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The Impact of Food Resources on Fitness of *Episyrphus Balteatus*

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ABSTRACT

Syrphids effectiveness as predators of aphids depends on the supply and quality of pollen and nectar. Pollen is required for reproduction and nectar for survival. Most investigations have focused on the interaction between prey and the predator while overlooking the importance of food foraging and supply during the different physiological phases. It is important to know how pollen and nectar supply affects the overall fitness of hoverflies. We investigated the impact of resource availability on the fitness of E. balteatus. Individual mated female syrphids were released in net cages with rape plant infested with Brevicoryne brassicae. Pollen and sugar supply was manipulated to simulate limitation in food resources. As a control, pollen and sugar were provided throughout the lifespan while the treatments included: pollen only, sugar only, withdraw of pollen during pre-oviposition and oviposition period. Oviposited eggs were counted daily and foraging patterns recorded with a video observation system. Feeding on pollen and sugar throughout resulted in a 2 fold the number of eggs compared to different shortage treatments. Lack of pollen during pre-oviposition and feeding on sugar only lead to a complete lack of egg laying. The highest longevity occurred if pollen and sugar were available throughout being twice as long as if feeding on sugar only. Feeding on pollen alone resulted in same longevity as when feeding pollen and sugar throughout. Syrphids contacted the food patch containing pollen quite often and for longer durations during the pre-oviposition period. The number of visits and durations then decreased during oviposition period. These results demonstrate that pollen availability is not only essential for oviposition but also enhanced survival. Consequently, lack of pollen sources during pre-oviposition has a negative impact on egg output and longevity.

***Key words**: Syrphidae, Foraging behavior, Pollen, Nectar, Oviposition, fitness.*

1.0. INTRODUCTION

In the agricultural landscape *Episyrphus balteatus* is one of the most efficient aphid specific predators and the most common hoverfly in central Europe [1]. Like many insect carnivores the adult life stage of hoverflies require pollen and nectar [2] while it's larvae feed on aphids and other soft bodied prey [3]. The survival of larvae depends upon the oviposition behavior of the adults since their larvae have limited movement and therefore sessile [4]. A female lifespan is characterized by three main periods: A pre-oviposition period which lasts between a week to 10 days [5-6], an oviposition period lasting about 10 to 14 days and a senescence period. Adult hoverflies can survive for more than 1 month [7]. In the absence of pollen hoverflies are not able to produce any eggs [8] however without any food shortage females can lay eggs from oviposition period throughout the entire lifespan [9]. Literature on the food requirements during different physiological period is scarce. In adult syrphids pollen provides proteins and amino acid [10] that is necessary for sexual maturation while nectar and honey dew provide carbohydrates for energy provision [11]. Syrphids effectiveness as predators of aphid depended on the supply and quality of pollen and nectar [12-13] but most investigations on their foraging behaviour have been concerned with the interaction between the prey and the predator, while overlooking the importance of pollen and nectar during the different periods [14]. A detailed understanding of how food supply affects the fitness of syrphids is needed. The objective of this work was therefore to investigate how a limitation in pollen supply affects the fecundity and survival of aphidophagous syrphid *E. balteatus*.

2.0 MATERIALS AND METHODS

2.1 Plant and insect culture

Broad beans (*vicia faba*. L) and rape plants (*Brassica napus* L.) were grown in plastic pots inside a nursery. A stock rearing of adult hoverflies (*Episyrphus balteatus*) was kept in flight cages (52 x40x 60 cm). They were fed on grounded bee pollen (Supplied by Imkerei Hohmann, Germany) and crystalline sugar bought from supermarket. Water was provided in Petri dishes on moist tissue paper. Broad bean plants (*Vicia faba* L.) infested with *Aphis fabae* Scopoli (Homoptera: Aphididae) were placed in the cages for 8 hours every day to stimulate oviposition. Frequently eggs were transferred to plastic boxes and larvae were fed on *Megoura viciae* (Harris) (Homoptera: Aphidae).

