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FORAGING SPEED OF CASTOR POLLINATORS

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ABSTRACT

The collected amount of nectar and pollen by the insect pollinators mainly depends upon the time spent on individual flowers referred to as the foraging speed. An experiment conducted at Department of Entomology, CCS Haryana Agricultural University, Hisar, Haryana evaluated the foraging speed of different insect pollinators on flowers of castor *Ricinus communis* cv. GCH-7 and DCH-177. *Apis cerana* F. was observed with maximum foraging speed (6.26 sec/ flower) followed by *Apis mellifera* L. (5.12 sec/ flower), *Apis dorsata* F. (4.20 sec/ flower), *Apis florea* F. (3.74 sec/ flower). The least foraging speed was observed with *Xylocopa iridipennis* Lepeletier (2.67 sec/ flower). Data taken at different time interval in a day indicated that the peak foraging speed of pollinators is between 10.00- 12.00 hr, while the least one was at 16.00-18.00 hr.

Key words: Castor, *Ricinus communis*, pollinators, foraging speed, honey bees, *Apis* spp., *Xylocopa iridipennis*, peak activity, foraging behaviour

Plant-pollinators relationship has been the subject of great interest to many pollination biologists. Honey bees are the principal pollinators in horticultural and agricultural crops. Yield of crops mainly depends upon insect mediated pollination which increases significantly with pollinators diversity and their visiting rates as well as foraging speed of pollinators (Eeraerts et al., 2019). Castor *Ricinus communis* L. belongs to Euphorbiaceae family, is an important non-edible oilseed crop, which commonly known as castor bean/ arandi (Nayak et al., 2020). Castor being cross pollinated, the role of pollinators is highly valued. For effective pollination pollinators must visit and forage the crop (Abrol, 2016). Currently, the consensus about clear management strategies to optimize insect mediated pollination is lacking (Rollin and Garibaldi, 2019). There are different parameters which determine the pollination performance and foraging speed is one among them. This study evaluates the foraging speed of pollinators in *R. communis* under agroecological conditions of Haryana.

MATERIALS AND METHODS

An experiment was conducted to determine the foraging speed of different castor pollinators under Haryana conditions, on two promising castor hybrids-GCH 7 and DCH 177 at the Research Area of Department of Entomology, CCS Haryana Agricultural University (CCS HAU), Hisar, Haryana. All samples were collected during 2018 and 2019, with the plot size 50x15 m. All the recommended crop production practices were followed as per CCSHAU package of practices. Randomized block design was used with five replications. The time spent by pollinators on a single flower, termed as foraging speed was observed in the most frequent insect visitors/ pollinators. The pollinator species were identified using the reference collections in Entomology Department. Observations were made at peak flowering period during August and September, at 2 hr intervals starting from morning 06.00 to evening 18.00 hr. For each major pollinator, ten observations were made and time spent/ flower in sec was computed for each. Data obtained were subjected to three way ANOVA using OPSTAT software and the results were compared using least significant difference (LSD, p=0.05).

RESULTS AND DISCUSSION

The observations on the foraging speed with cv. GCH-7 revealed significant differences among the pollinator species and time (Table 1). During 2018, irrespective of the pollinator species and time, the foraging speed varied from 1.41-12.92 sec/ flower; maximum speed was observed for *A. cerana* (6.92 sec/ flower) followed by *A. mellifera* (5.68); and the least with *X. iridipennis* (2.36). During 2019 also, similar trend was observed with the time spent varying from 2.11-8.58 sec/ flower. For both the years, the mean foraging speed in different day hours reached maximum

Table 1. Foraging speed of pollinators on flowers of *R. communis* cv. GCH-7 (2018, 2019)

