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FORAGING BEHAVIOUR AND POLLINATION EFFICIENCY OF FLORAL VISITORS ON EGYPTIAN CLOVER, *TRIFOLIUM ALEXANDRINUM* L.

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SUMMARY

The foraging behaviour and pollination efficiency of floral visitors on Egyptian clover, *Trifolium alexandrinum* was conducted at Forage Section, Department of Genetics and Plant Breeding, CCS, Haryana Agricultural University, Hisar during 2012 and 2013. The maximum foraging rate was recorded in N+P (nectar+pollen) foragers of *Apis dorsata* (7.2 flowers/min.), P (pollen) forager of *Apis florea* (7.2) and *Apis mellifera* (7.1) followed by pollen (6.3), least in nectar forager of *A. dorsata* (5.1) and *A. mellifera* (5.5). The maximum foraging speed was recorded in nectar forager *A. dorsata* (22.4 seconds/flower) followed by its pollen foragers (19.0). The *A. mellifera* foragers were recorded with minimum foraging speed for nectar+pollen (4.6 seconds/flower), pollen (4.9) and nectar (7.4). The larger bodied *A. dorsata* carried the maximum loose pollen grains (LPG) on their body (79,625) while the smallest species *A. florea* had minimum capacity (36,375) and the medium sized *A. mellifera* was recorded with intermediate capacity (73,250). On the basis of relative pollination efficiency (RPE), *A. dorsata* was the most efficient pollinators (16.4) of *T. alexandrinum* flowers followed by the pollen foragers (13.3).

Key words : Pollination efficiency, pollination index, foraging behaviour, Egyptian clover

Egyptian clover, *Trifolium alexandrinum* L. called *berseem* (Family Leguminaceae), is one of the most entomophilic crop requiring insects, especially bees for cross pollination. When insect visits the flower for floral rewards, they exert sufficient pressure on the standard and wing petals, as a result the stigma and anthers protrude from the keel petals with a jerk, "tripping" the anthers and releasing the pollen grains on to the stigma. As soon as the insect leaves after obtaining the reward thus, releasing the pressure, the flower returns to their former position inside the keel. During tripping, the anthers and stigma are pressed against the underside of a visiting pollinator's head and sternum where pollen gets attached. When such visitors visit another flower, they effect pollination. Adverse climatic changes related primarily to temperature and humidity affect forage yield and consequently accelerate flowering, resulting in low pollinator visitors and low seed setting. Field activity of bees was affected more by wind speed than by air temperature and relative humidity *A. florea* was reported to be the most efficient tripper of flowers and was least affected by weather conditions and was followed by *Megachile flavipes*, *P. smaragdula*, *A. mellifera* and *A. dorsata*. Thakur (2007) reported a correlation between insect visits, temperature and relative humidity. High temperature during flowering had negative effects on egg-laying (by queen), bee foraging activity and nectar secretion in Egyptian clover flowers Alghoson (2004) recommended pollen supplementary feeding for colonies during summer season.

MATERIALS AND METHODS

Foraging behaviour of honey bee foragers

Based on the abundance and frequency of floral visitors of *T. alexandrinum* as further quantified statistically, the most frequent honey bee species were further studied for their foraging behaviour that could contribute to actual pollination process (Plate 1). Using both these inputs, these probable insect pollinators were further grouped into:

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Plate 1. Working behaviour of honey bee foragers on *T. alexandrinum* flowers.

Nectar foragers (N)/side workers : The foraging groups that visited *T. alexandrinum* flowers only for nectar rewards and were designated as N foragers.

Pollen foragers (P)/top workers : The foraging groups that visited *T. alexandrinum* flowers only for pollen rewards and were designated as P foragers.

Nectar and pollen foragers (N+P)/side and top workers : The foraging groups that visited *T. alexandrinum* flowers for both nectar and pollen rewards and were designated as N+P foragers.

