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# Field Efficacy of Ready-Mix Insecticides against Insect Pests Infesting Black Gram

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## Abstract

In order to study the bio-efficacy of different ready-mix insecticides against insect pests in black gram, a field experiment was carried out on variety, T-9 during *Kharif*, 2019 and 2020 at Agronomy farm, B. A. College of Agriculture, Anand Agricultural university, Anand, Gujarat, India. The field trail was conducted in a completely Randomized Block Design (RBD) keeping three replications for each treatment. Among the evaluated eight ready-mix insecticides viz., flubendiamide 4% + buprofezin 20% SC, chlorantraniliprole 8.8% + thiamethoxam 17.5% SC and profenofos 40% + cypermethrin 4% EC proved effective against Bihar hairy caterpillar (*Spilosoma obliqua*). The treatments chlorantraniliprole 8.8% + thiamethoxam 17.5% SC, thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC and flubendiamide 4% + buprofezin 20% SC proved effective against leaf eating caterpillar (*Spodoptera litura*). The plots treated with thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, chlorantraniliprole 8.8% + thiamethoxam 17.5% SC and flubendiamide 4% + buprofezin 20% SC proved effective against spotted pod borer (*Maruca vitrata*) in black gram.

***Key words*:** Ready-mix insecticides, Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC, Bihar hairy caterpillar, Spotted pod borer, Black gram

Agriculture is influenced by a plethora of biotic stress which includes insects, diseases, and rodents that constitute a grave menace to food security and farmers livelihoods. Globally, up to 30 per cent of agricultural yields are affected by pests and diseases Anonymous [1]. Among the biotic stress, insect pests under different vagaries of climatic conditions often pose a serious threat to black gram production by increasing cost of cultivation and hamper the quality of the produce in multiple ways Jat *et al*. [3]. Black gram is a host for diverse array of arthropod pests. Among them leaf eating caterpillar, *Spodoptera litura* Fabricius; Bihar hairy caterpillar, *Spilosoma obliqua* Walker; gram caterpillar appeared as foliage feeders whereas spotted pod borer, *Maruca testulalis* Geyer and blue butterfly, *Lampides boeticus* Linnaeus are classified as pod borers, respectively Kumar and Singh [7] Yadav *et al*. [20]. The losses incurred due to defoliators and pod borers in black gram ranging from 27.7 and 67.8 per cent, respectively Justin *et al*. [4].

In Integrated Pest Management (IPM), chemical spraying practiced as a last resort, however continuous use of single insecticide against different insect pests resulted in high selection pressure which led to evolution of resistance and resurgence Ling *et al*. [8]; Matsumura and Morimura [9]; Su *et al*. [18]. However, there is a need to explore the possibility of utilizing effective eco-friendly insecticides, particularly ready-mix insecticides with different novel mode of action which is gaining momentum and can fit perfectly in IPM programme. Ready-mix insecticides have broad spectrum of activity, control more than one pest or pest species, synergistic joint action, lower quantity as well as cost, reduced application cost, saving time, less number of sprays, safe to farmer's health and environment. Regupathy *et al*. [14]; Sasmal *et al*. [16]; Das [2]. Therefore, integration of ready-mix insecticides in IPM which is considered as silver bullet approach to farmers which helps to ensure the control and delay in development of resistance against different insect pests. Hence, an attempt was made to study the effectiveness of different ready-mix insecticides against insect pest infesting black gram.

## MATERIALS AND METHODS

A field experiment was conducted at the Agronomy Farm, B. A. College of Agriculture AAU, Anand consecutively for two years *Kharif*, 2019 and 2020. Black gram cultivar T-9 was raised in plots of size 5.0 × 2.7 m with a spacing of 45 × 10 cm with recommended agronomic practices except for insect pest management. The experiment is laid out in a Randomized Block Design (RBD) with nine treatments including untreated control replicated thrice. The ready-mix insecticides include viz; Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC, Profenophos 40% + Cypermethrin 4% EC, Buprofezin 15% + Acephate 35% WP, Pyriproxifen 5% + Fenpropathrin 15% EC,

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Flubendiamide 4% + Buprofezin 20% SC, Fipronil 40% + Imidacloprid 40% WG, Deltamethrin 1% + Triazophos 35% SC, Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC and Untreated control (water spray). Two sprays were imposed using high volume knapsack spray (500 l/ha) at 15 days interval with the initiation of the insect-pest population. Pre-count and post-count insect-pest population was recorded from ten randomly selected plants of each net plot area before and after spraying. For chewing pests viz., leaf eating caterpillar, Bihar hairy caterpillar and spotted pod borer observations were recorded from ten randomly selected plants. The data of two sprays and two years were pooled and subjected to statistical analysis with SPSS software. Besides, the seed and haulm yield was also recorded from each net plot area and converted to kg/ha for statistical interpretation Steel and Torrie [17]. The increase in yield over control and avoidable losses and Incremental Cost Benefit Ratio (ICBR) was worked out by following formula given by Khosla [6] and Poul [12].