Pollinator	Time spent/ flower (sec)														
	2018							2019							Pooled mean
	06:00-08:00 hr	08:00-10:00 hr	10:00-12:00 hr	12:00-14:00 hr	14:00-16:00 hr	16:00-18:00 hr	Mean	06:00-08:00 hr	08:00-10:00 hr	10:00-12:00 hr	12:00-14:00 hr	14:00-16:00 hr	16:00-18:00 hr	Mean	
A. dorsata	3.75 (2.18)*	3.74 (2.17)	6.01 (2.64)	5.54 (2.55)	3.63 (2.15)	3.19 (2.04)	4.31 (2.30)	3.07 (2.01)	3.61 (2.14)	5.45 (2.54)	4.92 (2.43)	3.75 (2.18)	2.78 (1.94)	3.93 (2.22)	4.12 (2.26)
A. mellifera	4.65 (2.37)	5.81 (2.61)	7.87 (2.97)	7.60 (2.93)	4.85 (2.41)	3.35 (2.08)	5.68 (2.58)	4.55 (2.35)	4.79 (2.40)	7.59 (2.93)	4.78 (2.40)	3.58 (2.14)	2.53 (1.87)	4.63 (2.37)	5.16 (2.48)
A. cerana	4.53 (2.36)	6.07 (2.65)	12.92 (3.73)	8.19 (3.03)	6.42 (2.72)	3.41 (2.10)	6.92 (2.81)	3.80 (2.19)	6.69 (2.77)	8.58 (3.09)	7.31 (2.88)	5.11 (2.47)	3.54 (2.13)	5.83 (2.61)	6.38 (2.71)
A. florea	1.96 (1.72)	3.30 (2.07)	6.21 (2.68)	4.28 (2.29)	3.78 (2.18)	2.60 (1.89)	3.68 (2.16)	2.30 (1.81)	3.57 (2.13)	5.81 (2.60)	4.00 (2.23)	3.68 (2.16)	2.82 (1.95)	3.69 (2.16)	3.69 (2.16)
Vespa sp.	3.05 (2.01)	3.90 (2.21)	3.93 (2.22)	3.85 (2.20)	3.52 (2.12)	3.21 (2.05)	3.57 (2.13)	3.25 (2.06)	3.74 (2.17)	3.79 (2.19)	3.69 (2.16)	3.54 (2.13)	3.49 (2.12)	3.58 (2.14)	3.58 (2.14)
X. iridipennis	1.41 (1.55)	2.10 (1.76)	3.56 (2.13)	2.65 (1.91)	2.43 (1.85)	2.05 (1.74)	2.36 (1.83)	2.40 (1.84)	2.65 (1.76)	3.10 (2.26)	3.06 (2.01)	2.85 (1.96)	2.11 (1.76)	2.69 (1.92)	2.53 (1.87)
M. lanata	**	2.87 (1.96)	4.35 (2.31)	3.91 (2.21)	3.63 (2.15)	3.46 (2.11)	3.64 (2.15)	**	3.69 (2.16)	4.26 (2.29)	4.07 (2.25)	3.68 (2.16)	3.66 (2.16)	3.87 (2.20)	3.75 (2.18)
M. bicolor	**	2.58 (1.89)	3.84 (2.20)	3.80 (2.19)	3.74 (2.17)	3.15 (2.03)	3.42 (2.10)	**	3.67 (2.16)	4.16 (2.27)	4.05 (2.24)	4.00 (2.23)	3.54 (2.13)	3.88 (2.20)	3.65 (2.15)
Polistes sp.	**	3.07 (2.01)	4.07 (2.25)	3.74 (2.17)	3.04 (2.00)	**	3.48 (2.11)	**	3.89 (2.21)	4.29 (2.30)	3.79 (2.18)	3.71 (2.17)	**	3.92 (2.21)	3.70 (2.16)
Eristalinus sp.	3.02 (2.00)	3.46 (2.11)	3.85 (2.21)	3.37 (2.09)	3.13 (2.03)	**	3.36 (2.08)	3.29 (2.07)	3.91 (2.21)	4.27 (2.29)	3.95 (2.26)	3.49 (2.12)	**	3.78 (2.18)	3.57 (2.13)
Mean	3.19 (2.04)	3.69 (2.16)	5.66 (2.58)	4.69 (2.38)	3.81 (2.19)	3.05 (2.01)	4.01 (2.24)	3.23 (2.05)	4.02 (2.24)	5.13 (2.47)	4.36 (2.31)	3.73 (2.17)	3.05 (2.01)	3.92 (2.21)	3.97 (2.22)