To select important insect pollinators, their abundance data was statistically analyzed. Different aspects of foraging behaviour of different forager groups (N, P and N+P) were further recorded visually that included observations on alighting, reward gathering and departure movements. In addition, observations on the body contacts of foragers with anthers and/or stigma (top or side workers) were also recorded. A total of 25 individuals each for N, P and N+P foragers of each species were observed.

Pollination efficiency (PE) of honey bee species on *T. alexandrinum*

The pollination efficiency of respective foragers groups of three different honey bee species was analyzed using the method of Bohart and Nye (1960) as modified by Nagar and Chaudhary (2005). Following aspects were recorded:

Foraging rate

The foraging rate of different forager groups of the honey bee species was recorded in terms of number of flower visited per minute for floral rewards. It included the handling time and the time taken by the bee to move to the next flower (i.e. the hovering time but not the flight time between two flowers). The number of flowers visited per minute by a honey bee constituted one bee observation. In all, 25 bee observations were made for N, P and N+P foragers of each species of honey bees.

Foraging speed

The foraging speed of different forager groups was recorded in terms of time spent by them on each flower for floral rewards viz. N, P and N+P, separately. The time spent by a honey bee on 5 different flowers was recorded and the average was taken as one bee observation. In all, 25 bee observations were made for N, P and N+P foragers of each species of honey bees.

Loose pollen grains carrying capacity

The nectar, pollen and nectar+pollen foragers of three honey bee species were captured on the flowers gently with the help of a pair of forceps while foraging and preserved in glass vials (15ml capacity) containing 70 per cent ethanol. The hind legs of pollen foragers along with the pollen loads were amputed with the help of a pair of scissors before preservation while the nectar and nectar+pollen foragers were captured with their legs intact. Each group was separately placed in the marked vials that contained information on the type of honey bee species, reward group, replication, etc. These vials were then taken to the Apicultural Laboratory and stored in the freezer for further analysis at a later date. For analysis the vials after remove up from the freezer were kept at room temperature to liquefy the contents. The vials were then shaken thoroughly to remove the loose pollen grains sticking on the body of honey bees. Total volume of the rinsate was made to 3 ml before pollen

count. An aliquot of 0.01 ml (replicated 5 times) was taken and with the help of haemocytometer and binocular microscope (10x15 magnifications) the number of pollen grains were counted. Total number of pollen grains were calculated in the whole rinsate.

Pollination efficiency (PE) of honey bee species

The pollination efficiency of different foragers groups (N, P and N+P) of three honey bee species was assessed on the basis of their relative abundance and foraging behaviour parameters including foraging rate, foraging speed and the amount of loose pollen grains sticking on their bodies as per Bohart and Nye, 1960 as modified by Nagar and Chaudhary, 2005. This method was reported to be the more reliable for judging the effectiveness of an insect as pollinator. Accordingly, following ranks were given:

I. The maximum number of flowers visited per minute by a forager group was given the highest rank and vice-versa.
II. The minimum time spent per flower by a forager group was given the highest rank and vice-versa.
III. The forager group carrying maximum number of loose pollen grains on their body was given the highest rank and vice-versa.

The ranks were assigned on the basis of statistical analysis of the data on a 0-5 scale. Mid scores was assigned to the values statistically non-significant from both the lower and higher values for attributes. Average efficiency ratings thus, obtained was multiplied by the mean population abundance of each foraging group in order to obtain the pollination index (PI).

Pollination Index (PI)=Mean pollination efficiency (PE) x Mean abundance

RESULT AND DISCUSSION

Working behaviour of honey bee foragers on *T. alexandrinum* flowers:

