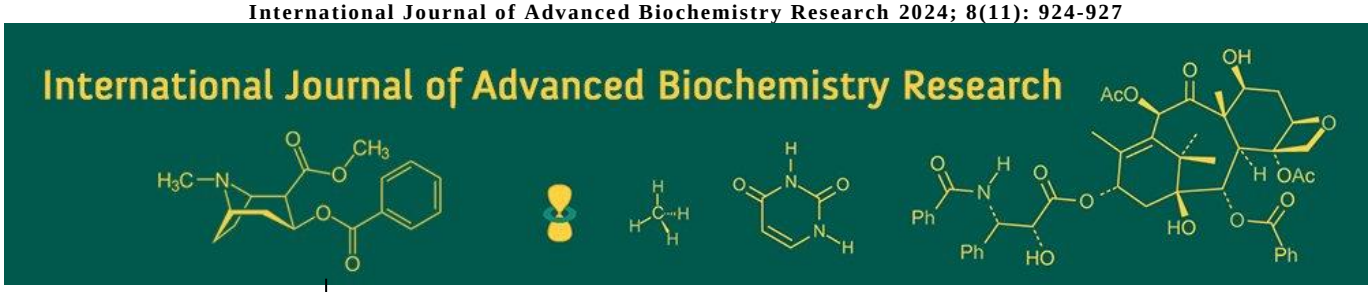

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Evaluation of different biorational based formulations on major pollinator fauna in sunflower ecosystem

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Abstract
Six different biorational based treatments were evaluated on the activity of major foraging honeybee pollinator fauna species in sunflower ecosystem during 2017-18 at ZARS, GKVK, Bengaluru. The bees *viz*., *Apis dorsata, Apis mellifera* and *Apis cerana indica* were the most frequent and abundant pollinators in sunflower. Among different biorationals evaluated, T_1 (Bt based), T_2 (Beauveria based), T_3 (HaNPV), T_4 (Azadiractin based) and T_5 (Spinosad based) treatments were found significantly increased mean number of pollinators. Similarly, T_6 (NSKE based) treatment did not show any deterrent effect on *A. mellifera* and *A. cerana indica*. *A. dorsata* and total pollinator fauna were shown reduced mean numbers per plant but recovered after 3rd day after treatment imposition from repellent action of NSKE. Except T_6, all the other treatments were shown increased mean number of total major pollinators. Biorational based formulations were found least effect on pollinator diversity and visitation rate compared to synthetic insecticides in sunflower ecosystem. Deterrent effect of some biorationals like NSKE are to be avoided during peak activity of pollinators. The results indicate the biorational based treatments are the most valued option in pollinator crops like sunflower. Similarly, faster recovery of bees which has augmented pollination services and has a greater relevance in enhancing the yield in sunflower, whenever the insecticides with less repellent activity were used in the IPM programmes.

Keywords: Biorationals, sunflower, *A. mellifera, A. cerana indica*, *A. dorsada*

Introduction
Sunflower is major oilseed crop native to the America. During 2018-19, the area under sunflower cultivation was 344.2 thousand hectares in India, with an annual production of 240.7 thousand tons and productivity of 699 kg/ ha. The cultivated sunflower is mainly confined to Southern states *viz.*, Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu, among these states, Karnataka occupies first in area with 216 thousand hectares, with annual production of 99 thousand tons and productivity of 458 kg/ ha. (Annon, 2018) [1]. During last two decades, microbial agents and botanicals have got interest in farmers in order to develop sustainable and environmentally safe measures against major pests and safer to major pollinator fauna in sunflower ecosystem.

Honeybees play a major role in pollinating sunflower. Contribution of insect pollination to sunflower yield mainly depends on the gradient of pollinator diversity and abundance. Pollinators were found to increase yield up to 40 percent (*i.e.*, 0.7 t/ha). Most frequent visitors in sunflower were *Apis* bees. The abundance study revealed that, *Apis* sp. constituted about 88.85 percent indicating the dominance of *Apis* (Hymenoptera) among sunflower pollinators (Jadhav *et al*., 2011) [4] therefore, pollination is crucial in hybrid seed production in sunflower by the honey bee. Tan *et al*., 2002 [15], reported seed yield and seed set have greatly increased due to honeybee pollination.

