

tri-trophic interaction among host plants, aphid species, and coccinella undecimpunctata l. under laboratory conditions.

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ABSTRACT

Tri-trophic interaction among host plants, aphid species, and the predator, *Coccinella undecimpunctata* L. under laboratory conditions were studied. The developmental time of immature stages, survival percentage, and consumption of *Coccinella undecimpunctata* L. by feeding on *Aphis gossypii* Glover, *Myzus persicae* Sulzer and *Aphis craccivora* Koch that were reared on each of eggplant (*Solanum melongena* L.), potatoes (*Solanum tuberosum* L.), and faba bean (*Vicia faba* L.) plants was also determined.

In respect of the developmental time of immature stages, the overall model, or among host plants or host plants-aphid species interaction indicated that there was no significant variation. Meanwhile, among aphid species, there was a significant variation.

No significant differences occurred for survival as an overall model. Among host plants or aphid species or host plants-aphid species interaction, there was no significant variation.

Regarding the consumption of the larval stage, the overall model, host plants, aphid species, or host plants-aphid species interaction revealed that there was a significant variation.

Clearly, the results of this study indicated that the developmental time of immature stages, survival percentage, and consumption of *C. undecimpunctata* by feeding on *A. gossypii*, *M. persicae* and *A. craccivora* that were reared on each of eggplant, potatoes, and faba bean plants had effects on the biological characteristics of this predator.

Keywords: Tri-trophic interaction, host plant, aphid species, *Coccinella undecimpunctata*, biological characteristic

INTRODUCTION

The effects of plants on entomophagous insects have been well documented in tri-trophic interaction studies (Campbell *et al.*, 1992; Bottrell *et al.*, 1998; Obyrcki and Kring, 1998; Giles *et al.*, 2000). Access to prey or changes in prey acceptability or suitability can dramatically influence natural enemies. The biochemical contents of plants may result in toxic or nutritionally poor prey and may increase mortality, slow developmental rates, decrease growth rates, and reduce fecundity of natural enemies. Plants have been shown to alter third trophic level dynamics in many ecological systems, however, the mechanisms of many tritrophic interactions are unknown (Hodek, 1993; Bottrell *et al.*, 1998; Giles *et al.*, 2000). The storage of nutritional contents (primarily fatty acids) in aphids is influenced by plant

species or cultivar (Dillwith *et al.*, 1993). Therefore, when evaluating the suitability of aphid prey, monitoring changes in their nutritional value among host plants is an essential component of tritrophic interaction studies (Giles *et al.*, 2000).

Aphid species, *Aphis gossypii* Glover, *Myzus persicae* Sulzer and *Aphis craccivora* Koch are of the most widespread species of aphids, and display large range of host-plants, covering very different families (El-Heneidy and Abdel-Samad, 2001; Fuchsberg *et al.*, 2007). Now, it is important to recognize the interactions that occur between the components of a management system; plant cultivars, preys and predators, when developing Integrated Pest Management systems (El-Heneidy and Abdel-Samad, 2001). Coccinellid species are generally polyphagous and consume most of the aphid species that they encounter (Hodek, 1996). Aphid species vary in suitability as prey, i.e., the degree to which they support successful development and reproduction (Kalushkov, 1998; Kalushkov and Hodek, 2004). The duration of coccinellid development and the fecundity and fertility of adult females may vary significantly among prey species that do support complete life histories (Michaud, 2000; Cabral *et al.*, 2006). A further layer of complexity arises via tri-trophic interactions (Price *et al.*, 1980) as the host plant may influence the nutritional quality of aphid prey for predators that consume them (Hodek, 1993; Giles *et al.*, 2002a, b; Vanhaelen *et al.*, 2002; Wu *et al.*, 2010).

