoot and fruit borer (*E. vittella*) on okra starts 4th to 5th weeks after germination both in *kharif* and *summer* seasons. The infested top tender shoots dry while flower, bud and developing fruit down prematurely. The infested shoots droop, wither and dry up. The holes in the fruits are filled with excrement after the larvae bore through them. Fruits with infestations get malformed and become unsafe to eat. It causes 52.33 to 75.75% fruit loss in the field. The fruit borer (*H. armigera*) is a polyphagous insect that attacks cotton, okra, tomato, chilli, cabbage, pea, pigeon pea, chickpea etc. throughout the world as well as in India. Damage is only caused by larvae. They bore the floral bud and fruits. The insects create circular openings in the fruits by penetrating through the sepals and petals, reaching the ovary to consume its contents. This action leads to the fruits wilting and eventually dropping from the plant (Pareek and Bhargava, 2003).

The sucking pest complex of okra consisting of aphids, leaf hoppers, whiteflies, thrips and mites causes 17.46% yield loss and failure to control them in initial stages was reported to cause 54.04% yield loss (Chaudhary and

Daderch, 1989). The whitefly is a significant economic threat to okra cultivation in numerous tropical and subtropical areas. As a polyphagous pest with global agricultural significance, it causes harm by feeding on sap, excreting honeydew and spreading viral diseases. Whitefly, besides causing direct damage, acts as a vector of yellow vein mosaic virus (YVMV), which is a major constraint for okra cultivation (Neeraja *et al.,* 2004). The jassids suck the cell sap from the lower surface of the leaves and inject toxic substance resulting in curling of leaves, because of which the plant growth is retarded. The sever infestation of the pest causes burning of leaves which fall later and results in 40-60% decrease in yield (Nagar *et al.,* 2017).

To avoid insect pest infestation and ensure high-quality crop yields, it's crucial to effectively manage pest populations using suitable management measures at the right time. The present study aims to assess various pre-mixed formulations against insect pest complex in okra crops (Subbireddy *et al.,* 2018).

MATERIALS AND METHODS

The variety Super Anamika was sown using the recommended agronomic practices at the Students' Instructional Farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during the *Kharif* season of 2023 in a Randomized Block Design (RBD) with 8 treatments and 3 replications. The plot size was 1.8 × 2.4 meters and the spacing between plant to plant and line to line was maintained at 45 cm × 30 cm. Two seeds per hill were dibbled at the depth of 4-5cm, maintaining 30 cm distance. After complete germination and establishment of plants, thinning was done to keep one plant per hill in whole experimental field. The efficacy of combination insecticides *i.e.*, imidacloprid 40% + fipronil 40% WG 500 g/ha, imidacloprid 40% + ethiprole 40% WG 500 g/ha, beta-cyfluthrin 8.49% + imidacloprid 19.81% OD 400ml g/ha, profenophos 40% + cypermethrin 4% EC 1250 ml/ha, thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC 150 ml/ha, deltamethrin 0.72% + buprofezin 5.65% EC 500 ml/ha, deltamethrin 1% + triazophos 35% EC 1000 ml/ha with control (water spray) against insect pest complex of okra were tested. Crop was monitored regularly for recording the occurrence of insect pest complex. The first spray of insecticides was done 45 days after sowing and the second 25 days after first spray. Pre-treatment observation was recorded a day before spray and post treatment count was observed on 3^{rd}, 7^{th} and 15^{th} days after spraying. The population of whitefly and jassid was recorded as No. of nymphs and adults present per three leaves on 5 randomly selected plants and for the Shoot and Fruit borer per cent shoot & fruit infestation was observed. The data of shoot/fruit infestation was taken by counting infested and un-infested shoots/fruits and expressed as percentage.

The per cent reduction of the population over control (PROC) in different treatments was calculated using Henderson and Tilton's (1955) formula as given below.

Per cent efficacy = 1 - $\sqrt{x+0.5}$ x $\sqrt{x+0.5}$ 100

Where,

T_a = Population in the treated plot after spray.

T_b = Population in the treated plot before spray.

C_a = Population in the control plot after spray.

C_b = Population in the control plot before spray.

The incremental cost-benefit ratio was determined for each treatment by using formula.

