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Functional response of the predatory bug *Orius sauteri* (Hemiptera: Anthocoridae) to chilli thrips *Scirtothrips dorsalis* (Thysanoptera: Thripidae) infested mango trees in Hainan province, China

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Abstract:

Scirtothrips dorsalis Hood. (Thysanoptera: Thripidae) is a very important pests in southern China, it can infest vegetable, ornamental plants and fruit crops as well as, transmission various tospoviruses pathogen to host plants. Also, *Oruis sauteri* is very widespread predator in China, it can be consumed different preys like, Aphids, thrips and spider mites. We measured the feeding consumption of *O. sauteri* different stages to 2nd larvae and adult female of *S. dorsalis* under three constant temperatures and different densities of prey. As well as, measured the functional response of *O. sauteri* different stages to 2nd larvae and adult female of *S. dorsalis*.The functional response of the*O. sauteri* different stages were fitted to II type of functional response (Holling, 1965).The feeding consumption of different *O. sauteri* stages increased with the temperatures and *O. sauteri*different stages. However, the female of *O. sauteri* consumed more 2nd larvae of *S. dorsalis* than 4th and 5th nymph of *O. sauteri.* Also, the females of *O. sauteri* consumed more females of *S. dorsalis* than 4th and 5th nymph of *O. sauteri.*AS well as, the increasing in temperatures lead to increase in attack rate and decreased the handling time as well as, increasing the limit of predation of *O. sauteri* different stages.

Introduction

Mango trees *Mangifera indica* Linnaeus (Anacardiaceae) is familiar cultivated in over 100 countries in the world, especially in tropical and subtropical regions as well as, it is one of the most important tropical fruits in China in terms of production, marketing and consumption due to their exotic flavor and delicious taste, as well as high nutritional value and give high yield. AS well as, China the second largest mango producer in the world with 5.1 million ton produced in 2018. Most of mango orchards cultivated in southern of china. Hainan Province is the largest mango producer in china, followed by Guangxi Autonomous Region, Guangdong Province, Yunnan Province, Sichuan Provinces and Fujian Province, (Chen, 2013 and NBSPRC, 2015). Mango orchards are attacked by several groups of pests i.e. floral malformation, powder mildew, anthracnose, fruit fly, stem borer and acarina (Amer *et al.*, 2017). The most important mango's pests in Hainan are thrips (Chen *et al.*, 2017 and Gao *et al.*, 2006) belonging to the Order: Thysanoptera which includes families of Thripidae, Aeolothripidae and Phlaeothripidae. Both immatures and adult females and males cause severe damages. Chili thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) is an important pest of various vegetable, ornamental and fruit crops in southern and eastern Asia, Africa, and oceania (Ananthakrishnan, 1993; CABI/EPPO, 1997; CAB, 2003 and Sandeep *et al.*, 2017). In Hainan, the dominant thrips species during the shoot period and young fruit stage was chili- thrips, S. *dorsalis* . Thrips are become primary and very dangerous pest on mango orchards in China (Huang, 2010 and Han *et al.*, 2015). It had wide range of host plants Over 100 host plants including 40 families (i.e., banana, beans, chrysanthemum, citrus, corn, cotton, cocoa, eggplant, ficus, grape, grasses, holly, jasmine, kiwi, litchi, longan, mango, onion, peach, peanut, pepper, rose, soybean, strawberry, tea, tobacco, tomato (Mound and Palmer 1981 and Mound , 2007). As well as, *S. dorsalis* also can transmit many viruses (i.e., chilli leaf curl (CLC) virus, and peanut necrosis virus (PBNV) (Mound and Palmer, 1981 and Ananthakrishnan, 1993) and tobacco streak virus (TSV) in groundnut crops in India (Rao *et al.* , 2003). Also, in Thailand AS well as, can transmit three viruses (i.e., melon yellow spot virus (MYSV), watermelon silver mottle virus (WsMoV), and capsicum chlorosis virus (CaCV) field crops was confirmed (Chiemsombat *et al.* , 2008). Chilli thrips attacks all young leaves, buds and fruits. Heavy infestation of these pests cause defoliation and drought branches on the plants due to turns tender leaves, buds, and fruits bronze to black in color as well as, causing considerable damages and consequently reduce mango production and bring down the marketing value by decreasing quantity and quality of fruits(Vivek Kumar *et al.* , 2014).