Pollinators are greatly affected by insecticides, which lower the honey bees in several ways. Primarily they come in contact with insecticides while foraging. The second way is more deadly, when the bee comes in contact with an insecticide carries it back to the colony in the form of contaminated pollen or nectar. With the spread of modern agricultural technologies, the insecticides or pesticides usage has been alarmingly increasing in our country leading to the occurrence of large-scale death of bees. So, knowledge on the relative safety of insecticides applied to entomophilous crops to control insects during flowering and immature

fruit stage is essential to obtain maximum benefit from bee pollination (Prakash and Kumaraswami, 1984) [11].
Biorational insecticide formulations are the safer molecules to pollinators in sunflower. Keeping this, present study was undertaken to evaluate certain biorational based treatments on safety to beneficial pollinator fauna in sunflower.

Materials and Methods

The study was conducted during *Kharif*-2017, at Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences, GKVK, Bengaluru in order to determine the effect of different biorational based treatments on major honey bee pollinator fauna in sunflower.
In order to express a viable formulation for sunflower, which are least effect on major honey bee fauna in sunflower ecosystem and focus on to minimize the hazards caused by chemical pesticides to the environment and non-target species, six biorational based insecticides along with two checks were evaluated and checked their effect on major pollinating bees in sunflower ecosystem.

Treatments evaluated on foraging activity of major honey bee pollinator fauna

Treatment 1: Imidacloprid 70 WS (5 g/kg) Seed treatment + metalaxyl 35 SD (5 g/kg) + handpicking and destruction of gregarious early instar larvae of defoliators (*Spodoptera litura* Fab. and *Spilarctia obliqua* Walker) + 2 sprays of *Bacillus thuringenesis* (2 ml/l) (50 and 70 DAS) (*Bt* based module)

Treatment 2: Imidacloprid 70 WS (5 g/kg) Seed treatment + metalaxyl 35 SD (5 g/kg) + handpicking and destruction of gregarious early instar larvae of defoliators (*S. litura* Fab. and *S. obliqua* Walker) + 2 sprays of *Beauveria bassiana* (2 g/l) (50 and 70 DAS) (*Beauveria* based module)

Treatment 3: Imidacloprid 70 WS (5 g/kg) Seed treatment + metalaxyl 35 SD (5 g/kg) + handpicking and destruction of gregarious early instar larvae of defoliators (*S. litura* Fab. and *S. obliqua* Walker) + 2 sprays with respective NPV formulations (1.25 ml/l) (50 and 70 DAS) (NPV based module)

Treatment 4: Imidacloprid 70 WS (5 g/kg) Seed treatment + metalaxyl 35 SD (5 g/kg) + handpicking and destruction of gregarious early instar larvae of defoliators (*S. litura* Fab. and *S. obliqua* Walker) + 2 sprays of Azadirachtin (2 ml/l) (50 and 70 DAS) (Neem based module)

Treatment 5: Imidacloprid 70 WS (5 g/kg) Seed treatment + metalaxyl 35 SD (5 g/kg) + handpicking and destruction of gregarious early instar larvae of defoliators (*S. litura* Fab. and *S. obliqua* Walker) + 2 sprays of Spinosad (0.1 ml/l) (50 and 70 DAS) (IIOR BIPM module)

Treatment 6: Imidacloprid 70 WS (5 g/kg) Seed treatment + metalaxyl 35 SD (5 g/kg) + handpicking and destruction of gregarious early instar larvae of defoliators (*S. litura* Fab. and *S. obliqua* Walker) 2 sprays of 5 % NSKE (50 DAS & 70 DAS) + two sprays of HaNPV (1.25 ml/l) (50 and 70 DAS) (IPM module -UASB)
T_7: Water spray
T_8: Untreated check

Observations

The mean number of pollinators was recorded on ten labeled plants. Pre-treatment counts were taken one day before and post treatment number was taken day after treatment imposition. Treatments were compared before and after treatment application.

Results

Effect of biorational treatments on *Apis mellifera*

There was no significant difference between the treatments before imposition of treatments. After treatment imposition, all the treatments were shown positive increased bee population in all the treatments. Neem based treatment (T_4) recorded the highest mean number of bees per plant followed by HaNPV (Table 1) (Fig 1).