$$\text{Increase in yield over control (\%)} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

$$\text{Avoidable losses (\%)} = \frac{\text{Yield in treatment with highest yield} - \text{Yield in respective treatment}}{\text{Yield in treatment with highest yield}} \times 100$$

## RESULTS AND DISCUSSION

*Efficacy of ready-mix insecticides against Bihar hairy caterpillar, Spilosoma obliqua*

The pre-count population of bihar hairy caterpillar recorded was found non-significant among different treatments which indicated that the infestation of the pest was in homogenous condition. All the ready-mixed formulations were significantly superior over the untreated control. The data computed for pooled over two sprays of *Kharif*, 2019 furnished in (Table 1) indicated that lowest (2.22 larvae/plant) population of *S. obliqua* was found in plots treated with flubendiamide + buprofezin which proved as superior, followed by chlorantraniliprole + thiamethoxam (2.35) and profenofos + cypermethrin (2.50) and remained at par with each other. The treatments thiamethoxam + lambda-cyhalothrin, pyriproxifen + fenpropathrin and buprofezin + acephate stood next to the above insecticides and exhibited the mean population 3.74, 3.91 and 4.09 larvae/plant, respectively by showing mediocre effectiveness in reducing the pest. The treatments, deltamethrin + triazophos (5.82 larvae/plant) followed by fipronil + imidacloprid (5.60) remained at par with other and proved as less effective.

Observations recorded on pre-count population in *Kharif*, 2020 showed that *S. obliqua* was almost homogenously distributed throughout the experimental field and varied between 6.13 to 8.55 larvae/plant (Table 1). All the treatments significantly differed over the untreated plot. The formulations flubendiamide + buprofezin recorded the lowest (2.04 larvae/plant) mean population and found highly effective which was at par with chlorantraniliprole + thiamethoxam (2.18) and profenofos + cypermethrin (2.31). The treatments thiamethoxam + lambda-cyhalothrin (3.50), pyriproxifen + fenpropathrin (3.66) and buprofezin + acephate (3.87) proved next effective combinations in controlling the pest. The ready-mix formulations, deltamethrin + triazophos and fipronil + imidacloprid registered the highest population of *S. obliqua* (5.57 and 5.34 larvae/ plant) which remained at par with each other and proved as less effective.

Table 1 Efficacy of ready-mix insecticides against Bihar hairy caterpillar (*Spilosoma obliqua)* infesting black gram

| Treatments | Conc. (%) | No. of larvae/plant | | | | | | | | Pooled over years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2019 | | | | 2020 | | | | |
| | | Pre-count population | 1st spray | 2nd spray | Pooled over sprays | Pre-count population | 1st spray | 2nd spray | Pooled over sprays | |
| $T_1$: Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC | 0.0088 | 3.00 (8.85) | 2.31b (4.89) | 1.74b (2.60) | 2.03c (3.74) | 2.58 (6.13) | 2.22b (4.45) | 1.73b (2.54) | 1.97b (3.50) | 2.00b (3.62) |
| $T_2$: Profenophos 40% + Cypermethrin 4% EC | 0.088 | 3.16 (9.52) | 1.98a (3.44) | 1.43a (1.61) | 1.70b (2.52) | 2.60 (6.27) | 1.89a (3.07) | 1.41a (1.54) | 1.65a (2.31) | 1.68a (2.42) |
| $T_3$: Buprofezin 15% + Acephate 35% WP | 0.125 | 3.15 (9.40) | 2.41b (5.31) | 1.83b (2.88) | 2.12c (4.09) | 2.98 (8.36) | 2.32b (4.87) | 1.82b (2.87) | 2.07b (3.87) | 2.09b (4.00) |
| $T_4$: Pyriproxifen 5% + Fenpropathrin 15% EC | 0.03 | 3.33 (10.62) | 2.36b (5.06) | 1.78b (2.76) | 2.07c (3.91) | 2.87 (7.72) | 2.27b (4.65) | 1.76b (2.66) | 2.01b (3.66) | 2.04b (3.79) |
| $T_5$: Flubendiamide 4% + Buprofezin 20% SC | 0.042 | 3.10 (9.10) | 1.89a (3.10) | 1.35a (1.34) | 1.62a (2.22) | 2.59 (6.23) | 1.80a (2.77) | 1.33a (1.32) | 1.57a (2.04) | 1.59a (2.13) |
| $T_6$: Fipronil 40% + Imidacloprid 40% WG | 0.08 | 3.30 (10.37) | 2.74c (7.06) | 2.13c (4.13) | 2.44d (5.60) | 3.01 (8.55) | 2.65c (6.54) | 2.14c (4.13) | 2.39c (5.34) | 2.42c (5.47) |
| $T_7$: Deltamethrin 1% + Triazophos 35% SC | 0.045 | 3.32 (10.52) | 2.79c (7.31) | 2.18c (4.34) | 2.48d (5.82) | 2.93 (8.08) | 2.70c (6.80) | 2.19c (4.35) | 2.44c (5.57) | 2.46c (5.70) |
| $T_8$: Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC | 0.0316 | 3.08 (8.96) | 1.93a (3.23) | 1.39a (1.47) | 1.66ab (2.35) | 2.77 (7.18) | 1.85a (2.94) | 1.37a (1.42) | 1.61a (2.18) | 1.64a (2.27) |
| $T_9$: Untreated Control | - | 3.28 (10.26) | 3.55d (12.06) | 3.72d (13.14) | 3.62e (12.60) | 2.97 (8.30) | 3.24d (9.98) | 3.48d (11.61) | 3.35d (10.79) | 3.48d (11.70) |
| S.Em. ± Treatment (T) | | - | 0.046 | 0.041 | 0.031 | - | 0.046 | 0.043 | 0.032 | 0.037 |
| Period (P) | | - | 0.038 | 0.034 | 0.025 | - | 0.038 | 0.035 | 0.026 | 0.047 |
| Spray (S) | | - | - | - | 0.015 | - | - | - | 0.015 | 0.027 |
| Year (Y) | | - | - | - | - | - | - | - | - | 0.010 |
| C. D. at 5% | T | NS | Sig. | Sig. | Sig. | NS | Sig. | Sig. | Sig. | Sig. |
| C. V. (%) | | 13.89 | 8.08 | 8.89 | 8.45 | 9.93 | 8.48 | 9.66 | 9.08 | 8.75 |

