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Insecticidal Effects on Pollinating Attributes of Linseed Foragers

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ABSTRACT

Linseed (*Linum usitatissimum* Linn.) is cultivated as cash crop by farmers in various regions of Maharashtra. Increased vigor and production of crop was naturally achieved through cross pollination by various foragers during blooming season. One of the major problems of crop health during the growth period is attacks of various pests. Farmers applied various insecticides to control pest attack, but on the other hand insecticides have adverse effect on foragers of particular crop. The present study attempted to assess insecticidal effect on foragers of linseed with respect to various pollinating attributes. In this field investigation, sowing of NL-97 variety seeds of linseed was carried out in two different farmlands, one with insecticides sprayed and another without insecticide application. Various attribute of pollination service was observed during this research on both crop fields alternately in highest blooming period. Observational data of pollinating attribute for each forager between both plots used to calculate percent difference. Results of the study revealed that abundance, foraging rate and foraging duration of foragers was significantly affected by insecticide application ($p<0.05$). *A. cerena indica, Halictus spp., Trigona spp*. and *Coccinella septempunctata* found as pollens of linseed attached on their body and considered as pollinators of particular crop. Foragers on bloom of treated field was observed after 36 (± 4) hour of insecticide application.

Key words: *Linum usitatissimum*, Pollinators, Insecticide, Pollinating efficiency, Percent sensitivity

Oilseed crops are the second most important determinant of agricultural economy, next only to cereals within the segment of field crops. Growth rates of seasonal oilseed crops like sunflower, safflower, niger and linseed is poor as these crops considered as secondary source of vegetable oil. In Maharashtra, there is high demand of soybean and groundnut oil so these crops have high growth rates. *Linum usitatissimum*, (linseed, flax) is popularly known as jawas in Maharashtra and cultivation of this crop by farmers generally aims to produce seed for preparation of oil. Flax stem used in preparation of fiber in linen industry. About 80% of the total linseed oil produced in India used for industries to manufacture of various products like paints, varnish, oilcloth, linoleum, printing ink and remaining about 20% is used by farmers [1].

Farmers in Satara district cultivated the linseed as a cash crop due to every part of the plant has specific economic importance. Linseed generally considered as self-pollinating crop but cross pollination known to increase yield and vigor. Cross pollination generally carried out by insects and they play predominant role to increase fruit set by pollination service [2]. During growth period of linseed, various pests attack to the crop predominately *Dasineura lini* [3]. This cause adverse effect on crop health and yield. Farmers are using large quantities of chemical as well as biological insecticides to control these insect pests. Insecticide causes direct toxic effects on various pests leading to mortality of pest and could also leads to sublethal effects such as, decreased nymphal survival and adult longevity, increased nymphal period, suppression of adult emergence, decreased oviposition period, fecundity and egg viability [4]. Application of aqueous extracts of medicinal plants like *A. indica* (neem) can provide protection from pest to crop plant is affordable to the poor farmers and it is eco-friendly as compared to the use of chemicals [5]. However, the use of insecticide has adverse effect on the pollinators and their pollination service. Thus, present study is planned to understand the effect of insecticide on pollinators and pollination of linseed.

MATERIALS AND METHODS

Experiment was conducted in farm of local farmer of Atit, Satara (Coordinates: 17° 32' 0" North, 74° 4' 0" East). In this field investigation, taken sowing of NL-97 variety seeds of linseed in two different farmlands of 0.25 Acre size, one with insecticides spray for control of insect pests damages crop and another as untreated control during December to March for three years (2019 to 2021). It is ensured that control plot was sufficiently isolated from treated to avoid any insecticide contamination. Observation and sampling was carried out in the highest blooming season. Collected insect species were

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observed examined and identified at Department of Zoology, Lal Bahadur Shashtri College, Satara.

Neem extract was effective in attack of bud fly pest [6-8]. Imidacloprid is used to control sucking insects, some chewing insects including termites, soil insects, and fleas on pets. Emulsifiers was generally applied to obtain better food quality. So, we used mixture of Neem Oil 80%, Imidacloprid 15% and Emulsifier 5% (NOIE insecticide) to study pollinator activity in both fields. Azadirachtin is act as antifeedant, antiovipositional and toxicity to insect pest which is main component of *A. indica* (neem) plant and provide protection against many insects [9].

