Insecticide compatibility with abundance and diversity of predatory fauna in wheat (*Triticum aestivum*) ecosystem

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Abstract
Assessment of the potential effects of insecticides on the natural enemies is an important part of IPM. The use of natural enemies in combination with selected insecticides which have no effect on them is effective in depressing the population density of the insect pest. In this context, an effort was made to know the diversity of predatory fauna and effect of seed dressers, soil applied chemicals and foliar spraying insecticides on their abundance in wheat during rabi, 2019–20. The investigation registered the activity of green lacewing (*Chrysoperla zastrowi sillemi*), coccinellids (*Coccinella transversalis*, *Cheilomenes sexmaculata*, *Illeis cincta*), syrphid (*Ischiodon scutellaris*) and spider (*Oxyopes lineatus*). Meanwhile, the results also revealed the peak activity of green lacewing, coccinellids, syrphids and spiders in seed treatment with thiamethoxam 30 FS @ 5 ml/kg seeds (1.20, 1.40, 0.73 and 0.67 per meter square area, respectively) followed by soil application of carbofuran 3G @ 30 kg/ha (1.17, 1.37, 0.70 and 0.62 per meter square, respectively) and both were found on par with untreated check (1.39, 1.51, 0.81 and 0.78 per meter square, respectively). Whereas, the least population was recorded in soil application of carbofuran 3G @ 30 kg/ha followed by a foliar application of cypermethrin 10 EC @ 0.5 ml/l (0.22, 0.24, 0.14 and 0.12 per meter square, respectively) over rest of the treatments. These results endorsed the biocompatibility of seed dressers (Thiamethoxam 30 FS), soil applied chemicals (Carbofuran 3G) and detrimental effects of foliar spraying insecticides (Cypermethrin 10 EC, Emamectin benzoate 5SG and Nimbecidine 1500 ppm) on population dynamics of natural enemy.

Keywords Abundance · Biocompatibility · Diversity · Insecticides · Natural enemies · Wheat

Introduction
Wheat (*Triticum* spp.) is one of the low input cereal crop, being grown in many parts of the world. Due to its unique baking quality, it has got prime importance as major food grain crop and consider it as ‘King of Cereals’ since from centuries. Wheat is less attacked by insect pests in field as compared to other food grain crops even though, insect pests and diseases together reported to cause 20 to 37 per cent yield loss (Pimentel 1997). In global perspective, 26 insect pests are reported to damage wheat crop, while 12 species have been reported from Indian Sub-continent which infest from planting to till harvest of the crop (Anonymous 2013). Heading and flowering stage of the wheat crop suffers greatly by insect pests and cause enormous damage in wheat. About six species of insect pests are reported to damage wheat crop starting from seedling to maturity stage and attain major pest status in wheat ecosystem (Freier et al. 2007). Aphids (*Rhopalosiphum padi* L., *Sitobion avenae* F., *Diuraphis noxia* S.) and green bug (*Shizaphis graminum*) feed on leaves and cause damage by injecting toxin whereas, shoot fly (*Atherigona approximata* Malloch, *A. soccata* Malloch, *A. oryzae* Malloch), pink stem borer (*Sesamia inferens* Walker), termites (*Odontotermes obesus* Rambur and *Microtermes obesus* Holmgren) and cut worms (*Agrotis ipsilon* Hufnagel) are causing significant damage in wheat by producing dead heart and white ear symptoms at vegetative and reproductive stage of the crop, respectively (Duveiller et al. 2007; Jambagi 2020; Jambagi et al. 2022, 2023). Since from many years, farmers are depending on many insecticides to tackle this pest attack. Due to indiscriminate usage of such agrochemicals, we are facing many puzzles in recent days viz., development of resistance in insects, outbreak and
resurgence of insect pests, gradual decrease in natural enemy population and frequent detection of insecticide residues in agricultural products. This necessitates the identification of alternative sustainable pest management strategies.