Figures in parentheses are re transformed values; those outside are $\sqrt{x}$ + 0.5 transformed values. Treatments means with the letter(s) in common are non- significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance

The data pertaining to pooled over years (2019 and 2020) presented in (Table 1) revealed that flubendiamide + buprofezin (2.13 larvae/plant) was found highly effective followed by chlorantraniliprole + thiamethoxam (2.27) and profenofos + cypermethrin (2.42). Further, all the treatments were at par with each other. The plots sprayed with thiamethoxam + lambda-cyhalothrin (3.62), pyriproxifen + fenpropathrin (3.79) and buprofezin + acephate (4.00) proved as next potent combinations which are at par with each other. The treatments deltamethrin + triazophos (5.70) and fipronil + imidacloprid (5.47) recorded highest population and designated as less effective in suppressing the *S. obliqua* population in black gram. The present findings are supported by Patidar and Kumar [11] who reported that chlorantraniliprole 18.5% SC was the most effective against Bihar hairy caterpillar followed by flubendiamide 39.35% SC in black gram. Kartikeyan *et al*. [5] reported that flubendiamide 4% + buprofezin 20% SC found effective in reduction of lepidopteran pests of rice. Thus, the present findings support the earlier researchers.

*Efficacy of ready-mix insecticides against Leaf eating caterpillar, Spodoptera litura*.

Observations recorded during *Kharif*, 2019 on pre - count populations showed that *S. litura* was homogenously distributed throughout the experimental field and varied between 2.63 to 4.41 larvae/plant (Table 2). All the treated plots are significantly superior in their performance over the control. Chlorantraniliprole + thiamethoxam recorded the lowest (0.37 larva/ plant) mean larval population and proved as highly effective. However, this treatment was at par with thiamethoxam + lambda-cyhalothrin (0.43) and flubendiamide + buprofezin (0.50). The next ready-mixed formulations *viz*., profenofos + cypermethrin (1.23), buprofezin + acephate (1.33) and pyriproxifen + fenpropathrin (1.46) showed mediocre in their effectiveness in reducing the pest. The treatments, fipronil + imidacloprid (2.50 larvae/plant) and deltamethrin + triazophos (2.36) registered the highest larval population and found less effective in managing the pest. Moreover, the latter two treatments were at par with each other.

Table 2 Efficacy of ready-mix insecticides against leaf eating caterpillar, (*Spodoptera litura)* infesting black gram

