

Studies on Floral Traits and Pollinator Foraging Behaviour in Onion (*Allium cepa* L.)

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ABSTRACT

Insect pollination services play a major role in onion, *Allium cepa* L. due to the prevalence of protandry. A study was conducted at the experimental fields of ICAR - Indian Institute of Horticultural Research, Bengaluru, Karnataka, India (13.13 °N; 77.49 °E) to understand the foraging behaviour of major insect pollinators associated with onion crop (cv. Arka Kalyan). Continuous surveillance revealed that onion took 70 - 75 days for flower bud initiation and 90 - 95 days for maximum flower opening. A single bulb produced 4.00 ± 1.05 flowering stalks which produced umbel inflorescence that consisted of numerous individual flowers called florets. The mean number of florets in an umbel (449.30 ± 29.47) and the duration of each floret (5.60 ± 0.52 days) were worked out. In general, each floret produced 6.00 - 7.00 anthers (Mean \pm SE: 6.10 ± 0.32) with a mean number of 1581 pollen grains per anther. A total of 1735 and 1852 individual pollinators were observed visiting the onion during 2020 and 2021, respectively. The floral visitor's data from transect sampling revealed their abundance as : *Apis florea* > *Trigona iridipennis* > *Apis dorsata* > *Apis cerana* > *Ischiodon scutellaris* > *Eristalis obliquus* for two consecutive years. Of all floral visitors, *A. florea* had recorded highest visits (26.92 %), while *Eristalis obliquus* recorded the least foraging visits (7.38 %). The observations on foraging behaviour revealed that major foraging activity was carried out by *A. cerana*, as it spent maximum amount of time on inflorescence (3.30 ± 0.82 umbel / min) followed by *A. dorsata* (2.50 ± 0.71 umbel / min) and the least with *T. iridipennis* (1.40 ± 0.52 umbel / min). However, time spent / umbel was maximum with *T. iridipennis* (45.80 ± 4.41 sec / umbel) and the least was found with *A. cerana* (16.10 ± 1.85 sec / umbel).

Keywords: Foraging behaviour, Nectar, Pollen, Protandry, Visitation rate, Onion

ONION (*Allium cepa* L.) is one of the major vegetables grown globally (Mohammad *et al.*, 2011) and there are several species of *Allium* that are cultivated mainly for their flowers instead of bulbs. Onion is a biennial which requires two growing seasons to produce seed. It produces edible bulbs in the first year and a hollow floral stem with a spherical inflorescence (= umbel) during the second year. In general, onion depends heavily on anthophilous (flower visiting) insects for seed set as anthers release pollen grains before the stigma becomes receptive, (= protandry). Therefore, in the absence of abundant pollinating insects, onion does not produce good quality seeds (Mohammad *et al.*, 2011) and thus cross pollination is the most extensively adopted method of seed production and anthophilous insects are essential for pollen transfer.

Among the several anthophilous insects reported, honey bees appear to be the major onion pollinators, because of their specific instinctive behavioural features that include pollen as well as nectar collection and pollen transfer efficiency (Abrol, 2010). However, honeybees reported to forage onion flowers mostly for nectar and during the process they are heavily covered with the pollen (Soto *et al.*, 2013). Additionally, a larger foraging range of honey bees in onion field makes them effective pollinators and therefore seed yield in onion is highly correlated with honey bee behaviour (Soto *et al.*, 2013).

The present study aims to generate systematic information on the various floral traits and pollinator interaction behaviour which might help in the quality onion seed production. Therefore, the present

investigation was carried out to understand the floral phenological traits along with the associated major pollinators in onion.

MATERIAL AND METHODS

The present study was conducted at the ICAR - Indian Institute of Horticultural Research (IIHR), Bengaluru (13°58' N, 77°35' E), Karnataka, India during 2019-20 and 2020-21 with an objective to understand the floral biology and phenology of onion from the view point of pollinator activity. The popular onion cultivar Arka Kalyan was used in the study. The bulbs were planted in raised beds (3 x 3 m) at a spacing of 30 cm in an area of one acre. Standard package of practices was followed and application of insecticide was completely avoided to encourage pollinator activity.