Nectar foragers (N)/side workers : All the three honey bee species (*A. dorsata*, *A. mellifera* and *A. florea*) exhibited side working behaviour with minor variations. *A. dorsata* and *A. mellifera* foragers after landing on the side of flower, gripped florets with forelegs, inserted its proboscis into corolla and foraged for nectar. After reward gathering from a flower, it departed mainly from the side of flower, but sometimes from top of flower also to the adjacent floret or new flower. *A. florea* foragers however, landed mainly on the side of flowers but sometimes on top of flowers too but departed mainly from top and occasionally from side of flowers. Side working honey bees collected only nectar through the side of flowers, acting as nectar thieves and their body parts don't come in contact with reproductive parts of *T. alexandrinum* flowers. The results are supported by Sihag (1988) who found a proportion of *A. florea* and *A. mellifera* population exhibiting side working behavior. However, according to Singh *et al.* (2012) the percentage of nectar foragers was much higher for *A. dorsata* (82.50%) and *A. cerana* (91.61%) than *A. mellifera* (58.15%) and Nectar foraging on *T. alexandrinum* was also reported by (Chowdhury *et al*., 1966, while Singh *et al.* (2012) reported that bees preferred nectar than pollen.

Pollen foragers (P)/top workers : All the three species also acted as top workers collecting pollen from noon till evening. *A. dorsata* and *A. mellifera* foragers reached top portion of flower after alighting either here or on petals or leaves. While retaining bulk of its body on the top of flowers with their hind legs, it directed her head towards the florets with dehisced pollen grains and made fast circular movements on the anther ring with their forelegs and head. It sometimes even nibbled the anthers and pollen. By exerting their body weight on the standard and keel of the floret, foragers "jerk-open" the reproductive column making stigma and anthers to protrude from the keel petals with a jerk. In the process, their ventral body parts get pressed with anther and stigma and get dusted with pollen grains. The subsequent movement of these foragers to next floret allows the transfer of this pollen onto the stigma of the flower resulting in pollination. This is termed as "jerk-pollination" and also as strenotribic mode of pollen collection. Foragers departed to adjacent floret on the same plant or another plant from top portion either walking or taking to wings. The pollen grains are periodically combed and packed onto its corbiculae. Similar pattern was followed by *A. florea* but at relatively faster speed. In top working, forger's body always "tripped" the flowers, touched the anthers and stigma fully and are thus, termed as "pollinators". These studies are in line with many who reported pollen foraging

behaviour by honey bees (Chowdhury *et al*., 1966; Sihag, 1988. The typical "tripping" or "jerk pollination" behavior has also been reported by many workers (Chowdhury *et al*., 1966).

Nectar and pollen foragers (N+P)/side and top workers : Both side and top foraging behaviour is exhibited by a proportion of population of all the three honey bee species viz. *A. dorsata*, *A. mellifera* and *A. florea*. The side workers alight on the petals, hold florets with their hind legs and inserted the proboscis through the corolla tube and foraged for nectar only from a few florets and then make irregular movements on the top of flower working as top workers (as explained above) on a sequence of florets. Though such movements are directed for nectar foraging, but in the process they get dusted with pollen grains which are collected and packed into corbiculae. Subsequent movements to next florets result in jerk-pollination or tripping, affecting pollination. These findings are aptly supported by many studies who reported tripping by honey bees while foraging for nectar (Chowdhury *et al*., 1966; Dhanda, 1998; Singh *et al.*, 2012). Singh *et al*. (2012) further reported the engagement of higher percentage of *A. mellifera* bees for nectar (58.15%) than pollen (4.09%) and nectar + pollen foragers (37.76%). However, in case of *A. dorsata* and *A. florea* highest proportion was for nectar (82.50 and 91.61%) and relatively lower for both nectar + pollen rewards (17.50 and 8.39%, respectively).

Pollination efficiency (PE) of honey bee species on *T. alexandrinum*

Foraging rate of different honey bee foragers : The mean foraging rate varied greatly across honey bees species and floral rewards (Table 1, 2, 3). Among the rewards, it was maximum for pollen and nectar+pollen (6.9 and 6.8 flowers/minute, respectively) and minimum for nectar foraging (5.5 flowers). Free (1993) while confirming that foraging rate is dependent upon the type of resource observed that for nectar foraging it was 6 and for pollen 16-20 flowers/min., while Benedek, (1976).

