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Effect of Different Insecticides on Yield, Yield Attributes and Pollinator Behaviour of Different Pigeon Pea Varieties

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ABSTRACT

Background: Yield of pigeon pea, besides other management practices, highly relies on variety and pollinators. Again, different insecticides are also known to immensely influence the abundance of these pollinators. Hence, the current study was conducted with objectives to record diversity of flower visitors and abundance of insect pollinators, to work out pollination efficiency of major pollinators and to evaluate the effect of different varieties and insecticidal treatments on the pollinator behaviour, yield and yield attributes of pigeon pea in order to reduce the ecological impact of chemicals as well as to increase the productivity of pigeon pea.

Methods: The experiment was designed in a Split plot arrangement replicated thrice. The varieties were assigned in main plots and had four levels such as UPAS-120, PA-406, PA-421 and PA-441. Types of insecticides applied were taken in the sub plots and it also had four levels *viz.* Quinalphos 25 EC (325 g a.i./ha), Lufenuron 5.4 EC (30 g a.i./ha), Deltamethrin 2.8 EC (12.5 g a.i./ha) and Indoxacarb 15.8 EC (50 g a.i./ha).

Result: Outcomes emanated from the study revealed that Megachile disjuncta, Xylocopa latipes and Megachile bicolor were the three most important pollinator bee species on kharif pigeon pea in the tarai region of Uttarakhand. Among the varieties, UPAS-120 and PA-441 had better cross pollination potential over the PA-406 and PA-421. Insecticides had overall negative impact on the insect pollinators. However, Deltamethrin 2.8 EC at recommended dose was found to have least impact on the insect pollinators. Quinalphos 25 EC and Lufenuron 5.4 EC were observed to be more deleterious on pollinators. The ultimate impact on the pollinator insects were profound on the yield and yield attributes of pigeon pea.

Key words: *Megachile bicolor*, *Megachile disjuncta*, Pigeon pea, Pollinator behaviour, *Xylocopa latipes*.

INTRODUCTION

Pigeon pea [*Cajanus cajan* (L.) Millspaugh] is one of the pulses of prime importance, which belong to family Fabaceae. In India, it is consumed as decorticated split seeds, popularly called as 'Dal'. It was widely adopted to provide a list of priority of issues regarding the research. Inputs and their efficient management was the main factors revealed from different studies enquiring for causes of lower productivity of pulses (Singh *et al.,* 2015).

Pre-anthesis cleistogamy is one of the important characters, found in flowers of pigeon pea (Sexena, 2006). According to Onim *et al.* (1979), in bud stage pigeon pea anthers dehisce although pollen germination starts after starting the withering of the flower that is 24-28 hours after dehiscence. Receptivity of stigma occurred 48 hours before the opening of the flower and continued afterward up to 4 days of flower opening (Luo *et al.*, 2009). For this character, there is a chance of insect pollination because of delay in pollen germination and stigma receptivity lasts even after the opening of the flower. Pollination, when took place by the help of pollen of the same flower it requires 54 hours to reach to the ovary and also pollen tube is reluctantly grown within the style (Datta and Deb, 1970). Long stamens of the flower are encouraged to insect outcrossing during the intermittent visit of the pollinators (Saxena, 2006). Being an often cross pollinated crop, pigeon pea registers 3-26 per cent cross pollination (Reddy *et al.*, 2004). In terms of yield increment due to cross pollination, 110 to 600 per cent yield increment was reported in often cross pollinated legumes (Abrol and Shankar, 2015).

Ivey *et al.* (2003) found that insects, those who visit the flower need not be an essential pollinator. Some of the insect visitors only visit to gather nectar, thus they do not play any role in pollination and perform as nectar thieve (Castro *et al.*, 2008). Those who come in contact with anther and stigma of the flower will carry a various amount of pollen (Adler and Irwin, 2005) and their visiting frequency also will be different while foraging (Monzon *et al.*, 2004). Among the different types of pollinators in pigeon pea, bees are the essential pollinators due to their intermittent visit to the field

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to collect more and more food (nectar and pollen) for raising their young ones due to their eusocial nature.

Very few studies have been conducted especially on the role of flower visitors/pollinators of pigeon pea and how they are productive in increasing yield especially in Pantnagar region. Detailed systematic studies are needed to understand the pollination requirements of pigeon pea. Hence, the current study was conducted with objectives to record diversity of flower visitors and abundance of insect pollinators, to work out pollination efficiency of major pollinators and to evaluate the effect of different varieties and insecticidal treatments on the pollinator behaviour, yield and yield attributes of pigeon pea to reduce the ecological impact of chemicals as well as increase the productivity of pigeon pea.

