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Foraging behaviour of *Eristalinus* and *Syrphini* on rapeseed (*Brassica campestris* L.)

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Abstract
A study was carried out on foraging behaviour of *Eristalinus* and *Syrphini* in respect to foraging activity, foraging rate, foraging speed, loose pollen grains and abundance in Assam Agricultural University, Jorhat during 2017-2018 and 2018- 2019 on pollination of rapeseed flower var. TS-38. The results revealed that the maximum number of flower visit by *Eristalinus* and *Syrphini* were made during 1000-1300 hours and 1100-1200 hours whereas minimum activity at 1500-1600 hours and 0700-0800 hours of the day respectively. Relative abundance of *Eristalinus* and *Syrphini* was recorded to be maximum at 1100-1200 and 1000-1300 hours of the day. The number of loose pollen grain adhering to the bodies of *Eristalinus* and *Syrphini* was recorded to be 1418.2 ± 44.19 and 1268.4 ± 60.33 in 2017-18 and during 2018-19 were 1333.2 ± 50.48 and 1294.6 ± 65.10 per forager. The maximum pollination index of 8.01 was recorded from *Syrphini* as compared to 7.20 *Eristalinus* in 2017-18 and during 2018-19 were recorded 7.40 from *Eristalinus* as compared to 7.21 of *Syrphini* on rapeseed. The present study revealed that *Eristalinus* and *Syrphini* made more visit during midday as compared to morning and evening with more activity, foraging rate and foraging speed to rapeseed flowers bloom whereas number of loose pollen grain adhered to body of *Eristalinus* was more compared to *Syrphini*.

Keywords: Foraging behaviour, *Eristalinus*, *Syrphini*, rapeseed pollination, pollination index

1. Introduction
Pollination relationship between pollinators and flowering plants developed in millions of years of evolution, serves the humanity directly through food security and indirectly maintain a healthy state and harmonious functioning of the ecosystem. Syrphid fly belongs to family Syrphidae, which is one of the largest families of the order Diptera and comprises the popularly called hover flies or flower flies or sun flies or drone flies. Syrphid flies are frequent flower visitors to a wide range of wild plants, as well as agricultural crops, and are often considered the second-most important group of pollinators after wild bees. Thangjam *et al.* [11] conducted an experiment and found that eleven species of insect pollinators belonging to five families under three orders *viz.*, Hymenoptera, Diptera and Lepidoptera were visited rapeseed flowers under natural condition and their foraging activity was highest during 0900-1100 hrs. Tara and Sharma [10] also found that Hymenoptera, Diptera, Lepidoptera, Coleoptera and Thysanoptera were the flower visitors of mustard. Of these, Hymenopterans were most important agents because of their high energy requirements and tendency for collecting provisions for their brood in the form of pollen and nectar. Ahmed and Rahman [1] observed that *Apis cerena* as foragers on rapeseed in Jorhat, Assam followed by *Eristalinus arvorum* F., *Apis mellifera*, *Episyrphus balteatus* Degear and *Apis florae*. It is now well established fact that honeybees are important for pollination of rapeseed crops. But other pollinators like dipteran pollinators *viz. Eristalinus* and *syrphids* are less studied. So, this study aims at studying the foraging behaviour of *Eristalinus* and *Syrphini* on rapeseed, *Brassica campestris* L.

2. Materials and Methods
The experiment was conducted in the ICR Farm and Apiculture laboratory, Department of Entomology, Assam Agricultural University, Jorhat during 2017-2018 and 2018- 2019 (Fig. 3). The experimental site was situated at 26°47′N latitude and 94°12′E longitude having an elevation of 86.6 m from mean sea level. All observations on the flower visitors and foraging behaviour were recorded on Rapeseed, *Brassica campestris* L. variety "TS-38" crop grown in