For the honey bee species, the maximum foraging rate was recorded for *A. florea* and *A. mellifera* (6.6 and 6.4 flowers/min., respectively) followed by *A. dorsata* (6.2) that was similar to *A. mellifera*. The findings are in contrary to Shivrana (1996) who recorded higher foraging rate for *A. dorsata* (28.24 flowers/min) followed by *A. mellifera* (23.58) and *A. florea* (11.99) and also by Abrol (1985) who also recorded almost similar values for *A. dorsata* (28.42) and *A. florea* (12.27). Similar results but with significantly lower values - 8.20 for *A. mellifera* followed by *A. dorsata* (3.70) and *A. florea* (3.60) were also reported by Dhanda (1998).

While considering these values for interactions among floral rewards and honey bees, the N+P foragers of *A. dorsata*; P foragers of *A. florea* and *A. mellifera* recorded maximum foraging rate (7.2, 7.2 and 7.1, respectively) followed by N+P foragers of *A. mellifera* and *A. florea* and P foragers *A. dorsata* (6.7, 6.6 and 6.3, respectively). The nectar foragers of *A. dorsata* (5.1), *A. mellifera* (5.5) and *A. florea* (5.9) visited minimum number of flowers/ minute. Considering the trend of reward preference among the honey bee species, *A. mellifera* and *A. florea* foraged more number of flowers/ minute for pollen (7.1 and 7.2) followed by N+P (6.7 and 6.6) and least for nectar (5.5 and 5.9 flowers/minute, respectively) while for *A. dorsata* maximum foraging rate was recorded for N+P (7.2), followed by P (6.3) and least for nectar foraging (5.1). Free, (1993) attributed greater value of pollinators to their longer tongue length.

Foraging speed of different honey bee foragers : The foraging speed of honey bees (Table 4, 5, 6) was significantly higher in 2013 as it spent longer time (15.0 seconds/flowers) on *T. alexandrinum* flowers to collect different rewards compared to only 11.4 seconds during 2012. Foragers of different honey bee species spent maximum time to collect nectar (15.0 seconds/flower) and pollen (13.7 seconds) than foraging for both the rewards concurrently i.e. N+P (11.0). The mean overall foraging speed was maximum for *A. dorsata* (17.9 seconds) followed by *A. florea* (16.1) and the minimum for *A. mellifera* (5.6 seconds/flower). These results are in contrast with Dhanda (1998) from the same location (Hisar) who reported *A. florea* with highest foraging speed (15.24/second) followed by *A. dorsata* (11.46) and *A. mellifera* (8.58). Shivrana (1996) again from the same location reported higher foraging speed for *A. florea* but with a drastically reduced value of only 4.93 seconds/flower while *A. dorsata* recorded lowest (2.01 seconds) and the *A. mellifera* securing second position with a foraging speed of only 2.41 seconds/ flower. He further observed shortest forging speed for *A. dorsata*, *A. mellifera* and *A. florea* at 1200, 1400 and again 1400 h, respectively, and the longest being at 1900

TABLE 1
Foraging rate of different honey bee foragers on *T. alexandrinum* during different years

Honey bee species	Mean foraging rate (No. of flowers visited/min) of forager groups							
	2012				2013			
	Nectar	Pollen	Nectar+Pollen	Mean	Nectar	Pollen	Nectar+Pollen	Mean
A. dorsata	5.0*	6.1	7.4	6.2	5.2	6.5	7.1	6.3
A. mellifera	7.0	6.8	6.6	6.8	4.0	7.5	6.8	6.1
A. florea	5.3	7.0	7.0	6.4	6.5	7.3	6.3	6.7
C. D. (P<0.05)		0.6		0.4		0.6		0.4
S. Em		0.2		0.1		0.2		0.1
Mean	5.8	6.6	7.0		5.2	7.1	6.7	
C. D. (P<0.05)		0.4				0.4		
S. Em		0.1				0.1		

Values are the mean of 25 observations.