Coccinella undecimpunctata L. is a generalist aphidophagous ladybeetle with a wide prey range (Ghanim and El-Adl, 1987 "a & b"; Darwish and Ali, 1991; El-Saadany *et al.*, 1999, Abdel-Salam, 2004). Use of this species as a biological control agent on various agricultural crops is now widespread (Ghanim and El-Adl, 1987 "a & b"; Abdel-Salam, 2004). A substantial literature exists on the relative suitability of different aphid species as prey for *C. undecimpunctata* (Ghanim and El-Adl, 1987 "a & b"; Abdel-Salam, 2004), but little is known of how host plants may affect this suitability. Aphid species, *A. gossypii*, *M. persicae* and *A. craccivora* are known to support both the development and reproduction of *C. undecimpunctata* (Ghanim and El-Adl, 1987 "a & b"; Abdel-Salam, 2004) and thus qualify as "complete" prey (Ghanim and El-Adl, 1987 "a & b"; Abdel-Salam, 2004). These aphid species are highly polyphagous aphids and common crop pests with great economic importance on a variety of crops (Barbagallo *et al.*, 2007).

However, scanty attention has been paid on the tri-trophic interaction between host plant, aphid species, and *C. undecimpunctata* in Mansoura, Egypt. Therefore, the aim of this study was to test for tri-trophic effects on the suitability of these three aphid species as prey for *C. undecimpunctata*. Understanding how tri-trophic interactions can affect prey suitability for *C. undecimpunctata* may improve our ability to gage the efficacy of this species in biological control programs against these and other aphids of economic importance.

MATERIALS AND METHODS

1. Plant and aphid cultures

Eggplant (*Solanum melongena* L.), potatoes (*Solanum tuberosum* L.), and faba bean (*Vicia faba* L.) plants were grown with covering the place of planting by Ajeryl. The area of previous mentioned plants were 144m² at Experimental Research Station, Faculty of Agriculture, Mansoura University. All agricultural practices were done as recommended by Ministry of Agriculture.

Aphid species *Aphis gossypii* Glover, *Myzus persicae* Sulzer and *Aphis craccivora* Koch were collected from fields at the Experimental Research Station, Faculty of Agriculture, Mansoura University. The plants were infested with aphid's species. Aphid species for use as prey in experiments were reared on each host plant in a separate area for at least 2 weeks before being fed to *Coccinella undecimpunctata* L.

2. Rearing of *C. undecimpunctata*

Adults of *C. undecimpunctata* were collected fields at the Experimental Research Station, Faculty of Agriculture, Mansoura University and reared on three aphid species namely, *A. gossypii*, *A. craccivora* and *M. persicae*. The eggs laid by females were removed daily, and monitored until hatching. To avoid cannibalism, the hatched larvae of the predator were reared individually in Petri-dishes (9 cm in diameter). All of the experiments were run in an incubator at 28.0±1.0°C, 75.0±5% RH and photoperiod of 14L: 10D. A piece of filter paper was placed on the bottom of each dish to provide a walking surface for the larvae. Twenty larvae from the predator were reared on each aphid species. Each reared larvae was considered to be a replicate. Each larva was provisioned daily with an ad libitum supply of aphids on a leaf. The consumption of aphids per day and developmental time of each stage were determined. The survival from eggs to adult eclosion was recorded.

Statistical analysis

Data for developmental time of immature stages, survival, and consumption of *C. undecimpunctata* were analyzed by 2-way ANOVA with host plants, and aphid species as fixed factors. When interaction terms were significant, independent variables were analyzed separately by one-way ANOVA, and the means were separated using Student-Newan-Keuls Test (Costat Software, 2004).

RESULTS AND DISCUSSION

Developmental times

In Table (1), 2-way ANOVA indicated that there was a significant variation on incubation period of *C. undecimpunctata* in the overall model (F= 3.89, df =8, P=0.000 ***, X²=7.75). Meanwhile, there was no significant variation among host plants or aphid species (F=1.08, df =2, P= 0.340 ns and F= 0.83, df =2, P=0.437 ns, respectively). There were significant variations in

the interaction between host plants and aphid species ($F=6.82$, $df= 4$, $P=0.000$ ***).