Five sub-sampling plot of 1 X 1 meter i.e., four at the corner and one at the center of plot were selected from both control and treated plots. Number of different insect species visited to the flowers of crop during blooming period was recorded as diversity. Insect visitors to crop were collected by using insect swipe net for further identification and morphological studies.

Relative abundance of insect visitor was recorded by counting number of various insects visited to flower. Total number of visits of each insect in one hour (total six observations with one hour interval each in a day) in selected area was recorded in control and treated plot alternately. Simultaneously foraging rates and foraging duration was studied. Number of flowers visited by insects in 10 minute was observed and recorded as foraging rate. Time spent on flower by each insect species (in seconds) was recorded as foraging duration.

Pollen grains carried by the insect on its body during foraging activity were counted as per method given by Kumar *et al.* [10]. Data of the pollination attributes viz., relative abundance of floral visitors, foraging rate, foraging duration, number of loose pollen grains attached to their body each insect species was used to calculate performance scores (PSs) as per the formula of Sihag and Rathi [11] given below:

$$P_{sij} = \frac{N_{ij}}{N_j} X\ S$$

Percent sensitivity to insecticide was also computed to find out percent change in pollination attribute due to insecticide by formula:

$$PS_i = \frac{(A_c - A_t)_i}{A} X\ 100$$

Difference in pollinator abundance, foraging rate, and foraging duration among different species was analyzed by using ANOVA. All the pollination attributes were compared between control and treated plots by using Student t-test. Percentage sensitivity of pollinator to insecticide for each pollinating attribute was calculated by obtaining the three years observational data on both the plots.

RESULTS AND DISCUSSION

Foragers on the linseed were observed for three years 2019 to 2021 on both control and treated plot. Abundance, foraging behavior and pollen load were studied. Total eight foragers were reported in this observation. The clear importance of foragers as crop pollinators and insecticide effect on their pollinating attributes, as shown in this study, illustrates how insecticide effect on foragers and crop-pollination services.

Table 1 Various pollinating attributes of foragers on linseed during observational year 2019 to 2021 (All Grand Mean Value)

Sr. No.	Name of insect	Year of Observation	*Abundance per hour		**Foraging rate per 10 minute		***Foraging Duration per seconds		Average Pollen load
			Controlled	Treated	Controlled	Treated	Controlled	Treated	Controlled
1	*Muscid fly*	2019	2.87 ± 1.12	1.20 ± 0.60	5.33 ± 1.40	1.53 ± 0.64	6.80 ± 1.37	11.20 ± 1.58	0.00
		2020	3.67 ± 0.81	1.27 ± 0.57	4.67 ± 1.07	1.47 ± 0.83	6.60 ± 1.31	12.33 ± 3.00	0.00
		2021	2.87 ± 1.22	1.27 ± 0.48	4.67 ± 1.60	1.80 ± 0.71	8.13 ± 1.04	14.73 ± 2.02	0.00
2	*Trigona spp.*	2019	2.67 ± 1.10	1.40 ± 0.55	4.73 ± 1.64	1.93 ± 0.84	5.80 ± 1.71	11.80 ± 1.91	25000.00
		2020	3.20 ± 1.04	1.27 ± 0.48	3.67 ± 1.27	1.67 ± 0.61	6.93 ± 1.32	13.93 ± 1.32	18333.33
		2021	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00
3	*Halictus spp.*	2019	2.67 ± 1.22	1.40 ± 0.63	3.93 ± 1.49	1.87 ± 0.89	5.60 ± 1.78	12.07 ± 2.22	22500.00
		2020	2.67 ± 0.91	1.13 ± 0.65	3.87 ± 1.21	1.47 ± 0.79	7.80 ± 1.25	11.53 ± 4.59	15000.00
		2021	2.73 ± 0.99	1.40 ± 0.51	4.07 ± 1.32	1.80 ± 0.70	7.93 ± 1.40	15.07 ± 2.48	15000.00
4	*Apis cerena indica*	2019	2.27 ± 0.91	1.13 ± 0.30	4.13 ± 1.38	1.73 ± 0.86	7.13 ± 2.21	14.33 ± 3.28	18333.33
		2020	2.33 ± 1.15	0.73 ± 0.15	2.80 ± 0.70	1.07 ± 0.38	6.33 ± 2.32	10.07 ± 1.41	16666.67
		2021	2.20 ± 0.87	1.33 ± 0.48	3.87 ± 1.09	1.60 ± 0.76	7.33 ± 1.45	15.13 ± 2.69	17500.00
5	*Hoverfly*	2019	1.60 ± 0.76	0.00 ± 0.00	6.33 ± 1.19	0.00 ± 0.00	9.67 ± 1.71	0.00 ± 0.00	0.00
		2020	1.60 ± 0.80	0.00 ± 0.00	2.87 ± 1.06	0.00 ± 0.00	8.40 ± 0.84	0.00 ± 0.00	0.00
		2021	1.87 ± 0.76	0.00 ± 0.00	3.93 ± 1.45	0.00 ± 0.00	9.07 ± 1.46	0.00 ± 0.00	0.00
6	*Eurema blanda*	2019	1.47 ± 0.55	0.00 ± 0.00	1.60 ± 0.71	0.00 ± 0.00	24.87 ± 6.48	0.00 ± 0.00	0.00
		2020	1.07 ± 0.33	0.67 ± 0.30	1.33 ± 0.81	0.93 ± 0.58	24.93 ± 7.62	15.67 ± 4.96	0.00
		2021	1.27 ± 0.57	0.00 ± 0.00	1.93 ± 0.97	0.00 ± 0.00	22.53 ± 6.04	0.00 ± 0.00	0.00
7	*Painted bug*	2019	1.40 ± 0.55	0.00 ± 0.00	1.60 ± 0.71	0.00 ± 0.00	24.20 ± 5.59	0.00 ± 0.00	0.00
		2020	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00
		2021	0.47 ± 0.30	0.00 ± 0.00	0.53 ± 0.33	0.00 ± 0.00	10.60 ± 5.79	0.00 ± 0.00	0.00
8	*C. septempunctata*	2019	1.27 ± 0.48	0.00 ± 0.00	1.73 ± 0.86	0.00 ± 0.00	22.07 ± 5.21	0.00 ± 0.00	7500.00
		2020	1.27 ± 0.60	0.00 ± 0.00	1.60 ± 0.64	0.00 ± 0.00	19.33 ± 2.37	0.00 ± 0.00	5833.33
		2021	0.87 ± 0.45	0.00 ± 0.00	1.20 ± 0.76	0.00 ± 0.00	15.33 ± 4.89	0.00 ± 0.00	4166.67