Oruis species is well known to be one of the important natural enemies of thripsin China (Tan *et al*., 2013). As well as, it is a polyphagous natural enemies which that had a lot of preys such as Aphids (Zhou *et al*., 2006 and Ahmadi *et al*., 2007) spider mites (Zhou *et al*., 2006) and the eggs of moths (Bullter and O'neil, 2007; Zhou *et al.*, 2006 and Zhou and Lei, 2002). As well as, its role in controlling many species of thrips (i.e. *Orius insidiosus* (Say) on *Thrips tabaci* Lindeman and *Orius laevigatus* (Fieber) on *Frankliniella occidentalis* (Pergande). Also, *Orius sauteri* (Poppius) has been studied its effective in decreasing the population density of *T. palmi* (NAGAI, 1993 and 1999 and Xux and Enkegaard, 2009). AS well as, there were most of insect pest can be efficiently controlled by *O. sauteri* (Zhang *et al*., 2007) and recorded as an important predator of many pests of thrips, spider mites, aphids and eggs of lepidopteran insects in fields and orchards in Japan, China, Korea, and Russian Far East (Yano, 1996 and Yang *et al*., 2018). Functional response is refers to the number of prey successfully attacked by predator during unit of time (Solomon, 1949) as well as, it described the relationship between the predator rate of consumption and prey density. There were many factors that affected in the functional response of a predator; the most important is temperature which both predators and predators are to be found, (McCaffrey and Horsburgh, 1986).

Functional responses according to prey consumption by the predator is very important studies which using natural enemies in biological control programs to decrease the pest densities on different crops (Lia and Yano, 2010; Ganjisaffar and Thomas, 2015 and (Wang *et al*., 2018). This study will provide us the basic information for optimal use of *O. sauteri*in biological control programs to control *S. dorsalis* on mango trees.This work was carried out to study the functional response of *O. sauteri* on different densities of the 2^{nd} larvae and adult female of chilli- thrips, *S.dorsalis*.

Materials and methods.

1. Predator rearing:

O. sauteri were obtained from Beijing Kuo Ye Bio-Tec co., Ltd Company (China) and had been reared for several generations under laboratory conditions at 26 ±2 °C, 60 ± 10% RH and L18:D6 photoperiod. The predators were reared using the methods described by (Isenhor and Yeargan, 1981). Adults and nymphs of *O. sauteri* were collected to be kept in plastic jars of 10 cm (diameter) ×20 cm (height) covered with muslin and held in place by means of rubber bands. Each jar was provided with both small balls of white foam to reduce cannibalism behavior and sufficient quantities of *Corcyra cephalonica* eggs as food supply for the enclosed predators. A piece of bean pod (*Phaseolus vulgaris*) was provided in each jar as an ovipostional substrate (Isenhor and Yeargan, 1981). Eggs are inserted into the tissue of bean pods. Bean pods with newly deposited eggs inside were kept in plastic jars previously described. Jars were examined daily until hatching. Soon after hatching; newly-hatched nymphs on bean pods were carefully transferred to plastic jars and provided with eggs of *Corcyra cephalonica.*

2. Prey colony:

Chilli- thrips, *S. dorsalis* was collected from mango orchards (*Mangifera indiaca*: Anacardiaceae) in Hainan province, China during 2018 from. The colony was maintained fresh mango leaves, which collected from the symptomatic plants and place them in a ziplock bag to prevent adults from escaping. As well as, put the infested mango leaves in metalic cages (100 x 135 x 135 cm) with nylon gauze sides under laboratory conditions at 26 ±2 °C, 60 ± 10% RH and L18:D6 photoperiod and we used the 2^{nd} larvae and adult female directly as a prey.