TABLE 2
Mean foraging rate of different honey bee foragers during different years on *T. alexandrinum*

Foragers	Mean foraging rate (No. of flowers visited/ min) forager groups		
	2012	2013	Mean
Nectar	5.8*	5.2	5.5
Pollen	6.6	7.1	6.9
Nectar+Pollen	7.0	6.7	6.8
C. D. (P<0.05)	0.4		0.3
S. Em	0.1		0.1
Mean	6.5	6.4	
C. D. (P<0.05)	NS		
S. Em	0.1		

Values are the mean of 75 observations.

TABLE 3
Mean foraging rate of different honey bee foragers on *T alexandrinum*

Honey bee species	Mean foraging rate (No. of flowers visited/ minute) of forager groups			
	Nectar	Pollen	Nectar+Pollen	Mean
A. dorsata	5.1	6.3	7.2	6.2
A. mellifera	5.5	7.1	6.7	6.4
A. florea	5.9	7.2	6.6	6.6
C. D. (P<0.05)		0.4		0.3
S. Em		0.1		0.1
Mean	5.5	6.9	6.8	
C. D. (P<0.05)		0.3		
S. Em		0.1		

Values are the mean of 50 observations.

h for all the honey bee species as also reported by Abrol (1985). In red clover (*T. pretense*), Palmer *et al*. (1966) recorded higher foraging speed for *A. mellifera* and short-tongued bumble bees, *B. terristris* (3.0 and 2.8 sec/ flower, respectively) than the long-tongued bumble bees, *B. ruderatus* (2.0 sec/flower).

The nectar foragers of *A. dorsata* spent maximum time on flowers (22.4 seconds) followed by its pollen gatherers (19.0 seconds/flower) and was further followed by pollen, N+P and nectar foragers of *A. florea* (17.3, 15.9 and 15.2 seconds, respectively) with moderate foraging speed. However, the N+P, pollen and nectar foragers of *A. mellifera* recorded the lowest foraging speed (4.6, 4.9 and 7.4 seconds, respectively). The pattern of foraging speed in *A. dorsata* and *A. mellifera* was similar but of significantly higher amplitude in *A. dorsata* (about 3 times that of *A. mellifera*), the nectar gatherers spending maximum time followed by pollen and N+P foragers. *A. florea* on the other hand, recorded maximum foraging speed (but with almost similar time periods) for pollen foragers, followed by N+P and nectar foragers and their values being significantly higher than the *A. mellifera*. Such studies on intra and inter- specific forager groups of honey bee species are not reported in the literature.

Loose pollen grains sticking on the body of different honey bee foragers : In *T. alexandrinum*, the *A. dorsata* foragers carried maximum numbers of loose pollen grains (LPG) on their body (79,625) and were followed by *A. mellifera* foragers that carried 73,250 LPG (Table 7, 8, 9). *A. florea* on the other hand, carried the lowest LPG (36,375) and these observations find support from Sharma and Singh (2003) but they reported miniscule values (8,125 each) for *A. dorsata* and *A. mellifera* and a mere 4,625 for *A. florea*. This LPG bearing capacity varied over the study period also and during 2012 lower LPG were recorded on honey bee bodies (60,083) than 2013 when its value was higher at 66,083. The maximum LPGs were carried by pollen foragers (69,750) while significantly smaller loads were carried by the nectar and N+P foragers carried (60.375

TABLE 4
Foraging speed of different honey bee foragers on *T. alexandrinum* during different years

Honey bee species	Mean foraging speed (time spent/flower) of forager groups (seconds)							
	2012				2013			
	Nectar	Pollen	Nectar+Pollen	Mean	Nectar	Pollen	Nectar+Pollen	Mean
A. dorsata	16.2*	15.3	11.8	14.4	28.7	22.7	12.9	21.4
A. mellifera	7.7	4.8	4.5	5.7	7.1	5.0	4.8	5.6
A. florea	15.9	12.8	14.0	14.2	14.5	21.8	17.8	18.0
C. D. (P<0.05)		2.0		1.2		5.1		3.0
S. Em		0.7		0.4		1.8		1.1
Mean	13.3	11.0	10.1	11.4	16.7	16.5	11.8	15.0
C. D. (P<0.05)		1.2				3.0		
S. Em		0.4				1.1		

Values are the mean of 25 observations.