*F ($p \leq 0.05$) For number of insects in both plot: Significant; t ($p \leq 0.05$) Between control and treated: Significant
**F ($p \leq 0.05$) For number of flowers visited: Significant; t ($p \leq 0.05$) Between control and treated: Significant
*** F ($p \leq 0.05$) For time spent on single flower: Significant; t ($p \geq 0.05$) Between control and treated: Insignificant

Table 2 Pollination efficiency ranking of insect pollinators on *Linum usitatissimum*on the basis of different pollinating attributes

Sr. No.	Insect species	Year of observation	Performance Score							Pollinating indices (PI)		Pollinating efficiency ranking	
			Abundance		Foraging rate		Foraging Duration		Pollen Counting				
			Control	Treated	Control	Treated	Control	Treated		Control	Treated	Control	Treated
1	*Muscid fly*	2019	1.416	1.871	1.451	1.735	124.859	35.286	0.000	0.000	0.000	0	0
		2020	1.857	1.999	1.795	1.778	97.370	41.209	0.000	0.000	0.000	0	0
		2021	1.869	2.533	1.848	2.769	79.603	24.396	0.000	0.000	0.000	0	0
2	*Trigona spp.*	2019	1.317	2.183	1.288	2.188	146.386	33.492	2.729	677.454	436.454	1	1
		2020	1.620	1.999	1.410	2.020	92.688	36.477	2.628	556.678	387.124	1	1
		2021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0	0
3	*Halictus spp.*	2019	1.317	2.183	1.070	2.112	151.614	32.751	2.456	524.754	370.882	2	2
		2020	1.350	1.788	1.487	1.778	82.390	44.067	2.151	355.783	301.285	2	2
		2021	1.782	2.800	1.611	2.769	81.610	23.857	3.270	765.904	604.842	1	1
4	*Apis cerena indica*	2019	1.119	1.767	1.125	1.961	119.024	27.572	2.001	299.826	191.241	3	3
		2020	1.181	1.157	1.077	1.293	101.469	50.487	2.389	308.485	180.487	3	3
		2021	1.434	2.667	1.531	2.462	88.287	23.752	3.815	739.782	594.743	2	2
5	*Hoverfly*	2019	0.790	0.000	1.723	0.000	87.832	0.000	0.000	0.000	0.000	0	0
		2020	0.810	0.000	1.103	0.000	76.505	0.000	0.000	0.000	0.000	0	0
		2021	1.217	0.000	1.558	0.000	71.409	0.000	0.000	0.000	0.000	0	0
6	*Eurema blanda*	2019	0.724	0.000	0.435	0.000	34.144	0.000	0.000	0.000	0.000	0	0
		2020	0.540	1.052	0.513	1.131	25.774	32.441	0.000	0.000	0.000	0	0
		2021	0.826	0.000	0.766	0.000	28.733	0.000	0.000	0.000	0.000	0	0
7	*Painted bug*	2019	0.691	0.000	0.435	0.000	35.084	0.000	0.000	0.000	0.000	0	0
		2020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0	0
		2021	0.304	0.000	0.211	0.000	61.079	0.000	0.000	0.000	0.000	0	0
8	*C. septempunctata*	2019	0.626	0.000	0.472	0.000	38.476	0.000	0.819	9.292	0.000	4	0
		2020	0.641	0.000	0.615	0.000	33.240	0.000	0.836	10.972	0.000	4	0
		2021	0.565	0.000	0.475	0.000	42.224	0.000	0.908	10.299	0.000	3	0