The overall model revealed that there was a significant variation for effects on first instar of the predator ($F= 3.75$, $df= 17$, $P= 0.000$ ***, $\chi^2 =17.16$) (Table 2). Among host plants, there was a significant variation ($F= 0.21$, $df=2$, $P=0.807$ ns). There was a significant variation between aphid species ($F= 4.57$, $df= 2$, $P=0.011$ *). There were significant variations in the interaction between host plants and aphid species ($F= 5.10$, $df= 4$, $P=0.000$ ***) (Table 1).

The 2-way ANOVA was significant as the overall model on the second larval instar (Table 1) ($F=1.156$, $df= 8$, $P= 0.329$ ns, $\chi^2= 21.07$). Among host plants or aphid species or host plants-aphid species interaction, there was no significant variation ($F=1.53$, $df= 2$, $P= 0.220$ ns, $F=1.53$, $df=2$, $P= 0.160$ ns and $F= 0.62$, $df=4$, $P=0.647$ ns, respectively).

The overall model indicated that there was a significant variation on the third larval instar ($F= 2.97$, $df=8$, $P=0.004$ **, $\chi^2= 12.01$). Among host plants, there was a significant variation ($F= 9.63$, $df= 2$, $P= 0.000$ ***). While, there was no significant variation among aphid species and host plants-aphid species interaction ($F=1.05$, $df= 2$, $P=0.350$ ns and $F=0.52$, $df= 4$, $P= 0.718$ ns, respectively).

Based on 2-way ANOVA, the overall model indicated that there was a significant variation on the fourth larval instar ($F= 2.32$, $df=8$, $P=0.022$ *, $\chi^2 = 15.32$). Among host plants or host plants-aphid species interaction, there was no significant variation ($F= 0.10$, $df=2$, $P= 0.903$ ns and $F=1.83$, $df= 4$, $P= 0.125$ ns, respectively). Meanwhile, there was a significant variation among aphid species ($F= 5.77$, $df= 2$, $P=0.003$ **).

Regarding the developmental time of larval stage, the overall model indicated that there was a significant variation ($F= 2.68$, $df=8$, $P=0.008$ **, $\chi^2 = 2.93$). Among host plants or interaction between host plants and aphid species, there was a significant variation ($F= 4.39$, $df= 2$, $P= 0.013$ *, and $F=2.96$, $df= 4$, $P=0.021$ *, respectively). No significant differences occurred among aphid species ($F= 0.40$, $df= 2$, $P=0.669$ ns).

Concerning the pupal stage duration, the overall model indicated that there was a significant variation ($F= 5.26$, $df=17$, $P=0.000$ ***, $\chi^2 = 5.59$). Among host plants, there was no significant variation ($F= 0.73$, $df= 2$, $P= 0.485$ ns). Meanwhile, there was a significant variation among aphid species, and host plants-aphid species interaction ($F= 5.71$, $df= 2$, $P=0.004$ ** and $F=7.19$, $df= 4$, $P= 0.000$ ***, respectively).

In respect of developmental time of immature stages, the overall model indicated that there was no significant variation ($F= 1.76$, $df=8$, $P=0.090$ ns, $F= 0.01$, $df= 2$, $P= 0.011$ ns, and $F=1.16$, $df=4$, $P=0.331$ ns, respectively). Among aphid species, there was a significant variation ($F= 4.58$, $df= 2$, $P= 0.1$ *).

Table (1). 2-way ANOVA of *C. undecimpunctata* developmental times when fed on three aphid species that were reared on each of three host plants under laboratory conditions (28±1°C and 70 ±5% R.H).

