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Research Article

Performance of *Nesidiocoris tenuis* (Hemiptera: Miridae) on Three Prey Types under Laboratory Conditions

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ABSTRACT

The zoophytophagous predator, Nesidiocoris tenuis is widely used in integrated pest management programs against various tomato (Solanum Lycopersicum L.) pests. Its effectiveness depends on the presence of diverse prey. The present study evaluated the performance of N. tenuis on the prey: Tuta absoluta eggs, Aphis gossypii nymphs and Tetranycus evansi in the laboratory. Every day nymphal stages of N. tenuis were provided with a quantity of 10, 15, 20, 30, 35 eggs of T. absoluta; 3, 8, 12, 16, 20 nymphs of T. evansi and 5, 10, 15, 20, 25 nymphs of A. gossypii, respectively. The predation capacity of immature stage; N1, N2, N3, N4, N5 and adults of N. tenuis was tested for a respective amount of 15, 25, 35, 45, 55 and 100 individuals for each prey type. Development time of N. tenuis nymphs was affected by prey type. The duration of the immature stage was shorter when the predator fed on A. gossypii nymphs. Food type had no impact on survival of N. tenuis nymphs. The predatory capacity of N. tenuis is greater on T. absoluta eggs. Regardless of the kind of prey, predation ability increases with the age of the predator. Female N. tenuis consumed more prey than males. Our results may have practical implications of interest in mass rearing systems of N. tenuis and contribute to the development of alternative integrated management methods against tomato pests.

***Keywords**: Tuta absoluta, Biological control, Life traits, Natural enemies, Predations.*

INTRODUCTION

Indigenous natural enemies play an important role in controlling invasive pests (Urbaneja et al., 2005; Perdikis et al., 2009; & Calvo et al., 2012). In sub-Saharan Africa, the lack of data is a hindrance to the development of biological control programs. *Nesidiocoris tenuis* (Reuter) (Hemiptera: Miridae) is a zoophytophagous predator and is known to prey on pests of tomato (*Solanum Lycopersicum* L.) on the Mediterranean coast and in sub-Saharan Africa (Alomar et al., 2002; Sánchez et al., 2003; Urbaneja et al., 2005; Sylla et al., 2016b; Mansour et al., 2018; & Garba et al., 2020).

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This predator is widely used in biological control programs against whiteflies, mainly in greenhouse crops (Gerling et al., 2001; Alomar et al., 2006; & Calvo et al., 2012). It also contributes to the control of thrips, leaf miners, aphids, mites, and lepidopterans (Perdikis et al., 1999; Calvo et al., 2009; & Van Lenteren, 2012).

The predator abundance in tomatoes in Senegal, particularly in the Niayes region, was reported by Sylla et al. (2016b). It is the only predator of *T. absoluta*, frequently encountered in tomato fields in sub-Saharan Africa (Mansour et al., 2018). It was reported as an effective biological control agent against the tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in fields (Sylla et al., 2016b; & Mansour et al., 2018).

Studies have shown the positive effect of prey diversity in the rapid establishment of generalist predators in cropping systems (Symondson et al., 2002; Bompard et al., 2013; & Mollá et al., 2014). Animal prey is required for *N. tenuis* to complete its development (Sanchez, 2009; Urbaneja et al., 2005; & Arnó et al., 2006). Prey diversity allows for predators to rapidly establish and increase populations (Urbaneja-Bernat et al., 2013; Mollá et al., 2014; & Urbaneja-Bernat et al., 2015). The simultaneous presence of *T. absoluta* and whiteflies in tomato crops increased the potential biocontrol of *N. tenuis* (Calvo et al., 2012). The life cycle of *N. tenuis* is relatively long when fed exclusively red mites or thrips (Urbaneja et al., 2003). Adults of *N. tenuis* can consume more than 100 *T. absoluta* eggs per day (Mollá et al., 2009; & Urbaneja et al., 2009). The predator is also capable of feeding on *A. gossypii* (Hemiptera: Aphididae) and *Tetranychus evansi* mite (Acari: Tetranychidae) (van Lenteren, 2012). These are all pests of cultivated tomato plants (Tendeng et al., 2017; Sylla et al., 2017 & 2018; & Diatte et al., 2018). The performance of *N. tenuis* in tomatoes relies on prey diversity. This study aims to evaluate the performance of *N. tenuis* on the prey foods *Tuta absoluta* eggs, *Aphis gossypii*, and *Tetranycus evansi* nymphs under laboratory conditions. The objectives were to assess the effect of prey foods on development time, survivorship, and predation rates of *N. tenuis.*