rabi seasons. This is a short duration variety about 90-95 days duration and it was developed by Assam Agricultural University, Jorhat, Assam. All insects visiting flowers of mustard were recorded following three methods: Visual counting, sweep net collection and bowl trapping (Fig. 4). Data on various parameters like abundance of *Eristalini* and *Syrphini* on rapeseed flowers, foraging rate, foraging speed and loose pollen grains were recorded on rapeseed from early morning (0700hr) till in the evening (1600hr) with a recording time of ten minutes and a time gap of ten minutes between two recording time intervals (Fig. 5 & Fig. 6). Sampling day was divided into twelve time intervals of one hour each from morning 07.00 hours to the evening 16.00 hours. Observations were repeated on different days during the flowering season. Most frequent species visiting rapeseed flowers were identified during these observations for further studies on foraging behaviour. Relative abundance of syrphid fly on the flower in terms of number of syrphid per meter square per five minute. Foraging rate was recorded in terms of number of flowers visited by a forager per minute. Foraging speed of syrphid fly on the flower was recorded by observing time spent by the forager on each flower using stop watch. The loose pollen grains sticking to the body of forager were estimated. The syrphid flies were captured gently by forceps to avoid shaking of its body from the flowers and its hind legs were amputated following the method given by Kumar [6]. Number of loose pollen grains adhering to the body of syrphid fly was determined by capturing the forager and killing immediately in 5 ml of 70% alcohol in glass vials. From the rinsate an aliquot of 0.02 ml (replicated three times), was taken on a counting dish under binocular microscope at 100× magnification and the pollen grains in the whole rinsate was then calculated. Pollination index of sryphid fly was assessed on the basis of their abundance and foraging behaviour such as foraging rate, foraging speed, number of loose pollen grains sticking to their bodies. The data were collected from measured plots of 26.5m x 20 m.

3. Results and Discussion

Data on and foraging behaviour and abundance of *Eristalinus* and *Syrphini* on rapeseed have been summarized as follows:

3.1 Foraging rate (number of flower visited/minute)

The foraging rate of *Eristalinus* and *Syrphini* on rapeseed was peak at 1000-1100 hour and 1100-1200 hour (3.85 ± 0.18 flower/min and 8.47 ± 0.36 flower/min), respectively while minimum foraging rate was recorded during same day hour 1500-1600 hour and 0700-0800 hour **(**2.45 ± 0.26 flower/min and 2.71 ± 0.16 flower/min), respectively. Mean foraging rate of *Eristalinus* and *Syrphini* (3.29 ± 0.26 and 4.98 ± 0.35), respectively were recorded in the year 2017 (Table 1). In the year 2018, the foraging rate of *Eristalinus* and *Syrphini* was peak at 1200-1300 hour and 1100-1200 hour (3.97 ± 1.05 flower/min and 7.18± 0.37 flower/min), respectively while minimum foraging rate was recorded during 0700-0800 hour and 1500-1600 hour (2.19 ± 0.03 flower/min and 2.77± 0.41 flower/min) and mean foraging rate (3.32 ± 0.42 flower/min and 5.03± 0.44 flower/min), respectively (Table 3). Similar results were also observed by Singh *et al.* [9] that minimum foraging rate (6.37 flowers/min) was observed for *Episyrphus balteatus* at 0900-1000hr followed by *E. balteatus* (8.49 flowers/min) at 1500- 1600hr on mustard bloom. Devi *et al.* [3] conducted an experiment in which foraging rate of 17.42 flowers/min for syrphid flies (*E. balteatus*) was reported on mustard bloom which is more or less in agreement with present findings. A study conducted by Sharma and Rana [7] reported that the average number of flowers visited per minute by *E. balteatus* was 1.57, respectively on cherry bloom.

3.2 Foraging speed (time spent, in sec /flower)

Eristalinus and *Syrphini* was found to spend 29.84 ± 3.10 and 7.15 ± 0.28 sec per flower (maximum foraging speed) during 0700-0800 hour and 19.86 ± 3.11 and 5.01 ± 0.08 sec per flower during 1000-1100 hour and 1100-1200 hour (minimum foraging speed), respectively on rapeseed. Mean foraging speed of *Eristalinus* and *Syrphini* (23.47±3.24 and 5.91 ± 0.10), respectively were recorded in the year 2017 (Table 1). In the year 2018, the foraging speed of *Eristalinus* and *Syrphini* was found maximum at 0700-0800 hour (28.24 ± 2.94 flower/min and 7.22 ± 0.27 flower/min), respectively while minimum foraging rate was recorded during 1000-1100 hour and 1100-1200 hour (18.62 ± 2.41 flower/min and 5.05 ± 0.06 flower/min) and mean foraging rate (22.82 ± 2.65 flower/min and 5.93 ± 0.09 flower/min), respectively (Table 3). Similar results were also observed by Singh *et al.* [8] that *E. balteatus* spent statistically maximum time of (8.77 sec/flower) at 0900-1000hr which was statistically at par with *Eupeodes frequens* (5.77 sec/flower) at 0900-1000hr, whereas, statistically minimum time spent per flower (3.71 sec/flower) was observed for *E. frequens* at 1200-1300hr followed by (4.56 sec/min) for *E. balteatus* 1500-1600hr, respectively on mustard bloom which is more or less in agreement with the findings of Bakshi [2] who reported the foraging speed of *E. balteatus* foraging over cherry bloom as 5.94 sec/flower.