MATERIALS AND METHODS

The experiment was conducted in Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India (29°N, 79.3°E, 248.8 m) during *kharif* season of 2016 and 2017. The experiment was designed in a Split plot arrangement replicated thrice. The varieties were assigned in main plots and had four levels such as UPAS-120, PA-406, PA-421 and PA-441. Types of insecticides applied were taken in the sub plots and it also had four levels *viz.* Quinalphos 25 EC (325 g a.i./ha), Lufenuron 5.4 EC (30 g a.i./ha), Deltamethrin 2.8 EC (12.5 g a.i./ha) and Indoxacarb 15.8 EC (50 g a.i./ha).

Observations on pollinator visits were recorded at 10 per cent flowering, peak flowering and cessation of flowering for 3 times a day. With a view to determine the volume of nectar present in of pigeon pea flower, 30 flowers were sampled from each plot and then by using the forceps the petals of the flower were removed. The flower was placed under microscope and with the help of graduated micro-capillary tube nectar was collected from the nectar gland. The observations were recorded twice a day at 06:30 a.m. and 02:30 p.m. Pollination efficiency of different insect pollinators was calculated on the basis of their relative abundance, foraging rate and the number of loose pollen grains sticking to their bodies. The pollination index was calculated by following the method suggested by Kumar *et al.* (2012). The insecticides were applied at onset of flowering stage. Pollinator abundance of insect pollinators was recorded before and after spray of insecticides for side by side comparisons. At the time of spraying insecticides, pest populations were below economic threshold level so the effects of insecticides on yield due to control of pest is ignored for current study.

For the yield estimation, yield from net plot area was harvested and expressed as yield in kg/ha. For yield attributes such as pods/plant, seeds/pod, 5 representative plants from each plot were selected and observed. For 100 seed weight, a representative sample was drawn from the net plot yield and counted for 1000 seeds and weighed, expressed as seed index in grams.

All the statistical analysis were done using IBM SPSS 24.0 software package developed by IBM Corp. (2016). Data from two years were subjected to combined analysis as the year to treatment variance was found to be in the acceptable limits (Gomez and Gomez, 1984). Duncan's multiple range test at 5% probability level was used for the purpose of mean comparison (Duncan, 1955).

RESULTS AND DISCUSSION

Total 25 species of flower visiting insects from 14 different families and 6 orders were observed during the experiment. They belonged to order Hymenoptera (15 spp.), Lepidoptera (5 spp.), Hemiptera (1 sp.), Diptera (2 spp.), Coleoptera (1 sp.), Thysanoptera (1 sp.), respectively (Table 1). Among the order Hymenoptera, the families Apidae (6 spp.), Megachilidae (7 spp.), Halictidae (1 sp.) and Scoliidae (1 sp.) were recorded. Among the 25 insect species recorded on the flowers of the pigeon pea, 8 species belonging to orders Lepidoptera, Coleoptera, Thysanoptera and Hemiptera were harmful and were not considered for further studies and study was mainly concentrated on the insect pollinators of pigeon pea (Table 1). Pollination efficiency ranking was based on the overall pollination rate, foraging behaviour and abundance. Highest pollination efficiency was observed for *Megachile disjuncta* which was followed by *Xylocopa latipes* and *Megachile bicolor*. Pollinators of *Apis sp.* were not found to be true pollinator on the investigation of body adhered pollens. Flower morphology had been observed to play a greater role in the pollination effectiveness of the insects. This results were in accordance to (Singh, 2016).

Among the varieties, PA-441 was most preferred by three species such as *Apis mellifera*, *Xylocopa latipes*, *Megachile bicolor* whereas UPAS-120 and PA-421 were preferred by two species each (Table 1). Keeping the efficiency rating in the mind, UPAS-120 was preferred by the most efficient pollinator and PA-441 was also preferred by two efficient pollinators. Thus this two varieties were largely benefitted by the insect pollinations (Table 2). There was also highest nectar volume recorded with these two varieties which were significantly higher than the rest of the varieties. Nectar volume is also known to be a factor for the attraction of the insect pollinators. It was also observed in the study that mean abundance followed the same trend of the nectar volume present in the flower. Higher abundance of pollinators resulted in significantly higher percentage of cross pollination and correspondingly higher fertilization rate in the varieties. However, effect of insecticides on the nectar volume was found non-significant. On the other hand, insecticides had affected the pollinator abundance and consequently affected the percent cross pollination and fertilization. Mean abundance of pollinators was found highest with Deltamethrin 2.8 EC followed by Quinalphos 25 EC and Indoxacarb 15.8 EC (Table 2).