MATERIALS AND METHODS

Plants and insects

The study was conducted at the Research Laboratory in Integrated Production and Protection of Horticultural Agroecosystems (L2PIA) in Cheikh Anta Diop University (14°41'05.14"N and 17°27'43.28"W). Tomato plants (*Solanum Lycopersicum* L., F1 Mongal) used in the experiments were at least 5 weeks old and grown in the greenhouse. Plants were grown using small plastic pots filled with commercial compost and watered daily. Colonies of *N. tenuis, T. absoluta*, *T. evansi,* and *A. gossypii* insects (about 500 individuals each) were collected from tomato fields in the Niayes area and transferred to the laboratory. Insects were reared on caged tomato plants (120 × 70 × 125 cm) at 28°C, 65±10% relative humidity, and a photoperiod 12L:12D.

Feeding bioassays

Development time and survival rate of immature stages of *N. tenuis* were evaluated on (a) *T. absoluta* eggs, (b) *T. evansi* nymphs, and (c) *A. gossypii* nymphs. Newly emerged *N. tenuis* nymphs (N1 stage) were individually transferred into Petri dishes (90 × 14 mm), with one tomato leaflet. Every day, the nymphs were checked and fed exclusively with one type of prey. The tomato leaflets were changed when necessary. The food quantity offered to each nymphal stage was estimated based on preliminary assays. The nymphal stages of *N. tenuis*, N1; N2; N3; N4 and N5 were respectively fed 10, 15, 20, 30, or 35 eggs of *T. absoluta;* 3, 8, 12, 16, or 20 nymphs of *T. evansi* and 5, 10, 15, 20, or 25 nymphs of *A. gossypii*. Nymph development and survival were monitored daily until either death or adulthood. Nymphs who died on the first day of the experiment were replaced with new ones, as it was assumed that mortality was not due to handling. A total of 45 replications were performed for each prey type.

The predatory capacity of each nymphal and adult stage (male and female) of

N. tenuis was evaluated on the three types of prey. Immature stages (N1 to N5) and newly emerged adults of *N. tenuis* were transferred individually into Petri dishes (90 × 14 mm), with one tomato leaflet. The quantity of prey tested for each nymphal and adult stage was estimated from preliminary experiments. The predation capacity of N1, N2, N3, N4, or N5 nymphs, and *N. tenuis* adult was tested for a respective quantity 15, 25, 35, 45, 55, or 100 individuals for each type of prey. After 24 h, the number of prey consumed by nymphs and adults of *N. tenuis* were counted. Twenty replicates were performed for each developmental stage of *N. tenuis* (nymphs and adults) for each modality. A control (prey without predator) was established for each prey type.

Statistical analyses

The data were analyzed with R software version 3.6.3 (Core Team 2020). Data were tested for normality (Shapiro-Wilk test) and homogeneity of variances (Bartlett test). Development time of immature stages (N1 to N5) and predation ability of *N. tenuis* were analyzed using generalized linear models (GLM) with a Poisson distribution (link=log). Survival rates were compared using a GLM with the binomial function (link=logit). Post hoc multiple comparisons of mean values were performed using the Newman Keuls method (*package multcomp*).

RESULTS

Development time of immature stages of *N. tenuis* was influenced by prey type (df=2; χ^2=14.11; P <0.01). The development time of immature stages of *N. tenuis* was shorter when fed exclusively *A. gossypii* nymphs compared to *T. absoluta* eggs and *T. evansi* nymphs (Figure 1).

