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Impact of EFNs number on plant vigour and ant visitations on Folivory in cotton, sesame and castor

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ABSTRACT

In cotton, among three genotypes EFNs number were highest in wild during summer. EFNs number and yield were highest in hybrid and lowest in variety during summer. In Sesame, the number of EFNs and yield were highest in variety during summer, lowest in wild during Kharif. In Castor, the same were highest in wild during summer and lowest in wild during Kharif. In cotton, the percentage of injured leaves was significantly lowest in wild in control (ant present) but it was significantly high in variety in treatment (ant excluded). In both sesame and castor, the percentage of injured leaves was significantly lowest in wild in control (ant present) and was significantly highest in hybrid in treatment (ant excluded). In all the three genotypes, the percentage of injured leaves was lower in control (ant present) than the treatment (ant excluded).

Key words: *Extrafloral nectaries, Plant vigour, Ants, Folivory, Cotton, Sesame, Castor*

Introduction

EFN is secreted mainly on the most valuable organs, that is, organs that are characterized by strong future contribution to the fitness of the plant and high construction costs (such as young leaves, developing fruits, etc.), and the plant secretes EFN in much higher amounts in response to herbivore-inflicted damage, that is, when enemy pressure is high (Heil, 2015). Extrafloral nectaries serves diverse ecological functions (Baker *et al.*, 1978; Becerra and Venable, 1989; Wagner and Kay, 2002; Heil, 2011), they are best known for protecting plants with indirect defence against herbivores by attracting predatory insects, predominantly ants (Bentley 1977b; Koptur 1992; Rosumek *et al.*, 2009; Heil, 2015).

Materials and Methods

Effect of EFNs number on plant vigour was estimated by recording the number of EFNs, yield of cotton (hybrid, variety), sesame and castor (hybrid, variety and wild) during *Summer* 2018 and *Kharif* 2018.

To estimate the effect of ant visitations on folivory, twelve plants were selected for the control (with ants) and treatment (without ants) in each of the three genotypes (hybrid, variety and wild) of cotton, sesame and castor. Plants of approximately the same height and in the same phenological state (no buds, flowers or fruits) were selected. Ants were prevented from climbing on treatment plants by applying to their base a sticky barrier of plants, castor oil at weekly intervals. Ants had free access to the control plants. The number of healthy and folivory leaves (injured leaves) was recorded for a month (4 counts). The percentage of injured leaves of control and treatment was calculated.

Results and Discussion

Effect of EFNs number on plant vigour

The results obtained from the studies on the effect of extrafloral nectaries number on plant vigour *Summer* and *Kharif* (2018) are furnished in Table 1. In cotton wild EFNs number were highest in *Summer* (146.26) and yield was nil in both *Summer* and *Kharif*. In hybrid, number of EFNs, yield were highest (99.09, 145.43) in *Summer*; lowest in variety (70.78, 95.05) during the same season. In sesame the number of EFNs, yield were highest (96.81, 12.82) in variety during *Summer*; lowest in wild during *Kharif* (40.78, 0.19). In castor the number of EFNs, yield were highest (343.38, 202.45) in wild during *Summer*; lowest in wild during *Kharif* (142.61, 163.09).

In cotton, among three genotypes EFNs numbers were highest in wild during *Summer* but yield was not recorded in both the *Summer* and *Kharif* because it was in the start of flowering stage during the end of the study period. But wild cotton will have more yield if it completes boll formation as they had more flowers per sympodial branches even in start of flowering stage, more EFNs number and less pest attack.

EFNs number and yield were highest in hybrid and lowest in variety during *Summer*. In Sesame, the number of EFNs and yield were highest in variety during *Summer*, lowest in wild during *Kharif*. In Castor, the same were highest in wild during *Summer* and lowest in wild during *Kharif* (Table 1). From the present study results it is clear that yield increases with EFNs number.

The above findings of the present study are in accordance with Sobrinho *et al*. (2002) whom reported that the potential protection conferred by ants may change in time, which may be linked to the resource quality or quantity offered by plants. There is no data regarding this variation in resource abundance and quality to *Triumfetta semitriloba* along its phenological cycle, but some of the obtained data may infer that these changes occur. Their results showed that January and February were the months with higher leaf abundance, which certainly caused higher EFNs abundance. Even though the number of leaves was high, and consequently the number of EFNs, there were fewer ants visiting the plants in

Table 1. Effect of extrafloral nectaries number on plant vigour (*Summer* and *Kharif*, 2018)