| Treatments | Conc. (%) | No. of larvae/plant | | | | | | | | Pooled over years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2019 | | | | 2020 | | | | |
| | | Pre-count population | 1st spray | 2nd spray | Pooled over sprays | Pre-count population | 1st spray | 2nd spray | Pooled over sprays | |
| $T_1$: Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC | 0.0088 | 1.98 (3.41) | 0.97a (0.46) | 0.94a (0.39) | 0.95a (0.43) | 1.80 (2.73) | 0.94a (0.39) | 0.91a (0.33) | 0.92a (0.36) | 0.94a (0.39) |
| $T_2$: Profenophos 40% + Cypermethrin 4% EC | 0.088 | 1.80 (2.75) | 1.32b (1.27) | 1.30b (1.19) | 1.31b (1.23) | 1.89 (3.07) | 1.26ab (1.10) | 1.22bc (1.04) | 1.24b (1.07) | 1.28ab (1.15) |
| $T_3$: Buprofezin 15% + Acephate 35% WP | 0.125 | 2.22 (4.41) | 1.36b (1.37) | 1.33b (1.29) | 1.35b (1.33) | 1.71 (2.43) | 1.30bc (1.21) | 1.27bcd (1.13) | 1.29b (1.16) | 1.32ab (1.25) |
| $T_4$: Pyriproxifen 5% + Fenpropathrin 15% EC | 0.03 | 1.83 (2.86) | 1.41b (1.51) | 1.38b (1.41) | 1.40b (1.46) | 1.61 (2.10) | 1.34bcd (1.30) | 1.31cde (1.23) | 1.33b (1.27) | 1.37ab (1.36) |
| $T_5$: Flubendiamide 4% + Buprofezin 20% SC | 0.042 | 2.14 (4.10) | 1.02a (0.55) | 0.98a (0.46) | 1.00a (0.50) | 1.73 (2.5) | 0.97a (0.46) | 0.94ab (0.39) | 0.96a (0.43) | 0.98a (0.49) |
| $T_6$: Fipronil 40% + Imidacloprid 40% WG | 0.08 | 2.09 (3.88) | 1.77c (2.65) | 1.69c (2.34) | 1.73c (2.50) | 2.00 (3.52) | 1.66d (2.25) | 1.63e (2.17) | 1.65c (2.21) | 1.69b (2.35) |
| $T_7$: Deltamethrin 1% + Triazophos 35% SC | 0.045 | 2.01 (3.54) | 1.72c (2.50) | 1.65c (2.22) | 1.69c (2.36) | 1.91 (3.13) | 1.61cd (2.11) | 1.58de (2.05) | 1.60c (2.08) | 1.65b (2.22) |
| $T_8$: Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC | 0.0316 | 1.77 (2.63) | 0.94a (0.39) | 0.91a (0.33) | 0.93a (0.36) | 1.64 (2.20) | 0.90a (0.32) | 0.87a (0.27) | 0.89a (0.30) | 0.91a (0.34) |
| $T_9$: Untreated Control | - | 2.18 (4.26) | 2.44d (5.46) | 2.58d (6.15) | 2.51d (5.81) | 2.00 (3.50) | 2.00e (3.51) | 2.07f (3.81) | 2.04d (3.66) | 2.27c (4.73) |
| S.Em. ± Treatment (T) | | - | - | 0.043 | 0.038 | 0.028 | - | 0.036 | 0.038 | 0.025 |
| Period (P) | | - | - | 0.035 | 0.031 | 0.023 | - | 0.029 | 0.031 | 0.021 |
| Spray (S) | | - | - | - | - | 0.013 | - | - | - | 0.012 |
| Year (Y) | | - | - | - | - | - | - | - | - | - |
| C. D. at 5% | T | NS | NS | Sig. | Sig. | Sig. | NS | Sig. | Sig. | Sig. |
| C. V. (%) | | 13.89 | 10.27 | 12.83 | 11.28 | 12.07 | 10.34 | 11.49 | 12.08 | 11.74 |

Figures in parentheses are re transformed values; those outside are $\sqrt{x}$ + 0.5 transformed values. Treatments means with the letter(s) in common are non- significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance

Results of pooled over two sprays of *Kharif*, 2020 presented in (Table 2) indicated that chlorantraniliprole + thiamethoxam recorded the lowest population (0.30 larvae/plant) was highly effective which was at par with thiamethoxam + lambdacyhalothrin (0.36) and flubendiamide + buprofezin (0.43). The treatments profenofos + cypermethrin (1.08), buprofezin + acephate (1.16) and pyriproxifen + fenpropathrin (1.27) proved as moderately effective. Although, fipronil + imidacloprid (2.21 larvae/plant) and deltamethrin + triazophos (2.08) recorded the highest mean larval population and proved as least effective against leaf eating caterpillar.

Pooled over years (2019 and 2020) data furnished in (Table 2) indicated that chlorantraniliprole + thiamethoxam (0.34) was found highly effective and was at par with thiamethoxam + lambda-cyhalothrin (0.39) and flubendiamide + buprofezin (0.49). Insecticides, profenofos + cypermethrin (1.15), buprofezin + acephate (1.25) and pyriproxifen + fenpropathrin (1.36) showed mediocre effectiveness in reducing the pest. The treatments fipronil + imidacloprid (2.35) followed by deltamethrin + triazophos (2.22) were less effective against leaf eating caterpillar population in black gram. Reddy and Paul [13] noticed that thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC and chlorantraniliprole 8.8% + thiamethoxam 17.5% SC were found superior in the management of *S. litura* over other treatments in cowpea. Thus, the findings are more or less in line with the past reports.