The percent survival of immature stages of *N. tenuis* was 80% for *T. absoluta*, 84% for *T. envasi* and 89% for *A. gossypii*. Prey food did not impact on survival of immature stages of *N. tenuis* (Df = 2; χ2 = 115.33; P = 0.504) (Figure 2).

Total number of prey consumed by *N. tenuis* during its lifespan was much greater in *T. absoluta* (3999 eggs) than in *A. gossypii* (2540 nymphs) and *T. evansi* (2007 nymphs). The type of prey subjected to the predator *N. tenuis* had a highly significant effect on predation capacity (Df=2; χ2 = 3359.8; P <0.001) (Table 1).

Numbers of *T. absoluta* eggs, *A. gossypii* nymphs, and *T. evansi* nymphs consumed by *N. tenuis* increased as development increased; it ranged from 94 (N1) to 611 (N5) when the predator fed *T. absoluta* eggs. This value varied between 61 (N1) and 403 (N5) and between 34 (N1) to 360 (N5) nymphs when the predator consumed *A. gossypii* nymphs and *T. evansi*, respectively. The number of prey consumed by immature stages of *N. tenuis* increased with the increasing developmental stage (df=4; χ2 =117.65; P<0.001). Female adults of *N. tenuis* consumed more prey than males (df=1; χ2 = 72.523; P<0.001) (Table 2).

DISCUSSION

The type of prey influenced the developmental duration of immature stages of *N. tenuis*. The development time of immature stages of *N. tenuis* was shorter when fed exclusively *A. gossypii* nymphs compared to *T. absoluta* eggs and *T. evansi* nymphs. This result is in line with previous studies showing that *Macrosiphum euphorbiae (Thomas)* (Hemiptera: Aphididae) and *M. persicae* aphids, are suitable prey for the *M. pygmaeus* predator with relatively short nymphal development time (Perdikis & Lykouressis, 2004; Perdikis et al., 2011; & Sylla et al., 2016a). The results obtained with *T. absoluta* eggs are similar to those of Mollá et al. (2014), who reported that *N. tenuis* completed its nymphal development after 13 days. However, a longer pupal development time (15.5 days) occurs when *N. tenuis* nymphs feed on *T. evansi* nymphs. The difference in duration of nymphal development of *N. tenuis* concerning prey types could be explained by the high mobility of *T. evansi* nymphs. The amount of prey consumed by *N. tenuis* is probably related to easy access to the prey. Easy availability of food would cause the predator to consume much more of one prey in terms of quantity at the expense of another prey and this has an impact on development time. The same phenomenon was observed by Urbaneja et al. (2003) who found that when *N. tenuis* feeds on mobile prey (the mite, *T. urticae*, and the thrips *F. occidentalis*), its nymphal development time is longer than when it feeds on immobile prey (eggs of *E. kuehniella* and nymphs of *B. tabaci*). With mobile prey in non-choice conditions, the predator loses a lot of energy in predation but does not eat as much or as often as necessary. The difference in duration of nymphal development of *N. tenuis* according to prey types could be attributed to the nutritional quality of the prey. It is known that the nutritional quality of the prey is an important characteristic that can influence the predator's choice as the greater the nutritional value of the prey, the better the predator's fitness (higher survival, greater fecundity, etc.) (Eubanks & Denno, 2000). Adequate nutrition is necessary for immature stages of *N. tenuis* to rapidly reach the adult stage (Urbaneja et al., 2005; Arnó et al., 2006; & Sanchez et al., 2009). That prey can reduce the development time of immature stages of a generalist predator could enhance biological pest control and rearing benefits by optimizing the diet of predators. Because species with short development times can complete more generations per time unit than species with long development times (Kindlmann & Dixon, 1999).

The survival was 80% for *T. absoluta*, 84% for *T. envasi* and 89% for *A. gossypii*. Food had no impact on the survival of immature stages of *N. tenuis*. Others recorded this same trend on Miridae predators. The study by Mollá et al. (2014) showed that feeding *T. absoluta* eggs and *E. kuehniella* eggs did not impact the survival of immature stages of *N. tenuis*. Feeding *T. absoluta* eggs, *E. kuehniella* eggs, *B. tabaci* nymphs, and *Macrosiphum euphorbiae* nymphs (Hemiptera: Aphididae) did not impact the survival of *M. pygmaeus* nymphs (Hemiptera: Miridae) (Sylla et al., 2016a).