Source of Variation	df	F	P
Egg	8	3.89	0.000 ***
Host Plants	2	1.08	0.340 ns
Aphids	2	0.83	0.437 ns
Host Plants X Aphids	4	6.82	0.0000 ***
Error	171		
Total	179		
X ²		7.75	
L1	8	3.75	0.000 ***
Host Plants	2	0.21	0.807 ns
Aphids	2	4.57	0.011 *
Host Plants X Predators	2	5.10	0.000 ***
Error	171		
Total	179		
X ²		17.16	
L2	8	1.15	0.329 ns
Host Plants	2	1.53	0.220 ns
Aphids	2	1.85	0.160 ns
Host Plants X Aphids	4	0.62	0.647 ns
Error	171		
Total	179		
X ²		21.07	
L3	8	2.97	0.004 **
Host Plants	2	9.63	0.000 ***
Aphids	2	1.054	0.350 ns
Host Plants X Aphids	4	0.52	0.718 ns
Error	164		
Total	172		
X ²		12.01	
L4	8	2.32	0.022 *
Host Plants	2	0.10	0.903 ns
Aphids	2	5.77	0.003 **
Host Plants X Aphids	4	1.83	0.125 ns
Error	307		
Total	324		
X ²		15.32292	
Larval stage	8	2.68	0.008 **
Host Plants	2	4.39	0.013 *
Aphids	2	0.40	0.669 ns
Host Plants X Aphids	4	2.96	0.021 *
Error	158		
Total	166		
X ²		2.93	
Pupal stage	8	5.26	0.000 ***
Host Plants	2	0.73	0.485 ns
Aphids	2	5.71	0.004 **
Host Plants X Aphids	4	7.19	0.000 ***
Error	146		
Total	154		
X ²		5.59	
Days from egg to emergence	8	1.76	0.090 ns
Host Plants	2	0.01	0.991 ns
Aphids	2	4.58	0.011 *
Host Plants X Aphids	4	1.16	0.331 ns
Error	146		
Total	154		
X ²		7.19	

The results in Table (2) indicated that the developmental times of *C. undecimpunctata* eggs, 2nd, 3rd, 4th instar larvae, total larval stage, and pupal stage when fed on *A. gossypii* that were reared on eggplant, potatoes, and faba bean were significantly influenced by the host plants used. Whereas, there was a significant difference occurred of 1st instar larvae and total of immature stages of *C. undecimpunctata* when fed the same aphid species that were reared on the same host plants.

An apparent significant difference was observed of significant difference occurred of eggs and pupal stage of *C. undecimpunctata* when fed on *M. persicae* that were reared on eggplant, potatoes, and faba bean with respect to the developmental times. Meanwhile, there was no significant difference was observed of 1st, 2nd, 3rd, 4th instar larvae, total larval stage, and total of immature stages.

As well as, there was a significant difference occurred of 4th instar larvae of *C. undecimpunctata* when fed on *A. craccivora* that were reared on eggplant, potatoes, and faba bean with respect to the developmental times (Table 2). Meanwhile, there was no significant difference was observed of eggs, 1st, 2nd, 3rd, 4th instar larvae and total larval stage, pupal stage, and total of immature stages (Table 2).

Giles *et al.* (2002a) found no significant effect of alfalfa cultivar, *Medicago sativa*, on the suitability of *Acyrtosiphum kondoi* as prey for either *Hippodamia convergens* Guerin-Meneville or *Coccinella septempunctata* L. Giles *et al.* (2002b) found that rearing *Acyrtosiphum pisum* Harris on alfalfa improved its suitability as prey for *C. septempunctata* compared to rearing it on *V. faba*, an effect the authors attributed to greater lipid storage by the aphids when feeding on the former plant. In addition, Wu *et al.* (2010) observed subtle differences in the suitability of *A. gossypii* as prey for *Hippodamia variegata* (Goeze) across five cucurbitaceous host plants; observed differences were attributed to nutritional differences. Thus, there exists a trend for aphids to be more suitable and nutritious prey for coccinellid predators when they are reared on a more suitable host plant. Francis *et al.* (2000) showed that *M. persicae* suitability as prey for *Adalia bipunctata* L. was reduced when the aphid was reared on *Brassica* spp. with elevated levels of glucosinolates. Similar results were obtained by Pratt *et al.* (2008) who fed *Adalia bipunctata* L. and *C. septempunctata* with *Brevicoryne brassicae* (L.) reared on diets with varying levels of sinigrin; higher levels had greater negative impact on the former species. In addition, Riddick *et al.* (2011) demonstrated that larvae of the coccinellid, *Stethorus punctillum* (Weise) experienced delayed development when foraging on two-spotted spider mites, *Tetranychus urticae* Koch, that were reared on *Phaseolus lunatus* L. (cv. Henderson) and correlated this with elevated concentrations of a cyanogenic glycoside that appeared to impede the mite's ability to utilize plant protein.

