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Pollinator diversity and effect of *Apis cerana* F. pollination on yield of mango (*Mangifera indica* L.)

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Abstract
Pollinator diversity and effect of *Apis cerana* F. pollination on yield of Mango (*Mangifera indica* L.) was studied at Assam Agricultural University, Jorhat during the year 2014-15 and 2015-16 from mid of February to August. The diversity of insect forager on Mango (*Mangifera indica* L.) was recorded and all total 11 (eleven) insect foragers were documented. Out of which, *Apis cerana* was found to be the most dominant forager (46.66%) followed by *A. mellifera* (08.00%), *A. florea* (07.00%), *Vespa magnifica* (8.00%), *Coccinella septempunctata* (05.00%), *Oecophylla smaragdina* (03.33%), *Pieris rapae* (02.66%) and *Papilio demoleus* (01.33%). The peak period of foraging activity on mango flower was found to be 0900-1000 hours. Fruit setting was more in the *Apis cerana* treated plots (42.29%) compared to that of open pollination (OP, 33.36%) and pollinator exclusion (PE, 31.03%). Maximum yield was recorded in *Apis cerana* treated plots (84.75q/ha) and lowest in PE (58.18q/ha). Foraging activity of honey bees had also been correlated with meteorological factors. The number of *Apis cerana* visited on mango flower showed a positive significant relationship with temperature and bright sunshine hours and negative with relative humidity and rainfall.

Keywords: Diversity, honeybee, pollination, mango, seed set, yield

1. Introduction
Mango, *Mangifera indica* L. also known as the national fruit of India is one of the most important tropical fruit belonging to the family Anacardiaceae [13]. India is one of the leading producers of mango and accounts for 65 percent of the world's total production. The total area under mango cultivation has been reported to be an area of 2263.0 thousand ha with production 19678.0MT in India [16]. Mango is also an excellent source of dietary fiber and vitamin B6, as well as a good source of vitamin A and vitamin C. They are rich in minerals like potassium; magnesium and copper [24]. Crop productivity is dependent on both natural and artificial factors. Pollination is one of the vital factors for fruit production. Mango flowers are pollinated by various insects such as wasps, ants, flies, butterflies, beetles, and bees as well as by wind [3, 2]. The significant role of insect pollinators in mango production has been recognized in many mango producing countries in the world. Mango panicles have a lot of hermaphrodite flowers [4] and [25] found that cross pollination had contributed largely in increase of mango fruit set. The hermaphrodite flowers are self-pollinated but incompatibility of some pollen and stigmas cause failure in mango fruit set [8], hence external agents are necessary to transfer the pollen of mango flower. Honey bees are the major pollinators contributing pollination of about 73 percent of the world's cultivated crops [22]. Out of the pollinators, *Apis cerana* is the dominant honey bee species and is effective pollinator of mango crop [23]. Considering the importance of honey bee, *A cerana* in the pollination of mango, the present study was conducted to determine the pollinator diversity and role of *A. cerana* F. pollination on yield of Mango (*Mangifera indica* L.).

2. Materials and Methods
The present experiment was laid out in the Experimental farm, Department of Horticulture, Assam Agricultural University, Jorhat during the year 2014-15 and 2015-16. A mango plantation of 10 years in age measuring 594 square meters was selected for the experiment. Mango variety "Amrapalli" was selected for conducting the experiment. The floral biology, particularly floral taxonomy was studied during peak flowering of mango. The treatments like open pollination (OP), Pollinator exclusion (PE), Bee pollination 1 (BP_1) @ 3hives/ha (single framed), Bee pollination 2 (BP_2) @ 5 hives/ha (double framed) and Bee pollination 3 (BP_3) @