2.2 Experimental setup

The experiments were conducted in 25 large net (2x2x2m) cages that were placed inside a green house. The temperature ranged between 20°- 28°C while the relative humidity was between 65-85%. In each net cage a single 3 days old mated naive female was released. Inside the experimental cages, pollen and sugar availability were manipulated to simulate a limitation of food resources (Table 1) while water was provided in a Petri dish on moist tissue paper. The bee pollen (supplied Imkerei Hohmann, Germany) was crushed using a grinder (Model A10) while sugar was in crystalline form (Supplied by supermarket). Five milligram of each food resource in a plastic Petri dish was placed inside the net cages. Both food resources were changed daily. Each of the five food manipulations was conducted simultaneously in five cages. To monitor the oviposition activity, each net cage was provided with two rape plants (20cm high) that were each infested with 50 cabbage aphids *Brevicoryne brassicae*. After 24 hours, laid eggs were counted and plants on which eggs had been laid were removed and replaced. A video observation system equipped with video cameras [15] was used to monitor the feeding behavior on pollen and sugar patches in all cages for the entire life span. The computer program Ethovision®XT (version 7.0, 2009, Noldus, Wangeningen, The Neatherlands) was used to analyse video recordings. Mean number of eggs laid per day for the entire life span, survival rates, feeding frequencies and total feeding time (pollen and sugar) were analyzed using analysis of variance (ANOVA, SAS® software Version 9.2, SAS Institute, 2008). When F-values were significant at the 5% level, Tukey´s test for multiple comparisons was carried out.

Table 1. Summary of the different food regimes that were adopted to simulate limited food resources. Unshaded regions indicate absence of the corresponding food source during that phase.

		Pre- oviposition period (1-11)	**Oviposition period (11-25)**	**Senescence period (> 25)**
Control	Sugar			
	Pollen			
Treatment 1	Sugar			
	Pollen			
Treatment 2	Sugar			
	Pollen			
Treatment 3	Sugar			
	Pollen			
Treatment 4	Sugar			
	Pollen			

3.0 RESULTS

3.1 The effects of food resources on longevity of *E. balteatus*

Our results on food impact on the longevity of *E. balteatus* showed a significant difference among the treatments (F= 22.24; df= 4; P<0.001). The longevity was 2 folds less in individuals who fed on sugar only (16±2.11 days) compared to the control (43±2.07 days). However there was no significant difference (F= 3.83; df = 4; P= 0.114) noted on longevity when *E. balteatus* were fed on pollen only compared to those who were supplied with pollen and sugar throughout (control). Pollen withdrawal during pre-oviposition period led to half fold decrease in longevity (22±1.10). On the converse, no significant difference (F=4.01; df= 4; P= 0.106) was noted in longevity when *E. balteatus* did not have access to pollen during oviposition period as compared to the control (Fig. 1).