*Efficacy of ready-mix insecticides against Spotted pod borer, Maruca vitrata*

Pre-count population of *M. vitrata* ranged between 2.65 to 4.29 larvae/plant in various treatments which were statistically non-significant. The data of pooled over two sprays

of *Kharif*, 2019 presented in (Table 3) indicated that thiamethoxam + lambda-cyhalothrin recorded lower larval population (0.34 larva/plant) and rendered as most effective treatment in reducing the *M. vitrata* population. However, it was statistically at par with chlorantraniliprole + thiamethoxam (0.42) and flubendiamide + buprofezin (0.49). The treatments buprofezin + acephate (1.16), fipronil + imidacloprid (1.24) and pyriproxifen + fenpropathrin (1.36) proved moderately effective in suppressing the pest and were on par with each other. In contrast, profenofos + cypermethrin recorded the highest (2.30 larvae/plant) followed by deltamethrin + triazophos (2.16) and proved less effective in controlling the pest.

Before spray population of *M. vitrata* in different treatments ranged between 2.20 to 4.51 larvae/plant which were homogenously distributed and statistically non-significant. Overall data of pooled over two sprays of *Kharif*, 2020 summarized in (Table 3) indicated that thiamethoxam + lambda-cyhalothrin recorded the minimum (0.58 larvae/ plant) and found highly effective over chlorantraniliprole + thiamethoxam (0.66) and flubendiamide + buprofezin (0.76) in mitigating the *M. vitrata* population. Moreover, they were at par with each other. The treatments buprofezin + acephate (1.47), fipronil + imidacloprid (1.61) and pyriproxifen + fenpropathrin (1.73) found mediocre in their effectiveness in reducing the pest and also found at par with each other. Profenofos + cypermethrin (2.78 larvae/plant) and deltamethrin + triazophos (2.62) found less effective in managing the spotted pod borer population in black gram and found at par with each other.

Pooled over years (2019 and 2020) presented in (Table 3) revealed that among the evaluated treatments, thiamethoxam + lambda-cyhalothrin (0.46 larva/plant) was found highly effective and remained at par with chlorantraniliprole + thiamethoxam (0.54) and flubendiamide + buprofezin (0.63). The succeeding potential insecticides were buprofezin + acephate (1.32), fipronil + imidacloprid (1.43) and pyriproxifen + fenpropathrin (1.55) found moderately effective and found at par with each other. The treatments profenofos + cypermethrin (2.54 larvae/plant) and deltamethrin + triazophos (2.39) were found less effective in controlling the population of *M. vitrata* in black gram. The present findings are supported by Reddy and Paul [13] who reported that thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC and chlorantraniliprole 8.8% + thiamethoxam 17.5% SC were found superior in the management of *M. vitrata* over other treatments in cowpea. According to Roy *et al.* [15] chlorantraniliprole 8.8% + thiamethoxam 17.5% SC and flubendiamide 24% + thiacloprid 24% SC combination was found most effective in controlling the larva of *M. testulalis* by 71.24 and 60.35 per cent, respectively in cowpea.

Table 3 Efficacy of ready-mix insecticides against spotted pod borer, (*Maruca vitrata*) infesting black gram