TABLE 5
Mean foraging speed of different honey bee foragers during different years on *T. alexandrinum*

Foragers	Mean foraging speed (time spent/flower) of forager groups (seconds)		
	2012	2013	Mean
Nectar	13.3	16.7	15.0
Pollen	11.0	16.5	13.7
Nectar+Pollen	10.1	11.8	11.0
C. D. (P<0.05)	NS		1.6
S. Em	0.8		0.6
Mean	11.4	15.0	
C. D. (P<0.05)	1.3		
S. Em	0.5		

Values are the mean of 75 observations.

TABLE 6
Mean foraging speed of different honey bee foragers on *T. alexandrinum*

Honey bee species	Mean foraging speed (time spent/flowers) of forager groups (seconds)			
	Nectar	Pollen	Nectar+Pollen	Mean
A. dorsata	22.4*	19.0	12.4	17.9
A. mellifera	7.4	4.9	4.6	5.6
A. florea	15.2	17.3	15.9	16.1
C. D. (P<0.05)		2.7		1.6
S. Em		1.0		0.6
Mean	15.0	13.7	11.0	
C. D. (P<0.05)		1.6		
S. Em		0.6		

Values are the mean of 50 observations.

and 59,125, respectively) and these results are supported by many who also reported that the pollen gatherers tend to have larger amount of loose pollen grains than nectar gatherers (Kumar *et al.*, 1985; Free, 1993).

The present results clearly revealed to correlate the loose pollen grain carrying capacity of selected honey bee species with their body size. The larger bodied *A. dorsata* carried the maximum while the medium *A. mellifera* carried intermediate loads and the smallest *A. florea* carried the minimum load and are in line with those of Sharma and Singh (2003).

Relative pollination efficiency of different foragers groups of different honey bee species : *A. dorsata* honey bees were the most efficient pollinators of *T. alexandrinum* with the mean maximum RPE of 13.0 followed by *A. mellifera* (10.7) and the *A. florea* was the least efficient with the RPE as low as 3.6. The other important observation emerging from the results are that the honey bees foraging for both the rewards i.e. nectar + pollen (10.2) and pollen alone (9.8) were most efficient in pollinating flowers compared to those foraging for nectar alone with an RPE of only 7.2. The foraging behavior adopted by the pollen foragers by working as top workers and affecting "jerk-pollination" or "tripping" worked in their favour compared to the nectar foragers who worked as side workers (nectar thieves) avoiding contact with reproductive column of flowers.

The N+P forgers of *A. dorsata* with the highest RPE value of 16.4 were thus, its most efficient pollinators followed by pollen foragers (13.3). In order of RPE, *A. mellifera* pollen and N+P foragers followed it with the values of 12.1 and 11.0, respectively. *A. florea* N+P and nectar foragers however, were the least efficient with RPE of 3.3 while its pollen foragers also had a very low RPE value of 4.1. No specific trend however, was observed among various foragers groups of three honey bee species. An interesting observation was the lower RPE values for the year 2013 compared to 2012 and it is mainly on account for the lower mean abundance of floral visitors

TABLE 7
Mean number of loose pollen grains of *T. alexandrinum* sticking on the bodies of different honey bee foragers

Honey bee species	Mean number of loose pollen grains sticking on the bodies of different honey bee foragers during different years								Overall mean
	2012				2013				
	Nectar	Pollen	Nectar+Pollen	Mean	Nectar	Pollen	Nectar+Pollen	Mean	
A. dorsata	75000*	89250	71250	78500	72750	91500	78000	80750	79625
A. mellifera	69750	78750	69000	72500	69750	75000	77250	74000	73250
A. florea	33000	36000	18750	29250	42000	48000	40500	43500	36375
C. D. (P<0.05)		NS		7601		NS		6469	4945
S. Em		4670		2696		3975		2295	1770
Mean	59250	68000	53000	60083	61500	71500	65250	66083	
C. D. (P<0.05)		7601					6469		
S. Em		2696					2295		

Values are the mean of 30 observations. NS–Not Significant.

