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Deviations from prediction model of predatory effect for Coccinellidae

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Abstract

Effective predation of coccinellids species is essential for plant protection programs in the field or glasshouse. The purpose of this study was to estimate deviations of predatory effect from predicted values based on the predatory effect model proposed by previous researchers. Two coccinellids species were used to cope with six different pests. There were differences between realized and theoretical data. Especially for aphid species there were very low deviations and in one case there were a positive deviation for both predators, indicating that Coccinellidae were underestimated in previous studies. As a conclusion, prediction model must be used as a guide for practical purposes and not for theoretical modeling. The choice of a predator species must be a result of extensive testing on the prey because differentiation of predatory effect is common to coccinellids and depends also on the locality of a species. *Coccinella septempunctata* found to be a better predator. The model predictions were in accordance only for *M. persicae* and *M. euphorbiae* measurements and predators-prey relationships were different on different plant leaves.

Keywords: Predators, effective predation, model, deviation, aphids

Introduction

Plant pests often cause great economic damages on plant production, thus in many cultivations chemical treatment is the most usual approach for a successful pest management (Deligeorgidis et al. 2007). In our times consumers demand a more environmental friendly approach that ensures sustainability and is generally considered healthier. Under these considerations, biological pest control arose in a more systematic basis, supported by many scientific data and techniques including the usage of useful insects, fungi, bacteria etc.

Coccinellids have been widely used in biological control for more than a century and the methods for using these predators have been remained rather unchanged. Augmentative and sometimes massive releases of coccinellids species are well documented and effective; however, infectious species continue to be used because of easy finding and collection. Some coccinellids species are considered specialized and characterized as aphidophagous (Kumar et al. 2014). Some experiments with aphidophagous coccinellids indicate that significantly suppress aphid abundance. Absence of predators by caging aphid-infested plants has resulted in higher aphid populations (Brown 2004; Michels et al. 2001) and greater population growth rates (Elliott and Kieckhefer 2000), indicating that coccinellids may reduce aphid populations. However, in some studies aphidophagous species of ladybirds are reported as ineffective in controlling aphid populations (van den Bosch and Messenger 1973). Pervez (2012) reported a full catalogue of predator-prey in India involving coccinellids and their predaceous activity.

Coccinella septempunctata L. (Coleoptera: Coccinellidae) is one of the most important species of coccinellids, which have been established throughout Europe in various glasshouse crops. *C. septempunctata* is usually found on flowers and leaves of various cultivated or other plants. It is predaceous usually on thrips, aphids, whiteflies, mites and lepidopteran eggs. *C. septempunctata* is also one of the most numerous coccinellids beetles in Greek fields (Deligeorgidis et al. 2005a, b). *Adalia bipunctata* L. (Coleoptera: Coccinellidae) is another common coccinellid found in Europe.

The polyphagous thrips species, *Frankliniella occidentalis* (Pergande) and *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) are major pests which cause serious damages in greenhouse crops worldwide (Broadbent et al. 1987; Mandel and van de Vrie 1988; van Lenteren and Woets 1988). *T. tabaci* and white fly *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae) as major pests in greenhouses can be controlled with predatory mites introduced in plants (Onillon 1990; Hoelmer et al. 1993). The biological control of thrips and whiteflies has been studied using several species of natural enemies such as spider beetles etc. Predator species usually of the families Anthocoridae, Coccinellidae, Chrysopidae are able to maintain the plant pest populations below damaging levels (Onillon1990).

Among many aphid species (Hemiptera: Aphididae), *Macrosiphum euphorbiae* (Thomas) is preferred rather than *Myzus persicae* (Sulzer) by the predator *C. septempunctata* (Shands and Simpson 1972). *Aphis spiraecola* (Patch) is another common aphid species in Europe.

The behavior of predators described by the second-degree models, involving number of aphids that consumes *C. septempunctata* (and other coccinellid species) or the percentage of aphids that escape, reveals more than one factors for reducing efficiency of predation (Deligeorgidis et al. 2005a). The purpose of this study was to estimate deviations from predicted values based on the predatory effect model proposed by Deligeorgidis et al. (2005a, 2011).