Insect natural enemies provide important ecosystem services by suppressing insect pest population in many agricultural crops. Most of the biological control agents including predators, parasitoids and spiders are naturally occurring agents which provide excellent regulation of many insect pests (Schmidt et al. 2004). Earlier workers (Schmidt et al. 2004; El-Wakeil and Volkmar 2013; Ranjith et al. 2018) were attempted to document the general predators and parasitoids; however, the specific pest-natural enemy interaction is still largely lacking in wheat ecosystem. Candidate predators and parasitoids for IPM programmes should thus be evaluated for susceptible to the pesticides used to control agricultural pests (Hassan et al. 1987). Assessment of the potential effects of insecticides on the natural enemies is therefore an important part of IPM programme (Holland et al. 2000; El-Wakeil et al. 2013). The use of natural enemies in combination with selected insecticides which have no effect on them is effective in depressing the population density of the insect pest. With this background, the present study was aimed to evaluate the potential effect of selected insecticides on diversity and abundance of predatory fauna in wheat.

Materials and methods

Preparation of research plot

The present investigation was carried out during rabi 2019–20 at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad –India by using wheat cultivar UAS-304 on medium black soil with maize as the previous crop under irrigated condition. The experiment was laid out in Randomised Block Design (RBD) with three replications of nine treatments including untreated check (UTC). The crop was sown with a row spacing of 23 cm apart in a plot size of 3 m × 2.7 m. All the crop production technologies were adopted as per the package of practice.

Selection of insecticides

The insecticides used for the control of shoot fly (Atherigona spp.), one of the major potential pest (noticed > 26% dead heart in wheat by Jambagi et al. 2021) in wheat has been considered for the investigation. This tends to reveal the effect of seed dressers, soil applying chemicals, foliar spraying insecticides and their combinations on natural enemies in field condition. Here, the prophylactic application of insecticides either as seed treatment or soil application has been done at the time of sowing whereas, the other foliar treatments were imposed at 15 Days After Emergence (DAE) by using knapsack sprayer with 450 l/ha spray fluid.

Estimation of natural enemies

General predators viz., green lacewing (grubs and adults), coccinellids (grubs and adults), syrphid fly (grubs and adults) and predatory spider (adults) population were recorded per one square meter area in each treatment at a day before spraying and at five, ten and fifteen days after spraying.

Statistical analysis

The obtained data were subjected to square root (\(\sqrt{x + 0.5}\)) transformation, analysis was done by using RBD design and values were analysed using Duncan’s Multiple Range Test (DMRT) (Duncan 1955) in M-STAT software.

Results

The investigation registered the activity of three predatory insects viz., green lacewing (Chrysoperla zastrowi sillemi Esben-Peterson), coccinellids (Coccinella transversalis Fabricius, Cheilomenes sexmaculata (Fabricius), Illeis cincta (Fabricius)), syrphids (Ischiodon scutellaris (Fabricius)) and one predatory spider (Oxyopes lineatus Latreille). A day before imposition of treatments, the population of all the predators viz., green lacewing, coccinellids, syrphids and spiders was uniform in all the plots and ranged from 0.75 to 0.91, 0.72 to 0.99, 0.42 to 0.52 and 0.28 to 0.46 per square meter area, respectively (Table 1, 2, 3 and 4). There was no significant difference with respect to its population in all the treatments including untreated check.

The observations recorded on population of Chrysoperla zastrowi sillemi per square meter area in wheat crop at different intervals are presented in Table 1. The pooled mean of chrysopid population at 5, 10 and 15 Days After Spraying (DAS) confirmed that the seed treatment with thiamethoxam 30 FS @ 5 ml/kg seed (T1) recorded maximum population of 1.20 followed by soil application of carbofuran 3G @ 30 kg/ha (T2) (1.17) besides untreated check (1.39). Whereas, soil application of carbofuran 3G @ 30 kg/ha followed by a spray of cypermethrin 10 EC @ 0.5 ml/l recorded least density (0.22) of C. zastrowi sillemi and found on par with seed treatment with thiamethoxam 30 FS @ 5 ml/l along with a spray of cypermethrin 10 EC @ 0.5 ml/l (0.25). During the investigation, we have recorded three coccinellid predators viz., Coccinella transversalis, Cheilomenes sexmaculata, and
Illeis cincta (fungal predator) in the field. As per the data presented in Table 2, the pooled mean of three intervals in different treatments confirmed that the untreated control (UTC) reported maximum coccinellid population of 1.51 per meter square area, followed by T1 (1.40) and T2 (1.37). Whereas, the least population was noticed in T8 (0.24) which was closely followed by T7 (0.28).