Incremental Benefit Cost Ratio = $\sqrt{x+0.5}$

All the data acquired were statistically analyzed using the standard Randomized Block Design method. The population data were into a square root transformation ($\sqrt{x+0.5}$).

RESULTS AND DISCUSSION

Whitefly *(B. tabaci)*

The experiment assessing the efficacy of certain combination insecticides against whitefly revealed that the plot treated with imidacloprid 40% + fipronil 40% WG 500g/ha was recorded lowest mean population of whitefly (2.24±0.06 per 3 leaves and 1.61±0.12 per 3 leaves, 77.51% & 82.48% PROC after first and second spray, respectively), followed by imidacloprid 40% + ethiprole 40% WG 500g/ha (2.64±0.25 per 3 leaves and 1.87±0.06 per 3 leaves, 73.49% & 79.65% PROC after the first and second spray, respectively) (Table 1). In contrast, the plot treated with profenophos 40% + cypermethrin 4% EC 1250ml/ha recorded highest mean population of whitefly with lowest percent reduction over control (4.07±0.29 per 3 leaves and 3.33±0.08 per 3 leaves, 59.14% & 63.76% after first and second spray, respectively). However, the untreated plot was recorded the 9.96±0.25 per 3 leaves and 9.19±0.23 per 3 leaves. imidacloprid 40% + fipronil 40% WG offers broad-spectrum control by targeting a wide range of pests through complementary modes of action. This combination enhances effectiveness, providing superior pest control compared to using either ingredient alone. Zote *et al*. (2018) conducted a study on various doses of Solomon to control the cashew tea mosquito bug and thrips. They found that the treatment betacyfluthrin 90% + imidacloprid 210% at a concentration of 1.5 ml per 10 liters was the most effective for managing of tea mosquito bug and thrips. Kumar *et al*. (2024) also noted that combination insecticide betacyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha was observed most effective against whitefly, Jassid and serpentine leaf miner. Yadav *et al*. (2024) also reported that imidacloprid 40% + fipronil 40% WG 500 g/ha was effective against the Brown Plant Hopper and Rice Gundhi bug. Kumar *et al.* (2019) also found that combination insecticides effectively manage sucking pests of Chilli.

Jassid (*A. biguttula biguttula*)

The efficacy of certain combination insecticides against jassid revealed that, plot treated with imidacloprid 40% + fipronil 40% WG 500g/ha was recorded lowest mean population of jassid (1.87±0.29 per 3 leaves and 1.21±0.22 per 3 leaves, 77.17% & 84.89% PROC after first and second spray, respectively), followed by imidacloprid 40% + ethiprole 40% WG 500g/ha was recorded mean population of jassid (2.19±0.22 per 3 leaves and 1.47±0.28 per 3 leaves, 73.26% & 81.65% PROC after the first and second spray, respectively) (Table 2). In contrast, the plot treated with profenophos 40% + cypermethrin 4% EC 1250ml/ha recorded highest mean population with lowest per cent reduction of jassid (3.51±0.39 per 3 leaves and 2.87±0.39 per 3 leaves, 57.14% & 64.17% PROC after first and second spray,

Table 1. Efficacy of certain combination insecticides against Whitefly, *B. tabaci* infesting okra