7 hives/ha (triple framed) were taken and replicated four times. Prior to the peak flowering *i.e.* when there was 10% of flowering, the crop was covered with nylon net except the open pollination treatments. In the bee pollinated treatments, standard nucleus hives of *A. cerana* with nurse bees @ 3hives/ha (single framed in nucleus hive), 5 hives/ha (double frame in nucleus hive) and 7 hives/ha (triple framed in nucleus hive) were placed inside the bee pollinated plots just before flowering. The foraging activity of different insect foragers was recorded at an hour interval from 0600 to 1700 hr of the day on randomly selected four branches per plants in four directions. Ten observations were recorded at an interval of two days for determining the effect of *Apis cerana* pollination on seed set and yield of mango. Number of *Apis cerana* visit on mango was recorded as per the methodology given by Dhara and Tandon (1993). In this method canopy of mango was divided into four different directions such as East, West, North and South. Observations on number of *A. cerana* were recorded from 0600 to 1700 hours during peak blooming period. Ten observations at two days interval were made and the average value was calculated out. The total number of fruits per plant was counted before harvesting in each treatment and the mean was calculated. After each harvesting the number of mature fruits was counted per plant. Then number of total fruits per plant was worked out by adding each harvested fruit count. Fruit weight per plant in different treatments was recorded and the yield is expressed in quintal per hectare. The correlation of foraging activities with various meteorological parameters such as temperature, relative humidity, rainfall and bright sunshine hours were worked out by using Karl Pearson's correlation method.

2.1 Statistical analysis

The experiment was carried out in a Randomized Block Design (RBD) consisting of five treatments which were replicated four times. It was statistically analysed by the Fisher's method of analysis of variance. The significance or non-significance of a given variance was determined by calculating the respective values of "F" and by comparing the calculated value of "F" at 5 percent probability level. The correlation of foraging activities with various meteorological parameters was worked out using Karl Pearson's correlation method.

3. Results and Discussion

3.1 Floral biology

Mango bears hermaphrodite and male flowers which are produced in the same panicle of a branch. Both types of flowers are born on same inflorescence *i.e.* and romonocious [15]. The mango inflorescence is basically terminal and the perianth consists of five petals and sepals that are ovate to ovoid in shape and the total number of flowers in a panicle may vary from 1000 to 6000. The size of individual flower varies from five to ten mm in diameter [14].

3.2 Insect foragers diversity on mango

From the present study all total of 11 species viz.; *Apis cerana, A. mellifera, A. florea, Vespa magnifica, Musca domestica, Episyrphous balteatus, Chrysomya megacephala, Coccinella septempunctata, Papilio demoleus, Pieris rapae* and *Oecophylla smargdina* were recorded. Out of these *Apis cerana* was recorded to be maximum (46.66%) followed by *Apis mellifera* (08.00%). Major pollinators included *Apis cerana* and *A. mellifera* and an allodapine bee (*Braunsapis hewitti*) of the Apidae and sweat bees (*Halictus* sp. and *Lasioglossum* sp.) of the Halictidae among the Hymenoptera and *Chrysomya megacephala, Chrysomya pinguis* and *Musca domestica* of the Diptera, which were considered to be the dominant species due to their frequent appearance [23, 12]. Other foragers which were found but in lesser number were *Coccinella septempunctata* (05.00%), *Oecophylla smargdina* (03.33%), *Pieris rapae* (02.66%) and *Papilio demoleus* (01.33%) (Table 1). The honey bees as the chief pollinator in mango flowers followed by the vespid wasps [18]. The relative abundance of the insect foragers of the mango flower is presented in Fig 1.

