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* sp.), coccinellids (*Coccinella transversalis*, *Cheilomenes sexmaculata*, *Illeis cincta*), syrphids and spider (*Oxyopes* sp.). 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.

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 (Anon. 2013). 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). 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 x 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 2020) 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

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* sp.), coccinellids (*Coccinella transversalis*, *Cheilomenes sexmaculata*, *Illeis cincta*), syrphids and one predatory spider (*Oxyopes* sp.). The observations recorded on population of *Chrysoperla* sp. 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 (T_1) recorded maximum population of 1.20 followed by soil application of carbofuran 3G @ 30 kg/ha (T_2) (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 chrysopids 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 T_1 (1.40) and T_2 (1.37). Whereas, the least population was noticed in T_8 (0.24) which was closely followed by T_7 (0.28).

Table 1
Impact of insecticidal treatments on *Chrysoperla* sp. population in wheat

Tr. No.	Treatments	Dosage	Number of Chrysoperla/m ²				
			1 DBS	5 DAS	10 DAS	15 DAS	Mean
1	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
2	Soil application of Carbofuran 3G	30 kg/ha	0.81 (1.14) ^a	0.92 (1.19) ^a	1.21 (1.31) ^{ab}	1.39 (1.37) ^{abc}	1.17
3	T ₁ + One spray of Nimbecidine 1500 ppm	5 ml/kg + 3 ml/l	0.83 (1.15) ^a	0.71 (1.10) ^{ab}	0.79 (1.14) ^{ab}	0.98 (1.22) ^{bcd}	0.83
4	T ₂ + One spray of Nimbecidine 1500 ppm	30 kg/ha + 3 ml/l	0.78 (1.13) ^a	0.75 (1.12) ^{ab}	0.76 (1.12) ^{ab}	0.92 (1.19) ^{cd}	0.81
5	T ₁ + One spray of Emamectin benzoate 5 SG	5 ml/kg + 0.2 g/l	0.81 (1.14) ^a	0.45 (0.97) ^{bc}	0.51 (1.00) ^{ab}	0.76 (1.12) ^d	0.57
6	T ₂ + One spray of Emamectin benzoate 5 SG	30 kg/ha + 0.2 g/l	0.75 (1.12) ^a	0.41 (0.95) ^{bc}	0.49 (0.99) ^{ab}	0.74 (1.11) ^d	0.55
7	T ₁ + One spray of Cypermethrin 10 EC	5 ml/kg + 0.5 ml/l	0.86 (1.17) ^a	0.23 (0.85) ^c	0.25 (0.87) ^b	0.28 (0.88) ^e	0.25
8	T ₂ + One spray of Cypermethrin 10 EC	30 kg/ha + 0.5 ml/l	0.79 (1.14) ^a	0.19 (0.83) ^c	0.22 (0.85) ^b	0.24 (0.86) ^e	0.22
9	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
	S. Em±		0.08	0.06	0.06	0.07	-
DBS: Day Before Spraying							
DAS: Days After Spraying							
NS: Non-Significant							

Tr. No.	Treatments	Dosage	Number of Chrysoperla/m ²				
			1 DBS	5 DAS	10 DAS	15 DAS	Mean
	CD at 5%		NS	0.18	0.18	0.20	-
	CV (%)		12.92	9.76	9.64	9.82	-
DBS: Day Before Spraying							
DAS: Days After Spraying							
NS: Non-Significant							