3. Predation consumption by different developmental stages of *Orius* *sauteri*:

Newly individual hatched nymphs of *O. sauteri (*0-12 hrs) were collected from the stock colony which reared in laboratory and were put in separate plastic petri dishes (7 cm diameter) and provided with 2^{nd} instar of larvae of *S.dorsalis*. We checked the number of prey which had been consumed by *O. sauteri* different nymphal stages by using a stereomicroscope (20×). All petri dishes were checked for predation consumsion after 24 h, and the number of second instar larvae of *S. dorsalis* which consumed by different developmental stages of *Oruissauteri* (4^{th} ,5^{th}) during 24 h period.

Couples of newly emerged adults (male and female) were placed separately in plastic petri dish (6cm diameter) without preys to stimulate mating occurrence. Twelve hrs later, males were removed to another petri dish. Then, these dishes were supplied with different densities of prey (20, 40, 60, 80 and 100 individuals 2^{nd} instars larvae of *S. dorsalis*). The tests were conducted for a 24 h period. We checked the number of prey which had been consumed by adults of *O. sauteri* by using a stereomicroscope (20×).

There were 20 replicates per each thrips density. A predator was tested only once. A control experiment consisted of a similar setup but without the predator.

4. *Orius sauteri* functional response to *Scirtothrips dorsalis* different densities at three constant temperatures:

The predation ability of the developmental stages (4^{th}, 5^{th} and females) of *O. sauteri* to feeding on 2^{nd} larvae and adult of *S. dorsalis* at three constant temperatures (22, 26 and 30oc) and various densities were compared by analysis of variance (ANOVA) using SPSS for (Windows version 18). Also, we used analysis of variance to compare differences in the numbers of 2^{nd} larvae and adult *S. dorsalis* which consumed by *O. sauteri* between different densities and temperatures. The mean values were compared using Tukey test at the P= 0.05 level of significance. The functional response data were fitted to type-II responses (Holling, 1959). Parameters of a type-II model were estimated by the random predator equation:

$$\boldsymbol{N_a = N_t[\,1 - \exp\,(aTP_t/1 + aT_hN_t)]}$$

where $N_a$is the rate consumption of predator on prey during selected time period (24 h); a' is the instantaneous attack rate; N is the density of prey ; T is the selected predation period (1 day); T_h is the duration of one prey consumption by predator, i.e., the handling time. The potential maximum *Na* (*Na*-max) was estimated by dividing instantaneous attack rate by the handling time (Holling, 1959).

Results and discussion

1.Functional response of (4^{th}, 5^{th} and females) of *Orius sauteri* to 2^{nd} larvae of *Scirtothrips dorsalis* at three constant temperatures :

With regard to Data on Table (1) and graphically illustrated in Figure (1) showed that the functional response of (4^{th}, 5^{th} and females) of *O. sauteri* to 2^{nd} larvae of *S. dorsalis* at three constant temperatures (22, 26 and 30°C)were typed II response (Holling, 1965) and they approximated by the functional reaction disk equation. As well as, Data on Table (1) showed the different parameters of functional response of different stages of *O. sauteri* to 2^{nd} larvae of chili-thrips. There was a general increase in thrips consumption with increasing temperature. There was also an increase in thrips consumption with a corresponding increase in prey density, indicating that *O. sauteri* functionally responded to this prey species. The predation rate (1/b) on *S. dorsalis* 2^{nd} larvae was increased with predator stages. We found that the predation rate increased on females and 5^{th} of *O. sauteri*. The increasing in temperatures lead to increase in predation rate(1/b). Whereas, the rate of successful search (a) was also, increased with predator stage and increasing with increasing temperatures. The handling time(b)was decreased with increased in and increasing of prey densities and the shorter handling time and searching time and at higher densities of prey. As well as, the *O. sauteri* can kill more thrips at high densities also in high temperatures as well as, females and 5^{th} of *O. sauteri* can kill more thrips than 4^{th} of temperatures thrips. The Predation efficiency (a/b) was increased with increasing temperatures and predator stages. The 5^{th} nymph and females of chili-thrips consumed more thrips than 4^{th} nymph at three temperatures.