3.3 Foraging behaviour of *Apis cerana* on mango

The results showed that the peak period of visit by *A. cerana* on mango was 0900-1000 hours of the day (Table 2). The peak foraging activity of honey bees in the pollination of guava was observed between 0900 and 1100 hour [9]. Similar results were reported by [21] that the foraging behaviour of *Apis mellifera* on cucumber that foraging activity of honey bees was more during the morning hours. The number of *A. cerana* per sq. m. per minute was recorded to be maximum (09.75) at 0900-1000 hours and minimum (01.90) at 1300-1400 hours of the day. Highest visitation frequency and abundance was found in *Apis cerana* than that of *A. mellifera* on apple flowers [17]. The activity started from 0600 hours, with the highest activity recorded during 0900-1100 hours (16-20 bees/panicle) and lowest during 1400-1700 hours (2-5 bees/panicle) and none after 1800 hours. Similarly the foraging activity of honey bees on cucumber was more in 0900-1000 hours and minimum in 1300-1400 hours [10]. The number of *A. cerana* visited on mango was correlated with different meteorological parameters and it was found that there was a positive significant relationship, with temperature (r= 0.39, $P<0.05$) and bright sunshine hours (r= 0.35, $P<0.05$) while a negative significant relationship with relative humidity (r= -0.09, $P<0.05$) and rainfall (r= -0.43, $P<0.05$). The frequency of flower visited per minute was recorded to be maximum (11.64) at 0900-1000 hours and minimum (03.49) at 1300-1400 hours of the day. The frequency of flower visited by *A. cerana* on mango exhibited a positive and significant relationship with temperature (r= 0.18, $P<0.05$) and bright sunshine hours (r= 0.91, $P<0.05$) but a negative significant relationship with relative humidity (r= -0.76, $P<0.05$) and rainfall (r=-0.94, $P<0.05$). During mid-day, due to high temperature and exhaustion of nectar in flower, there was less number of visited by bees. High frequency visit of *A. cerana* on citrus during morning hours was reported and it gradually decreased in the noon hours [7]. The time taken for foraging by *A. cerana* on mango flowers showed a positive significant relationship with temperature (r= 0.266, $P<0.05$) and bright sunshine hours (r= 0.833, $P<0.05$) while a negative significant correlation with relative humidity (r= -0.78, $P<0.05$) and rainfall (r= -0.89, $P<0.05$). The maximum time spent per flower was found to be 06.48 ± 0.06 seconds 0900-1000 hours of the day and minimum was 04.15 ± 0.08 seconds 1300-1400 hours of the day. The maximum number of foragers per square meter per minute and the maximum time spent during 0900-1000 hours of the day indicating the best time of foraging on buckwheat [19]. On the other hand, an average visit of 248 to 275 flowers/trip by *Apis cerana* was recorded on guava flowers [1]. The maximum pollen load carried by *A. cerana* was weighed to be 05.98 mg at 0900-1000 hours and minimum was 02.31mg at 1300-1400 hours of

the day (Table 3). On Sesamum, maximum pollen load was found to be 8.34 ± 0.14 mg during 0900-1000 hours while minimum to be 2.31 ± 0.08 mg during 1500–1600 hours of the day [6].

3.4 Effect of *Apis cerana* pollination on fruit set and yield

The effect of *Apis cerana* pollination in respect to yield per plant and yield per hectare were found to be significant. Table 4 showed that there was a significant increase in the fruit set of the crop and the average fruit per plant was found to be 141.67±0.55. The maximum fruit per plant was found to be 164.12±0.37 in BP_3 treatment and it was significantly higher from other treatments. The fruit set percentage was recorded to be highest in BP_3 (42.29%) followed by BP_2 (41.43%) and there was significant difference among all the treatments whereas, lowest fruit set was recorded in PE treatments (31.03%). Maximum numbers of fruit setting/ panicle (1.00) was with the bee pollination followed by the natural pollination (0.90) [26]. In guava the percent fruit set (88.00) and number of seeds per fruit (446.50) was maximum in trees caged with *A. cerana* [20]. Bee pollinated plants produced maximum yield which was significantly higher from OP and PE treatments. The table 5 showed that the highest yield was recorded in BP_3 (84.75±0.77 q/ha) and the lowest was 58.18±0.70 q/ha in PE. BP_3 showed 23.66 percent, BP_2 14.35 percent, BP_1 9.93 percent yield increase over OP treatment, and the yield increase was 45.66 percent, 34.70 percent and 29.49 percent in BP_3, BP_2 and BP_1 over PE treatments, respectively. The maximum enhancement of fruit yield (160.82%) compared to open pollination without honey bee hives was recorded in the trees nearest (25 m) to *A. mellifera* bee colonies [14]. Similar pattern of result in Assam lemon and confirmed that honey bee treated plots showed the highest fruit set (77%) compared to (46%) in naturally open pollinated crop [6]. Maximum yield of Assam lemon was obtained in bee pollination treatment (48.88 tonnes/ha) against 32.89 tonnes/ha in without bee pollination and 44.05 tonnes/ha in open pollination treatment. There was 89.45% yield increase of Assam lemon in bee pollination treatment over without bee pollination [7].