Table (2). Developmental times^a (average ±SEM) in days of immature stages of *C. undecimpunctata* when fed on three aphid species that were reared on three host plants under laboratory conditions (28±1°C and 70 ±5%R.H).

Host Plant	Aphid species	Incubation period	Larval instars					Pupal stage	Days from egg to emergence
			1 st	2 nd	3 rd	4 th	Total		
Eggplant	<i>A.gossypii</i>	2.35± 0.16aA	1.95± 0.16aA	1.20± 0.16aA	1.42± 0.16aA	2.00± 0.17aA	6.56± 0.17aA	2.88± 0.18bA	11.88± 0.35aA
	<i>M.persicae</i>	1.75± 0.16bB	1.35± 0.16bA	1.30± 0.16aA	1.37± 0.16aA	1.83± 0.17aA	5.89± 0.17bA	3.56± 0.35aA	11.25± 0.53aA
	<i>A.craccivora</i>	2.40± 0.16aA	1.55± 0.11bA	1.15± 0.16aA	1.11± 0.16aA	1.76± 0.17aB	5.53± 0.34bA	2.86± 0.19bA	11.29± 0.57aA
Potatoes	<i>A.gossypii</i>	2.30± 0.16aA	1.20± 0.16aB	1.05± 0.16aA	1.45± 0.16abA	2.15± 0.32aA	5.85± 0.16aA	3.28± 0.16aA	11.39± 0.49aB
	<i>M.persicae</i>	2.30± 0.16aA	1.50± 0.16aA	1.26± 0.16aA	1.60± 0.16aA	2.1± 0.32aA	6.45± 0.16aA	2.63± 0.162bB	11.42± 0.32aA
	<i>A.craccivora</i>	2.15± 0.16aA	1.35± 0.16aA	1.05± 0.1aA	1.15± 0.16bA	2.50± 0.17aA	6.06± 0.33aA	3.24± 0.17aA	11.59± 0.69aA
Faba bean	<i>A.gossypii</i>	1.75± 0.16bA	1.40± 0.16aB	1.20± 0.16aA	1.44± 0.17aA	2.00± 0.17aA	6.11± 0.67aA	2.78± 0.17abA	10.56± 0.49aB
	<i>M.persicae</i>	2.35± 0.16aA	1.55± 0.16aA	1.26± 0.16aA	1.33± 0.17aA	2.06± 0.17aA	6.22± 0.49aA	2.41± 0.17bB	11.12± 0.86aA
	<i>A.craccivora</i>	2.25± 0.32aA	1.45± 0.158aA	1.30± 0.16aA	1.05± 0.16bA	1.80± 0.16aB	5.60± 0.47aA	2.95± 0.16aA	10.85± 0.79aA

^aMeans followed by the same small letter in a column among host plant in each aphid species and the same capital letter among aphid species in each host plant are not significantly different at the 5% level of probability (Student- Newman-Keuls Test).

Survival

No significant differences were observed for survival as an overall model (F= 0.87, df=8, P=0.541 ns, X²=13.40) (Table 3). Among host plants or aphid species or host plants-aphid species interaction, there was no significant variation (F= 0.13, df= 2, P= 0.878 ns, F= 2.46, df= 2, P=0.088 ns, and F=0.45, df= 4, P= 0.770 ns, respectively).

Table (3). 2-way ANOVA of *C. undecimpunctata* survival when fed on three aphid species that were reared on each of three host plants under laboratory conditions (28±1°C and 70 ±5% R.H).