Each value mean of ten observations; *Figures in parentheses square root transformed values; ** No pollinators activity

Factors	CD ($p \leq 0.05$)	SE (m)
Year	(0.025)	(0.009)
Time	(0.044)	(0.016)
Year x Time	(0.062)	(0.022)
Pollinator	(0.057)	(0.02)
Year x Pollinator	(0.08)	(0.029)
Time x Pollinator	(0.138)	(0.05)
Year x Time x Pollinator	(0.196)	(0.07)

Table 2. Foraging speed of pollinators on flowers of *R. communis* cv. DCH-177 (2018 and 2019)

Pollinator	Time spent/ flower (sec)														
	2018							2019							Pooled mean
	06:00-08:00 hr	08:00-10:00 hr	10:00-12:00 hr	12:00-14:00 hr	14:00-16:00 hr	16:00-18:00 hr	Mean	06:00-08:00 hr	08:00-10:00 hr	10:00-12:00 hr	12:00-14:00 hr	14:00-16:00 hr	16:00-18:00 hr	Mean	
A. dorsata	4.50 (2.34)*	5.24 (2.49)	5.76 (2.60)	5.61 (2.57)	3.71 (2.17)	3.13 (2.03)	4.65 (2.37)	3.27 (2.06)	3.68 (2.16)	5.32 (2.51)	4.81 (2.41)	3.69 (2.16)	2.78 (1.94)	3.92 (2.21)	4.29 (2.30)
A. mellifera	4.90 (2.42)	6.04 (2.65)	7.58 (2.92)	7.52 (2.91)	4.78 (2.40)	3.42 (2.10)	5.70 (2.58)	4.44 (2.33)	4.81 (2.41)	7.09 (2.84)	4.63 (2.37)	3.46 (2.11)	2.46 (1.86)	4.48 (2.34)	5.09 (2.46)
A. cerana	5.53 (2.55)	6.51 (2.74)	9.92 (3.30)	7.51 (2.91)	6.30 (2.70)	3.43 (2.10)	6.53 (2.74)	3.71 (2.17)	6.80 (2.79)	8.41 (3.06	7.19 (2.86)	5.03 (2.45)	3.37 (2.91)	5.75 (2.59)	6.14 (2.67)
A. florea	2.96 (1.99)	3.98 (2.23)	6.10 (2.66)	3.95 (2.22)	3.75 (2.18)	2.53 (1.88)	3.87 (2.20)	2.68 (1.91)	3.67 (2.16)	5.67 (2.58)	3.91 (2.21)	3.59 (2.14)	2.75 (1.93)	3.71 (2.17)	3.79 (2.18)
Vespa sp.	3.55 (2.13)	4.28 (2.29)	4.10 (2.25)	3.27 (2.06)	3.48 (2.11)	3.60 (2.14)	3.71 (2.17)	3.22 (2.05)	3.79 (2.19)	3.66 (2.15)	3.61 (2.14)	3.31 (2.07)	3.30 (2.07)	3.48 (2.11)	3.59 (2.14)
X. iridipennis	2.85 (1.96)	2.41 (1.84)	4.32 (2.30)	3.55 (2.13)	2.68 (1.91)	1.97 (1.72)	2.96 (1.99)	2.15 (1.77)	2.51 (1.87)	3.01 (2.00)	3.00 (2.00)	2.95 (1.98)	2.40 (1.84)	2.67 (1.91)	2.81 (1.95)
M. lanata	**	3.50 (2.12)	4.42 (2.32)	3.87 (2.20)	3.84 (2.20)	3.38 (2.09)	3.80 (2.19)	**	3.80 (2.19)	4.14 (2.26)	3.64 (2.15)	3.51 (2.12)	3.41 (2.10)	3.70 (2.16)	3.75 (2.17)
M. bicolor	**	3.11 (2.02)	4.45 (2.33)	4.05 (2.24)	3.25 (2.06)	3.49 (2.12)	3.67 (2.16)	**	3.51 (2.12)	4.02 (2.24)	3.91 (2.21)	3.82 (2.19)	3.37 (2.09)	3.72 (2.17)	3.69 (2.16)
Polistes sp.	**	3.82 (2.19)	4.52 (2.35)	3.78 (2.18)	3.07 (2.01)	**	3.79 (2.19)	**	4.07 (2.25)	4.24 (2.28)	3.74 (2.17)	3.54 (2.13)	**	3.89 (2.21)	3.84 (2.20)
Eristalinus sp.	3.47 (2.11)	3.96 (2.22)	3.88 (2.20)	3.50 (2.12)	3.62 (2.14)	**	3.68 (2.16)	3.33 (2.08)	4.00 (2.23)	4.12 (2.26)	3.38 (2.09)	3.77 (2.18)	**	3.73 (2.17)	3.70 (2.17)
Mean	3.96 (2.22)	4.28 (2.29)	5.50 (2.55)	4.66 (2.37)	3.84 (2.20)	3.11 (2.02)	4.23 (2.28)	3.25 (2.06)	4.07 (2.25)	4.96 (2.44)	4.18 (2.27)	3.66 (2.16)	2.98 (1.99)	3.85 (2.20)	4.04 (2.24)