3.3 Relative abundance (Number of foragers/m^2/5min) during different day hours

The data on abundance (number/m^2/5min) of *Eristalinus* and *Syrphini* was highest on 1100-1200 hour and 1000-1100 hour (10.77 ± 0.34 and 8.51 ± 0.04, respectively) and lowest during 1500-1600 hour and 0700-0800 hour (1.56 ± 0.31 and 2.48 ± 0.07, respectively). Mean abundance of *Eristalinus* and *Syrphini* (4.31 ±0.25 and 6.02 ± 0.12), respectively were recorded in the year 2017 (Table 1). In the year 2018, the abundance (number/m^2/5min) of *Eristalinus* and *Syrphini* was highest on 1100-1200 hour and 1200-1300 (9.52 ± 0.69 and 7.41 ± 0.38) while lowest during 0700-0800 hour (1.66 ± 0.33 and 1.98 ± 0.11) and mean abundance (4.43 ± 0.43 and 5.42 ± 0.14), respectively (Table 3). As compared to the present study only 2.97 syrphids/m^2/5min were observed on *Brassica oleracea* (Devi *et al.*) [5] and 1.84 syrphids/m^2/5min were observed on *Brassica oleracea* var. GH-1 (Devi and Ombir)[4]. More or less similar results found by Singh *et al.* [9] that *E. balteatus* was found significantly most abundant visitor with a mean population of (5.21 syrphids/m^2/5min) than *E. frequens* (3.51 syrphids/m^2/5min) on mustard bloom.

3.4 Loose pollen grain

The data recorded on loose pollen grains on the body of *Eristalinus* and *Syrphini* revealed that more number of average loose pollen grains was adhered to the body of *Eristalinus* (1418.2 ± 44.19 nos.) and *Syrphini* (1268.4 ± 60.33 nos.) in the year 2017 (Table 2 and Fig 1). In the year 2018, loose pollen grains on the body of *Eristalinus* and *Syrphini* carried were more. The number of average loose pollen grain adhered to the body of *Eristalinus* was 1333.2 ±

50.48 nos. and *Syrphini* was 1294.6 ± 65.10 nos., respectively (Table 4 and Fig 2). Singh *et al.* [9] found that *E. balteatus* had more average number of loose pollen grains (475.5 pollen grains) on their body than *E. frequens* (305.4 pollen grains) on mustard bloom. As compared to present study only 140 loose pollen grains were found adhering to the body of *E. balteatus* foraging on radish under similar conditions (Sharma *et al.*) [8].

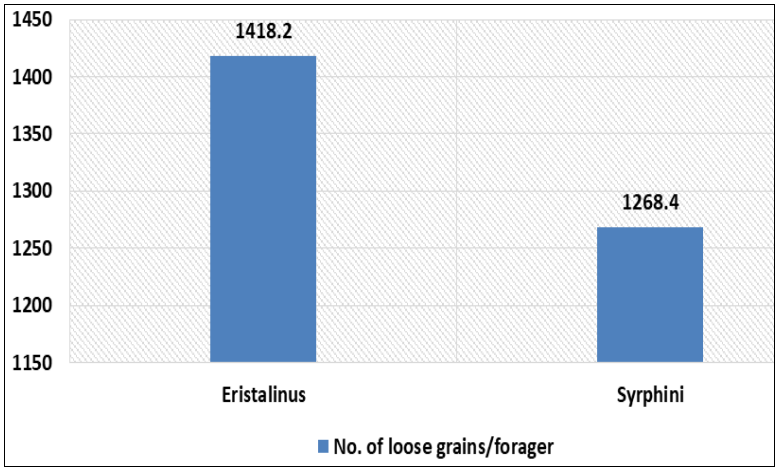

Fig 1: Number of loose pollen grains adhering to the body of syrphids fly on rapeseed during 2017