Source of Variation	df	F	P
Survival	8	0.87	0.541 ns
Host Plants	2	0.13	0.878 ns
Aphids	2	2.46	0.088 ns
Host Plants X Aphids	4	0.45	0.770 ns
Error	171		
Total	179		
	X ²	13.40	

Data in Table (4) indicated that the survival percentages of immature stages of *C. undecimpunctata* when fed on *A. gossypii* that were reared on eggplant, potatoes, and faba bean were 80, 90, and 90%, respectively with not significantly influenced by the host plants used.

No significant differences occurred of immature stages of *C. undecimpunctata* when fed on *M. persicae* that were reared on eggplant, potatoes, and faba bean with respect to survival percentages. Meanwhile, there was a significant difference occurred of immature stages of *C. undecimpunctata* when fed on *A. craccivora* that were reared on eggplant, potatoes, and faba bean with respect to survival percentages (Table 4).

Jalalii and Michaud (2012) noted that survival of immature *A. bipunctata* to adult emergence was significantly better when each prey aphid was reared on its host plant of origin than on the reciprocal host plant, and each aphid species yielded higher immature beetle survival than the other when reared on its host plant of origin. The nature of the interaction between host plant and aphid species varied somewhat among life stages of the coccinellid, the suitability of prey as reflected in survival.

Table (4). Survival^a of immature stages of *C. undecimpunctata* when fed on three aphid species that were reared on three host plants under laboratory conditions (28±1°c and 70-±5%R.H).

Host Plant	Aphid species	Total Survival %
Eggplant	<i>A.gossypii</i>	80 aA
	<i>M.persicae</i>	80 aA
	<i>A.craccivora</i>	70 aB
Potatoes	<i>A.gossypii</i>	90 aA
	<i>M.persicae</i>	90 aA
	<i>A.craccivora</i>	85 aB
Faba bean	<i>A.gossypii</i>	90 aA
	<i>M.persicae</i>	85 aA
	<i>A.craccivora</i>	100 aA

^aMeans followed by the same small letter in a column among host plant in each aphid species and the same capital letter among aphid species in each host plant are not significantly different at the 5% level of probability (Student- Newan-Keuls Test).

Consumption of the larval instars

With respect to the consumption, the overall model, aphid species, and host plant-aphid species interaction revealed that there was a significant variation for effects on the first instar of the predator (F=8.74, df= 8, P= 0.000 ***; for overall model, F=4.81, df= 2, P= 0.009 ** for aphid species, and F=15.04, df=4, P= 0.000 ***; for interaction) (Table 5). Among host plants, there was no significant variation (F= 0.06, df =2, P=0.943 ns).

The 2-way ANOVA was significant as the overall model and host plant-aphid species interaction on the second larval instar (Table 5) (F=3.99, df= 8, P= 0.000***, and F=6.98, df= 4, P= 0.000***, respectively). Among host

plants or aphid species, there was no significant variation ($F=1.97$, $df=2$, $P=0.142$ ns, and $F=0.04$, $df=2$, $P=0.956$ ns, respectively).

The overall model and host plant-aphid species interaction indicated that there was a significant variation on the third larval instar ($F=3.02$, $df=8$, $P=0.003$ **, and $F=4.75$, $df=4$, $P=0.001$ **, respectively). While, there was no significant variation among host plants or aphid species ($F=1.97$, $df=2$, $P=0.142$ ns and $F=0.46$, $df=2$, $P=0.630$ ns, respectively).

Based on 2-way ANOVA, the overall model, host plants, aphid species, or host plants-aphid species interaction revealed that there was a significant variation on the fourth larval instar ($F=13.79$, $df=8$, $P=0.000$ ***, $F=10.97$, $df=2$, $P=0.000$ ***, $F=15.26$, $df=2$, $P=0.000$ ***, and $F=14.69$, $df=4$, $P=0.000$ ***, respectively) with respect to the consumption.