*Figures in parentheses are $\sqrt{x+0.5}$ transformed values

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

Table 2
Impact of insecticidal treatments on coccinellid population in wheat

Tr. No.	Treatments	Dosage	Number of coccinellids/m ²				
			1 DBS	5 DAS	10 DAS	15 DAS	Mean
1	Seed treatment with Thiamethoxam 30 FS	5 ml/kg	0.98 (1.22) ^a	0.94 (1.20) ^a	1.40 (1.38) ^a	1.86 (1.54) ^a	1.40
2	Soil application of Carbofuran 3G	30 kg/ha	0.81 (1.14) ^a	0.95 (1.20) ^a	1.36 (1.36) ^a	1.81 (1.52) ^a	1.37
3	T ₁ + One spray of Nimbecidine 1500 ppm	5 ml/kg + 3 ml/l	0.87 (1.17) ^a	0.65 (1.07) ^{ab}	0.96 (1.21) ^{ab}	1.28 (1.33) ^b	0.96
4	T ₂ + One spray of Nimbecidine 1500 ppm	30 kg/ha + 3 ml/l	0.72 (1.10) ^a	0.63 (1.06) ^{ab}	0.94 (1.20) ^{ab}	1.23 (1.32) ^b	0.93
5	T ₁ + One spray of Emamectin benzoate 5 SG	5 ml/kg + 0.2 g/l	0.86 (1.17) ^a	0.34 (0.92) ^{bc}	0.46 (0.98) ^{bc}	0.54 (1.02) ^c	0.45
6	T ₂ + One spray of Emamectin benzoate 5 SG	30 kg/ha + 0.2 g/l	0.83 (1.15) ^a	0.31 (0.90) ^{bc}	0.43 (0.96) ^{bc}	0.51 (1.00) ^c	0.42
7	T ₁ + One spray of Cypermethrin 10 EC	5 ml/kg + 0.5 ml/l	0.81 (1.14) ^a	0.22 (0.85) ^c	0.28 (0.88) ^c	0.33 (0.91) ^c	0.28
8	T ₂ + One spray of Cypermethrin 10 EC	30 kg/ha + 0.5 ml/l	0.79 (1.14) ^a	0.19 (0.83) ^c	0.23 (0.85) ^c	0.29 (0.89) ^c	0.24
9	Untreated check (UTC)	-	0.99 (1.22) ^a	0.95 (1.20) ^a	1.49 (1.41) ^a	2.10 (1.61) ^a	1.51
	S. Em±		0.07	0.06	0.08	0.07	-
DBS: Day Before Spraying							
DAS: Days After Spraying							
NS: Non-Significant							

Tr. No.	Treatments	Dosage	Number of coccinellids/m ²				Mean
			1 DBS	5 DAS	10 DAS	15 DAS	
	CD at 5%		NS	0.19	0.23	0.20	-
	CV (%)		10.27	10.70	11.90	9.63	-
DBS: Day Before Spraying							
DAS: Days After Spraying							
NS: Non-Significant							

*Figures in parentheses are $\sqrt{x+0.5}$ transformed values

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

The similar trend was also observed in abundance of syrphid 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* sp. 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 T₈ (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.

Table 3
Impact of insecticidal treatments on syrphid population in wheat

Tr. No.	Treatments	Dosage	Number of syrphids/m ²				
			1 DBS	5 DAS	10 DAS	15 DAS	Mean
1	Seed treatment with Thiamethoxam 30 FS	5 ml/kg	0.51 (1.00) ^a	0.58 (1.04) ^{ab}	0.75 (1.12) ^a	0.86 (1.17) ^{ab}	0.73
2	Soil application of Carbofuran 3G	30 kg/ha	0.43 (0.96) ^a	0.56 (1.03) ^{ab}	0.71 (1.10) ^a	0.83 (1.15) ^{abc}	0.70
3	T ₁ + One spray of Nimbecidine 1500 ppm	5 ml/kg + 3 ml/l	0.48 (0.99) ^a	0.42 (0.96) ^{abc}	0.62 (1.06) ^{ab}	0.66 (1.08) ^{abc}	0.57
4	T ₂ + One spray of Nimbecidine 1500 ppm	30 kg/ha + 3 ml/l	0.43 (0.96) ^a	0.40 (0.95) ^{abc}	0.63 (1.06) ^{ab}	0.64 (1.07) ^{abc}	0.56
5	T ₁ + One spray of Emamectin benzoate 5 SG	5 ml/kg + 0.2 g/l	0.49 (0.99) ^a	0.25 (0.87) ^{abc}	0.32 (0.91) ^{bc}	0.36 (0.93) ^{abc}	0.31
6	T ₂ + One spray of Emamectin benzoate 5 SG	30 kg/ha + 0.2 g/l	0.45 (0.97) ^a	0.24 (0.86) ^{bc}	0.29 (0.89) ^{bc}	0.32 (0.91) ^{abc}	0.28
7	T ₁ + One spray of Cypermethrin 10 EC	5 ml/kg + 0.5 ml/l	0.49 (0.99) ^a	0.11 (0.78) ^c	0.18 (0.82) ^c	0.21 (0.84) ^{bc}	0.17
8	T ₂ + One spray of Cypermethrin 10 EC	30 kg/ha + 0.5 ml/l	0.42 (0.96) ^a	0.09 (0.77) ^c	0.15 (0.81) ^c	0.17 (0.82) ^c	0.14
9	Untreated check (UTC)	-	0.52 (1.01) ^a	0.62 (1.06) ^a	0.79 (1.14) ^a	1.01 (1.23) ^a	0.81
	S. Em±		0.06	0.07	0.07	0.09	-
DBS: Day Before Spraying							
DAS: Days After Spraying							
NS: Non-Significant							