Materials and Methods

In the prefecture of Central Macedonia an experiment was contacted involving common predacious coccinellid and various pests. The basic experimental unit was a single tomato or cucumber leaf (approximately 15-20cm^2) collected from infested greenhouse cultivation in a 15×15×10 cm clear plastic cage. The cages had three openings, each of 3×2 cm, covered with dense material made of muslin (0.06 mm opening) for airing. Each leaf in the cage was held away from the upper internal part of the cage with sticky tape. Two-day old females of *C. septempunctata* and *A. bipunctata* (collected from original rearing kept in the laboratory for 9 months at 25 ± 1^{o}C) were used for all experiments and were starved for 24 h before use by placing them on the infested leaves in individual cages. *M. euphorbiae, M. persicae* and *A. spiraecola* were collected from greenhouse cultivation of tomato and cucumber (under fully controlled conditions). Adults of *T. tabaci*, *F. occidentalis* and *T. vaporariorum* were collected from laboratory colonies reared on tomato leaves (Deligeorgidis 2005a,b) or greenhouse cultivation of infested tomato and cucumber. After introduction of the prey (the infested leaves) and the predator, all cages were held in controlled environment chambers at a temperature of 22 ± 1°C, 65 ± 2% relative humidity (RH), with a 16 h light: 8 h dark photoperiod and intensity of light 9000 Lux, after which survivor of prey was counted. One single female *C. septempunctata* corresponded to a prey number over 20 per cage. Initial prey number counted alive is presented in Table 1. Each treatment was replicated six times (6 infested leaves). Six more cages (treatments) were used as control (check). In these cages there were all prey species but in absence of the predator (no beetles) and mortality after 24h was measured and found 0 (no mortality).

The measurements on the predatory effect of were based on the percentage of prey consumed by the predator to their initial number before the introduction of the predator, then effective predation was calculated in the basis of escapes% (Deligeorgidis et al. 2005a,b,c; 2011).Statistical analysis (including line regression) was based on both the original data and transformed data means (pest counts) according to the formula:

$$x' = \sqrt{x+1} \quad \text{(Fasoulas 1979)}$$

T-criterion on escapes' proportions comparisons was used (Fasoulas 1979) and number of replications was usually six. Original data are presented in all tables. Deviations from original theoretical models were also calculated and b-values were estimated (Deligeorgidis et al. 2005 a,b,c; 2011) according to realized data from cultivations (in all cages).

Results

Table 1 presents total initial number of prey for each species and theoretical escapes(%) under biological control according to Deligeorgidis et al. (2005a,b,c) for both cultivations (cucumber and tomato) and for the two predators *C. septempunctata* and *A. bipunctata*. Data were calculated under the model presented in Figure 1 (adopted from Deligeorgidis et al. (2005c). Statistically significant differences (on the limit of 0.05) were found between the proportions of cucumber and tomato. In cucumber, aphid species showed less escapes in comparison to other species, but not in tomato.

Table 1. Total initial number of prey for each species and theoretical escapes (%) under biological control according to Deligeorgidis et al. (2005 a,b,c) for both cultivations (cucumber and tomato) and for the two predators (*C. septempunctata* / *A. bipunctata*)

Species	Cucumber		Tomato	
	Total pest	% escapes*	Total pest	% escapes*
F. occidentalis	34	59/64	24	32/30
T. tabaci	22	41/35	21	40/35
T. vaporariorum	33	53/48	35	61/56
M. persicae	44	41/39	52	45/44
M. euphorbiae	41	38/37	43	42/40
A. spiraecola	35	28/20	38	28/22
* Significant differences at 0.05 level between cucumber and tomato				