Table 1: Diversity of insect foragers of mango flowers.

S. No	Common name	Scientific name	Order	Family	% relative abundance
1.	Indian bee	*Apis cerana* F.	Hymenoptera	Apidae	46.66
2.	Western bee	*Apis mellifera* L.	Hymenoptera	Apidae	8.00
3.	Little bee	*Apis florea* F.	Hymenoptera	Apidae	7.00
4.	Wasp	*Vespa magnifica* (Smith)	Hymenoptera	Vespidae	8.00
5.	Ant	*Oecophylla smaragdina* F.	Hymenoptera	Formicidae	3.33
6.	Syrphid fly	*Episyrphous balteatus* (Degeer)	Diptera	Syrphidae	8.00
7.	House fly	*Musca domestica* L.	Diptera	Muscidae	6.00
8.	Blowfly	*Chrysomya megacephala* F.	Diptera	Calliphoridae	6.66
9.	Ladybird beetle	*Coccinella septempunctata* L.	Coleoptera	Coccinelidae	5.00
10.	Cabbage butterfly	*Pieris rapae* L.	Lepidoptera	Pyrallidae	2.66
11.	Lemon butterfly	*Papilio demoleus* L.	Lepidoptera	Papilionidae	1.33

Table 2: Foraging behaviour of *Apis cerana* on mango.

Time of observation (Hrs)	No of *Apis cerana*/ sq.m/ min (±SE)	Frequency of floret visited/min (±SE)	Time spent/ floret(sec.) (±SE)
0600-0700	02.75 ± 0.22	09.30±0.15	05.15 ± 0.12
0700-0800	03.30 ± 0.27	11.12±0.19	05.66 ± 0.06
0800-0900	08.60 ± 0.17	09.03±0.09	05.94± 0.07
0900-1000	09.75 ± 0.25	11.64±0.23	06.48 ± 0.06
1000-1100	08.75 ± 0.15	06.94±0.07	05.83 ± 0.10
1100-1200	08.30 ± 0.18	07.54±0.12	05.43 ± 0.08
1200-1300	05.85 ± 0.21	08.09±0.12	05.00 ± 0.09
1300-1400	01.90 ± 0.16	03.49±0.06	04.15 ± 0.08
1400-1500	03.05 ± 0.11	05.92±0.10	05.21 ± 0.07
1500-1600	02.90 ± 0.14	05.42±0.15	04.68± 0.08
1600-1700	02.30 ± 0.15	04.52±0.04	04.56±0.08
Mean	04.59 ± 0.18	07.26±0.12	05.25 ± 0.08

Mean of 10 observations

Table 3: Number of flower visit/trip by *Apis cerana* on mango.

Time of observation (hr)	No of flower visit/trip	Pollen load per trip (mg)
0600-0700	219.50±3.34	04.15±0.0.30
0700-0800	235.75±2.02	04.65±0.45
0900-1000	264.00±1.41	05.22±0.0.46
1000-1100	257.37±1.25	05.98±0.50
1100-1200	235.00±2.04	03.92±0.0.32
1200-1300	170.62±4.21	03.25±0.26
1300-1400	135.85±1.93	02.31±0.12
1400-1500	182.00±2.64	03.17±0.17
1500-1600	154.75±3.42	02.39±0.15
Mean	206.13±3.21	03.54±0.30
S.Ed±	3.91	0.47
CD (P=0.05)	8.53	0.91

Table 4: Effect of *Apis cerana* pollination on fruit set of mango.