Tr. No.	Treatments	Dosage	Number of syrphids/m ²				
			1 DBS	5 DAS	10 DAS	15 DAS	Mean
	CD at 5%		NS	0.21	0.23	0.28	-
	CV (%)		9.37	10.49	10.64	12.92	-
DBS: Day Before Spraying							
DAS: Days After Spraying							
NS: Non-Significant							

*Figures in parentheses are $\sqrt{x+0.5}$ transformed values

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

Table 4
Impact of insecticidal treatments on spider population in wheat

Tr. No.	Treatments	Dosage	Number of spiders/m ²				
			1 DBS	5 DAS	10 DAS	15 DAS	Mean
1	Seed treatment with Thiamethoxam 30 FS	5 ml/kg	0.37 (0.93) ^a	0.51 (1.00) ^{ab}	0.58 (1.04) ^{ab}	0.92 (1.19) ^{ab}	0.67
2	Soil application of Carbofuran 3G	30 kg/ha	0.28 (0.88) ^a	0.48 (0.99) ^{ab}	0.51 (1.00) ^{abc}	0.87 (1.17) ^{abc}	0.62
3	T ₁ + One spray of Nimbecidine 1500 ppm	5 ml/kg + 3 ml/l	0.40 (0.95) ^a	0.26 (0.87) ^{abc}	0.29 (0.89) ^{bcd}	0.54 (1.02) ^{bcd}	0.36
4	T ₂ + One spray of Nimbecidine 1500 ppm	30 kg/ha + 3 ml/l	0.34 (0.92) ^a	0.24 (0.86) ^{abc}	0.28 (0.88) ^{bcd}	0.51 (1.00) ^{cd}	0.34
5	T ₁ + One spray of Emamectin benzoate 5 SG	5 ml/kg + 0.2 g/l	0.45 (0.97) ^a	0.19 (0.83) ^{bc}	0.21 (0.84) ^{cd}	0.32 (0.91) ^{de}	0.24
6	T ₂ + One spray of Emamectin benzoate 5 SG	30 kg/ha + 0.2 g/l	0.37 (0.93) ^a	0.17 (0.82) ^{bc}	0.19 (0.83) ^{cd}	0.28 (0.88) ^{de}	0.21
7	T ₁ + One spray of Cypermethrin 10 EC	5 ml/kg + 0.5 ml/l	0.44 (0.97) ^a	0.10 (0.77) ^c	0.14 (0.80) ^d	0.15 (0.81) ^e	0.13
8	T ₂ + One spray of Cypermethrin 10 EC	30 kg/ha + 0.5 ml/l	0.29 (0.89) ^a	0.10 (0.77) ^c	0.12 (0.79) ^d	0.13 (0.79) ^e	0.12
9	Untreated check (UTC)	-	0.46 (0.98) ^a	0.56 (1.03) ^a	0.75 (1.12) ^a	1.02 (1.23) ^a	0.78
	S. Em±		0.06	0.06	0.06	0.06	-
DBS: Day Before Spraying							
DAS: Days After Spraying							
NS: Non-Significant							