The similar trend was also observed in abundance of syrphid, Ischiodon scutellaris population (Table 3) where, the pooled mean population of 5, 10 and 15 DAS ranged from 0.14 to 0.81 per meter square area with T1 (0.73) being superior over other insecticidal treatments besides untreated check (0.81) and closely followed by T2 (0.70). During the experiment, we have also looked over the diversity of spider population and registered one predatory spider, Oxyopes linea tus in the experimental plots. The pooled mean of three intervals in different treatments also confirmed the trend, where the peak spider population was recorded in T1 (0.67) and T2 (0.62) where they found numerically on par with untreated check (0.78). The lowest density of 0.12 observed from T9 (Table 4). In overall observations, the population of all the predators were present to a greater extent within untreated plot compared with the treated ones.

Discussion

A comprehensive understanding of biological and environmental interaction in agriculture, which constitutes a phytobiome is an important focal point for the development of sustainable crop production approach (Way and Heong 1994). This could advocate us regarding the soil health maintenance and natural tackling of many insect pests in the field condition. In the modern agriculture, utilisation of many agrochemicals including fungicides, herbicides, insecticides etc. can hit ecosystem badly with huge deleterious effects, as a result we are facing many health issues in recent days. Therefore, it is clearly evident that the new approaches towards modernising agriculture are must needed and to this end, there must be fundamental knowledge to estimate the required levels of biodiversity in agricultural crops. There are several natural agents recorded in wheat field, which have potential to take care of many of insect pests in the field. The most diverse group of predators viz., Coleoptera (Coccinellidae), Diptera (Syrphidae), Neuroptera (Chrysopidae and Hemerobiidae), Aranea and many hymenopteran wasps were denoted in the arthropoda faunal structure as reported by Malschi (2008) who pioneer in scientific studies on insect pest of wheat and their associated natural enemies.

Table 1 Impact of insecticidal treatments on Chrysoperla zastrowi sillemi population in wheat

| Tr. No. | Treatments | Dosage | 1 DBS | 5 DAS | 10 DAS | 15 DAS | Mean |
|---------|------------|--------|-------|-------|--------|--------|------|
| T1      | Seed treatment with Thiamethoxam 30 FS | 5 ml/kg | 0.89 (1.18)a | 0.94 (1.20)a | 1.25 (1.32)ab | 1.41 (1.38)ab | 1.20 |
| T2      | Soil application of Carbofuran 3G | 5 ml/kg | 0.81 (1.14)a | 0.92 (1.19)a | 1.21 (1.31)ab | 1.39 (1.37)ab | 1.17 |
| T3      | T1 + One spray of Nimbecidine 1500 ppm | 30 kg/ha | 0.83 (1.15)a | 0.71 (1.10)ab | 0.79 (1.14)ab | 0.98 (1.22)abc | 0.83 |
| T4      | T2 + One spray of Nimbecidine 1500 ppm | 30 kg/ha | 0.78 (1.13)a | 0.75 (1.12)ab | 0.76 (1.12)ab | 0.92 (1.12)cd | 0.81 |
| T5      | T1 + One spray of Emamectin benzoate 5 SG | 5 ml/kg | 0.81 (1.14)a | 0.45 (0.97)bc | 0.51 (1.00)ab | 0.76 (1.12)d | 0.57 |
| T6      | T2 + One spray of Emamectin benzoate 5 SG | 5 ml/kg | 0.75 (1.12)a | 0.41 (0.95)bc | 0.49 (0.99)ab | 0.74 (1.11)d | 0.55 |
| T7      | T1 + One spray of Cypermethrin 10 EC | 5 ml/kg | 0.86 (1.17)a | 0.23 (0.85)c | 0.25 (0.87)b | 0.28 (0.88)c | 0.25 |
| T8      | T2 + One spray of Cypermethrin 10 EC | 5 ml/kg | 0.79 (1.14)a | 0.19 (0.83)c | 0.22 (0.85)b | 0.24 (0.86)c | 0.22 |
| T9      | Untreated check (UTC) | - | 0.91 (1.19)a | 0.95 (1.20)a | 1.54 (1.43)a | 1.69 (1.48)a | 1.39 |