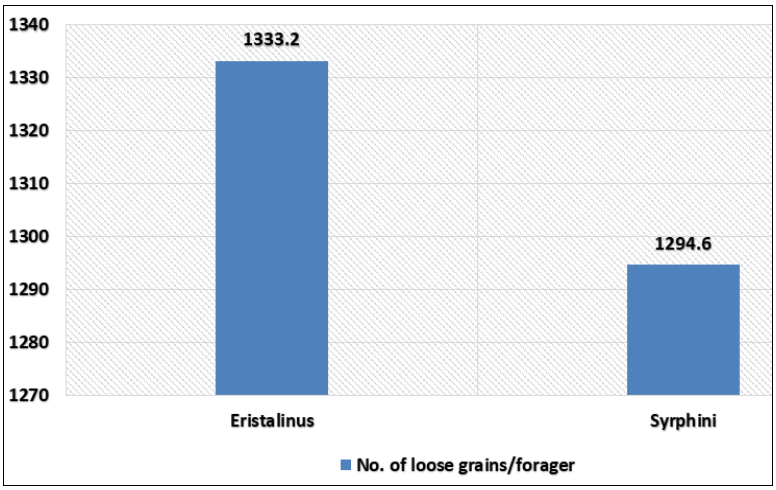

Fig 2: Number of loose pollen grains adhering to the body of syrphids fly on rapeseed during 2018

3.5 Pollination index

The data on pollination index showed that *Syrphini* (8.01) scored higher value than *Eristalinus* (7.20) on rapeseed bloom in the year 2017 (Table 2). In the year 2018, the pollination index recorded high for *Eristalinus* (7.40) than *Syrphini* (7.21) on rapeseed bloom (Table 4). Singh *et al.* [9] revealed that *E. balteatus* attained higher rank than *E. frequens*, indicating (6.93) and (5.83) pollination index on mustard bloom.

Table 1: Foraging rate, foraging speed and relative abundance of *Eristalinus* and *Syrphini* on rapeseed during 2017

Time of observation (Hrs)	Foraging rate (Number of flowers visited/minute)		Foraging speed (Time spent/flower, Sec.)		Number of foragers /m²/5min	
	Eristalinus	***Syrphini***	***Eristalinus***	***Syrphini***	***Eristalinus***	***Syrphini***
0700-0800	3.00 ± 0.34	2.71 ± 0.16	29.84±3.10	7.15 ± 0.28	1.84± 0.17	2.48 ± 0.07
0800-0900	3.34 ± 0.29	3.94 ± 0.40	24.64±3.03	7.02 ± 0.06	2.07 ± 0.18	5.41 ± 0.32
0900-1000	3.75 ± 0.17	4.79 ± 0.42	20.06±5.12	6.95 ± 0.05	3.29 ± 0.17	6.72 ± 0.12
1000-1100	3.85 ± 0.18	6.17 ± 0.41	19.86±3.11	5.22 ± 0.09	7.22 ± 0.24	8.51 ± 0.04
1100-1200	3.40 ± 0.09	8.47 ± 0.36	20.88±3.24	5.01 ± 0.08	10.77 ± 0.34	7.32 ± 0.10
1200-1300	3.17 ± 0.33	7.06 ± 0.68	21.64±4.20	5.09 ± 0.07	6.50 ± 0.18	7.89 ± 0.16
1300-1400	3.35 ± 0.33	5.01 ± 0.35	23.24±2.39	5.07 ± 0.09	3.72 ± 0.26	6.70 ± 0.11
1400-1500	2.73 ± 0.37	3.54 ± 0.32	24.42±2.42	5.28 ± 0.08	1.85 ± 0.37	6.51 ± 0.11
1500-1600	2.45 ± 0.26	3.18 ± 0.11	26.62±2.54	6.42 ± 0.14	1.56 ± 0.31	2.65 ± 0.08
Mean ± SE	3.29 ± 0.26	4.98 ± 0.35	23.47±3.24	5.91 ± 0.10	4.31 ±0.25	6.02 ± 0.12