2.Functional response of (4^{th}, 5^{th} and females) of *O. sauteri*to females of *S. dorsalis* at three constant temperatures :

The obtained results in Table (2) showed that, the functional response of (4^{th}, 5^{th} and females) of *O. sauteri* to females of *S. dorsalis* was also, fitted by type II model of response. There was increasing in the numbers of the adult females of *S. dorsalis* killed by the predator, *O. sauteri* with an increase in temperature and thrips density, the functional responses of *O. sauteri* preying on adults female of *S. dorsalis* at various densities (Figure, 2), show that the functional response curves were affected by differences in the predation rates over 24-h period of *O.sauteri* at all the densities and temperature ranges. The functional response parameters showed that, The attack rates against females of thrips were significantly increased at each of the three constant temperatures (Table 2). The handling times for females of thrips was decreased with an increase in temperature and predator stages while for the adults. the rate of successful search (a) was also, increased with predator stage and increasing with increasing temperatures.

There were many researchers have mentioned that, *Oruis sp*. show a II type of functional response (Holling, 1965).All type of functional response has been indicated in the western flower thrips, *Frankliniellaoccidentalis* (Pergande) (Coll and Ridgway ,1995), *S. dorsalis* (Wang *et al*., 2014), *Aphis gossypii* Glover and *Thrips palmi* (Nagi, 1993). Also, McCaffrey and Horsburgh (1986) reported that functional response of *O. insidiosus* to *Panonychus ulmi* (Koch) were (Holling's type I and II) as well as, Lia and Yano (2010) also, founded the functional response of predatory bug *Orius sauteri* (Poppius) to Thrips palmi Karny on eggplant leaves were type I and Type II curves. This study also, showed the type II functional response of *O. sauteri* to *S. dorsalis* (Tables 1 and 2) and (Figures 1 and 2).

McCaffrey and Horsburgh (1986) studied the effect of different temperatures on the rate of successful search and the handling time of functional response of *O. insidiosus* to *P. ulmi* at, he found that the increasing in temperatures lead to increase in attack rate and decreased the handling time as well as, in this study also, showed that the handling time of 4^{th}, 5^{th} and adult females of *O. sauteri* decreased with increasing in temperatures at 26 and 30℃ as well as, the Predation efficiency and the predation rate increased with each increase in temperatures and increase of prey densities. (Isenhor and Yeargan, 1981a) mentioned that, the predation rate of *O. insidiosus* was increased with increase of prey densities.

This study was aimed to know the effects of temperatures , different densities of prey and predators stages on parameters of functional response of *O. sauteri.* This study was used for evaluating the biological control of *S. dorsalis* on mango trees. Generally, we found that, the different developmental stages (4^{th}, 5^{th} and females) of *O. sauteri* to 2^{nd} larvae and females of *S. dorsalis* were fitted by type II model of response. The (4^{th}, 5^{th} and females) of *O. sauteri* was consumed more 2^{nd} larvae of *S. dorsalis* than females because adult female of chili- thrips are more able to move and fly than larvae, and the *Oruis* may escape attack by the predators, thereby resulting in more larvae being killed at all temperatures and different densities. The feeding consumption increased at 30°C than other temperatures. The functional response parameters was affected by temperatures, various densities and predator stages, the increasing in temperatures lead to increase in attack rate and decreased the handling time as well as, increasing the limit of predation of *O. sauteri* different stages.