TABLE 8
Mean number of loose pollen grains sticking on the bodies of different honey bee foragers during different years

Foragers	Mean number of loose pollen grains sticking on the bodies of different honey bee foragers		
	2012	2013	Mean
Nectar	59250*	61500	60375
Pollen	68000	71500	69750
Nectar+Pollen	53000	65250	59125
C. D. (P<0.05)	NS		4945
S. Em	2504		1770
Mean	60083	66083	
C. D. (P<0.05)	4037		
S. Em	1446		

Values are the mean of 30 observations. NS–Not Significant.

TABLE 9
Overall mean number of loose pollen grains sticking on the bodies of different honey bee foragers

Honey bee species	Mean number of loose pollen grains sticking on the bodies of different species of honey bee foragers			
	Nectar	Pollen	Nectar+Pollen	Mean
A. dorsata	73875*	90375	74625	79625
A. mellifera	69750	76875	73125	73250
A. florea	37500	42000	29625	36375
C. D. (P<0.05)		NS		4945
S. Em		3.066		1770
Mean	60375	69750	59125	
C. D. (P<0.05)		4945		
S. Em		1770		

Values are the mean of 20 observations. NS–Not Significant.

TABLE 10
Relative pollination efficiency of different forager groups of honey bee species

Honey bee species	2012			2013		
	Nectar	Pollen	Nectar+Pollen	Nectar	Pollen	Nectar+Pollen
A. dorsata	11.4	16.3	20.4	7.2	10.3	12.3
A. mellifera	10.3	12.1	10.8	7.8	12.2	11.3
A. florea	2.2	3.8	2.8	4.3	4.3	3.8

in general (19.61 and 17.94 bees/m^2/5minute, respectively) and *A. dorsata* in particular (4.90 and 3.08 bees/m^2/5minute, respectively). Though *A. florea* abundance was higher in 2013, but it could not compensate for the lower proportion of *A. dorsata*, being predominantly nectar foragers, thus relatively poor pollinators.

In the descending order of values of RPE, the value of various honey bee foragers groups worked out as: *A. dorsata* (N+P) > *A. dorsata* (P) > *A. mellifera* (P) > *A. mellifera* (N+P) > *A. dorsata* (N) > *A. mellifera* (N) > *A. florea* (P) >*A. florea* (N+P) = *A. florea* (N).

It is abundantly clear from the results that *A. dorsata* was the most efficient pollinators of *T. alexandrinum* flowers and its nectar + pollen foragers were vividly the most efficient pollinators with an RPE of 16.4 followed closely by its pollen forager with an RPE of

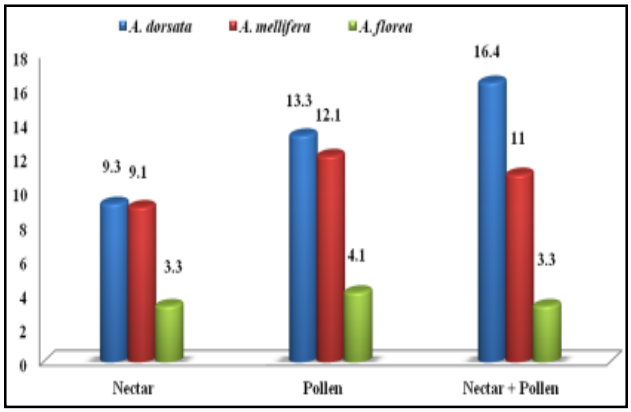

Fig. 1. Mean relative pollination efficiency of different forager groups of honey bee species.

13.3. Sharma and Singh (2003) following a different method, reported highest pollination index for *A. dorsata* (53,194), moderate for *A. mellifera* (36,083) and the lowest (7,021) for *A. florea* and described *A. dorsata* as the most efficient pollinator followed by *A. mellifera* and *A. florea.* In contrast, Dhaliwal and Atwal (1976) reported tripping efficiency of insect visitors of *T. alexandrinum* in order of *A. florea* > *Megachile flavipes* > *Ptithitis smargdula* >*A. mellifera* > *A. dorsata*.