| Treatments | Conc. (%) | No. of larvae/plant | | | | | | | | Pooled over years |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2019 | | | | 2020 | | | | |
| | | Pre-count population | 1st spray | 2nd spray | Pooled over sprays | Pre-count population | 1st spray | 2nd spray | Pooled over sprays | |
| $T_1$: Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC | 0.0088 | 1.78 (2.65) | 0.96a (0.42) | 0.87a (0.26) | 0.91a (0.34) | 1.94 (3.27) | 1.09a (0.71) | 0.97a (0.45) | 1.03a (0.58) | 0.97a (0.46) |
| $T_2$: Profenophos 40% + Cypermethrin 4% EC | 0.088 | 2.13 (4.03) | 1.76c (2.60) | 1.58c (2.00) | 1.67c (2.30) | 2.08 (3.83) | 1.89c (3.09) | 1.72c (2.47) | 1.81e (2.78) | 1.74d (2.54) |
| $T_3$: Buprofezin 15% + Acephate 35% WP | 0.125 | 1.86 (2.95) | 1.35b (1.34) | 1.21b (0.98) | 1.28b (1.16) | 1.65 (2.23) | 1.47b (1.67) | 1.33b (1.27) | 1.40c (1.47) | 1.34b (1.32) |
| $T_4$: Pyriproxifen 5% + Fenpropathrin 15% EC | 0.03 | 1.89 (3.08) | 1.43b (1.52) | 1.30b (1.20) | 1.37b (1.36) | 1.70 (2.40) | 1.56b (1.94) | 1.42b (1.53) | 1.49d (1.73) | 1.43c (1.55) |
| $T_5$: Flubendiamide 4% + Buprofezin 20% SC | 0.042 | 1.80 (2.74) | 1.03a (0.57) | 0.95a (0.41) | 0.99a (0.49) | 1.71 (2.43) | 1.18a (0.91) | 1.05a (0.61) | 1.12b (0.76) | 1.05a (0.63) |
| $T_6$: Fipronil 40% + Imidacloprid 40% WG | 0.08 | 1.90 (3.12) | 1.39b (1.40) | 1.25b (1.08) | 1.32b (1.24) | 2.24 (4.51) | 1.52b (1.82) | 1.37b (1.40) | 1.45cd (1.61) | 1.38bc (1.43) |
| $T_7$: Deltamethrin 1% + Triazophos 35% SC | 0.045 | 2.19 (4.29) | 1.72c (2.43) | 1.56c (1.89) | 1.64c (2.16) | 2.05 (3.72) | 1.85c (2.95) | 1.67c (2.30) | 1.76e (2.62) | 1.70d (2.39) |
| $T_8$: Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC | 0.0316 | 1.95 (3.31) | 1.00a (0.50) | 0.91a (0.33) | 0.95a (0.42) | 1.64 (2.20) | 1.14a (0.81) | 1.01a (0.52) | 1.07ab (0.66) | 1.01a (0.54) |
| $T_9$: Untreated Control | - | 2.17 (4.19) | 2.33d (4.91) | 2.49d (5.69) | 2.41d (5.30) | 2.23 (4.48) | 2.40d (5.28) | 2.54d (5.96) | 2.47f (5.62) | 2.44c (5.46) |
| S.Em. ± Treatment (T) | | - | 0.042 | 0.035 | 0.027 | - | 0.041 | 0.038 | 0.028 | 0.020 |
| Period (P) | | - | 0.034 | 0.029 | 0.022 | - | 0.034 | 0.031 | 0.023 | 0.016 |
| Spray (S) | | - | - | - | 0.13 | - | - | - | 0.013 | 0.009 |
| Year (Y) | | - | - | - | - | - | - | - | - | 0.009 |
| C. D. at 5% | T | NS | Sig. | Sig. | Sig. | NS | Sig. | Sig. | Sig. | Sig. |
| C. V. (%) | | 15.31 | 12.38 | 11.09 | 11.81 | 13.68 | 11.20 | 11.06 | 11.16 | 11.47 |

Figures in parentheses are re transformed values; those outside are $\sqrt{x}$ + 0.5 transformed values. Treatments means with the letter(s) in common are non- significant by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance

*Impact of different ready-mix insecticides on seed and haulm yield*

The data on effect of different ready-mix insecticides on seed and haulm yield in pooled over years was presented in (Table 4) indicated that the treatments thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC yielded significantly higher (1047 and 1309 kg/ha) seed and haulm yield followed by fipronil 40% + imidacloprid 40% WG (1022 and 1270 kg/ha), chlorantraniliprole 8.8% + thiamethoxam 17.5% SC (1019 and 1277 kg/ha), deltamethrin 1% + triazophos 35% SC (962 and 1208 kg/ha) and profenophos 40% + cypermethrin 4 % EC (870 and1088 kg/ha). However, all the treatments were at par with each other. The treatments, flubendiamide 4% + buprofezin 20% SC (848 and 1060 kg/ha) and buprofezin 15% + acephate 35% WP (820 and 1025 kg/ha) were found as second best in producing seed and haulm yield of black gram. Moreover, all the above treatments were on par with each other. Whereas, ready-mix insecticide pyriproxifen 5% + fenpropathrin 15% EC (760 and 950 kg/ha) recorded lower seed and haulm yield of black gram. Swami and Kumar [19]

reported that higher seed yield of black gram was obtained in plots treated with thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC with 3.30 q/ha. Which are in accordance with present findings.

*Increase in seed and haulm yield over control*

The per cent increase in seed and haulm yield of black gram over control ranged from 24.19 to 51.61 and 38.89 to 91.37 per cent due to application of insecticides (Table 4). The chronological order of various treatments based on per cent increase in yield over control given in bracket is: thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC (51.61 and 91.37%) > fipronil 40% + imidacloprid 40% WG (49.21 and 86.84%) > chlorantraniliprole 8.8% + thiamethoxam 17.5% SC (48.85 and 86.70%) > deltamethrin 1% + triazophos 35% SC (43.42 and 76.61%) > profenophos 40% + cypermethrin 4% EC (34.71 and 59.06%) > flubendiamide 4% + buprofezin 20% SC (32.58 and 54.97%) > pyriproxifen 5% + fenpropathrin 15% EC (24.19 and 38.89 %) > buprofezin 15% + acephate 35% WP (29.92 and 49.85%). Maximum yield loss could be avoided with spray application of thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC & fipronil 40% + imidacloprid 40% WG.