Table (1): Effect of different densities 2nd larvae of *Scirtothrips dorsalis* on the attack rate (a), handling time and maximum consumption rate on 4th, 5th and females of *Orius sauteri* derived from random predator equation at three constant temperatures.

Predator stages	Temperatures	Coefficient of correlation (r)	Functional reaction disk equation	The rate of successful search(a)	Handling time (b)	Predation efficiency (a/b)	The expected maximum consumption/ day (1/b)	χ^2 Chi-square	P
4th	22°C	0.9893	Na=0.3880N/(1+0.04148N)	0.38809	0.1069	3.63	9.35453695	0.09074	0.999
	26°C	0.9674	Na=0.5887N/(1+0.04333N)	0.58878	0.0736	7.99	13.58695652	0.25302	0.992
	30°C	0.91	Na=0.68723N/(1+0.02810N)	0.68723	0.0409	16.80	24.44987775	1.02898	0.905
5th	22°C	0.968	Na=0.38800.80 /(1+0.0630N)	0.6351	0.0782	10.36	12.82051282	0.03497	0.999
	26°C	0.9231	Na=0.7336N/(1+0.0528N)	0.7336	0.0528	13.89	18.93939394	0.91053	0.923
	30°C	0.9747	Na=0.7384N/(1+0.0270N)	0.7384	0.0366	20.17	27.32240437	0.50680	0.972
Female	22°C	0.9684	Na=0.7722N/(1+0.0517N)	0.7722	0.0672	11.52	14.92537313	0.22187	0.994
	26°C	0.9184	Na=0.8306N/(1+0.0359N)	0.8306	0.0433	19.18	23.09468822	1.36996	0.849
	30°C	0.9796	Na=1.0259N/(1+0.0292N)	1.02595	0.0285	35.99	35.0877193	0.36673	0.985