Observations were recorded on the flowering period, flowering duration, days to first flower bud initiation, number of days for maximum flowering, number of flowering stalks per bulb, number of florets per umbel, life of single floret and flower colour through visual examination. Parameters like pollen size (mm), length of style (cm) etc. were measured in the laboratory with the help of a stereomicroscope. Nectar volume (μl) was recorded by measuring the nectar quantity from individual floret ($n = 20$) with the help of bore micropipette (Kavitha and Reddy, 2018).

To study the foraging activity of major floral visitors on onion flowers, species wise visitation rate, observations were recorded continuously during maximum flowering period for 15 days. Observations were recorded from randomly selected flowers ($n = 5$) representing six randomly selected spots. The foraging behaviour of individual bee was studied by recording the number of florets visited by an individual bee per minute and the time spent on each floret with the help of stopwatch. The working behaviour of individual bee on florets was observed visually and type of foraging behaviour (either top or side worker) was recorded. The data on foraging behaviour of major floral visitors were compiled and analysed using statistical software SPSS and means were compared using Tukey's multiple comparison test (HSD).

RESULTS AND DISCUSSION

Floral Traits

Onion being a biannual crop it takes two growing seasons to produce flowers/seeds, *i.e.*, seed-bulb-seed. In the present investigation onion variety Arka Kalyan started flowering between 70 to 75 days after bulb planting and the maximum flowering was recorded between 90 to 95 days. The flowering duration lasted for 35 to 40 days. Flowers were produced on a single elongated stalk called scape which is hollow from inside. An individual bulb produced on an average 4.00 ± 1.05 flowering stalks of 50.80 ± 6.60 cm height. Each flowering stalk produced an inflorescence (= umbel) that comprised of numerous small florets. These florets are enclosed in 2-3 white membranous sheaths that called as spathe. Each umbel consisted of 449.30 ± 29.47 florets (Mean \pm SE) (Range : 397 - 526) and the duration of each floret lasted for 5.60 ± 0.52 days (Mean \pm SE) (Range : 5-6 days). Anthesis was observed during the early photo phase (0600 to 0700 hr) and it occurred in succession from outer layer towards the centre of the umbel. Anther dehiscence took place throughout the day (0700 to 1700 hr). Both the perianth segments ($n = 6$) and stamens ($n = 6$) were arranged in two whorls. The mean length of the style and stamen was 0.30 ± 0.03 cm (Mean \pm SE) and 0.50 ± 0.04 cm (Mean \pm SE), respectively. Onion flowers are usually protandrous, as stigma becomes receptive after the pollen shedding. However, geitonogamy is also a possibility if both male and female flowers occur at the same time within the inflorescence (Devi *et al.*, 2015). The mean number of anthers per each floret was 6.10 ± 0.32 (mean \pm SE) anthers (Range : 6 to 7) with a mean number of pollen grains of 9486.20 ± 329.08 (Range : 7452-12376). The pollen grains were found to be wet and sticky with a size of 0.04×0.02 mm (length x diameter). In onion florets, nectaries are usually exposed and located below the ovary. The mean quantum of nectar produced by each floret was 1.72 ± 0.19 μl (Range: 1.24-2.31 μL). The nectar acted as main source of attractant for flower visiting insects (Table 1).

TABLE 1

Floral biology and phenology of onion

Floral traits	Observations
Days from planting to flower bud initiation	70-75 days
Flowering duration	35-40 days
No. of days for maximum flowering	90-95 days
Duration of individual floret	5.60 ± 0.52 days
Type of Inflorescence	Umbel
Number of flowering stalks/ bulbs	4.00 ± 1.05
Length of flowering stalk	50.80 ± 6.6 cm
Number of florets per umbel	449.30 ± 29.47
Length of pistil	0.38 ± 0.04 cm
Length of style	0.30 ± 0.03 cm
Ovary type	Superior
Length of Stamen	0.50 ± 0.04 cm
Number of anthers / flowers	6.10 ± 0.32
Anther's type	Bilocular
Anther dehiscence mode	Longitudinal
Pollen shape	Oval/ Oblate
Pollen type	Wet and sticky
Size of pollen grain (length*diameter)	0.04*0.02 mm
Number of pollen grain/floret	9486.20 ± 329.08
Type of pollination	Cross pollination
Nectaries	Present
Position of nectaries	Lower part of ovary
Nectar quantity	1.72 ± 0.19 µl