*Avoidable losses*

Looking to the losses in seed yield of black gram it varied from 2.40 to 27.42 in different treatments (Table 4). The lowest avoidable loss (2.40%) was recorded in the treatment of fipronil 40 % + imidacloprid 40% WG followed by chlorantraniliprole 8.8% + thiamethoxam 17.5% SC (2.77%). The losses were calculated as 8.19, 16.91 and 19.04 per cent in the treatments of deltamethrin 1% + triazophos 35% SC, profenophos 40% + cypermethrin 4% EC and flubendiamide 4% + buprofezin 20% SC. In contrast the highest avoidable losses were recorded in the treatments of pyriproxifen 5% + fenpropathrin 15% EC (27.42 %) followed by buprofezin 15% + acephate 35% WP with (21.70).

Table 4 Impact of ready-mix insecticides on seed and haulm yield of black gram and avoidable losses

| Treatments | Conc. (%) | Seed yield (kg/ha) | | | Haulm yield (kg/ha) | | | Increase in yield over control (%) | Avoidable losses (%) | Increase in yield over control (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | Pooled | 2019 | 2020 | Pooled | Seed | | Halm |
| $T_1$: Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC | 0.0088 | $1041^{a}$ | $1054^{a}$ | $1047^{a}$ | $1301^{a}$ | $1318^{a}$ | 1309a | 51.61 | - | 16.88 |
| $T_2$: Profenophos 40% + Cypermethrin 4% EC | 0.088 | $863^{abcd}$ | $878^{abcd}$ | $870^{abcd}$ | $1078^{abc}$ | $1098^{abcd}$ | $1088^{abcd}$ | 34.71 | 16.91 | 21.70 |
| $T_3$: Buprofezin 15% + Acephate 35% WP | 0.125 | $823^{cd}$ | $818^{cd}$ | $820^{cd}$ | $1029^{bc}$ | $1022^{cd}$ | $1025^{cd}$ | 29.92 | 21.70 | 27.43 |
| $T_4$: Pyriproxifen 5% + Fenpropathrin 15% EC | 0.03 | $764^{d}$ | $757^{d}$ | $760^{d}$ | $955^{c}$ | $946^{d}$ | $950^{d}$ | 24.19 | 27.42 | 19.02 |
| $T_5$: Flubendiamide 4% + Buprofezin 20% SC | 0.042 | $845^{bcd}$ | $851^{bcd}$ | $848^{bcd}$ | $1056^{abc}$ | $1065^{bcd}$ | $1060^{bcd}$ | 32.58 | 19.04 | 2.37 |
| $T_6$: Fipronil 40% + Imidacloprid 40% WG | 0.08 | $1017^{ab}$ | $1028^{ab}$ | $1022^{ab}$ | $1271^{ab}$ | $1285^{ab}$ | $1278^{ab}$ | 49.21 | 2.40 | 7.72 |
| $T_7$: Deltamethrin 1% + Triazophos 35% SC | 0.045 | $968^{abc}$ | $955^{abc}$ | $962^{abc}$ | $1220^{ab}$ | $1194^{abc}$ | $1208^{abc}$ | 43.42 | 8.19 | 2.44 |
| $T_8$: Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC | 0.0316 | $1021^{ab}$ | $1016^{ab}$ | $1018^{ab}$ | $1277^{a}$ | $1270^{ab}$ | $1274^{ab}$ | 48.85 | 2.77 | 47.75 |
| $T_9$: Untreated Control | - | $523^{e}$ | $490^{e}$ | $507^{e}$ | $707^{d}$ | $662^{e}$ | $684^{e}$ | - | 51.61 | - |
| S.Em. ± Treatment (T) | | 0.56 | 0.56 | 0.35 | 0.73 | 0.70 | 0.45 | - | - | - |
| Year (Y) | | - | - | 0.187 | - | - | 0.239 | - | - | - |
| T × Y | | - | - | 0.561 | - | - | 0.716 | - | - | - |
| C. D. at 5% | T | Sig. | Sig. | Sig. | Sig. | Sig. | Sig. | - | - | - |
| | Y | - | - | - | | - | - | - | - | - |
| | T × Y | - | - | NS | | - | NS | -- | - | - |
| C. V. % | | 11.14 | 11.13 | 11.14 | 11.48 | 11.11 | 11.30 | - | - | - |

Treatment means with the letter(s) in common are non-significant by Duncan's New Multiple Range Test (DNMRT) at 5 % level of significance