Tr. No.	Treatments	Dosage	Number of spiders/m ²				
			1 DBS	5 DAS	10 DAS	15 DAS	Mean
	CD at 5%		NS	0.19	0.17	0.18	-
	CV (%)		11.68	12.51	11.01	10.17	-
DBS: Day Before Spraying							
DAS: Days After Spraying							
NS: Non-Significant							

*Figures in parentheses are $\sqrt{x+0.5}$ transformed values

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

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 are 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 Hemerobidae), 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 and conducted extensive research in winter wheat for several years. 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 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 (green lacewing, coccinellids, syrphids and spiders) 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 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; Srinivas 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.

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.

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Competing interests

The authors declare that they have no competing interests

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

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.

Ethics approval and consent to participate

Not applicable

Consent to participate

Not applicable

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References

1. Ahire RV (2008) Evaluation of newer insecticide thiamethoxam as seed dresser for the management of early season pests in soybean. Doctoral dissertation, Vasantrya Naik Krishi Vidyapeeth, Parbhani
2. Anita VS (2009) Non-chemical approaches for the management of shoot fly *Atherigona soccata* Rondani in *kharif* sorghum. Dissertation, University of Agricultural Sciences Dharwad, Karnataka, India
3. Anonymous (2013) Hundred years wheat research in India. Directorate of Wheat Research, Karnal, pp 171–172

4. Anonymous (2014) Satyagopal K, Sushil SN, Jeyakumar P, Shankar G, Sharma OP, Sain SK, Boina DR, Chattopadhyay D, Srinivasa Rao N, Sunanda BS, Asre R, Murali R, Kapoor KS, Arya S, Kumar S, Patni CS, Sharma I, Ravindra H, Shivanna BK, Saharan MS, Kaur D, Singh B, Sharma RK, Chokar RS, Karnatak AK, Ruchira Tiwari, Deepshikha, BR Patel, Surajit Khalko, Nripendra Laskar, Ayon Roy, Tapan Kumar Hath, LV Ghetiya, Sathyanarayana N, Latha S (2014) AESA based IPM package for Wheat. pp 58. <https://farmer.gov.in/imagedefault/ipm/wheat.pdf>
5. Balasaheb BA (2014) Bio efficacy of different insecticides against sorghum shoot fly, *Atherigona soccata* Rondani in Rabi season. Dissertation, MPKV, Rahuri, Maharashtra, India
6. Biradar A (2015) Management of shoot fly (*Atherigona soccata* Rondani) in *Rabi* sorghum. Dissertation, University of Agricultural Sciences Dharwad, Karnataka, India
7. Brown GW, Bifulco A, Veiel HOF, Andrews B (1990) Self-esteem and depression. *Social psych psych epidem* 25(5):225–234
8. Croft BA, Whalon ME (1982) Selective toxicity of pyrethroid insecticides to arthropod natural enemies and pests of agricultural crops. *Entomophaga* 27(1):3–21
9. Dinter A (1995) Untersuchungen zur Populationsdynamik von Spinnen (Arachnida: Araneae) in Winterweizen und deren Beeinflussung durch insektizide Wirkstoffe [dissertation]. [Göttingen]: Cuvillier Publisher, Goettingen Universität. ISBN 3-89588-171-6 Cuvillier Verlag Göttingen 383 p
10. Duffield SJ, Aebischer NJ (1994) The effect of spatial scale of treatment with dimethoate on invertebrate population recovery in winter wheat. *J Appl Ecol* 31:263–281
11. Duncan DB (1955) Multiple range and multiple F tests. *Biometrics* 11(1):1–42
12. El-Wakeil NE, Gaafar N, Vidal S (2006) Side effect of some Neem products on natural enemies of *Helicoverpa*, *Trichogramma* spp. and *Chrysoperla carnea*. *Arch Phytopathol Plant Prot* 39:445–455
13. El-Wakeil N, Gaafar N, Sallam A, Volkmar C (2013) Side effects of insecticides on natural enemies and possibility of their integration in plant protection strategies. In: Trdan S (ed) *Development of Safer and More Effective Technologies Agricultural and Biological Sciences*. InTech Open Access Publisher, Insecticides, pp 1–56
14. Hassan SA, Albert R, Bigler F, Blaisinger P, Bogenschütz H, Boller E, Vanwetswinkel G (1987) Results of the third joint pesticide testing programme by the IOBC/WPRS-Working Group “Pesticides and Beneficial Organisms”. *J Appl Entomol* 103(1-5):92–107
15. Holland JM, Winder L, Perry JN (2000) The impact of dimethoate on the spatial distribution of beneficial arthropods in winter wheat. *Ann appl biol* 136(2):93–105
16. Jambagi SR (2020) Status and management of shoot fly in wheat. Dissertation, University of Agricultural Sciences Dharwad, Karnataka, India
17. Kaethner M (1991) No side effects of neem on the aphidophagous predators *Chrysoperla carnea* and *Coccinella septempunctata*. *Anz Schädlnsgskde Pflanzenschutz Umweltschutz* 64:97–99
18. Katole SR, Patil PJ (2000) Biosafety of imidacloprid and thiamethoxam as seed treatment and foliar sprays to some predators. *Pestology* 24(11):11–13