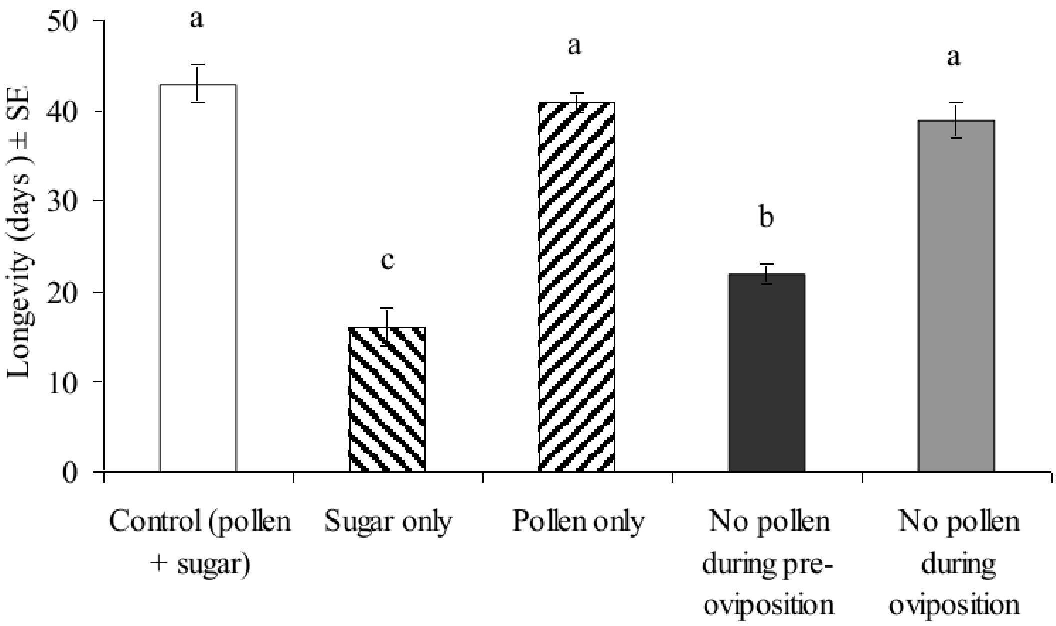

Fig. 1. The impact of food resources on longevity of *E. balteatus*. Bars indicate the standard error. Different lower-case letters above means indicate significant differences (Tukey HSD, P< 0.05)

3.2 The impact of food resources on egg laying

Egg laying started earliest after 13 days when *E. balteatus* fed on pollen throughout their lifespan and when they were denied access to pollen during oviposition. However egg laying started 2 days earlier in the control compared to the treatments. Food resources supply had an effect on egg laying in *E. balteatus*. There was no significant difference (F = 2.47; df = 4; P = 0.274) in egg laying when *E. balteatus* fed on pollen alone (95.14±7.13) as compared to the control. When *E. balteatus* were fed on sugar only throughout their lifespan no eggs were laid. (Fig. 2). Similarly no egg laying was realized when pollen was withdrawn during pre-oviposition period. On the converse, there was half fold decrease in eggs laid when pollen was withdrawn during oviposition period (55.46± 5.14) (Fig 2) as compared to when they were supplied with pollen and sugar throughout their lifespan (control) (103.27±8.15 eggs/day ±SE). The differences were significant (F= 5.89; df= 4; P< 0.001).

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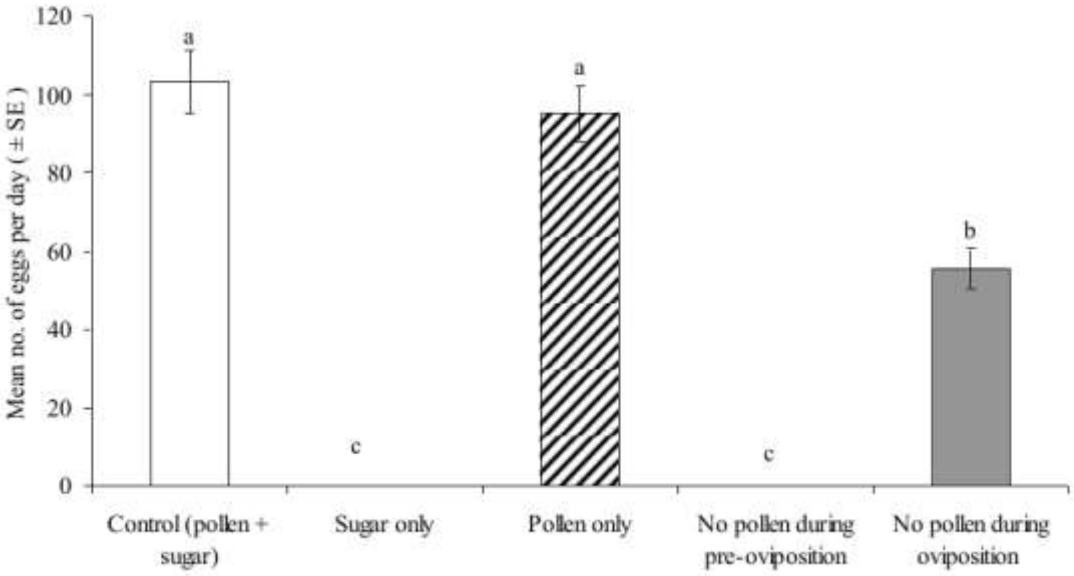