Season	Cotton						Sesame						Castor					
	Hybrid		Variety		Wild		Hybrid		Variety		Wild		Hybrid		Variety		Wild	
	Mean no. EFNs/ plant*#	Yield/ plant (g)*	Mean no. EFNs/ plant*#	Yield/ plant (g)*	Mean no. EFNs/ plant*#	Yield/ plant (g)*	Mean no. EFNs/ plant*%	Yield/ plant (g)*	Mean no. EFNs/ plant*%	Yield/ plant (g)*	Mean no. EFNs/ plant*%	Yield/ plant (g)*	Mean no. EFNs/ plant*#	Yield/ plant (g)*	Mean no. EFNs/ plant*#	Yield/ plant (g)*	Mean no. EFNs/ plant*#	Yield/ plant (g)*
Summer	99.09± 3.88	145.4± 6.92	70.78± 2.88	95.05± 7.21	146.2± 3.07	—	57.77± 2.85	9.32± 0.45	96.81± 3.95	12.82± 0.67	44.39± 0.79	0.25± 0.01	192.3± 7.53	189.9± 9.17	157.6± 6.43	170.0± 8.88	343.3± 6.14	202.4± 9.77
Kharif	87.66± 3.43	138.5± 6.64	75.81± 3.09	95.66± 5.00	133.0± 2.38	—	58.83± 2.30	10.04± 0.48	68.78± 2.80	10.65± 0.55	40.87± 0.73	0.19± 0.009	175.9± 6.88	178.6± 8.62	142.6± 5.82	163.0± 8.52	311.6± 5.58	194.74± 9.40

*Mean of four replications
#Mean of twelve counts
%Mean of eight counts
Mean values followed by standard deviation

these months than in May. This may be indirect evidence that the resource quality offered by the plants in May is more attractive to ants, coincident with the pre-floral stage. The possible herbivory decrease in this stage may prevent the plant to direct energy to produce leaves, allowing the energy allocation to reproductive structures. Other authors have already suggested the importance of ants decreasing herbivory in vegetative parts and its role in reproductive output increase (Bentley, 1977a; Oliveira *et al*., 1999). Studies on peach (*Prunus persicae*) EFN confirmed that the presence of extrafloral nectaries is related to lower herbivory rates and higher productivity (Mathews *et al.,* 2009 and Mathews *et al.*, 2007).

Increased EFN secretion rates have been shown to increase the number of ant workers foraging on plants (Heil *et al.,* 2001; Kost and Heil, 2005), have been related to higher survival rates of ant workers (Lach *et al.,* 2009) and other predators (Limburg and Rosenheim, 2001) and can increase ant activity and aggressiveness (Heil *et al*., 2009; Ness, 2006; Sobrinho *et al*., 2002). Indeed, indirect defence via ants represents one of the few antiherbivore defence strategies for which a clear effect on net herbivory rates and plant fitness has been shown for different species (Chamberlain and Holland, 2009).

For Lima bean (*Phaseolus lunatus*), an increased defence against herbivores was linked unambiguously to an augmented EFN supply (Kost and Heil 2005). Thus, a positive correlation of investment with benefit for the plant has been shown for EFN.

Similar to the present study results, Mondor *et al*. (2013) also reported that plant vigour may be correlated with overall EFN numbers, the smallest plants may be the most heavily defended on the basis of EFNs per unit of above-ground biomass. Many field studies have demonstrated that extrafloral nectaries can increase plant fitness by the ants visiting which deterred leaf herbivores (Koptur, 1979, Stephenson, 1982), flower herbivores (Deuth, 1977; Schemske, 1980; Horvitz and Schemske, 1984), and seed predators (Inouye and Taylor, 1979; Pickett and Clark, 1979).

The role of EFNs as a factor that increases plant

Table 2. Effect of ant visitations on folivory of cotton

Genotype#	Percentage of injured leaves (%)		SEd	CD (0.05)
	Control (ant present)*	Treatment (ant excluded)*		
Hybrid	22.91 (28.59)	26.45 (30.94)	0.58	1.84
Variety	14.88 (22.68)	32.35 (34.65)	0.59	1.90
Wild	4.2 (11.82)	5.17 (13.13)	0.18	0.58

*Mean of twelve plants
#Mean of four counts
Values in parentheses are arc sine transformed
Ants includes *Camponotus sericeus, Camponotus rufoglaucus, Camponotus compressus, Myrmicaria brunnea, Pheidole sp., Monomorium scabriceps, Crematogaster sp., Solenopsis geminata, Meranoplus bicolor, Tetraponera nigra, Oecophylla smaragdina, Paratrechina longicornis, Monomoium criniceps, Monomorium sp.*
Herbivores includes *Amrasca devastans, Phenacoccus solenopsis, Sylepta derogata, Aphis gossypii, Myllocerus sp.*

Table 3. Effect of ant visitations on folivory of sesame

Genotype#	Percentage of injured leaves (%)		SEd	CD (0.05)
	Control (ant present)*	Treatment (ant excluded)*		
Hybrid	24.25 (29.49)	31.37 (33.30)	0.65	2.09
Variety	22.91 (28.59)	27.96 (31.91)	0.59	1.89
Wild	14.65 (22.50)	16.00 (23.56)	0.34	1.10

*Mean of twelve plants
#Mean of four counts
Values in parentheses are arc sine transformed
Ants includes *Camponotus rufoglaucus, Camponotus compressus, Solenopsis geminata, Monomorium scabriceps.*
Herbivores includes *Antigastra sp., Heteracris littoralis, Empoasca lybica, Chorthippus brunneus.*

fitness by acting as an effective anti-herbivore defense mechanism was confirmed by Chamberlain and Holland (2009) which coincides with the observations of present study.