19. Malschi D (2008) Environment, agriculture, sustainable development. Optimization of integrated wheat pest management technologies under the dynamics of agroecological changes in Transylvania. Ed. Argonaut, Cluj-Napoca, 250
20. Meena BL, Dadhich SR, Kumawat RL (2002) Efficacy of some insecticides against ladybird beetle, *Coccinella septempunctata* L. feeding on fenugreek aphid, *Acyrtosiphon pisum* (Harris.). Ann Biol 18:171–173
21. Pimentel D (1997) Techniques for reducing pesticide use: economic and environmental benefits. John Wiley and Sons
22. Prakash KS (2014) Efficacy of different seed dressers on sorghum shoot fly *Atherigona soccata* (Rondani). Dissertation, University of Agricultural Sciences Dharwad, Karnataka, India
23. Schmidt MH, Thewes U, Thies C, Tschamtker T (2004) Aphid suppression by natural enemies in mulched cereals. Entomol Experiment et Applicata 113(2):87–93
24. Schmutterer H (1997) Side effects of neem (*Azadirachta indica*) products on insect pathogens and natural enemies of spider mites and insects. J Appl Entomol 121:121–128
25. Smith TM, Stratton GW (1986) Effects of synthetic pyrethroid insecticides on non-target organisms. Residue Rev 97:93–120
26. Solangi BK, Lanjar AG, Lohar MK (2007) Comparative toxicity of some insecticides on 4th instar grub of *Coccinella septempunctata* L. under laboratory conditions. Sarhad J Agric 23:1091–1096
27. Srinivasan G, Babu PCS (2000) Effect of neem products on predatory green lacewing, *Chrysoperla carnea*. Pest Res J 12:123–126
28. Swaran D (1999) Effect of some important insecticides on the adults of *Coccinella septempunctata* L. Predating on different aphid species. J Entomol Res 23:127–131
29. Thomas CFG, Hol EHA, Everts JW (1990) Modelling the diffusion component of dispersal during recovery of a population of linyphiid spiders from exposure to an insecticide. Func Ecolo 4:357–368
30. Way MJ, Heong KL (1994) The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice—a review. Bull Entomol Res 84(4):567–587
31. Wiles JA, Jepson PC (1994) Sub-lethal effects of deltamethrin residues on the within-crop behaviour and distribution of *Coccinella septempunctata*. Entomol Exp Appl 72:33–45