Fig. 2. Mean number of eggs laid by *E. balteatus* when food resources were varied. Bars indicate the standard error. Different lower-case letters above means indicate significant differences (Tukey HSD, P< 0.05)

3.3 The activities of *E. balteatus* on food patch

The data was analyzed in two phases; pre-oviposition and during oviposition period to determine which food resources was most visited as this might indicate the level of importance of different food resources. Landing on food patch was influenced by the available food resource during the pre-oviposition period. There was a half fold decrease in the number of landing on the food patch when sugar was the only food resource (4.42 ±0.73 visits/day) compared to the control. The difference was significant (F=5.03; df=4; P=0.028; Fig. 3 A). There was no significant difference on landing on the food patch when pollen only or no pollen during oviposition period was the treatment compared to the control (F=3.61; df=4; P=0.781; Fig. 3 A). During oviposition period, landing on food patch was influenced by the food resource. There was a significant decrease on landing (3.42 ± 0.62 visits / day) when sugar only was compared to the control (F=2.64; df=4; P=0.011; Fig. 3 B). Pollen only compared to the control did not affect the rates of landing on food patch. A half fold decrease on the number of landing was noted when no pollen during oviposition (2.36 ±0.68 visit/ day) was compared to the control.

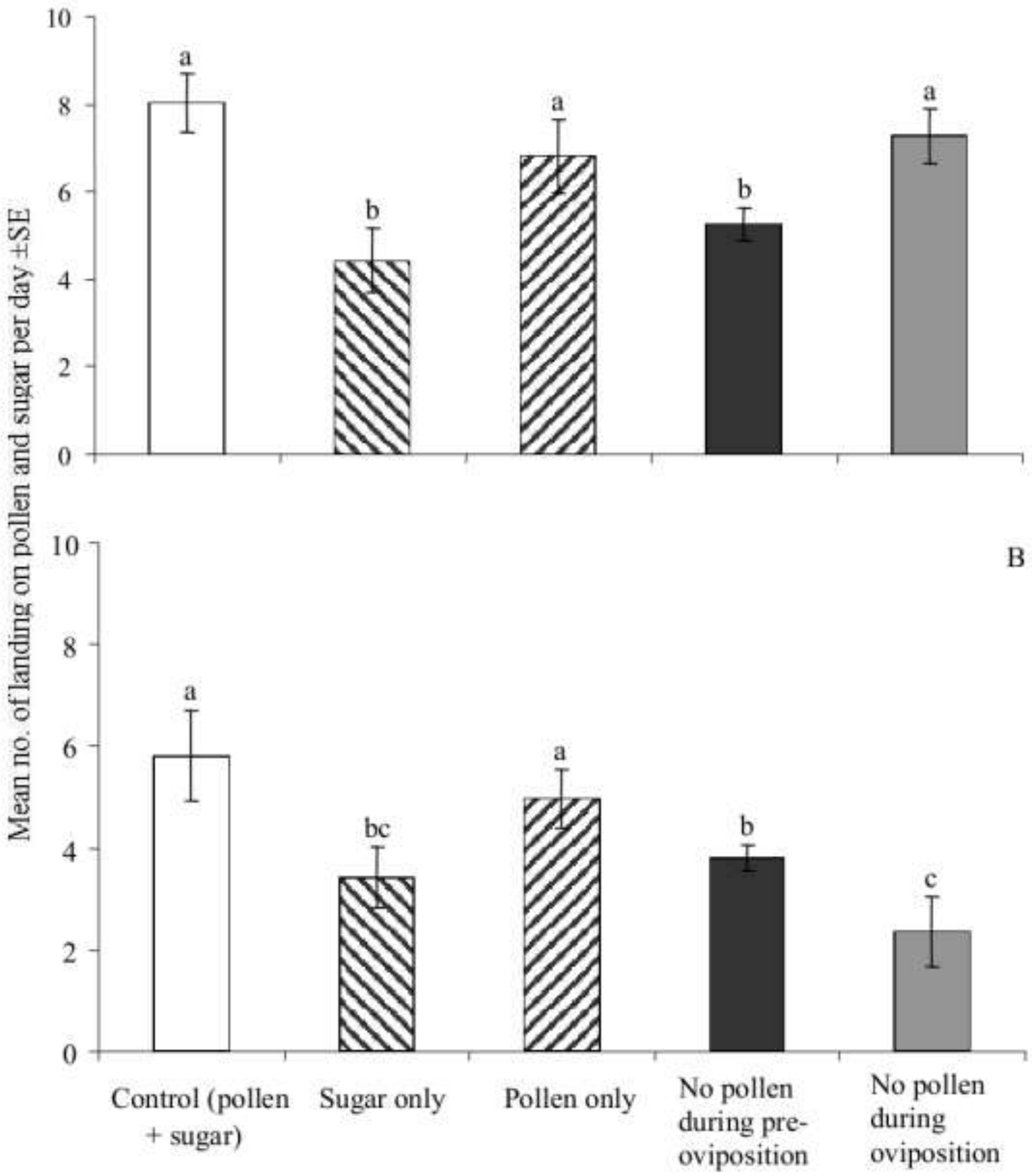