Means followed by same alphabet in a column do not differ significantly (0.05) by DMRT

DBS Day Before Spraying, DAS Days After Spraying, NS Non-Significant
*Values in parentheses are √x + 0.5 transformed values
and conducted extensive research in winter wheat for several years. El-Wakeil and Volkmar (2013) also documented the diversity of general predators (lacewings, coccinellids, syrphids, spiders, dance flies and thrips predators) and parasitic wasps (Aphidius spp.). While investigating biodiversity of natural enemies associated with wheat ecosystem, Ranjith et al. (2018) recorded nine species of natural enemies including coccinellids (Coccinella septempunctata, Menochilus sexmaculatus and Hippodamia variegate), Syrphids (Episyrphus balteatus), ground beetle (Abacetus spp.) and a braconid wasp (Cotesia spp.). In another study, Schmidt et al. (2004) exemplified the parasitic role of gall midge, Aphidoletes cf. aphidimyza and predatory potential of hover flies and spiders in keeping aphid, Rhopalosiphum padi population under check in mulched cereals. Meanwhile, National Institute of Plant Health Management (NIPHM)-Government of India also enlisted several predatory insects in AESA based IPM Package for wheat (Anonymous 2014). So, in this context the present investigation emphasises the biosafety of chemical insecticides to the predatory fauna in field condition.

In this extensive investigation, there is no significant difference among the treatments including untreated check in the natural enemy population (green lace wing, coccinellids, syrphids and spiders) a day before spraying, though they received chemicals at the time of sowing either as seed treatment or soil application. The present findings can be supported by Anita (2009) who observed Chrysoperla sp. and coccinellid population per plant in imidacloprid 70 WS (2 g/kg seed) and endosulfan 35 EC (0.07%) treated plots were on par with untreated check. Biradar (2015) also confirmed the similar trend of Chrysoperla sp. and coccinellid population dynamics in seed dressers, who noticed non-significant difference among the chemical treatments including untreated control. As the prophylactic seed dressing chemicals not directly come in contact with natural enemies, there will be least direct harmful effect and they remain safe to predatory fauna. The observations recorded at different intervals, after the insecticide spray endorsed the significant difference among the treatments regarding predatory insects. The peak activity of all the natural enemies (i.e. Green lacewing, Chrysoperla zasowi sillei; Coccinellids, Coccinella transversalis Fabricius, Cheilomenes sexmaculata (Fabricius), Illeis cincta (Fabricius); Syrphids, Ischiodon scutellaris (Fabricius); Predatory spider, Oxyopes lineatus Latreille) was observed in T1 (seed treatment with thiamethoxam 30 FS @ 5 ml/kg seed) and T2 (soil application of carbofuran 3 G @ 30 kg/ha) which were on par

