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Foraging duration of pollinators and their movement on *Ricinus communis*

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Abstract
An experiment was conducted at CCS Haryana Agricultural University, Hisar in order to find out the foraging duration of different insect pollinators of castor crop for two years of study. Results indicated the industrious nature of social bees when compared to other pollinators which worked about 10.20, 10.14, 10.39, 09.22 hours in a day in case of *A. dorsata, A. cerana, A. mellifera, A. florea*. In this study *A. mellifera,* was showing highest working hours while *Polistes* sp. was lowest working period. It also noticed that percent of movement of bee species between flowers of two sexes i.e. male to male flowers was more as compare to male to female flowers. During the two consecutive year 2018 and 2019, among the four honey bee species, *A. florea* had highest percent of movement between flowers, male to male flowers for both of the castor hybrids.

Keywords: Castor, *R. communis*, honey bee, Pollinators

Introduction
Castor (*Ricinus communis* L.), commonly known as castor-bean, castor oil plant, palma-christi, and wonder tree, belongs to the spurge family Euphorbiaceae and locally known as arandi. It is an important non-edible oilseed crop, occupies the fifth position among the most commonly growing nine annual oilseed crops. Initially, castor was believed to have four centers of origin: (i) East Africa (Ethiopia), (ii) India, (iii) Northwest and Southwest Asia and Arabian Peninsula, and (iv) China. However, Ethiopia has been considered as the most probable site of origin because of the high diversity [1]. The major castor growing countries are India, China, Brazil, Africa, USA, and many other Asian countries [2]. Approximately 75% of agricultural food crops have shown increased production as a result of mainly bee pollination [3].

Pollination is an important phenomenon in agricultural systems where the major pollinator-dependent crops are fruit and vegetable crops, spices and plantation crops, pulses, oilseeds, etc. Long-lasting coevolution between flowering plants and pollinators association has made the both partners intimately connected and reciprocally dependent on each another. Their interaction rests mostly on a mutualistic exchange: plants invest in the production of nectar and pollen to reward pollinators in return, sustain plant reproduction by vectoring their pollen to the conspecific flower. Being highly cross-pollinated crop, wind play major role and insects may play some part in pollination process. For effective pollination pollinators should do more number of visits *i.e.* their foraging duration as well as their movement between flowers (male to female flowers). So in this experiment we have calculated foraging duration of different insect pollinators on castor crop and their movement between flowers of two sexes to know their pollination efficiency.

Materials and Methods
For recording foraging duration the most common (12) visitors of castor hybrids was taken into account. Observations were made on *R. communis* cv. GCH -7 and DCH -177 for consecutive two years *i.e.* 2018 and 2019. Experiment was conducted at Research Farm and Apicultural laboratory of Department of Entomology, CCS Haryana Agricultural University, Hisar. For movement between flowers of two sexes (male and female) during peak flowering period of castor most important pollinators i.e. *Apis* sp. was considered.

Duration of foraging: During this period the first visit of foragers were be recorded on castor as initiation time. Similarly the time when there were no further forager visiting the plant was calculated i.e. foraging period between initiation and cessation of foraging activity. Observations were recorded at fortnightly interval from initiation of flowering to end the flowering period.

Duration of foraging = Initiation time – Cessation time

Movement of four honey bee species on flowers of two sexes (male and female) of castor flower at peak flowering period: The determination of movement of four honey bee species namely, *Apis dorsata, A. florea, A.mellifera* and *A. carana* was recorded in term of the per cent movement from male to female flowers and male to male flowers. For the purpose, a total of twenty bees of each species were observed for recording the movement of honey bees.

Results and Discussions:

Initiation and cessation time (foraging duration) of different insect visitors on *R. communis*