Effect of biorational treatments on *Apis dorsata*

Among the different treatments, all the treatments were shown increased mean number of bees but, T_6 (NSKE 5 %) treatment showed some deterrent effect after the treatment application. Later, the number of visitations and mean number per plant was recovered from the deterrent action of NSKE. Bt based treatment (T_3) recorded the highest mean number of bees per plant followed by T_3 (HaNPV) and neem based (T_4) recorded highest mean number of bees per plant (Table 1) (Fig 2).

Effect of biorational treatments on *Apis cerena indica*

After treatment imposition, there was no effect of different formulation on the mean number of bees per plant and Bt based treatment (T_1) recorded highest mean number of bees per plant (Table 1) (Fig 1).

Effect of biorational treatments on total major pollinators

Treatments were found statistically non-significant before spray. After treatment imposition, all the treatments were shown increased mean number of total pollinators. Among these, T_1 (Bt based), T_3 (HaNPV) and T_4 (Neem based) treatments were recorded highest mean number per plant. T_6 (NSKE) treatment recorded lowest mean number of total pollinator fauna (Table 1) (Fig 1).

Discussion

Present investigation revealed that, among various biorational based treatments evaluated on sunflower all the treatments were shown positive effect on mean number of bees or total pollinators in sunflower except NSKE (T_6) based treatment. Similar results were also put forth by Pal, (2014) who studied the efficacy of different fungi *viz.*, mixture of *V. lecanii* + *N. rileyi*, mixture of *M. anisopliae* + *N. rileyi, V. lecanii, B. bassiana* and *M. anisopliae* against *H. armigera* infesting seed lucerne plot. Among these, all the entomopathogenic fungi did not show significant differences in bee visitation rate at second days after spray application. Similarly, in the present study the entomopathogenic fungi, *B. bassiana* (T_2), Bt (T_1) and HaNPV (T_3) treatments did not show any effect on the mean number of bees after spray and found safer to honey bees. Dutta *et al*., 2016 revealed that azadiractin 1 EC was safest to foraging honey bee (9.64/plot/5 min). Similar result was found in the present investigation, T_4 (Azadiractin based) recorded highest mean number of bees.

In the present investigation, NSKE (T_6) based treatment recorded lowest mean number of A. dorsata and total pollinator fauna. This might be due to its repellent or deterrent property. Kambrekar and Jahagirdar (2021) [5] investigated the repellent proprieties of insecticides targeted at the management of pigeon pea pod borer, *Helicoverpa armigera* along with the recuperation of three species of honey bees under field condition. Results revealed that recovery percentage of honey bees (*A. florea*, *A. cerana* and *A. dorsata*) for the treated field had the fastest rate in the plots treated with Neem Seed Kernel Extract followed by chlorantraniliprole compared to other insecticides. Further, normal activity (100 % recovery) of the bees was realized in the treatment with Neem seed kernel extract and chlorantraniliprole which took only 2 and 3 days as compared to more than 7 days for other insecticides. Among the bee species studied, *A. dorsata* resumed its normal activity sooner than *A. cerana* and *A. florea*. In the present study there was no effect of NSKE on *A. cerena* and *A. florea* this might due to less population during the study period. *A. dorsata* shown decreased mean number after treatment application, but recovered and attain its normal activity after 3 days after treatment imposition.

Similarly, Singh *et al.* (2010) [7] evaluated different plant products *viz.*, *Pongamia glabra* (seed oil-1 %), *Azadirachta indica* (Seed kernel extract-5 %), formulated neem product (Achook-0.8 %), *A. indica* (seed oil-1 %), and *A. indica* (leaf extract-10 %) exhibited repellent action on the insect pollinators of coriander and found that plant origin insecticides showed a reduction in pollinator intensity ranging from 14.52 percent to 25.06 percent. However, plots treated with seed oil (1 %) of *A. indica* continued to show a deterrent effect and the pollinator intensity decreased by 21.57 percent. Singh *et al*., 2010 [7], who also reported that 3 days after treatment imposition percent visiting rate of insect pollinators was increased in plots treated with NSKE (5 %) and neem leaf extract (10 %). NSKE did not deter the honey bees in the field Pashte and Patil 2017 [10]; Nauman *et al*., 1994 [8]; Sonatakke and Dash 1996 [14]; Elzen *et al*., 2004 [3] Umrao *et al*., 2012 [16]; Kumar *et al*., 2010 [7] and Kumar and Singh 2012 [6].