Means in the column followed by the same letter(s) do not differ significantly at five per cent level by Tukey's HSD test.

The above findings are in accordance with Devi *et al.* (2015) who reported that in onion inflorescence is present at the top of the green plant which is hollow from the inside and each inflorescence had 50-2000 florets. Farkas *et al.* (2012) observed huge variation (0.10 to 3.80 µL per flower) in the nectar production in *Allium ursinum* L. ssp. *Ucrainicum* from three different habitats. Kavitha and Reddy (2018) reported that onion took 64 - 67 days for flower bud initiation and 88 - 91 days for maximum flowering.

Abundance of Major Floral Visitors

In this study, a total of 1735 and 1852 individual floral visitors were observed visiting the onion inflorescence during 2020 and 2021, respectively. Of which a total of fifty-nine species of insect floral visitors from five major taxonomic groups (orders) were recorded during the study period. Of these, honey bees (O: Hymenoptera, Family: Apidae) and hover flies (O: Diptera, Family: Syrphidae) were the most abundant floral visitors. Therefore, honeybees and syrphids were further observed for their foraging behaviour in particular. The data from transect sampling revealed the abundance of individual forage visitors as: *Apis florea* > *Trigona iridipennis* > *Apis dorsata* > *Apis cerana* > *Ischiodon scutellaris* > *Eristalis obliquus* for two consecutive years. *Apis florea* had the highest mean per cent forage visit (26.92 %), while *Eristalis obliquus* recorded the least mean per cent forage visits (7.38 %). All the floral visitors found collecting both pollen and nectar from the onion inflorescence (Table 2). Abrol (2010) recorded the dwarf honey bee *A. florea* as the most abundant flower visitor of onion and it comprised > 94 per cent of the total visitors. Hosamani *et al.* (2019) also observed *A. florea* as the most abundant floral visitor in onion. Jyothi *et al.* (2017) recorded honey bees (55.75 %) as the most abundant floral visitors of pigeon pea at Bengaluru.

Foraging Behaviour of Major Floral Visitors

The pollen collectors *viz.*, *A. dorsata*, *A. cerana*, *A. florea*, *T. iridipennis*, *I. scutellaris* and *E. obliquus* were considered as active pollinators as these were foraging actively during anthesis. These floral visitors also observed to be top workers while foraging on onion inflorescence. The foraging indices of floral visitors *viz.*, number of umbels visited / bee visit, number of floral visit / min and time spent / flower are varied significantly as presented in Table 4. The rock bee *A. dorsata* had visited the maximum number of umbels in a single visit (14.50 ± 1.25, Mean ± SE) followed by *A. cerana* and *A. florea*, while *T. iridipennis* visited the least number of umbels in a single visit. Observations on foraging time spent / umbel revealed that stingless bee *T. iridipennis* spent

TABLE 2
Major floral visitors of onion (*Allium cepa* L.)

Order	Family	Floral visitor	Forage source	Working behaviour
Hymenoptera	Apidae	<i>Apis florea</i> L.	PN	Top
		<i>Apis dorsata</i> F.	PN	Top
		<i>Apis cerana</i> F.	PN	Top
		<i>Tetragonula iridipennis</i> (Smith)	PN	Top
Diptera	Syrphidae	<i>Ischiodon scutellaris</i> Fab.	PN	Top
		<i>Eristalis obliquus</i> Wiedemann	PN	Top

P (Pollen), N (Nectar)