The amount of prey consumed by *N. tenuis* during its development was higher on *T. absoluta* (3999 eggs) than in *A. gossypii* (2540 nymphs) and *T. evansi* (2007 nymphs). The type of prey offered to the *N. tenuis* had a significant effect on its predation ability. The predator consumed more *T. absoluta* eggs than other prey. This can be explained by the easy access to *T. absoluta* eggs, immobile prey is much easier to overcome than mobile prey, as the predator takes less effort to find them. Second, that *T. absoluta* eggs are smaller in size than *A. gossypii* and *T. evansi* nymphs could explain the difference in prey quantity consumed by the predator. The study of Mollá et al. (2014) found that *N. tenuis* consumes more *T. absoluta* eggs that are smaller than *E. kuehniella* eggs that have a larger or smaller size. The performance of the predator on *T. absoluta* eggs, followed by *A. gossypii* nymphs, is due to their nutrient qualities (explained earlier). The predatory ability of *N. tenuis* increases with evolution of its development; in addition, females consume more than males, regardless of type of prey. This can be explained due to females need protein sources for maturation of their eggs; this is in agreement with Perdikis et al. (1999) and Ba (2017).

Table 1: Numbers of prey of each species consumed by the predator *N. tenuis.*

Prey food	Abundance	Mean		Maximum	Minimum	P_{value}
T. absoluta	3999	29.40	a	70	3	
A. gossypii	2540	18.96	b	40	2	<0.001***
T. evansi	2007	15.44	c	35	1	

Means sharing common letters are not significantly different, 5%, from one another

Table 2: Numbers of prey consumed by different developmental stages of *N. tenuis* according to species

Prey food	States	Abundance	Mean		Maximum	Minimum	P_{value}
T. absoluta	N1	94	5.22	f	7	3	
	N2	211	10.55	e	14	8	
	N3	414	20.70	d	26	18	
	N4	538	28.32	c	33	24	<0.001***
	N5	611	30.55	c	36	25	
	Male	941	47.05	b	60	31	
	Femelle	1190	62.63	a	70	54	
A. gossypii	N1	61	3.21	f	5	2	
	N2	156	8.21	e	10	6	
	N3	303	15.95	d	18	14	
	N4	355	18.68	cd	21	12	<0.001***
	N5	403	21.21	c	26	16	
	Male	557	29.32	b	38	22	
	Female	705	35.25	a	40	23	
T. evansi	N1	34	2.00	g	3	1	
	N2	125	6.58	f	9	3	
	N3	235	12.37	e	15	9	
	N4	281	15.61	d	20	10	<0.001***
	N5	360	18.95	c	26	13	
	Male	438	21.90	b	28	17	
	Female	534	29.67	a	35	23	

Means sharing common letters are not significantly different, 5%, from one another