Table 2 Impact of insecticidal treatments on coccinellid (Coccinella transversalis, Cheilomenes sexmaculata, Illeis cincta) population in wheat

| Tr. No. | Treatments                        | Dosage   | 1 DBS | 5 DAS | 10 DAS | 15 DAS | Mean |
|--------|-----------------------------------|----------|-------|-------|--------|--------|------|
| T1     | Seed treatment with Thiamethoxam 30 FS | 5 ml/kg  | 0.98  | 0.94  | 1.40   | 1.86   | 1.40 |
|        |                                   |          |  (1.22)a | (1.20)a | (1.38)b | (1.54)a |      |
| T2     | Soil application of Carbofuran 3G  | 30 kg/ha | 0.81  | 0.95  | 1.36   | 1.81   | 1.37 |
|        |                                   |          |  (1.14)a | (1.20)a | (1.36)a | (1.52)a |      |
| T3     | T1 + One spray of Nimbecidine 1500 ppm | 5 ml/kg + 3 ml/l | 0.87  | 0.65  | 0.96   | 1.28   | 0.96 |
|        |                                   |          |  (1.17)a | (1.07)b | (1.21)b | (1.33)b |      |
| T4     | T2 + One spray of Nimbecidine 1500 ppm | 30 kg/ha + 3 ml/l | 0.72  | 0.63  | 0.94   | 1.23   | 0.93 |
|        |                                   |          |  (1.10)a | (1.06)b | (1.20)b | (1.32)b |      |
| T5     | T1 + One spray of Emamectin benzoate 5 SG | 5 ml/kg + 0.2 g/l | 0.86  | 0.34  | 0.46   | 0.54   | 0.45 |
|        |                                   |          |  (1.17)a | (0.92)c | (0.98)c | (1.02)c |      |
| T6     | T2 + One spray of Emamectin benzoate 5 SG | 30 kg/ha + 0.2 g/l | 0.83  | 0.31  | 0.43   | 0.51   | 0.42 |
|        |                                   |          |  (1.15)a | (0.90)c | (0.96)c | (1.00)c |      |
| T7     | T1 + One spray of Cypermethrin 10 EC | 5 ml/kg + 0.5 ml/l | 0.81  | 0.22  | 0.28   | 0.33   | 0.28 |
|        |                                   |          |  (1.14)a | (0.85)c | (0.88)c | (0.91)c |      |
| T8     | T2 + One spray of Cypermethrin 10 EC | 30 kg/ha + 0.5 ml/l | 0.79  | 0.19  | 0.23   | 0.29   | 0.24 |
|        |                                   |          |  (1.14)a | (0.83)c | (0.85)c | (0.89)c |      |
| T9     | Untreated check (UTC)              | -        | 0.99  | 0.95  | 1.49   | 2.10   | 1.51 |
|        |                                   |          |  (1.22)a | (1.20)a | (1.41)a | (1.61)a |      |
| S. Em ± |                                   |          |      |       |        |        |      |
| CD at 5%|                                   |          | 0.07  | 0.06  | 0.08   | 0.07   | -    |
| CV (%) |                                   |          | 10.27 | 10.70 | 11.90  | 9.63   | -    |

Means followed by same alphabet in a column do not differ significantly (0.05) by DMRT

DBS Day Before Spraying, DAS Days After Spraying, NS Non-Significant

*Values in parentheses are $\sqrt{x + 0.5}$ transformed values
with untreated check. Whereas, the least population was recorded in T8 and T7 where the foliar spray of cypermethrin 10 EC (0.5 ml/l) was found to be having some detrimental effects on predators. Croft and Whalon (1982) and Brown et al. (1990) studied the effect of some pyrethroid insecticides on natural enemies of some agricultural crops and noticed similar results as of us. Pyrethroid insecticides caused decline in coccinellid population to the extent of 38 to 72 per cent (Meena et al. 2002; Solangi et al. 2007) which is in agreement with the present findings. The similar detrimental effects were also observed in many coccinellid predators (Smith and Stratton 1986; Duffield and Aebischer 1994; Wiles and Jepson 1994; Holland et al. 2000; Meena et al. 2002) and syrphids (Swaran 1999). Earlier workers investigated the effect of neem products on green lacewing (Kaethner 1991; Srinivasan and Babu 2000; El-Wakeil et al. 2006), predatory spider (Thomas et al. 1990; Dinter 1995; Schmutterer 1997) and found that, all the neem based botanical insecticides were safer to them. Meanwhile, Katole and Patil (2000), Ahire (2008) and Prakash (2014) noticed higher population of coccinellids, chrysopids and spiders in thiamethoxam 30 FS (5 ml/kg seed) seed treated sorghum plots followed by imidacloprid 17.8 SL (10 ml/kg seed). Balasaheb (2014) reported peak population of coccinellids and Crossopalpus sp. in seed treated with imidacloprid 48 FS followed by thiamethoxam 25 WG in sorghum, which highlights the benefits of prophylactic chemical application.