Tr. No.	Treatments	Dose/ha	*Population of whitefly per 3 leaves (Mean+SD)					
			First Spray			Second Spray		
			DBS	After Spray	PROC	DBS	After Spray	PROC
T_1	Imidacloprid 40% + Fipronil 40% WG	500g	7.36±0.25 (2.80)	2.24±0.06 (1.66)	77.51	3.96±0.34 (2.11)	1.61±0.12 (1.45)	82.48
T_2	Imidacloprid 40% + Ethiprole 40% WG	500g	7.91±0.39 (2.90)	2.64±0.25 (1.77)	73.49	4.09±0.23 (2.14)	1.87±0.06 (1.54)	79.65
T_3	Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD	400mL	7.82±0.23 (2.88)	2.93±0.04 (1.85)	70.58	4.29±0.17 (2.19)	2.26±0.06 (1.66)	75.41
T_4	Profenophos 40% + Cypermethrin 4% EC	1250mL	7.02±0.34 (2.74)	4.07±0.29 (2.14)	59.14	4.44±0.34 (2.22)	3.33±0.08 (1.96)	63.76
T_5	Thiamethoxam 12.6% + Lambda Cyhalothrin 9.5% ZC	150mL	8.04±0.27 (2.92)	3.33±0.11 (1.96)	66.57	4.31±0.20 (2.19)	2.59±0.07 (1.76)	71.82
T_6	Deltamethrin 0.72% + Buprofezin 5.65% EC	500mL	7.73±0.33 (2.87)	3.88±0.32 (2.09)	61.04	4.42±0.34 (2.22)	3.04±0.17 (1.88)	66.92
T_7	Deltamethrin 1% + Triazophos 35% EC	1000mL	7.78±0.38 (2.88)	3.59±0.13 (2.02)	63.96	4.38±0.23 (2.21)	2.80±0.17 (1.82)	69.53
T_8	Control (Water spray)	-	8.02±0.38 (2.92)	9.96±0.25 (3.23)	-	8.04±0.30 (2.92)	9.19±0.23 (3.11)	-
	SEm±		**-**	**(0.03)**	**-**	**(0.02)**	**(0.02)**	**-**
	CD at 5%		**(NS)**	**(0.08)**	**-**	**(0.07)**	**(0.06)**	**-**

Figures in the parenthesis are $\sqrt{x} + 0.5$ transformed values, DBS= Day before spray, DAS= Days after spray, *Mean of three replications, PROC= Per cent reduction over control

Table 2. Efficacy of certain combination insecticides against Jassid, *A. biguttulla biguttulla* infesting okra

Tr. No.	Treatments	Dose/ha	*Population of jassid per 3 leaves (Mean+SD)					
			First Spray			Second Spray		
			DBS	After Spray	PROC	DBS	After Spray	PROC
T_1	Imidacloprid 40% + Fipronil 40% WG	500g	6.44±0.56 (2.64)	1.87±0.29 (1.54)	77.17	3.27±0.23 (1.94)	1.21±0.22 (1.31)	84.89
T_2	Imidacloprid 40% + Ethiprole 40% WG	500g	6.47±0.20 (2.64)	2.19±0.22 (1.64)	73.26	3.56±0.30 (2.01)	1.47±0.28 (1.41)	81.65
T_3	Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD	400mL	6.36±0.23 (2.62)	2.50±0.28 (1.73)	69.47	3.69±0.23 (2.05)	1.74±0.35 (1.50)	78.28
T_4	Profenophos 40% + Cypermethrin 4% EC	1250mL	6.51±0.41 (2.65)	3.51±0.39 (2.00)	57.14	4.24±0.17 (2.18)	2.87±0.39 (1.83)	64.17
T_5	Thiamethoxam 12.6% + Lambda Cyhalothrin 9.5% ZC	150mL	6.20±0.29 (2.59)	2.96±0.33 (1.86)	63.86	3.80±0.12 (2.07)	2.19±0.30 (1.64)	72.66
T_6	Deltamethrin 0.72% + Buprofezin 5.65% EC	500mL	6.64±0.38 (2.67)	3.36±0.35 (1.96)	58.97	3.98±0.33 (2.12)	2.76±0.40 (1.81)	65.54
T_7	Deltamethrin 1% + Triazophos 35% EC	1000mL	6.24±0.34 (2.60)	3.18±0.15 (1.92)	61.17	3.87±0.29 (2.09)	2.47±0.39 (1.72)	69.16
T_8	Control (Water spray)	-	6.33±0.24 (2.61)	8.19±0.24 (2.95)	-	7.16±0.27 (2.77)	8.01±0.30 (2.92)	-
	SEm±		**-**	**(0.03)**	-	**(0.03)**	**(0.03)**	-
	CD at 5%		**(NS)**	**(0.08)**	-	**(0.08)**	**(0.09)**	-