A. dorsata forager's agility reflected in their higher loose pollen grain carrying capacity (79,625), moderate foraging rate (6.2 flower/min), maximum foraging speed (17.9 second/ flower) and higher mean population (4.90 bees/ m^2/5minute, respectively) from the feral colonies that made them far more efficient pollinators than any other honey bee species. *A. mellifera* on the other hand recorded highest rank in foraging speed (5.6 second/flower), moderate foraging rate (6.4 flower/min), moderate loose pollen grain carrying capacity (73,250) and medium population (2.69 bees/m^2/ 5minute) from managed hives. It appears that the *A. dorsata* by its virtues are better pollinators of *T. alexandrinum* in particular and legumes in general but their absolute values in a locality will always be dynamic in response to their migrated population (hives density, destruction by humans, etc.). The second best pollinator, despite some of its inherent defects, has an advantage that its population can be enhanced (in absence of *A. dorsata* and other natural pollinators) by managed pollination by human beings.

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REFERENCES

Abrol, D.P. 1985: Analysis of biophysical interaction in causing foraging behavior of some bees- A study in bioenergetics. Ph.D. Thesis submitted to CCS Haryana Agricultural University, Hisar, India.

Alghoson, N.I. 2004: Bees and honey plants in Saudi Arabia, *Arabic*, pp.184.

Bohart, G.E. and Nye, W.P. 1960: Insect pollinators of carrot in Utah. *Bulletin of Utah Agric. Experi. station*, pp. 419.

Chowdhury, J.B., Mehta, R.K. and Joshi, A.B. 1966: Pollination in Berseem. *Indian J. Genet. and Pl. Breeding*, **26**: 118-120.

Dhaliwal, J.S. and Atwal A.S. 1976: Note on the effect of air temperature, relative humidity and wind velocity on bees visiting berseem at Ludhiana. *Indian J. Agric. Sci.*, **46:** 50-51.

Dhanda, J.S. 1998: Abundance and foraging behavior of wild bees on different crops. M.Sc. Thesis submitted to CCS, Haryana Agricultural University, Hisar, Haryana, India.

Free, J.B. 1960: The behaviour of honeybees visiting the flowers of fruit trees. *J. Animal Eco.*, **29**: 385-395.

Free, J.B. 1993: Insect pollination of crops. Academic Press, London, UK, pp. 684.

Kumar, J., Mishra, R.C. and Gupta, J.K. 1985. The effect of mode of pollination on *Allium* species with observation as pollinators. *J. Apicul. Res.*, **24**: 62-66.

Nagar, P. and Chaudhary, O.P. 2005: Relative pollination efficiency of *Apis cerana* F. and *Apis mellifera* L. in strawberry. *Korean J. Apicul.*, **20**: 151-158.

Palmer, J.T., Forster, I.W. and Clinch, P.G. 1966: Observations on the pollination of Montgomery red clover (*Triflolium pratense* L.). *Newzeland J. Agric. Res.*, **9:** 738-747.

Sharma, S.K. and Singh, J.R. 2003: Pollination efficiency of *Apis sp.* on Egyptian clover (*Trifolium alexandrinum* L.) *Forage Res.*, **28**: 218-219.

Shivrana, S. 1996: Studies on foraging dynamics of some *Apis* sp. Ph.D. Thesis submitted to CCS, Haryana Agricultural University, Hisar, Haryana, India.

Singh, J., Yadav. S. and Chhuneja, P.K. 2012: Quantitative and qualitative enhancement in *Trifolium alexandrium* seed production through pollination by *Apis mellifera*. *Indian J. Appli. Entom.*, **26**: 50-53.

Thakur, S.S. 2007: Effect of ecological conditions on bee behaviour on different crops at Pantnagar, Uttrakhand. *J. Entomo. Res.*, **31**: 247-250.