Regarding the consumption of the larval stage, the overall model, host plants, aphid species, or host plants-aphid species interaction revealed that there was a significant variation ($F=23.59$, $df=8$, $P=0.000$ ***, $F=8.69$, $df=2$, $P=0.000$ ***, $F=19.88$, $df=2$, $P=0.000$ ***, and $F=33.12$, $df=4$, $P=0.000$ ***, respectively)

The results in Table (6) indicated that the consumption of *C. undecimpunctata* 2nd, 3rd, 4th instar larvae and total larval stage when fed on *A. gossypii* that were reared on eggplant, potatoes, and faba bean were not significantly influenced by the host plants used. Whereas, there was a significant difference occurred of 1st instar larvae of *C. undecimpunctata* when fed the same aphid species that were reared on the same host plants. An apparent significant difference was observed of 1st, 2nd, 3rd, 4th instar larvae and larval stage of *C. undecimpunctata* when fed on *M. persicae* that were reared on eggplant, potatoes, and faba bean with respect to the consumption.

In addition, there was a significant difference occurred of 1st, 2nd, 4th instar larvae and total larval stage of *C. undecimpunctata* when fed on *A. craccivora* that were reared on eggplant, potatoes, and faba bean with respect to the consumption (Table 6). Meanwhile, there was no significant difference was observed of 3rd instar larvae.

Clausen (1940) mentioned that an increase in the consumption rate and total number of aphids eaten by predator larvae on aphids from partially resistant cultivar could be due to the undersized aphids recorded in this cultivar. Smith (1978) pointed out that the nutritional value of the same aphid species might vary from one host plant to another. Shannag and Obeidat (2006) reported that total consumption by *C. septempunctata* larvae was higher when the consumed *Aphis fabae* Scop. that were obtained from partially resistant host plants, where approximately 648.9 aphids were needed during development. In contrast, only 569 aphids from susceptible faba bean plants were devoured by each predator larva during larval growth. The predator larvae using aphids from susceptible faba bean plants as a source of food were considerably more efficient in converting food to body mass.

In conclusion, the results of this study demonstrate the potential of tri-trophic interactions between host plants and aphid species to affect predator performance. Therefore, it seems that host plants-aphid species interaction

can have a great indirect impact on the food consumption and efficiency of this predator's conversion of food to body mass. As well as, this study illustrate the importance of carefully selecting host plant-aphid combinations to optimize the mass-rearing of coccinellids for biological control programs, and thus levels of biological control, may vary among agricultural crops bearing the same aphid species.

Table (5). 2-way ANOVA of larval instars consumption of *C. undecimpunctata* when fed on three aphid species that were reared on each of three host plants under laboratory conditions (28±1°C and 70 ±5%R.H).

Source of Variation	df	F	P
L1	8	8.74	0.000 ***
Host Plants	2	0.06	0.943 ns
Aphids	2	4.81	0.009 **
Host Plants X Aphids	4	15.04	0.000 ***
Error	171		
Total	179		
X ²		46.11	
L2	8	3.99	0.000 ***
Host Plants	2	1.97	0.142 ns
Aphids	2	0.04	0.956 ns
Host Plants X Aphids	4	6.98	0.000***
Error	171		
Total	179		
X ²		25.55	
L3	8	3.02	0.003 **
Host Plants	2	1.97	0.142 ns
Aphids	2	0.46	0.630 ns
Host Plants X Aphids	4	4.75	0.001 **
Error	166		
Total	174		
X ²		45.97	
L4	8	13.79	0.000 ***
Host Plants	2	10.97	0.000 ***
Aphids	2	15.26	0.000 ***
Host Plants X Aphids	4	14.69	0.000 ***
Error	159		
Total	167		
X ²		31.25	
Larval Stage	8	23.59	0.0000 ***
Host Plants	2	8.69	0.0003 ***
Aphids	2	19.88	0.0000 ***
Host Plants X Aphids	4	33.12	0.0000 ***
Error	159		
Total	167		
X ²		17.16	

Table (6). Mean number of aphids^a consumed by larval instars of *C. undecimpunctata* when fed on three aphid species that were reared on three plants under laboratory conditions (28±1°C and 70±5%R.H).