In order to evaluate the effect of insecticides on the abundance of pollinators, species wise pre-treatment and post treatment abundance readings were compared side by side (Table 3). Deltamethrin 2.8 EC was found to have

Table 1: Pollination scores, preferred variety and efficiency rankings of different pollinator species (pooled over years).

Species	Mean abundance (No./m²/5 min)	Loose pollen grain (No.)	Pollination Efficiency Index(PEI)	Foraging rate (Avg. no.of flower visited/min)	Pollination efficiency	Pollination efficiency ranking	Most preferred variety
Apis dorsata	12.85±1.84	6500	83525	8.00	668200	5th	UPAS-120
Apis cerana indica	7.40±1.57	13500	99900	8.00	799200	4th	PA-421
Apis mellifera	4.59±1.11	8500	39015	8.33	324994	6th	PA-441
Xylocopa latipes	4.72±0.79	211500	998280	6.00	5989680	2nd	PA-441
Megachile bicolor	3.80±1.27	133500	507300	10.00	5073000	3rd	PA-441
Megachile disjuncta	10.18±2.07	238500	2427930	7.00	16995510	1st	UPAS-120
Megachile anthracina	1.31±0.32	33500	43885	4.00	175540	7th	PA-421

Table 2: Effect of varieties and different insecticides on nectar volume, mean abundance of pollinators, % cross pollination and % fertilization of pigeon pea (pooled over years).

Treatments	Nectar volume/flower (µl)	Mean abundance of pollinators (No. of poll./m²/5min)	% Cross pollination	% Fertilization
Varieties				
UPAS-120	4.69^{a}	5.06^{a}	19.6^{a}	23.1^{a}
PA-441	4.62^{a}	5.00^{a}	19.1^{a}	23.7^{a}
PA-421	4.25^{b}	4.67^{b}	12.3^{b}	14.1^{b}
PA-406	3.98^{c}	4.59^{b}	11.1^{c}	10.7^{c}
Insecticides				
Quinalphos 25 EC	4.33^{a}	4.48^{b}	15.4^{c}	18.1^{b}
Lufenuron 5.4 EC	4.32^{a}	3.64^{c}	11.3^{d}	12.2^{c}
Deltamethrin 2.8 EC	4.34^{a}	4.90^{a}	17.8^{a}	21.2^{a}
Indoxacarb 15.8 EC	4.32^{a}	4.53^{b}	16.1^{b}	18.9^{b}
Interaction	NS	**	**	**

Note: Means are compared with Duncan's multiple range test at 5% probability level. Treatments sharing same letters are not significantly differing. NS: Non-significant. *: Significant at p=0.05; **: Significant at p=0.01.

Table 3: Effect of insecticides on abundance of bee pollinators, data pooled over years (No. /m²/5 min).

Treatments		*A. dorsata*	*A. ceranaindica*	*A. mellifera*	*A. florea*	*X. latipes*	*M. bicolor*	*M. disjuncta*	*M. anthracina*
Quinalphos	Pre treatment	14.22±0.19^{a}	7.56±0.38^{a}	6.11±0.77^{a}	1.89±0.19^{a}	7.89±0.19^{a}	4.22±0.19^{a}	10.00±0.67^{a}	0.56±0.19^{b}
25 EC	Post treatment	11.29±1.45^{b}	8.48±1.23^{a}	4.48±0.79^{b}	0.52±0.50^{b}	1.33±1.36^{b}	4.09±0.46^{a}	2.95±2.35^{b}	2.67±0.64^{a}
Lufenuron	Pre treatment	12.56±1.35^{a}	5.22±0.19^{b}	4.11±0.51^{a}	2.56±0.19^{a}	3.89±0.51^{a}	1.67±0.33^{a}	9.00±0.33^{a}	1.22±0.84^{a}
5.4 EC	Post treatment	6.86±3.14^{b}	6.81±2.90^{a}	4.76±0.52^{a}	0.29±0.41^{b}	1.95±1.82^{a}	0.71±0.58^{b}	2.95±2.35^{b}	2.76±1.96^{a}
Deltamethrin	Pre treatment	11.11±0.38^{a}	6.33±0.33^{a}	3.56±0.19^{a}	1.44±0.07^{a}	4.22±0.19^{a}	3.33±0.33^{a}	8.78±0.19^{a}	0.44±0.19^{b}
2.8 EC	Post treatment	11.95±1.11^{a}	7.10±3.40^{a}	5.86±4.41^{a}	0.71±0.25^{b}	2.71±1.32^{b}	2.00±2.30^{a}	7.90±2.33^{a}	5.00±2.65^{a}
Indoxacarb	Pre treatment	11.78±0.38^{a}	6.22±0.38^{a}	4.67±0.33^{a}	1.22±0.19^{a}	5.00±0.33^{a}	2.67±0.33^{b}	8.89±0.69^{a}	0.67±0.33^{b}
15.8 EC	Post treatment	8.47±2.80^{b}	6.09±2.43^{a}	5.90±4.48^{a}	1.09±0.81^{a}	1.52±0.98^{b}	5.10±1.14^{a}	5.81±1.04^{b}	2.29±1.01^{a}