The present data on initiation and cessation time of different insect species show the variations in duration of working among the 12 insects on *R. communis*. All the four honey bees *viz.*, *A. dorsata*, *A. mellifera*, *A. florea*, and *A. cerana* had initiated their foraging activity early in the morning and continued their activity up to the evening. Results revealed that *A. dorsata*, *A. cerana*, *A. mellifera*, *A. florea*, *X. iridipennis*, *Camponotus* sp., *Calliphora* sp.and *Eristalinus* sp. initiated their activity early in the morning (before 08.00 AM) at 07.20, 07.13, 06.46, 07.48, 07.37.07.51, 07.31 and 07.43 AM while rest other species *viz.*, *Polistes* sp., *M. lanata*, *Vespa* sp., *M. bicolor* started their activity little bit late in the morning (after 08.00 AM) at 08.33, 08.32, 08.23, 08.59 AM respectively. Meanwhile *Polistes* sp., *X. iridipennis*, *Vespa* sp., *Camponotus* sp., *Calliphora* sp and *Eristalinus* sp. ended their activity early in the afternoon (before 05.00 PM) at 15.43, 16.44, 16.30, 16.58, 16.30, 15.46 PM and *A. dorsata*, *A. cerana*, *A. mellifera*, *A. florea*, *M. lanata*, *M. bicolor* observed to be active till the evening i.e. 17.40, 17.28, 17.25, 17.10,17.04,17.11 PM respectively. The results indicates the industrious nature of social bees when compared to other pollinators which worked about 10.20, 10.14, 10.39, 09.22 hours in a day in case of *A. dorsata*, *A. cerana*, *A. mellifera*, *A. florea* while *Polistes* sp., *X. iridipennis*, *M. lanata*, *Vespa* sp., *M. bicolor Camponotus* sp., *Calliphora* sp.and *Eristalinus* sp. had working duration of 07.10, 09.07, 08.32, 08.07, 08.12, 09.06, 08.58 and 08.02 h, respectively. In this study *A. mellifera*, with highest working hours while *Polistes* sp. was lowest working period (Table 1; Figure 1).

In general, foraging activity of diurnal insect pollinators starts with commencement of sunrise. Majority of pollinators are adaptive in nature, they know the particular time of flowers blossom and restrict their foraging activity accordingly. They also have the ability to change the foraging clock according to the phase changes of diurnal light-dark cycles. As foraging behaviour is endogenously driven behavioral pattern which can be triggered by biotic as well as abiotic conditions [4]. The initiation and cessation time for individual insect visitors may differ considerably.

Table 1: Initiation and cessation activity time of different floral visitor species on *R. communis*

Pollinator	2018			2019			Pooled Activity (hrs)		
	Activity (hrs)			Activity (hrs)					
	Initiation	Cessation	Working hours	Initiation	Cessation	Working hours	Initiation	Cessation	Working hours
A. dorsata	7:16	17:38	10:22	7:25	17:43	10:18	7:20	17:40	10:20
A. cerana	7:09	17:28	10:19	7:18	17:28	10:10	7:13	17:28	10:14
A. mellifera	6:42	17:13	10:31	6:51	17:38	10:47	6:46	17:25	10:39
A. florea	7:51	17:08	9:17	7:45	17:12	9:27	7:48	17:10	9:22
Polistes sp.	8:25	15:52	7:27	8:42	15:35	6:53	8:33	15:43	7:10
X. iridipennis	7:33	16:48	9:15	7:42	16:41	8:59	7:37	16:44	9:07
M. lanata	8:19	17:09	8:50	8:45	16:59	8:14	8:32	17:04	8:32
Vespa sp.	8:52	16:48	7:56	7:54	16:13	8:19	8:23	16:30	8:07
M. bicolor	8:49	17:15	8:26	9:09	17:08	7:59	8:59	17:11	8:12
Camponotus sp.	7:45	16:54	9:09	7:58	17:02	9:04	7:51	16:58	9:06
Calliphora sp.	7:53	16:12	8:19	7:10	16:48	9:38	7:31	16:30	8:58
Eristalinus sp.	7:39	15:35	7:56	7:48	15:57	8:09	7:43	15:46	8:02

The increase in the working hour of the day is due to early visit of *A. mellifera* then the other pollinators. The daily rhythms of flower visits mainly depend on, the body size of the pollinator species, the daily patterns of variation in weather and nectar standing crop. The differences in working period of expected to occur due to their dynamic response to various environmental factors and the initiation and cessation of time of their foraging activity significantly vary among the species [5]. In general, larger bee species were more active in cooler and more humid hours of the morning and smaller species forage later, during warmer and drier hours [6].

Results are in tune with Rao [7] who reported that *A. dorsata* was having maximum 11.09 working hours, followed by *A. mellifera*, *A. cerana*, *M .lanata* and *M. cephalotes* which had of 10. 47, 9.51, 9.08 and 8.47 h, working duration on sesame crop respectively. *B. campestris* var. varuna the maximum foraging duration was in case of *A. dorsata* (515.00, 517.00 min) followed by *A. cerana* (480.67, 482.00 min), *A. mellifera* (410.00, 407.00 min) while least foraging duration was recorded in *A. florea* (320.33, 318.67 min) during the year 2001-02 and 2002-03 respectively [8].