Each value mean of ten observations; *Figures in parentheses square root transformed values; ** No pollinators activity

Factors	CD ($p \leq 0.05$)	SE(m)
Year	(0.028)	(0.01)
Time	(0.048)	(0.017)
Year X Time	(0.068)	(0.025)
Pollinator	(0.062)	(0.022)
Year X Pollinator	(0.088)	(0.032)
Time X Pollinator	(0.153)	(0.055)
Year X Time X Pollinator	(0.216)	(0.078)

at 10.00-12:00 hr with the least values being at 16.00-18.00 hr. The pooled data revealed that the speed was 3.97 sec/ flower. Amongst the ten pollinators, *A. cerana* spent more time (6.38 sec) and *X. iridipennis* the least (2.53 sec); and no activity was observed for *Megachile lanata*, *Megachile bicolor* and *Polistes* sp. during morning (06.00-08.00 hr), while *Polistes* sp. and *Eristalinus* sp. activity was not found during evening (16.00-18.00 hr). With castor hybrid DCH-177 also same trend was observed (Table 2); in 2018, the mean time spent by a single pollinator varied from 1.97-9.92 sec/ flower and the maximum speed was in *A. cerana* (6.53 sec/ flower) followed by *A. mellifera* (5.70) and lowest in *X. iridipennis* (2.96); in 2019, it ranged between 2.15 to 8.41 sec/ flower. The maximum foraging speed was at 10.00-12.00 hr and the minimum at 16.00-18.00 hr. The pooled data revealed a mean value of 4.04 sec/ flower.

Comparative analysis of cv. GCH-7, DCH-177 revealed a mean value of 3.97 and 4.04 sec/ flower, respectively (Table 3); foraging speed of an individual bee varied from 2.67 to 6.26 sec/ flower; and *A. cerana* was showing maximum speed (6.26 sec/ flower), and the least speed was in *X. iridipennis*. This result corroborates with the least speed observed in X. *tenuiscapa* (Singh, 2016). Mohapatra and Sontakke (2012) also observed in sesame flower that with *A. cerana, A. dorsata* and *A. florea* it varied from 4.7 to 11.0 sec. Rao (2019) observed these as- *A. florea* (8.43), *A. mellifera* (6.51), *A. cerana* (6.22), *A. dorsata* (5.58), *M. cephalotes* (3.87) and *M. lanata* (4.06 sec/ flower). The peak time was between 10.00 to 12.00 hr. The time spent/ flower varies during foraging in various crops (Brunet, 2009). Nayak et al. (2019) also reported foraging speed of *Bombus haemorrhoidalis* (6.31 sec/ flower) and *A. mellifera* (11.50 sec/ flower) to be maximum during 10-12 hr in Kiwi fruit. Yankit (2016) and Ahmad et al. (2015) observed similar values for *B. haemorrhoidalis* on cucumber and tomato under polyhouse.