Treatments	Flower/branch (±SE)	Flower/plant (±SE)	Fruit/branch	Fruit/plant	Fruit set (%)
PE	71.62 ± 0.55	362.87 ±0.62	11.25 ±0.14	112.62 ± 0.96	31.03
OP	81.62 ± 0.62	371.25 ±0.75	20.87 ±0.62	123.87 ± 0.55	33.36
BP_1	90.62 ± 0.37	378.25 ± 0.52	26.50 ±0.54	149.37 ± 0.37	39.48
BP_2	98.25 ± 0.32	382.25 ± 0.75	30.37 ±0.87	158.37 ± 0.51	41.43
BP_3	112.12 ± 0.37	388.00 ± 0.54	32.87 ±0.37	164.12 ± 0.37	42.29
Mean	90.85 ± 0.45	376.52 ± 0.63	24.37 ±0.51	141.67 ± 0.55	
S.Ed±	0.65	0.90	0.78	0.76	
CD (P=0.05)	1.43	1.98	1.72	1.67	

Mean of 4 observations

PE- Pollinator exclusion; OP- Open pollination; BP_1- Bee pollination 1 (BP_1) @ 3 hives/ha; BP_2- Bee pollination 2 (BP_2) @ 5 hives/ha; BP_3- Bee pollination 3 (BP_3) @ 7 hives/ha

Table 5: Effect of *Apis cerana* pollination on yield of mango.

Treatments	Yield/ plant (kg) (±SE)	Yield/ha (q) (±SE)	Yield increase over PE (%)	Yield increase over OP (%)
PE	14.75 ± 0.47	58.18 ± 0.70	-	-
OP	23.06 ± 0.48	68.53± 0.21	17.7	-
BP_1	26.56± 0.20	75.34 ± 0.31	29.49	9.93
BP_2	30.12 ± 0.16	78.37 ± 0.51	34.70	14.35
BP_3	33.38 ± 0.67	84.75± 0.77	45.66	23.66
S.Ed±	0.63	0.65		
CD (P=0.05)	1.38	1.42		

Mean of 4 observations

PE- Pollinator exclusion; OP- Open pollination; BP_1- Bee pollination 1 (BP_1) @ 3 hives/ha; BP_2- Bee pollination 2 (BP_2) @ 5 hives/ha; BP_3- Bee pollination 3 (BP_3) @ 7 hives/ha

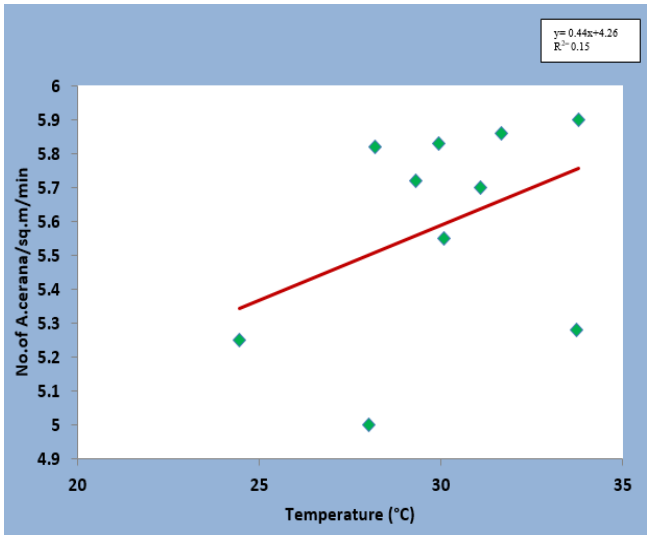

Fig 1: Relationship of temperature (°C) with number of *Apis cerana* VISIT on mango