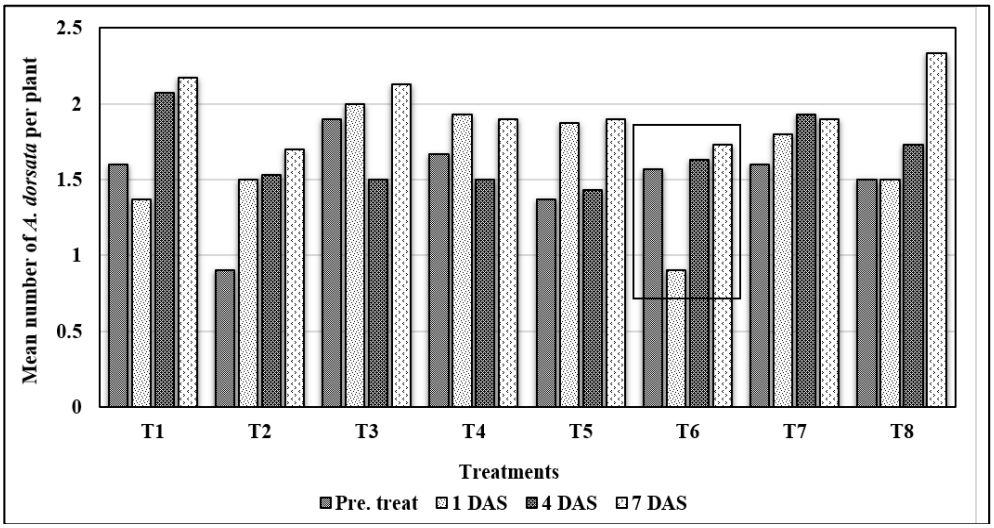
Similarly, Shabarsish (2018) [12] reported the toxicity of the insecticides on the foraging activity of bees was Emamectin benzoate > spinosad > cyantraniliprole > indoxacarb > NSKE > chlorantraniliprole > Bt > HaNPV. In the present investigation, HaNPV and Bt based treatments did not show effect on the mean number of bees and total pollinator fauna in sunflower.

Table 1: Effect of biorational treatments on mean number of bees and total pollinators per plant

IPM Modules	Mean number per plant							
	Apis mellifera		*Apis dorsata*		*Apis cerana indica*		Total pollinators (*)	
	Before Spray	After spray	Before Spray	After spray	Before Spray	After spray	Before spray	After spray
T_1	0.93	1.30	1.60	2.07	0.43	0.50	9.70	10.9
T_2	0.88	1.17	0.90	1.50	0.34	0.34	7.06	8.10
T_3	0.82	1.27	1.90	2.00	0.20	0.37	9.37	9.47
T_4	0.97	1.33	1.67	1.93	0.27	0.33	9.22	9.37
T_5	1.04	1.23	1.37	1.87	0.30	0.30	8.40	8.50
T_6	0.81	0.80	1.57	0.90	0.29	0.30	9.01	6.30
T_7	0.82	1.10	1.60	1.80	0.47	0.50	8.87	10.67
T_8	0.81	0.87	1.50	1.50	0.40	0.40	9.13	9.83
F-test	NS	*	NS	*	NS	*	NS	*
SEm±	-	0.10	-	0.13	-	0.04	-	0.26
CD @ 5 %	-	0.29	-	0.41	-	0.11	-	0.80
CV (%)	19.38	14.68	21.35	14.8	20.85	15.14	18.97	5