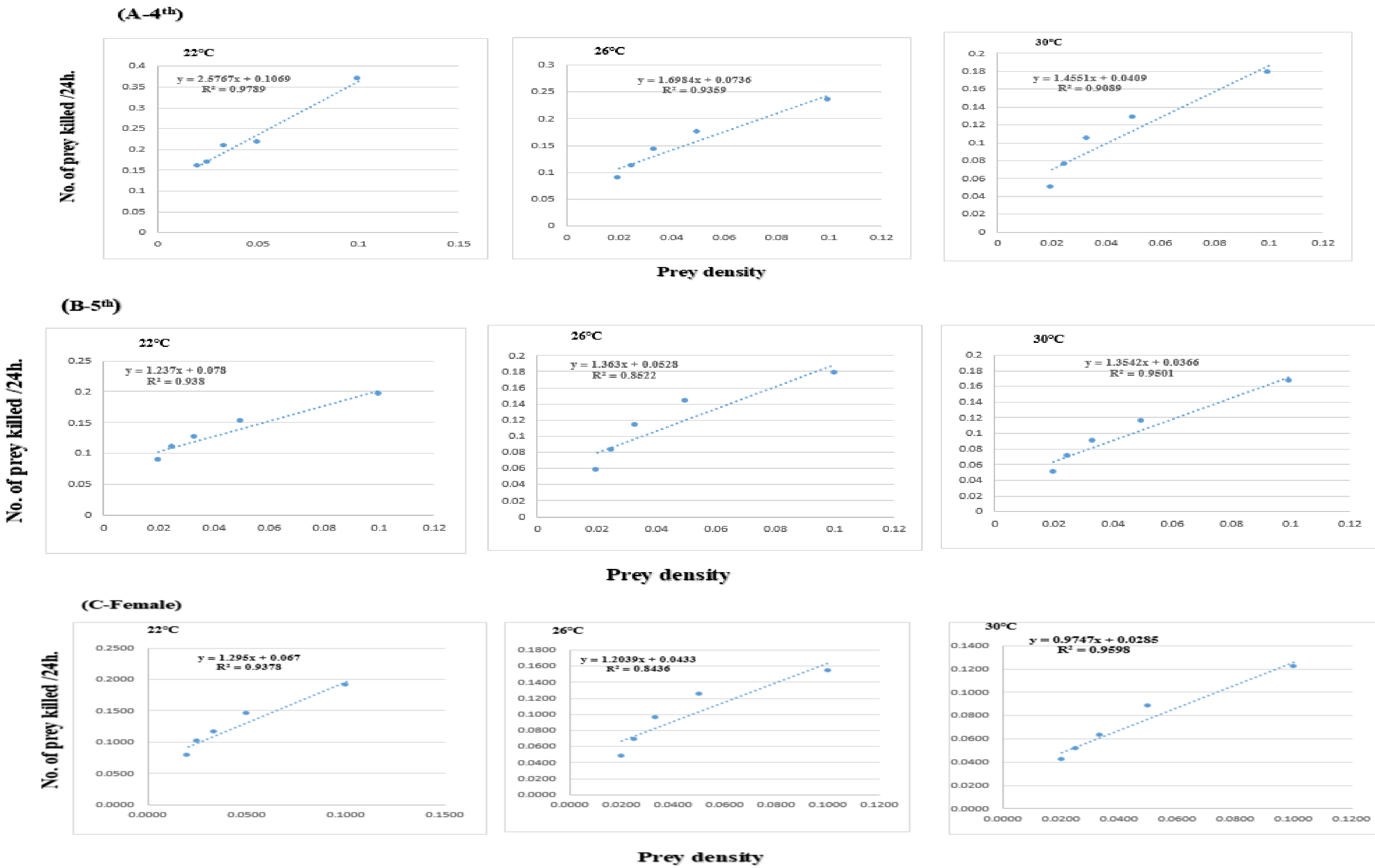

Figure 1 (A, B and C): Observed functional response of 4th, 5th and female of *Orius sauteri* to 2nd larvae of *Scirtothrips dorsalis* at three constant temperatures.

Table (2): Effect of different densities of *Scirtothrips dorsalis* females on the attack rate (a), handling time and maximum consumption rate on 4th, 5th and females of *Orius sauteri* derived from random predator equation at three constant temperatures.

Predator stages	Temperatures	Coefficient of correlation (r)	Functional reaction disk equation	The rate of successful search(a)	Handling time (Th)	Predation efficiency (a/Th)	The expected maximum consumption/ day (1/Th)	χ^2 Chi-square	P
4th	**22°C**	0.9423	Na=0.533N/(1+0.1104N)	0.533447	0.207	2.577	4.83	0.17157	0.99652
	26°C	0.9104	Na=0.60088N/(1+0.1017N)	0.600889	0.1694	3.547	5.90	0.25397	0.99259
	30°C	0.9723	Na=0.6101N/(1+0.05674N)	0.610165	0.093	6.560	10.75	0.29332	0.99024
5th	22°C	0.9074	Na=0.6090N/(1+0.09325N)	0.609087	0.1531	3.978	6.53	0.20202	0.99523
	26°C	0.9377	Na=0.7304/(1+0.0901N)	0.730460	0.1234	5.919	8.10	0.05654	0.99648
	30°C	0.8872	Na=0.7910N/(1+0.0711N)	0.791014	0.09	8.789	11.1	0.34516	0.98672
Female	22°C	0.9455	Na=0.5648/N/(1+0.05055N)	0.531688	0.1085	4.900	9.216	0.41154	0.98152
	26°C	0.9576	Na=0.5648/N/(1+0.05055N)	0.564844	0.0895	6.311	11.17	0.44144	0.97895
	30°C	0.988	Na=0.6088/N/(1+0.0371N)	0.608828	0.0611	9.964	16.36	0.10230	0.99874