Table 3. Comparative foraging speed of pollinators on *R. communis*

Pollinators	Time spent/flower (sec)		
	GCH-7	DCH-177	Pooled Mean
A. dorsata	4.12 (2.26)	4.29 (2.30)	4.20 (2.28)
A. mellifera	5.16 (2.48)	5.09 (2.46)	5.12 (2.47)
A. cerana	6.38 (2.71)	6.14 (2.67)	6.26 (2.69)
A. florea	3.69 (2.16)	3.79 (2.18)	3.74 (2.17)
Vespa sp.	3.58 (2.14)	3.59 (2.14)	3.58 (2.14)
X. iridipennis	2.53 (1.87)	2.81 (1.95)	2.67 (1.91)
M. lanata	3.75 (2.18)	3.75 (2.17)	3.75 (2.18)
M. bicolor	3.65 (2.15)	3.69 (2.16)	3.67 (2.16)
Polistes sp.	3.70 (2.16)	3.84 (2.20)	3.77 (2.18)
Eristalinus sp.	3.57 (2.13)	3.70 (2.17)	3.64 (2.15)
Mean	3.97 (2.22)	4.04 (2.24)	4.00 (2.23)

Factor	CD (p≤0.05)	SE(m)
Pollinator	(0.084)	(0.03)
Cultivar	(0.065)	(0.023)
Pollinator x Cultivar	(0.205)	(0.074)

*Figures in parentheses square root transformed values

The mean foraging speed was found to be maximum in *A. dorsata* (4.64 sec), and the least with *A. florea* (3.32 sec), and maximum being at 09.00-1.00, and minimum during 03.00-5.00 pm for all the honey bees (Das et al. 2019). In contrast to the present study, foraging speed in *A. florae* varied (167.50- 216.71 sec) followed by *A. dorsata* (5.04-6.47 sec), *A. mellifera* (5.79-9.50 sec) and *A. cerana* (5.44-6.57 sec) on pumpkin flower (Lalita and Kumar, 2017). Jat et al. (2017) observed maximum foraging speed with the nectar forager *A. dorsata* (22.4 sec/ flower) followed by its pollen foragers (19.0) while *A. mellifera* recorded with minimum foraging speed for nectar+ pollen (4.6 sec/ flower), pollen (4.9) and nectar (7.4) on Egyptian clover. Negussie et al. (2013) reported the least foraging speed for *A. mellifera* i.e, 8±1 sec/ inflorescence and 22±2 sec/tree on jatropha. Rianti et al. (2010) also observed such speeds in polliantors. Ahmad et al. (2017) found that *A. cerana* spent 6.24± 0.12 sec and visited 10.50± 0.18 flowers/ min; *A. mellifera* 8.44± 0.38 sec/ flower and visited 9.40± 0.12 flowers/ min on apple. But Devi et al. (2016) reported maximum foraging speed value of *A. florea* (44.70 sec) in mustard. Nagpal (2020) observed *Apis florea* (6.08 sec), *A. dorsata* (3.41 sec), *A. mellifera* (2.60 sec) and *A. cerana indica* (2.33 sec). Poonam (2019) revealed that *A. florea* spent the maximum time (5.3 sec) followed by *A. dorsata* (1.7 sec), *A. mellifera* (1.6 sec) and *A. cerana* (1.3 sec) in early sown rapeseed-mustard.

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