Table 2: Pollination index of *Eristalinus* and *Syrphini* on rapeseed during 2017

Pollinators	No. of loose grains/forager (Mean ± SE)	Rank assigned on the basis statistical analysis			Average	Relative abundance (Number/m²/5min)	Pollination index
		Foraging rate	Foraging speed	Loose pollen grains			
Eristalinus	1418.2 ± 44.19	1	2	2	1.67	4.31	7.20
Syrphini	1268.4 ± 60.33	2	1	1	1.33	6.02	8.01

Table 3: Foraging rate, foraging speed and relative abundance of *Eristalinus* and *Syrphini* on rapeseed during 2018

Time of observation (Hrs)	Foraging rate (Number of flowers visited/minute)		Foraging speed (Time spent, in sec/flower)		Number of foragers/m^2/5min	
	Eristalinus	***Syrphini***	***Eristalinus***	***Syrphini***	***Eristalinus***	***Syrphini***
0700-0800	2.19 ± 0.03	3.19± 0.45	28.24 ± 2.94	7.22 ± 0.27	1.66 ± 0.33	1.98 ± 0.11
0800-0900	3.39 ± 0.57	3.55± 0.54	23.24 ± 2.34	7.08 ± 0.05	2.24 ± 0.29	3.76 ± 0.08
0900-1000	3.46 ± 0.33	5.18± 0.37	18.82 ± 4.06	6.95 ± 0.03	4.35 ± 0.52	5.97 ± 0.10
1000-1100	3.95 ± 0.43	6.02± 0.92	18.62 ± 2.41	5.16 ± 0.05	7.17 ± 0.62	6.76 ± 0.01
1100-1200	3.4 ± 0.15	7.18± 0.37	19.66 ± 2.6	5.05 ± 0.06	9.52 ± 0.69	6.53 ± 0.10
1200-1300	3.97 ± 1.05	7.01± 0.44	20.66 ± 3.45	5.05 ± 0.10	6.97 ± 0.52	7.41 ± 0.38
1300-1400	3.52 ± 0.52	6.03± 0.2	22.44 ± 1.7	5.09 ± 0.07	4.10 ± 0.14	6.71 ± 0.12
1400-1500	3.23 ± 0.34	4.3± 0.24	23.64 ± 1.75	5.29 ± 0.08	1.96 ± 0.39	5.88 ± 0.28
1500-1600	2.77 ± 0.41	2.77± 0.41	25.22 ± 2.56	6.47±0.12	1.90 ± 0.41	3.77 ± 0.09
Mean ± SE	3.32 ± 0.42	5.03± 0.44	22.82 ± 2.65	5.93 ± 0.09	4.43 ± 0.43	5.42 ± 0.14

Table 4: Pollination index of *Eristalinus* and *Syrphini* on rapeseed during 2018

Pollinators	No. of loose grains/forager (Mean ± SE)	Rank assigned on the basis statistical analysis			Average	Relative abundance (number/m^2/5min)	Pollination index
		Foraging rate	Foraging speed	Loose pollen grains			
Eristalinus	1333.2 ± 50.48	1	2	2	1.67	4.43	7.40
Syrphini	1294.6 ± 65.10	2	1	1	1.33	5.42	7.21

Fig 3: View of the experimental plot

Fig 4: Bowl trapping method on rapeseed

Fig 5: *Eristalinus* foraging on rapeseed flower

Fig 6: *Syrphini* foraging on rapeseed flower

4. Conclusions

The foraging behaviour of *Eristalinus* and *Syrphini* varied significantly during different day hours. The foraging activity was recorded to be maximum at 1100-1300 hours and 1100-1200 Whereas minimum at morning and evening hours of the day. The number of loose pollen grain adhering to the bodies of *Eristalinus* was more as compared to *Syrphini* per forager. The maximum pollination index of 7.40 was recorded from *Eristalinus* as compared to 7.21 of *Syrphini* on rapeseed. The results of the investigation revealed that *Eristalinus* and *Syrphini* was the important as well as effective forager of rapeseed.

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