Note: Pre and Post treatment data are compared with Duncan's multiple range test at 5% probability level within each insecticides treatments. Treatments sharing same letters are not significantly differing.

significantly negative impact on *A. florea* and *X. latipes*; other pollinators were not affected or positively affected. Lufenuron 5.4 EC was having net negative impact on the abundance of *A. dorsata*, *A. florea, M. bicolor* and *M. disjuncta*. Indoxacarb 15.8 EC was found to reduce the abundance of *A. dorsata*, *X. latipes* and *M. disjuncta* significantly. Quinalphos 25 EC was found to have significantly negative impact on the abundance of *A. dorsata, A. mellifera, A. florea, X. latipes* and *M. disjuncta* (Table 3). These results well justify the trends in Table 2.

Economic yield and yield attributes such as pods/plant, seeds/pod were found to be significantly affected by both the factors. However, effect on the 100 seed weight was found to be unaffected by the levels of insecticide as it was varietal character. Highest yield was recorded from UPAS-120 (1181.3 kg/ha) followed by PA-441 (1160.1 kg/ha). Among insecticidal treatments highest yield was recorded from Deltamethrin 2.8EC (1219.8 kg/ha). Number of pods as well as number of seeds per pod was determined by the fertilization percentage and hence followed the same trend. UPAS-120 and PA-441 were observed to have highest pods/ plant and seeds/pod. Among insecticides, Deltamethrin 2.8 EC with the least negative impact on pollinators had highest

Table 4: Effect of varieties and different insecticides on yield and yield attributes of pigeon pea (pooled over years).

Treatments	Yield (kg/ha)	Pods/ plant	Seeds/ pod	100 seed weight (g)
Varieties				
UPAS-120	1181.3^{a}	130.4^{a}	3.22^{a}	7.04^{b}
PA-441	1160.1^{b}	127.2^{a}	3.25^{a}	6.97^{b}
PA-421	1059.3^{c}	119.1^{b}	3.01^{b}	7.10^{a}
PA-406	991.5^{d}	113.3^{c}	2.98^{b}	7.15^{a}
Insecticides				
Quinalphos 25 EC	1115.3^{c}	122.3^{b}	3.1^{c}	7.6^{a}
Lufenuron 5.4 EC	906.1^{d}	99.9^{c}	2.9^{d}	7.8^{a}
Deltamethrin 2.8 EC	1219.8^{a}	134.5^{a}	3.5^{a}	7.8^{a}
Indoxacarb 15.8 EC	1127.7^{b}	124.3^{b}	3.2^{bc}	7.4^{a}
Interaction	**	*	**	NS

Note: Means are compared with Duncan's multiple range test at 5% probability level. Treatments sharing same letters are not significantly differing.

NS: Non-significant *: Significant at p=0.05 **: Significant at p=0.01.

pods/plant and seeds/pod. On the contrary, treatments having lower pods/plant and seeds/pod were having higher 100 seed weight due to the more availability of photo synthates to the seeds.

CONCLUSION

Outcomes emanated from the current study revealed that *Megachile disjuncta, Xylocopa latipes* and *Megachile bicolor* were the three most important pollinator bee species on *kharif* pigeon pea in the *tarai* region of Uttarakhand. Among the varieties, UPAS-120 and PA-441 had better cross pollination potential over the PA-406 and PA-421. Insecticides had overall negative impact on the insect pollinators. However, Deltamethrin 2.8 EC at recommended dose was found to have least impact on the insect pollinators. Quinalphos 25 EC and Lufenuron 5.4 EC were found to be more deleterious on pollinators. The ultimate impact on the pollinator insects were profound on the yield and yield attributes of pigeon pea. Not only the yield and economic damage to the farmers, these practices can cause more harm to the agro-ecosystem. This study is expected to provide a guidance to the farmers for increasing the pigeon pea yield in the area through selection of varieties and more ecologically feasible pest management options for a sustainable future.

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