Abundance was recorded as number of species /m2 / hour in both crop fields simultaneously. *Muscid fly* (3.67 ± 0.81) and *Trigona spp.* (3.20 ± 1.04) was reported as most abundant forager. *Muscid fly* were reported dominant foragers on the linseed by Navatha *et al*. [12]. ANOVA showed significant difference between abundance of observed insect visitors on both control and treated plot ($p<0.05$) in entire three years observation (Table 1). Abundance of all the insect visitors was observed some difference in insecticide spraying plot. In insecticide sprayed plot, foragers were obtained after 36 (± 4) hours of spraying. T-test analysis showed significant decrease in forager abundance on treated plot during all three years ($p<0.0009$). Observed foragers were found sensitive to insecticide. *Eurema blanda* observed as most sensitive to insecticide (74.36%). Abundance of *Muscid fly* in treated plot was decreased by 42.78% and followed by 36.68% of in case of *Apis cerena indica*. Minimum decrease in abundance was seen in *Trigona spp.* 24.81% (Table 3). Abundance of bees was noticed highest compared to other insect visitor. Bees fulfill their nutritional requirements through consumption of nectar, honey and pollen. Abundance of pollinator insect plays important role in pollination success [13]. Abundance of foragers significantly decreased in treated plot as bees, other insect visitors and pest are sensitive to insecticide. Spraying of insecticides known to be affected the bee pollination service.

Highest foraging rate i.e., number of flower visited / minute / m^2 was observed in *Hoverfly* (6.33 ± 1.19), *Muscid fly* (5.33 ± 1.40), *Trigona spp.* (4.73 ± 1.64) and *Halictus spp.* (4.07 ± 1.32) (Table 1). ANOVA analysis revealed significant differences in foraging rate of various pollinators in both, control and treated plots ($p< 0.025$) during three years observation. T-test showed significant decrease in foraging rate of controlled and treated plot during all three years ($p<0.004$). Highest decrease in foraging rate in treated plot was noticed in case of *Eurema blanda* 72.55% followed by *Muscid fly* 50.61% (Table 3). ANOVA result showed significant difference in foraging duration of foragers during all three years ($p< 0.012$). It is noticed that insects observed on the blooms of insecticide treated plot visit minimum number of flowers and did not rest on the flowers directly; they may smell the flowers firstly. Number and diversity of insects visitors may increase or decrease to the particular crop plant, based on intensity of the flowering species available for forage and density of flowers [14]. Foraging rate of pollinator was decreased significantly on the treated plot due to insecticide spraying, may be because of its smell and pollen loss due to spraying.