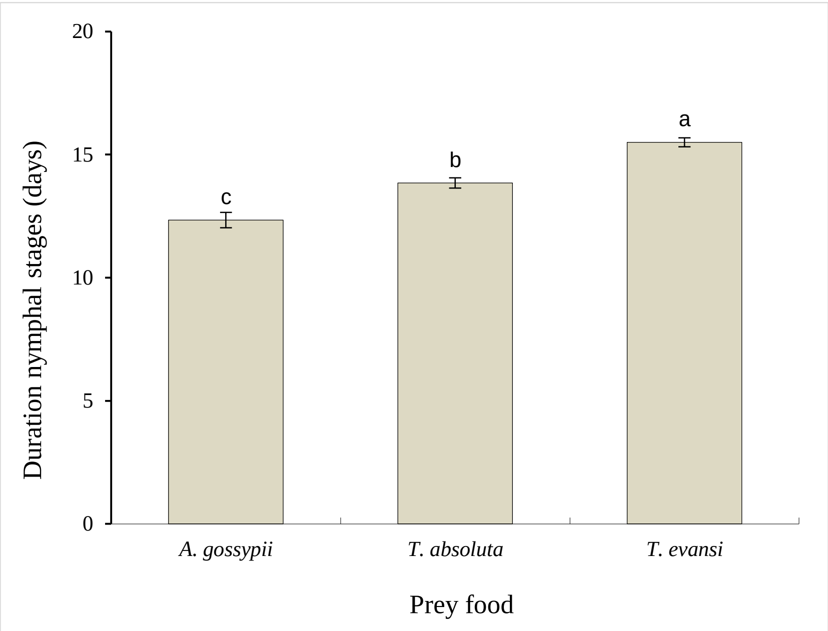

Figure 1: Average development time of *N. tenuis* pupae (N1 to N5) as a function of prey. The error bars correspond to the standard error (mean ±SE). Bars topped by the same letter are not statistically different (*P < 0.05*).

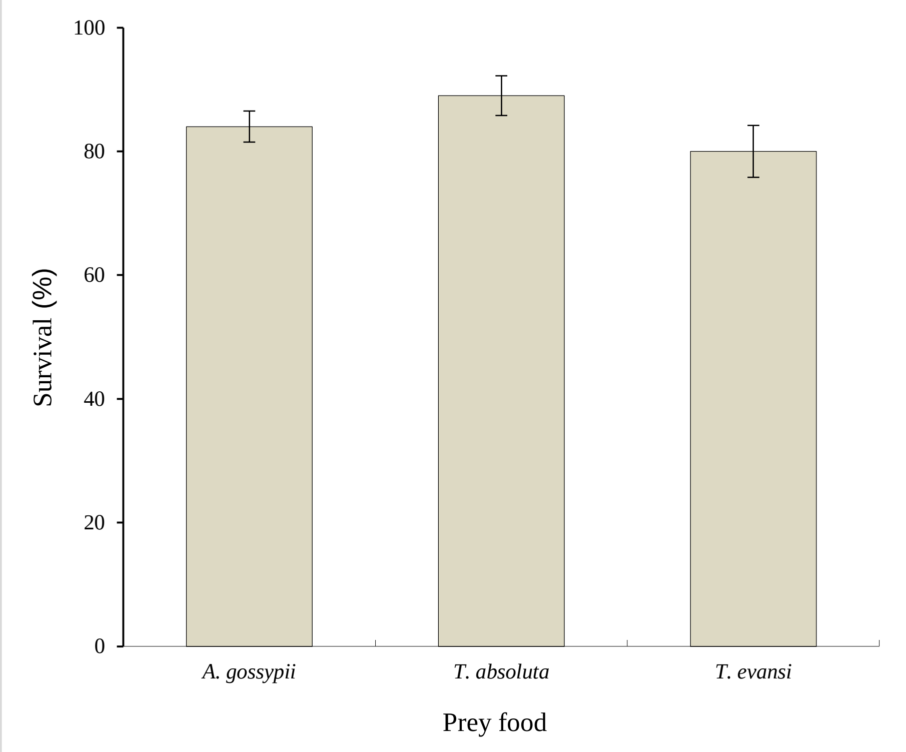

Figure 2: Mean survival percentage of *N. tenuis* nymphs as a function of prey. Error bars are standard error (mean ±SE).

CONCLUSIONS

Our results show that prey mobility could increase the development time of immature stages of *N. tenuis*. Its predatory ability is greater on immobile and small prey than on mobile and large prey. Further studies on the fertility, longevity and preference of *N. tenuis* on different prey types need to be conducted. The study confirms the generalist character of the predator *N. tenuis* and makes it an effective biological control agent against *T. absoluta* in Senegal. The study also contributes to developing alternative integrated management methods against tomato pests.

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OS, SS, KD: Conceived and designed the experiments
OS, MM: Performed the experiments
OS, SS: Analyzed the data
BL, MD, ET, IAN, AB, SOS, PD, KD: Contributed materials
OS, SS: Wrote the paper

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Availability of data and materials:
All data are available in the manuscript.

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