Host Plants	Aphid species	Larval instars				
		1 st	2 nd	3 rd	4 th	Total
Eggplant	<i>A.gossypii</i>	23.35± 2.69 aA	44.05± 1.58 aA	66.60± 5.85aA	142.39± 3.33aA	276.72± 3.49aA
	<i>M.persicae</i>	12.30± 0.16 bC	35.85± 0.158 bB	60.84± 2.43aB	124.68± 2.11aC	233.79± 3.08bC
	<i>A.craccivora</i>	19.25± 0.79 cB	40.90± 1.42abB	66.89± 0.49aA	130.29± 2.57aAB	257.82± 7.38abB
Potatoes	<i>A.gossypii</i>	22.45± 1.58 abA	41.4± 0.79aA	66.35± 0.47aA	175.10± 0.15aA	305.40± 1.74aA
	<i>M.persicae</i>	19.75± 0.158bB	35.50± 1.58bB	55.60± 1.74bB	154.35± 8.66aB	265.20± 8.6bB
	<i>A.craccivora</i>	26.10± 0.79aA	45.25± 3.16aA	69.25± 0.32aA	159.0± 10.33aA	299.56± 12.17aA
Faba bean	<i>A.gossypii</i>	16.05± 0.63aB	40.0± 3.95abA	64.06± 2.49bA	166.33± 2.49bA	288.06± 2.66bA
	<i>M.persicae</i>	29.55± 1.11bA	45.05± 0.63aA	70.53± 7.14aA	234.28± 1.83aA	383.06± 0.33aA
	<i>A.craccivora</i>	17.65± 1.74bB	36.75± 3.95bB	62.85± 0.63bA	119.80± 0.32cB	237.05± 9.65cB

^aMeans followed by the same small letter in a column among host plant in each aphid species and the same capital letter among aphid species in each host plant are not significantly different at the 5% level of probability (Student- Newman-Keuls Test).

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التداخل الغذائي الثلاثي بين العائل النباتي والفريسة الحشرية ومفترس أبو العيد ١١
نقطة تحت الظروف المعملية
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تم دراسة التداخل الغذائي الثلاثي بين العائل النباتي والفريسة الحشرية ومفترس أبو العيد ١١ نقطة تحت الظروف المعملية . حيث تم تحديد فترات النمو للأطوار غير الكاملة ونسب البقاء والإفتراس لمفترس أبو العيد ١١ نقطة وذلك بالتغذية على حشرة من القطن ، من الخوخ الأخضر ومن البقوليات والتي تربت على كل من الباذنجان ، البطاطس وال فول البلدي. أوضحت النتائج فيما يتعلق بفترات النمو للأطوار غير الكاملة أن النموذج العام لتأثير العوائل النباتية الثلاثة وكذلك التداخل بين العوائل النباتية وأنواع حشرات المن الثلاثة المدروسة لم يوضح وجود فروق معنوية بينما كان تأثير أنواع حشرات المن معنوى. أشارت نتائج الدراسة أنه لا يوجد تأثير معنوى وذلك فى النموذج العام وكذلك لا يوجد تأثير للعوائل النباتية المدروسة ، أنواع حشرات المن الثلاثة والتداخل بين العوائل النباتية وأنواع المن الثلاثة وذلك على نسبة البقاء للأطوار غير الكاملة للمفترس أبو العيد ١١ نقطة وفيما يتعلق بإستهلاك الأعمار اليرقية أوضحت النتائج من النموذج العام التأثير المعنوى لكل من العائل النباتي وأنواع حشرات المن الثلاثة . بوضوح، أشارت نتائج هذه الدراسة أن فترات الأطوار غير الكاملة ونسبة البقاء والإستهلاك لمفترس أبو العيد ١١ نقطة والتي تغذت على حشرات من القطن ، من الخوخ الأخضر ومن البقوليات والتي تم تربيتها على كل من الباذنجان والبطاطس، والفول البلدي لها آثار على الخصائص البيولوجية لهذا المفترس.

قام بتحكيم البحث

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