Effect of ant visitations on folivory

The results obtained from the effect of ant visitations on folivory of cotton are presented in Table 2. The percentage of injured leaves was significantly lowest in wild (4.2) in control (ant present). The percentage of injured leaves was significantly highest in variety (32.35) in treatment (ant excluded). The results obtained from the effect of ant visitations on folivory of sesame are presented in Table 3. The percentage of injured leaves was significantly lowest in wild (14.65) in control (ant present). The percentage of injured leaves was significantly highest in hybrid (31.37) in treatment (ant excluded). The results obtained from the effect of ant visitations on folivory of castor are presented in Table 4. The percentage of injured leaves was significantly lowest in wild (13.63) in control (ant present). The percentage of injured leaves was significantly highest in hybrid (52.69) in treatment (ant excluded).

In cotton, the percentage of injured leaves was significantly lowest in wild in control (ant present) but it was significantly highest in variety in treatment (ant excluded) (Table 2). In both sesame and castor the percentage of injured leaves was significantly lowest in wild in control (ant present) and was significantly highest in hybrid in treatment (ant excluded) (Table 3; Table 4). This may be due to more number of EFNs in wild genotype than hybrid and variety during vegetative stage of cotton, sesame and castor which attracted more ant visitations on plants indirectly decreased folivory.

Mathews (2004) also confirmed this and stated that, the significant interaction between ants and EFNs in May revealed that if ants were present, the trees with EFNs had substantially less folivory (an average of 4%, as compared to 60%) for trees without EFNs. If ants were excluded, trees with EFNs did not benefit from the EFNs; they were as vulnerable to herbivory as trees without EFNs. Trees with the ant exclusion treatment still had arthropod predators, such as coccinellids, cantharids, and asilids, in the canopies. However, the other predators did not effectively provide protection from herbivores during May, because herbivory rates were comparable for trees with and without EFNs under the ant exclusion treatment in May. Therefore, when leaves first emerge in the spring, investment in leaf EFNs as a defense strategy appears to be highly effective but dependent on ants.

Several authors have demonstrated that associations between ants and EFN-bearing plants can decrease foliar herbivory (Rutter and Rausher, 2004) and/or increase fruit set (Nascimento and Del-Claro, 2010). Oliveira and Del-Claro (2005) showed that in cerrado vegetation, leaf herbivory can surpass 50% in ant excluded plants. This supports the present study results.

Oliveira and Freitas (2004) reported that ants did affect the oviposition behavior of *E. bechina* females, but this was shown to depend on the level of ant visitation to the host plant, with females laying fewer eggs on plant branches highly visited by ants than on ant-excluded ones.

Ants, which attack many species of lepidopteran larvae (Jaynes and Marucci, 1947; Sudd, 1965; Tilman, 1978; Way an Khoo, 1992; Daane and Dlott, 1998), probably consumed (or removed from the

Table 4. Effect of ant visitations on folivory of castor

Genotype#	Percentage of injured leaves (%)		SEd	CD (0.05)
	Control (ant present)*	Treatment (ant excluded)*		
Hybrid	45.66 (42.50)	52.69 (46.54)	1.05	3.34
Variety	22.06 (28.00)	48.26 (44.00)	1.06	3.35
Wild	13.63 (21.66)	28.57 (32.30)	0.48	1.55

*Mean of twelve plants
#Mean of four counts
Values in parentheses are arc sine transformed
Ants includes *Myrmicaria brunnea, Monomorium scabriceps, Solenopsis geminata, Pheidole sp., Camponotus rufoglaucus, Camponotus compressus, Meranoplus bicolour, Camponotus sericeus, Tetraponera nigra.*
Herbivores includes, *Spodoptera litura, Achaea janata, Euproctis fraterna, Trialeurodes ricini.*

trees) the late-instar *G. molesta* larvae as they emerged from terminal shoots in search of pupation sites.

Mathews (2004) stated that ants were responsible for 19-60% of pest reduction on terminals that were partially or fully caged. Other natural enemies removed 1.5-25% of the sentinel pupae. Larval survival was lowest in the presence of ants. Also he reported that, when ants were present, a significant ~15-fold increase in folivory was observed for leaves without EFNs as compared to leaves with EFNs. This is in confirmation with present study results.

Also few other studies reported that, ants are voracious generalists and may significantly impact a wide range of herbivores (Way and Khoo, 1992; Stradling, 1987). The removal of the coconut caterpillar (*Opisina arenosella* Walker) eggs by several ant species contributed significantly to control of this pest (Way *et al.*, 1989).

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