Fig. 3. The frequency of *E. balteatus* landing on sugar and pollen during pre-oviposition period (A) and oviposition period(B). Bars indicate the standard error. Different lower-case letters above means indicate significant differences (Tukey HSD, P< 0.05)

During pre-oviposition period, the amount of time spent on food patch was influenced by the available food resource (F= 3.64; df=4; P= 0.017) Fig 4A. There was more than a half fold decrease on the time spent on food patch (27.58 ± 3.14 min/ day) when sugar only was provided compared to the control (Fig. 4A) . Duration of feeding didn't differ between pollen only and the control. Significantly more than half fold decrease in feeding duration (24.95 ± 3.36 min / day) was noted when no pollen during pre-oviposition treatment was compared to the control (67.21± 3.25 min/day). When food resources were varied during oviposition period, there were significant differences among the different treatments (F= 5.11; df= 4; P= 0.041; Fig. 4B). Feeding durations were half fold lower in sugar only (30.17±3.54 compared to the control (57.34±4.55 min /day) Fig. 4B. However there were no significant differences (F= 4.89; df=4; P= 0.068) when pollen only and no pollen during pre-oviposition treatments were compared to the control. On the contrary when no pollen during oviposition treatment was compared to the control, there was half fold decrease in the amount of time spent on the food patch (26.84 ±3.13) Fig 4B