Figures in the parenthesis are $\sqrt{x+0.5}$ transformed values, DBS= Day before spray, DAS= Days after spray, *Mean of three replications, PROC= Per cent reduction over control

respectively). However, the untreated plot was recorded the 8.19±0.24 per 3 leaves and 8.01±0.30 per 3 leaves. imidacloprid 40% + fipronil 40% WG provides broad-spectrum control, effectively targeting a wide array of pests through its complementary modes of action. This combination increases effectiveness, delivering better pest control than using either ingredient separately. Furthermore, it supports resistance management by employing two distinct modes of action, which helps delay the onset of pest resistance. Kumar *et al*. (2024) also noted that combination insecticide betacyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha was observed most effective against whitefly, Jassid and serpentine leaf miner. Yadav *et al*. (2024) also reported that imidacloprid 40% + fipronil 40% WG 500 g/ha was effective against the Brown Plant Hopper and Rice Gundhi bug.

Shoot & fruit borer (*E. vittella*)

The data regarding the efficacy of certain combination insecticides against shoot & fruit borer revealed that the plot treated with imidacloprid 40% + fipronil 40% WG 500g/ha was recorded lowest mean damage (3.40±0.13 per cent shoot damage and 2.61±0.07 per cent fruit damage, 71.36% & 78.87% PROC after first and second spray, respectively) followed by beta-cyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha (3.77±0.15 per cent shoot damage and 2.91±0.27 per cent fruit damage, 68.24% & 76.44% PROC after the first and second spray, respectively). In contrast, the plot treated with deltamethrin 0.27% + buprofezin 5.65% EC 500ml/ha recorded highest mean damage (5.26±0.12 per cent shoot damage and 4.39±0.08 per cent fruit damage, 55.69% & 64.45% PROC after first and second spray, respectively). However, the untreated plot was recorded the (11.87±0.19 per cent shoot damage and 12.35±0.15 per cent fruit damage) (Table 3). imidacloprid 40% + fipronil 40% WG offers a powerful tool for pest control. This formulation leverages the strengths of both insecticides, providing a broader spectrum of activity, enhancing efficacy through synergistic effects, and aiding in resistance management. Donawade *et al.,* (2020) evaluated insecticides against sugarcane top shoot borer (*S. excerptalis*) and found Chlorantraniliprole 18.5 SC to be the most effective treatment fipronil 5 SC was the second most effective. Kumar *et al*. (2024) also noted imidacloprid 40%+fipronil 40% WG 500 g/ha second most effective treatment against tomato fruit borer (*H. armigera*).

Effect of Treatments on Yield of Okra

The crop yields showed significant differences among all the treatments. The highest yield was recorded in plot treated with imidacloprid 40% + fipronil 40% WG 500g/ha, producing 95.27 q/ha (Table 4). This was followed closely by betacyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha, which resulted in a yield of 93.67 q/ha. The lowest yield was observed with deltamethrin 0.27% + buprofezin 5.65% EC 500ml/ha, which produced 78.60 q/ha. The combination insecticide delivers higher yields by effectively targeting a broad range of pests with its dual-action formula. This enhances pest control, ensures healthier crops, and reduces the risk of pest resistance, leading to improved plant health and increased productivity. Studies and trials have shown that fields treated with this combination experience significantly higher yields compared to those treated with single-ingredient insecticides. The results of the present study are in accordance with findings of Sreenivas *et al.* (2019), who reported that the highest fruit yield was recorded in the

Table 3. Efficacy of certain combination insecticides against Shoot & fruit borer, *E. vittella* infesting okra