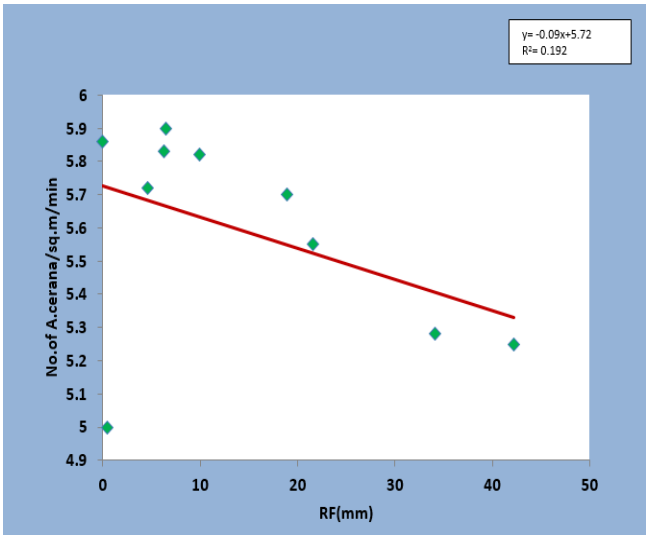

Fig 3: Relationship of Rainfall (mm) With Number OF *Apis cerana* visit on Mango

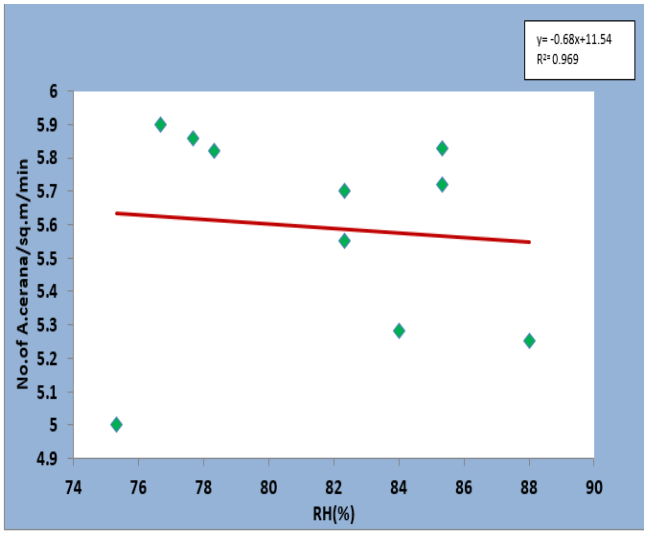

Fig 2: Relationship of Relative humidity (%) with number of *Apis cerana* VISIT on MANGO.

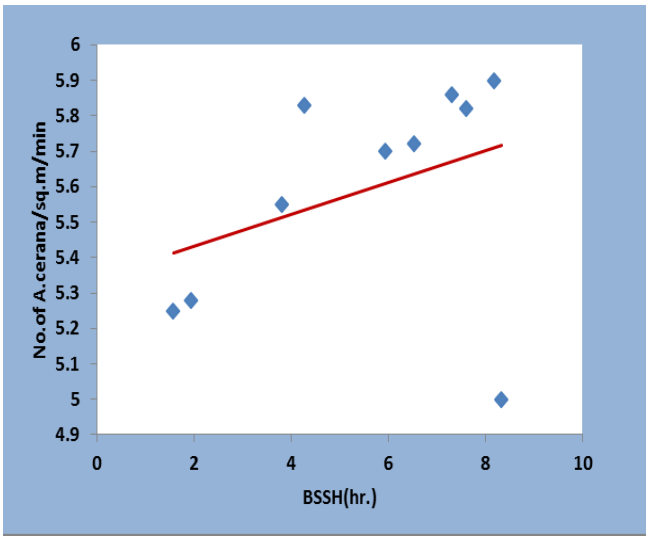

Fig 4: Relationship of B.S.S.H with number of *Apis cerana* visit on Mango.

4. Conclusion

The results of the investigation revealed that *Apis cerana* was the most dominant as well as much more efficient pollinator of mango compared to other insects. The fruit set and yield of mango increased significantly in 7 bee hive/ha followed by 5 bee hive/ha plot due to its very high pollination efficiency.

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