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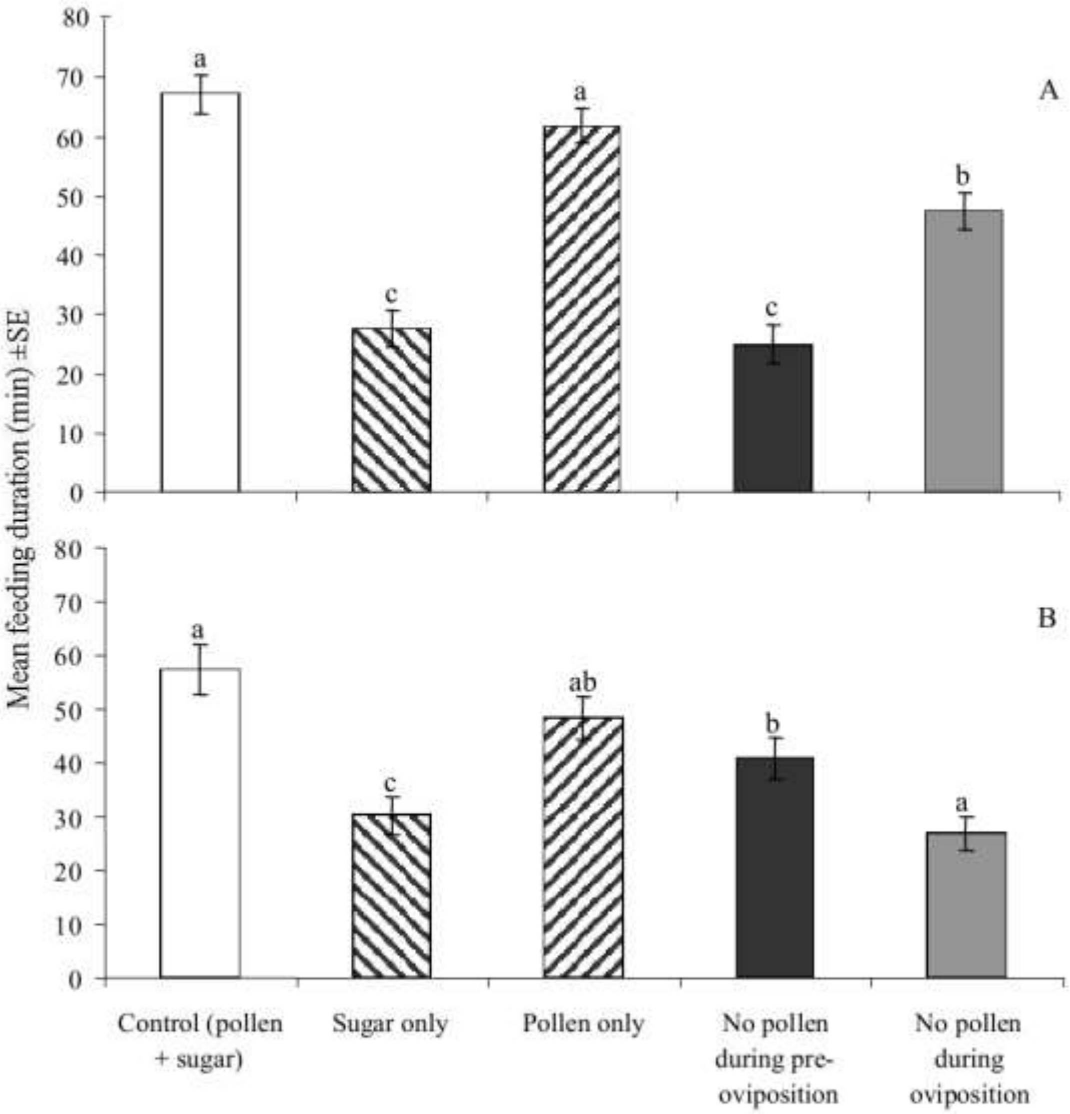

Fig. 4. The mean feeding durations of *E. balteatus* on sugar and pollen during pre-oviposition (A) and ovipositon period (B). Bars indicate the standard error. Different lower-case letters above means indicate significant differences (Tukey HSD, P< 0.05)