Table 5 Economics of ready-mix insecticides evaluated against insect-pests infesting black gram

| Treatments | Quantity of insecticides required for 2 sprays (g or ml/ha) | Price of insecticides (₹/lire or kg) | Cost of insecticides (₹/ha) | Labour charges (₹/ha) | Total cost of treatments (₹/ha) | Yield (kg/ha) | | Net gain over control (kg/ha) | | Realization (₹/ha) | Net return (₹/ha) | ICBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Seed | Haulm | Seed | Haulm | | | |
| $T_1$: | 0.40 | 3375 | 1350 | 1232 | 2582 | 1047 | 1309 | 540 | 624 | 34020 | 31438 | 1:13.18 |
| $T_2$: | 2.00 | 1300 | 2600 | 1232 | 3832 | 870 | 1088 | 363 | 403 | 22869 | 1037 | 1: 5.97 |
| $T_3$: | 2.50 | 3328 | 8320 | 1232 | 9552 | 820 | 1025 | 313 | 340 | 19719 | 10167 | 1: 2.06 |
| $T_4$: | 1.50 | 1784 | 2437 | 1232 | 3669 | 760 | 950 | 253 | 265 | 15939 | 12270 | 1: 4.34 |
| $T_5$: | 1.75 | 1050 | 1837 | 1232 | 3070 | 848 | 1060 | 341 | 375 | 21483 | 18413 | 1: 7.00 |
| $T_6$: | 1.00 | 13000 | 13000 | 1232 | 14232 | 1022 | 1278 | 515 | 585 | 32445 | 18213 | 1: 2.28 |
| $T_7$: | 1.25 | 720 | 900 | 1232 | 2132 | 962 | 1208 | 455 | 523 | 28665 | 26533 | 1:13.45 |
| $T_8$: | 1.2 | 8590 | 10308 | 1232 | 11540 | 1018 | 1274 | 511 | 592 | 32193 | 20653 | 1: 2.79 |
| $T_9$: | - | - | - | - | - | 507 | 685 | - | - | - | - | - |

*Labour charges @ ₹ 348.20 /unskilled labour + 268/labour/day/ha

*Total labour charges for one spray: 526 ₹/ha for application of insecticides; For 2 sprays, 2 x 526= 1052 ₹/ha

*Market price of black gram seed and haulm price, 63 ₹/kg and 1.50₹/kg, respectively

*Economics*

Economics of various ready-mix insecticides evaluated against insect-pests of black gram presented in (Table 5) revealed that highest (34,020 ₹/ha) net realization was obtained from the plots treated with thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC followed by fipronil 40% + imidacloprid 40% WG (32,455 ₹/ha) and chlorantraniliprole 8.8% + thiamethoxam 17.5% SC (32,193 ₹/ha). The treatments

deltamethrin 1% + triazophos 35% SC, profenophos 40% + cypermethrin 4% EC and flubendiamide 4% + buprofezin 20% SC have registered with 28,665, 22,869 and 21,483 ₹/ha net realization, respectively. The lowest net realization was obtained in plots treated with pyriproxifen 5% + fenpropathrin 15% EC (15,939 ₹/ha) and buprofezin 15% + acephate 35% WP (19,719 ₹/ha).

Looking to the ICBR, the highest (1: 13.45) return was obtained with the treatment of deltamethrin 1% + triazophos 35% SC followed by thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC (1: 13.18) and flubendiamide 4% + buprofezin 20% SC (1: 7.00). The ICBR calculated for the treatments of profenophos 40% + cypermethrin 4% EC, pyriproxifen 5% + fenpropathrin 15% EC and chlorantraniliprole 8.8% + thiamethoxam 17.5% SC was 1:5.97, 1:4.34 and 1:2.79, respectively. The lowest ICBR was recorded in the treatments of buprofezin 15% + acephate 35% WP (1:2.06) and.fipronil 40% + imidacloprid 40% WG (1:2.28) which has least economic importance. The present findings are in conformity with Pathade *et al.* [10] who reported that deltamethrin 1% EC + triazophos 35% EC found as the most economically viable treatment with higher ICBR of (1:20.02) in pigeon pea.

## CONCLUSION

In culmination, ready-mix insecticides viz., flubendiamide 4% + buprofezin 20% SC, chlorantraniliprole 8.8% + thiamethoxam 17.5% SC and profenofos 40% + cypermethrin 4% EC proved effective against Bihar hairy caterpillar While, treatments chlorantraniliprole 8.8% + thiamethoxam 17.5% SC, thiamethoxam 12.6 % + lambda-cyhalothrin 9.5% ZC and flubendiamide 4% + buprofezin 20% SC indicated significant reduction of leaf eating caterpillar. However, the plots treated with thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, chlorantraniliprole 8.8% + thiamethoxam 17.5% SC and flubendiamide 4% + buprofezin 20% SC proved effective against spotted pod borer in black gram. The higher seed and haulm yield was obtained from the plots treated with thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC and it was at par with fipronil 40% + imidacloprid 40% WG, chlorantraniliprole 8.8% + thiamethoxam 17.5% SC and buprofezin 15% + acephate 35% WP. The highest Incremental Cost Benefit Ratio (ICBR) was calculated from the plots treated with deltamethrin 1% + triazophos 35% followed by thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC (1:13.18) and flubendiamide 4% + buprofezin 20% SC.

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