Predator conservation in the field can be achieved by reducing both chemical and physical disturbance to the habitat. Natural enemy densities and diversities are significantly higher in fields that have not been sprayed with pesticides. Restricting insecticide treatment to critical stages of the pest life cycle or limiting spraying to mid-day, when many wandering natural enemies are inactive and in sheltered areas, can help conserve predating organisms. Natural enemies can recolonize if there is enough time between chemical applications but multiple applications per season can destroy natural enemy communities. Some pesticides are also retained in natural enemies and can be harmful to spiders that consume their webs on a daily basis.

### Table 3

**Impact of insecticidal treatments on syrphid, *Ischiodon scutellaris* population in wheat**

| Tr. No. | Treatments                                      | Dosage       | Number of syrphids/m² |
|---------|-------------------------------------------------|--------------|-----------------------|
|         |                                                 | 1 DBS | 5 DAS | 10 DAS | 15 DAS | Mean |
| T1      | Seed treatment with Thiamethoxam 30 FS          | 5 ml/kg     | 0.51 (1.00)³   | 0.58 (1.04)²   | 0.75 (1.12)³   | 0.86 (1.17)²   | 0.73 |
| T2      | Soil application of Carbofuran 3G               | 30 kg/ha    | 0.43 (0.96)³   | 0.42 (0.96)²   | 0.56 (1.03)³   | 0.71 (1.10)³   | 0.83 (1.15)³   | 0.70 |
| T3      | T1 + One spray of Nimbecidine 1500 ppm          | 5 ml/kg + 3 ml/l | 0.48 (0.99)³ | 0.42 (0.96)² | 0.62 (1.06)³   | 0.66 (1.08)³   | 0.70 |
| T4      | T2 + One spray of Nimbecidine 1500 ppm          | 30 kg/ha + 3 ml/l | 0.43 (0.96)³ | 0.40 (0.95)² | 0.63 (1.06)³   | 0.64 (1.08)³   | 0.56 |
| T5      | T1 + One spray of Emamectin benzoate 5 SG      | 5 ml/kg + 0.2 g/l | 0.49 (0.99)³ | 0.25 (0.87)²   | 0.32 (0.91)³   | 0.36 (0.93)³   | 0.31 |
| T6      | T2 + One spray of Emamectin benzoate 5 SG      | 30 kg/ha + 0.2 g/l | 0.45 (0.97)³ | 0.24 (0.86)²   | 0.29 (0.89)³   | 0.32 (0.91)³   | 0.30 |
| T7      | T1 + One spray of Cypermethrin 10 EC            | 5 ml/kg + 0.5 ml/l | 0.49 (0.99)³ | 0.11 (0.78)² | 0.18 (0.82)³   | 0.21 (0.84)³   | 0.17 |
| T8      | T2 + One spray of Cypermethrin 10 EC            | 30 kg/ha + 0.5 ml/l | 0.42 (0.96)³ | 0.09 (0.77)² | 0.15 (0.81)³   | 0.17 (0.82)³   | 0.14 |
| T9      | Untreated check (UTC)                           | -            | 0.52 (1.01)³   | 0.62 (1.06)²   | 0.79 (1.14)³   | 1.01 (1.23)³   | 0.81 |

Means followed by same alphabet in a column do not differ significantly (0.05) by DMRT

DBS Day Before Spraying, DAS Days After Spraying, NS Non-Significant

*Values in parentheses are \(\sqrt{x + 0.5}\) transformed values
**Conclusions**

From the foregone discussion, it is evident that the seed dressing and soil applied chemicals were relatively safer and can be incorporated in future pest management programmes, where the natural biocontrol agents play a vital role. Nevertheless, our investigation also substantiated the apparent deleterious qualitative and quantitative effects of foliar spraying insecticides on natural enemy population. In this context, there should be consideration of extent of activity and potential of natural predatory and parasitoid insects while recommending the insecticide spray.