4.0 DISCUSSION

Our results shows that the availability of proteins and carbohydrates in the diet of adult *E. balteatus* during specific physiological periods influence their survival and oviposition. Feeding on pollen only throughout an individual life-time resulted in equal longevity and fecundity as compared to the provision of both pollen and sugar (control). Lack of access to pollen during the pre-oviposition period or feeding on sugar as the only food source completely impaired the egg laying and reduced longevity considerably. The results of the present study suggests that changes in the availability of food resources has a far reaching effect on egg laying behavior and survival of syrphids and are in agreement with the findings of [16,8] that the reproductive capacity and longevity of predators such as syrphids is dependent on availability of suitable food resources. While using flowers as a nectar and pollen source [8] found that when flowers are available during the pre-oviposition period only, females produced eggs in the first week of reproduction. However, in the following two weeks, almost no eggs are produced by these females anymore. On the contrary, those with flowers access continued to lay eggs. Similarly, in our findings when *E. balteatus* were allowed access to pollen during pre-oviposition and denied the same thereafter, they still laid eggs albeit the numbers were low. Lower oviposition rate may be an indication that bee pollen is not optimal in fecundity compared to flower pollen. Most pollen ingestion period by females occurs during the pre-oviposition period and this activity coincides with the time of yolk deposition in the eggs [17]. Pollen provides syrphid with nitrogen needed for maturation of the ovaries and also to sustain the production of eggs, hence pollen is an important food resource which should be supplied throughout the lifespan of a syrphid for continuous oviposition. In hoverflies, reproduction only occurs when pollen is available. For example females of *Sphaerophoria scripta* laid no eggs in the absence of pollen food sources [18]. Nutrition has been shown to affect egg development in many insects [19] and in our study when *E. balteatus* had no access to pollen during pre-oviposition period they did not lay any eggs and were unable to compensate even after they accessed it later. Presumably if syrphids are denied protein during vitellogenesis, their egg chambers are degenerated by apoptosis like it is the case in drosophila [20]. Complete lack of egg output was also observed when *E. balteatus* fed on sugar only throughout their lifespan corroborating the findings of [21] who found that syrphids were unable to produce any eggs when they were reared on honeydew or sucrose alone. In these natural predators it is believed that most pollen ingestion period by females coincide with the time of yolk deposition in the eggs until the oocytes occupies up to 90% of the follicle [17] however continuous pollen supply is necessary to ensure sustained egg production [9]. In this study, the longevity of *Episyrphus balteatus* was hypothesized to be affected by food resource supply. We found that the highest survival was noted when *E. balteatus* was supplied with pollen and sugar throughout the lifespan. There was no significant difference when *E. balteatus* was supplied with pollen only or when pollen and sugar were withdrawn during oviposition period. On the contrary, a complete withdraw of pollen during the pre-oviposition period significantly reduced the longevity. In addition, feeding on sugar only elicited the lowest survival rates. Other findings with *S. scripta* indicate that when females had pollen as an additive, they lived 3 fold more than those without it. In the absence of any food (water only) adult female *S. scripta* only survived for 1.9 days [18]. A prolongation of adult lifespan has been documented after providing syrphids with pollen or a mixture of honey and 10% pollen [22]. These findings agreed with our results whereby those female who fed on pollen and sugar throughout their lifespan had the highest longevity while those that fed on sugar only had the lowest. From our study a comparison of landing on the food patch has revealed higher landing rates on food patch containing pollen during the pre-oviposition period. Sugar only as a food resource was half fold visited by the syrphids. This is probably because eggs are maturing at this stage and therefore there are higher requirements for protein sources. For example in syrphid *Rhingia campestris* pollen requirements are normally high while yolk deposits are being laid down in eggs [17]. Although carbohydrates are needed at all stages, during pre-oviposition its role is not as important as proteins. On the contrary, landing rates on food patch went down during oviposition period. Presumably this is owing to the low food requirements and a priority shift to oviposition of the already mature eggs. Our results show higher feeding duration during pre-oviposition compared to oviposition period. Our findings supports the previous findings [8] which suggest that female syrphids most probably focus on food foraging during the first week after emergence, and thereafter they focus more on oviposition sites. From our study, little amount of time was invested in sugar only during pre-oviposition and oviposition period. Female hoverflies need sugar but the peak is at the beginning and end of yolk deposition [17]. A decrease in the feeding time even on food patch containing pollen was evident during oviposition period. In *Eupeodes corollae* pollen consumption is higher before any egg collection and then a decrease occurs [16].

5.0 CONCLUSION

In conclusion this study has demonstrated differences in food requirements during different physiological periods of hoverflies. Most importantly, we have shown the essence of pollen availability during pre-oviposition period. Furthermore, pollen should be available throughout their diet to ensure sustained fecundity and prolonged longevity. However further studies should be undertaken to determine the fitness of the resulting offspring after the realized fecundity from the different food manipulations.

CONFLICT OF INTEREST

The author declare that there is no conflict of interest with the funding organization

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