TABLE 3
Abundance of major pollinators in onion

Species	Abundance		Per cent Forage visit		
	2020	2021	2020	2021	Mean
<i>Apis florea</i> L.	457	501	26.34	27.50	26.92
<i>Apis dorsata</i> F.	358	394	20.63	21.62	21.12
<i>Apis cerana</i> F.	226	173	13.02	9.49	11.25
<i>Tetragonula iridipennis</i> (Smith)	401	449	23.11	24.64	23.87
<i>Ischiodon scutellaris</i> Fab..	172	163	9.91	9.4	9.42
<i>Eristalis obliquus</i> Wiedemann	121	142	6.97	7.79	7.38

TABLE 4
Foraging behaviour of major insect pollinators in onion

Species	No. of umbels visited/visit	Time spent/umbel (seconds)	No. of umbels visited/min
<i>Apis florea</i>	5.10 ± 1.20 ^b	37.30 ± 3.23 ^c	1.80 ± 0.63 ^{ab}
<i>Apis dorsata</i>	14.50 ± 1.25 ^d	19.00 ± 2.53 ^a	2.50 ± 0.71 ^b
<i>Apis cerana</i>	7.30 ± 1.58 ^c	16.10 ± 1.85 ^a	3.30 ± 0.82 ^c
<i>Tetragonula iridipennis</i>	3.50 ± 1.08 ^a	45.80 ± 4.41 ^d	1.40 ± 0.52 ^a
<i>Ischiodon scutellaris</i>	3.90 ± 0.87 ^{ab}	27.40 ± 6.41 ^b	2.20 ± 0.63 ^{ab}
<i>Eristalis obliquus</i>	4.20 ± 0.63 ^{ab}	27.00 ± 4.37 ^b	2.40 ± 0.84 ^b

maximum amount of time (45.80 ± 4.41 sec, Mean \pm SE) followed by *A. florea* (37.30 ± 3.23 , Mean \pm SE) and *I. scutellaris* (27.40 ± 6.41 , Mean \pm SE), while *A. cerana* had spent the least amount of time (16.10 ± 1.85 sec). However, the number of umbels visited / min was maximum with *A. cerana* (3.30 ± 0.82) and it was the least with *T. iridipennis* (1.40 ± 0.52 , Mean \pm SE). These findings are in accordance with

Karuppaiah *et al.* (2018) who reported that *A. cerana* carried out the maximum foraging activity (3.17 umbels / min) followed by *A. dorsata* (3.00 umbels / min) and *A. florea* (2.00 umbels / min). Abrol (2010) reported that during different hours of the day, *A. florea* visited 1.33 ± 0.26 (Mean \pm SE) and 6.17 ± 0.58 (Mean \pm SE) umbels and flowers / min respectively. Karuppaiah *et al.* (2018) noticed that in onion, time spent by the

floral visitor per flower was maximum with *Tetragonula* sp. (27.50 sec/umbel) followed by *A. florea* (18.83 sec/umbel) and *A. dorsata* (17.83 sec / umbel) and *A. cerana* (14.56 sec / umbel). Kuberappa *et al.* (2012) recorded the maximum intensity (7.31 / plant / 5 min) of *Apis florea* in chamomile flowers. How frequently the pollinator visits the flowers and their foraging rates are believed to be the important predictors of pollinator effectiveness and percent pollination was found to be directly related with the frequency of visitation and foraging rates of floral visitors.

The findings of the present study showed that the little bee *A. florea* was found to be the most abundant floral visitor in onion during the study period. However, number of umbels visited/min was maximum with Asian honey bee, *A. cerana* and the time spent / umbel (seconds) was maximum with stingless bee, *T. iridipennis*. Our results on surveillance and foraging behaviour of various floral visitors in onion helped in understanding the floral visitor's abundance and their comparative pollination efficiency. Further studies on the quantum of pollen/ nectar harvest and subsequent effective stigmatic pollen deposition by the individual floral visitor in different geographical regions/ seasons will help us better quantify the pollination services of specific floral visitors in onion. Such information serves as a basis for future inundate release of effective floral visitors to support pollination in onion.

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