Tr. No.	Treatments	Dose/ha	*Per cent Shoot & fruit borer damage (Mean+SD)					
			Shoot damage			Fruit damage		
			First Spray			Second Spray		
			DBS	Mean	PROC	DBS	Mean	PROC
T_1	Imidacloprid 40% + Fipronil 40% WG	500g	10.58±0.22 (3.33)	3.40±0.13 (1.97)	71.36	9.78±0.25 (3.21)	2.61±0.07 (1.76)	78.87
T_2	Imidacloprid 40% + Ethiprole 40% WG	500g	10.24±0.21 (3.28)	4.43±0.21 (2.22)	62.68	9.88±0.17 (3.22)	3.51±0.18 (2.00)	71.58
T_3	Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD	400mL	10.49±0.57 (3.31)	3.77±0.15 (2.07)	68.24	9.69±0.20 (3.19)	2.91±0.27 (1.85)	76.44
T_4	Profenophos 40% + Cypermethrin 4% EC	1250mL	10.18±0.30 (3.27)	4.84±0.19 (2.31)	59.22	9.94±0.23 (3.23)	3.72±0.25 (2.05)	69.88
T_5	Thiamethoxam 12.6% + Lambda Cyhalothrin 9.5% ZC	150mL	10.37±0.36 (3.30)	4.05±0.15 (2.13)	65.88	9.52±0.25 (3.17)	3.18±0.15 (1.92)	74.25
T_6	Deltamethrin 0.72% + Buprofezin 5.65% EC	500mL	10.59±0.38 (3.33)	5.26±0.12 (2.40)	55.69	9.76±0.24 (3.20)	4.39±0.08 (2.21)	64.45
T_7	Deltamethrin 1% + Triazophos 35% EC	1000mL	10.28±0.24 (3.28)	5.21±0.21 (2.37)	56.87	9.63±0.31 (3.18)	4.15±0.09 (2.16)	66.40
T_8	Control (Water spray)	-	10.60±0.21 (3.33)	11.87±0.19 (3.53)	-	10.01±0.28 (3.24)	12.35±0.15 (3.58)	-
	SEm±		**-**	**(0.02)**	**-**	**(0.02)**	**(0.02)**	**-**
	CD at 5%		**(NS)**	**(0.07)**	**-**	**(0.06)**	**(0.07)**	**-**

Figures in the parenthesis are $\sqrt{x + 0.5}$ transformed values, DBS= Day before spray, DAS= Days after spray, *Mean of three replications, PROC= Per cent reduction over control

Table 4: Economics of certain combination insecticides against insect pest complex in okra

Tr. No.	Treatments	Dose/ha	Yield (q/ha)	Incremental B:C ratio	Rank
T_1	Imidacloprid 40% + Fipronil 40% WG	500g	95.27	4.90	VI
T_2	Imidacloprid 40% + Ethiprole 40% WG	500g	90.63	3.33	VII
T_3	Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD	400mL	93.67	17.12	II
T_4	Profenophos 40% + Cypermethrin 4% EC	1250mL	81.27	11.91	V
T_5	Thiamethoxam 12.6% +Lambda Cyhalothrin 9.5% ZC	150mL	86.57	21.21	I
T_6	Deltamethrin 0.72% + Buprofezin 5.65% EC	500mL	78.60	13.01	IV
T_7	Deltamethrin 1% + Triazophos 35% EC	1000mL	85.83	15.15	III
T_8	Control (Water spray)	-	60.13	-	-

Prevailing market price of okra during 2023 = 22/kg, Labour charge = 300/day/labour, Sprayer charge =100/day, two sprays performed during entire crop season

imidacloprid 17.8 SL 0.30 spray treatment, which yielded 109.99 and 108.66 q/ha in Raichur and Bidar, respectively.

Incremental Cost-Benefit Ratio of Treatments

The highest net return of Rs. 69,701 per hectare was found in plot treated with betacyfluthrin 8.49% + imidacloprid 19.81% OD 400 ml/ha, followed by net return of Rs. 64,193 per hectare was found in plot treated with imidacloprid 40% + fipronil 40% WG 500 g/ha (Table 4). The lowest net return of Rs. 37,727 per hectare observed in plot treated with deltamethrin 0.27% + buprofezin 5.65% EC 500 ml/ha. However, the most effective and economical treatment thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC 150 ml/ha found with incremental benefit-cost ratio of 1:21.21.

CONCLUSION

Based on the results of this study, the combination insecticide imidacloprid 40% + fipronil 40% WG 500g/ha proved to be the most effective treatment in managing whitefly, jassid, and shoot & fruit borer, consistently recording the lowest pest populations and damage across all observations, resulting in the highest okra yield of 95.27 q/ha. Moreover, the economic analysis highlighted the highest net return for betacyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha, suggesting this treatment is economically viable while maintaining effective pest control. In conclusion, the combination insecticides, particularly imidacloprid 40% + fipronil 40% WG and betacyfluthrin 8.49% + imidacloprid 19.81% OD, are highly effective for managing pests, improving crop yields, and offering better economic returns, making them valuable tools in integrated pest management programs.

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