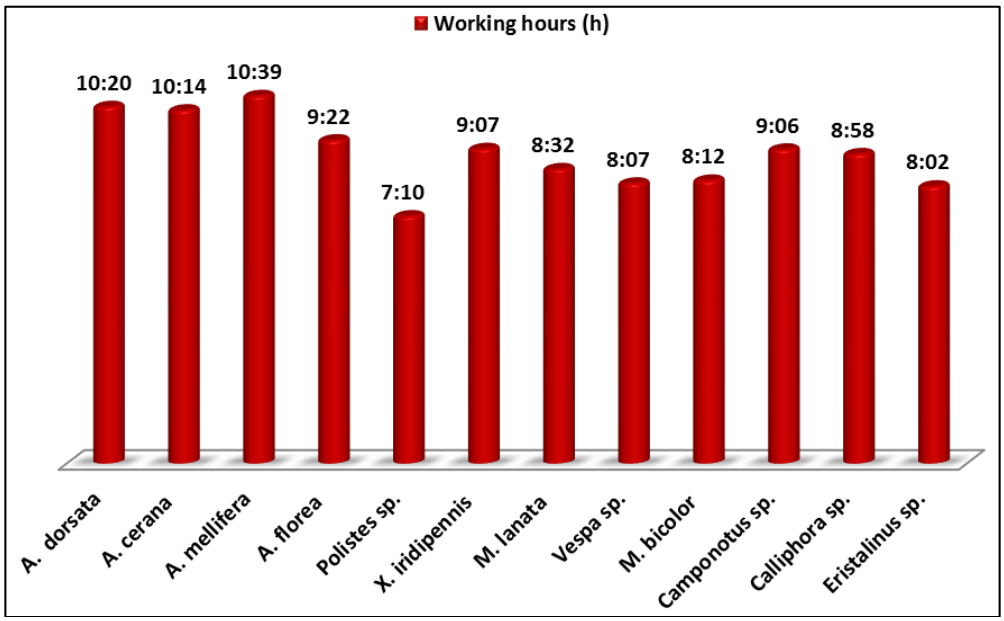

Fig 1: Working duration (hrs) of insect pollinators of *R. communis*

Movement of four honey bee species between flowers of two sexes

Data regarding the per cent movement of four honey bee species between flowers of two sexes of two castor hybrids, GCH -7 and DCH -177 are narrated in Table 2. It also noticed that percent of movement of bee species between flowers of two sexes i.e. male to male flowers was more as compare to male to female flowers. During the two consecutive year2018 and 2019,among the four honey bee species, *A. florea* had highest percent of movement between flowers, male to male flowers for both of the castor hybrids.

Table 2: Per cent movement of four honey bee species between flowers of two sexes of *R. communis* cv. GCH -7 and DCH- 177 during different flowering periods in 2018 and 2019

Honey bee species	Per cent movement between flowers							
	GCH - 7				DCH- 177			
	2018		2019		2018		2019	
	Male to male flower (%)	Male to female flower (%)	Male to male flower (%)	Male to female flower (%)	Male to male flower (%)	Male to female flower (%)	Male to male flower (%)	Male to female flower (%)
A. dorsata	65	35	68	32	58	42	62	38
A. mellifera	60	40	63	37	55	45	57	43
A. cerana	70	30	75	25	63	37	67	33
A. florea	76	24	78	22	71	29	74	26

During the year 2018 and 2019 in GCH -7 cultivar the movement of *A. florea*, between flowers of two sexes (male to male: male to female) was 76, 78, 24, 22 followed by *A. cerana* 70, 75, 30, 25 *A. dorsata* 65, 68, 35, 32, *A. mellifera* 60, 63, 40, 37 respectively. In DCH-177cultivar, the movement of *A. florea* from male to male flowers was highest (71%) followed by *A. cerana* (63%), *A. dorsata* (58%) and *A. mellifera* (55%)while male to female flowers movement was highest in case of *A. mellifera* (45%) followed by *A. dorsata* (42%) *A. cerana* (37%) and *A. florea* (29%), during the year 2018.Similar trend of per cent movement between flowers was also followed in the year 2019.

The insect pollinators which move more frequently from male to female flowers are rated as better pollinators as compare to the pollinators which move more frequently from male to male flowers. However these depend on the crops and type of pollinators as in some cases more number of pollen grains are collected by visiting male flowers first and then pollinating female flowers. As castor is known as pollen plant, hence the chances of movement of *Apis* sp. between male to male flower was more as compare to male to female. Results are in tune with Panwar, [9] who also reported male to male flowers movement was highest in case of *Apis florea* (78%), *Apis cerana* (70%), *Apis mellifera* (65%) and *Apis dorsata* (55%) on pumpkin flower.

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