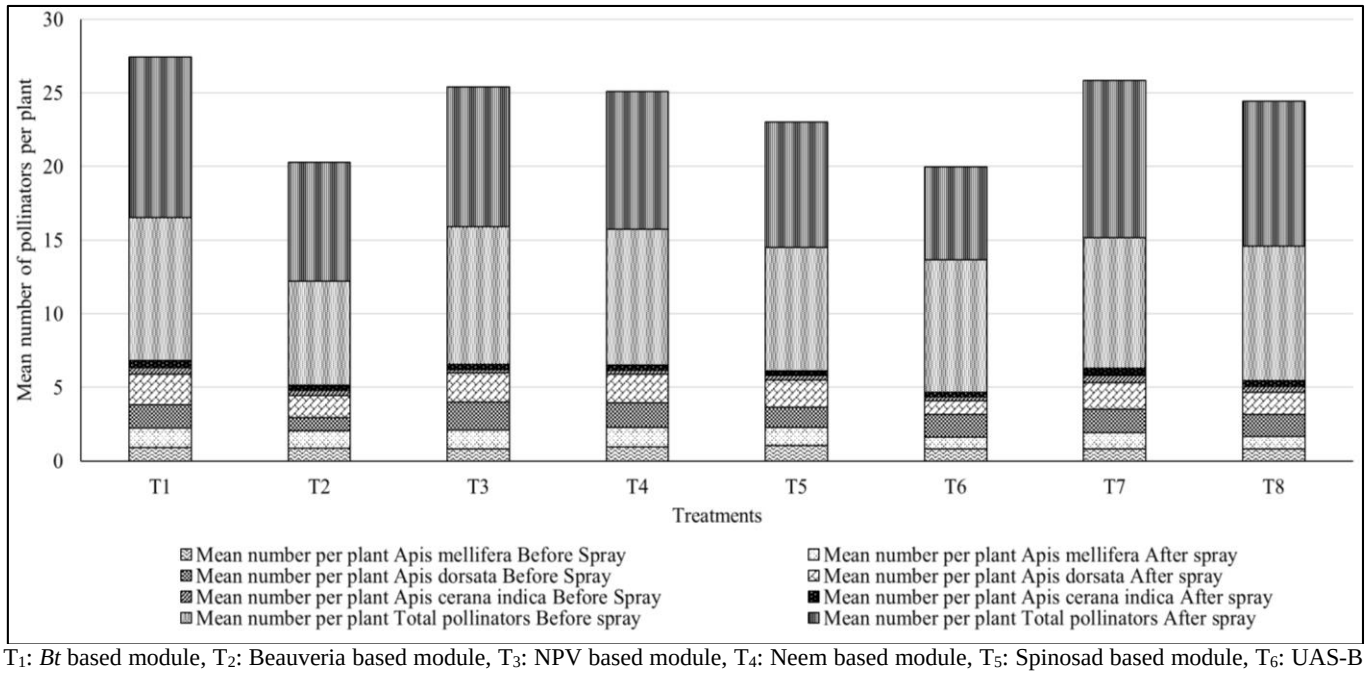
**A. mellifera, A. dorsata, A. florea, A. cerana indica, Tetragonula* sp and others (Syrphids,etc.)

T_1: *Bt* based module, T_2: Beauveria based module, T_3: NPV based module, T_4: Neem based module, T_5: Spinosad based module, T_6: UAS-B module, T_7: Water spray, T_8: Untreated control



T_1: *Bt* based module, T_2: Beauveria based module, T_3: NPV based module, T_4: Neem based module, T_5: Spinosad based module, T_6: UAS-B module, T_7: Water spray, T_8: Untreated control

Fig 1: Recovered population of *Apis dorsata* from deterrent effect of neem seed kernel extract at 4th day after spray



T_1: *Bt* based module, T_2: Beauveria based module, T_3: NPV based module, T_4: Neem based module, T_5: Spinosad based module, T_6: UAS-B module, T_7: Water spray, T_8: Untreated control

Fig 2: Effect of biorational treatments on mean number of bees and total pollinators per plant

Conclusion

Biorational based formulations like Bt, *B. bassiana*, HaNPV and neem-based treatments did not show any effect on the pollinator visitation or mean number bees or total major pollinators in sunflower. Similarly, Botanical insecticides like NSKE was found to have some repellent or deterrent action on the pollinator visitation when applied to crop during day time or during peak activity of bee's visitation. Therefore, application of formulations which are having repellent action on bees or other pollinators should be applied during evening time when the activity of pollinators is minimum in sunflower. Further study is required on residual action of blue and green labelled chemicals on pollinators.

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