**Authors’ contributions** All the authors were contributed to the study where, first author was Post Graduate student who conducted the experiment while, second author was advisory committee chairman and rest of the two authors were the members of advisory committee of the student and actively involved in analysis and manuscript preparation. All authors read and approved the final manuscript.

**Availability of data and materials** All data generated during this study are included in this manuscript and available with corresponding author.

**Code availability** Not applicable.

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**Table 4** Impact of insecticidal treatments on spider, *Oxyopes lineatus* population in wheat

| Tr. No. | Treatments | Dosage | Number of spiders/m² |
| --- | --- | --- | --- |
| | | | 1 DBS | 5 DAS | 10 DAS | 15 DAS | Mean |
| T₁ | Seed treatment with Thiamethoxam 30 FS | 5 ml/kg | 0.37 (0.93) | 0.51 (1.00) | 0.58 (1.04) | 0.92 (1.19) | 0.67 |
| T₂ | Soil application of Carbofuran 3G | 30 kg/ha | 0.28 (0.88) | 0.48 (0.99) | 0.51 (1.00) | 0.87 (1.17) | 0.62 |
| T₃ | T₁ + One spray of Nimbecidine 1500 ppm | 5 ml/kg + 3 ml/l | 0.40 (0.95) | 0.26 (0.87) | 0.29 (0.89) | 0.54 (1.02) | 0.36 |
| T₄ | T₂ + One spray of Nimbecidine 1500 ppm | 30 kg/ha + 3 ml/l | 0.34 (0.92) | 0.24 (0.86) | 0.28 (0.88) | 0.51 (1.00) | 0.34 |
| T₅ | T₁ + One spray of Emamectin benzoate 5 SG | 5 ml/kg + 0.2 g/l | 0.45 (0.97) | 0.19 (0.83) | 0.21 (0.84) | 0.32 (0.91) | 0.24 |
| T₆ | T₂ + One spray of Emamectin benzoate 5 SG | 30 kg/ha + 0.2 g/l | 0.37 (0.93) | 0.17 (0.82) | 0.19 (0.83) | 0.28 (0.88) | 0.21 |
| T₇ | T₁ + One spray of Cypermethrin 10 EC | 5 ml/kg + 0.5 ml/l | 0.44 (0.97) | 0.10 (0.77) | 0.14 (0.80) | 0.15 (0.81) | 0.13 |
| T₈ | T₂ + One spray of Cypermethrin 10 EC | 30 kg/ha + 0.5 ml/l | 0.29 (0.89) | 0.10 (0.77) | 0.12 (0.79) | 0.13 (0.79) | 0.12 |
| T₉ | Untreated check (UTC) | - | 0.46 (0.98) | 0.56 (1.03) | 0.75 (1.12) | 1.02 (1.23) | 0.78 |

S. Em ± 0.06 0.06 0.06 0.06 -
CD at 5% NS 0.19 0.17 0.18 -
CV (%) 11.68 12.51 11.01 10.17 -

Means followed by same alphabet in a column do not differ significantly (0.05) by DMRT

DBS Day Before Spraying, DAS Days After Spraying. NS Non-Significant

*Values in parentheses are √x + 0.5 transformed values

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**Declarations**

**Ethics approval and consent to participate** Not applicable.

**Consent to participate** Not applicable.

**Consent for publication** Not applicable.

**Competing interests** The authors declare that they have no competing interests.

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