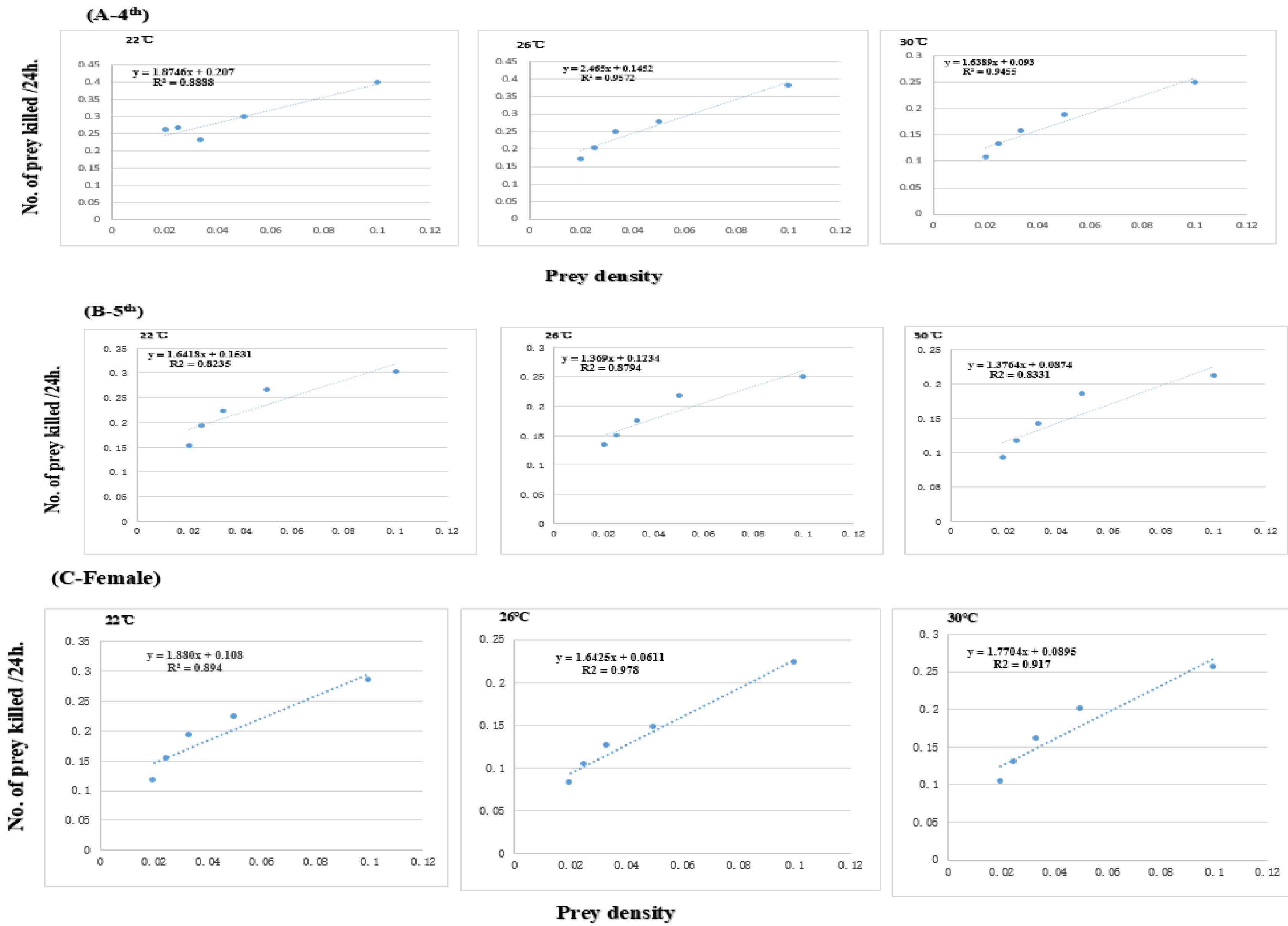

Figure 2 (A, B and C): Observed functional response of 4th, 5th and female of *Orius sauteri* to females of *Scirtothrips dorsalis* at three constant temperatures.

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