Time spend by insect on a single flower in second is recorded as foraging duration. This attribute was reported as insignificantly increased in treated plots during all three years ($p< 0.10$). Minimum foraging duration was recorded in case of *A. cerena indica* (6.33 ± 2.32) followed by *Muscid fly* (6.60 ± 1.31) and *Trigona spp.* (6.93 ± 1.32). *Eurema blanda* (24.93 ± 7.62), *Painted bug* (24.20 ± 5.59) and *C. septempunctata* (22.07 ± 5.21) noticed as maximum time spend on single flower (Table-1). *A. cerena indica* 30.34%, *Halictus spp* 28.98% and *Muscid fly* 27.86% observed increased duration in treated plot (Table 3). It was observed that forging duration is inversely proportional to pollination efficiency of insect species [15]. It is observed that, insects don't choose flowers randomly for resting on insecticide treated blooms they choose minimum number of flower and after choosing they spend maximum time in single flower as compare to foraging duration on the bloom of control plot. Exposure to the insecticide and fungicide reduced the individual foraging performance [16]. Pesticide exposure on flower has adverse effect on foraging activity of bees, their life span and colony dynamics [17]. The number of bee trips to flowers increases but foraging efficiency decreases after pesticide exposure [18].

Those foragers observed as pollen attached to their body part during foraging behavior are reported as pollinators. *Trigona spp*. (25,000), *Halictus spp*. (22,500), *A. cerena indica* (18,333.33) and *Coccinella septempunctata* (7500) are the foragers of linseed crop with their average pollen load and found as pollinators of linseed crop (Table 1). *A. cerena indica* and *Halictus spp.* observed during entire three years of observation so they may consider as predominant pollinators of linseed crop. Abundance, foraging rate and foraging duration may affect on the pollen attachment. Decrease in insect activity affect on pollen attaching to body of pollinator which leads to minimize pollination efficiency of pollinator. The amount of pollen attached on the body of the particular insect species is presumed to be an important factor influencing its value as a pollinator [19]. Insect morphology is essential parameter for carrying pollen. Thorax and hind leg of bees have long hairs, and therefore they could play important roles in pollination effectiveness as they can hold more pollen [20].

Table 3 Percent sensitivity to different pollinating attributes of foragers on linseed during year 2019 to 2021

Insect species	Mean percent decrease in treated plot compared to control plot		
	Abundance	Foraging rate	Foraging duration
Muscid fly	42.78	50.61	-27.86
Trigona spp.	24.81	26.50	-2.55
Halictus spp.	34.59	39.76	-28.98
Apis cerena indica	36.68	42.40	-30.34
Hoverfly	NA	NA	NA
Eurema blanda	74.36	72.55	74.27
Painted bug	66.67	66.67	66.67
C. septempunctata	NA	NA	NA

Performance score and pollinating indices showed that *Trigona spp*., *Halictus spp.* and *Apis cerena indica* is efficient pollinator of linseed in control and treated plot but their abundance, foraging rate and foraging duration was affected due to insecticide spray. *Trigona spp.* observed as highest pollination efficiency ranking based on performance score (Table 2). Pollen carrying capacity and insect foraging activity influence on the pollination efficiency of pollinators [21]. Large numbers of foragers are observed sensitive to insecticide. Less or no use of insecticide in farming systems during blooming is more beneficial for pollinators and pollination [22]. Insecticide like imidaclopride (used during this research period) can have negative impacts for bees, even in sub-lethal ways [23]. Oilseed crops like safflower, sunflower, mustard etc. is visited by a large diversity of pollinators and directly effect on pollination for increased yields. In insect pest management practices in various crop fields including cucumber, insecticide should not be applied in the morning time as this is the most preferable time for pollinator activity [24]. Use of insecticides to control crop pests could have knock on implications for both crop productivity and pollinator conservation. Therefore, we like to advice a more sustainable and limited use of insecticides on agricultural crops especially for oil seed crops and if possible, avoids the insecticides spray at blooming stage.

CONCLUSION

Comparative study on control and treated plot noticed that, spray of insecticides significant effect on abundance, foraging rate and foraging behavior on foragers of linseed crop. Application of insecticide during blooming period may favors self-pollination by avoiding the foragers who have lead role in cross pollination. Those species able to carry pollen can perform the function of pollination and we call them predominant pollinator of linseed crop. *Trigona spp., Halictus spp*. and *A. cerena indica* are the pollinators of linseed crop out of observed eight foragers. Comparison for abundance, foraging rate and foraging behavior between control and treated plot shows significant difference and it directly effect on pollination service. Here we conclude, application of insecticide significantly effects on the pollinating attributes of foragers during the blooming period resulting minimum chances of cross pollination by foragers.

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