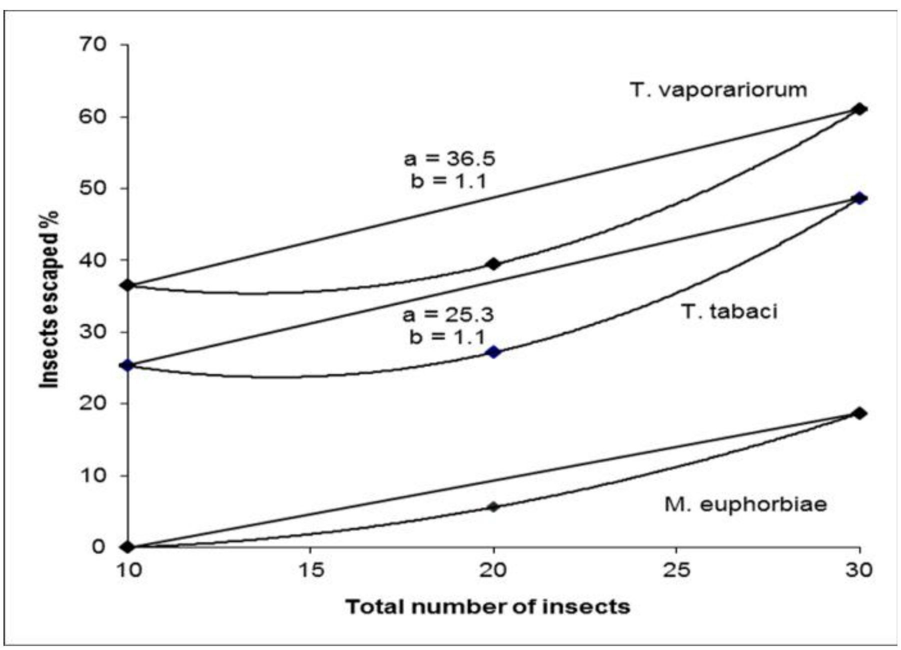

Figure 1. Predictions according to the theoretical second-degree model describing the relation between the total number of pest (Total number of insects) and the percentage (%) of insects that may survive (Insects escaped %). Theoretical maximum linear models included for *T. vaporariorum* and *T. tabaci,* and *M. euphorbiae* (adopted from Deligeorgidis et al. (2005b,c)

In Table 2, actual predation was calculated for both cultivations (cucumber and tomato) and for the two predators *C. septempunctata* and *A. bipunctata*. Escapes (%) were measured with a pick at 64.11% for *F. occidentalis* and a very low calculation at 18.13% for *A. spiraecola*. Statistically significant differences (on the limit of 0.05) were found between the proportions of cucumber and tomato.

Table 2. Actual predation for both cultivations (cucumber and tomato) and for the two predators *C. septempunctata* and *A. bipunctata*. Escapes (%) of all prey species: *T. tabaci*, *F. occidentalis*, *T. vaporariorum M. euphorbiae*, *M. persicae* and *A. spiraecola* per predator (*C. septempunctata* / *A. bipunctata*)

Species	Cucumber		Tomato	
	Total pest	% escapes*	Total pest	% escapes*
F. occidentalis	34	64.11/	25	33.16/
T. tabaci	22	43.38/	21	41.92/
T. vaporariorum	33	58.1/	35	65.05/
M. persicae	44	41/	52	/
M. euphorbiae	41	39.07/	43	43.72/
A. spiraecola	35	25.15/18.13	38	23.7/20.94
* Significant differences at 0.05 level between cucumber and tomato				

In Table 3, deviations (%) from original models have been calculated and presented for both cultivations (cucumber and tomato) and for the two predators *C. septempunctata* and *A. bipunctata*. Some problems with *M. persicae* measurements lead to non-reliable data that are also presented for comparison only. Statistically significant differences were found for percentage (deviation) over ±3%. *M. persicae* and *M. euphorbiae* measurements were found without statistically significant deviations from proposed model. The b-slope values estimated (after line regression model, according to Deligeorgidis et al. 2005a,b) are presented in Table 4; Starting from 0.33 and climbing to 5, for the two predators *C. septempunctata* and *A. bipunctata*.

Table 3. Deviations (%) from original models for both cultivations (cucumber and tomato) and for the two predators *C. septempunctata* and *A. bipunctata* on all prey species: *T. tabaci, F. occidentalis, T. vaporariorum, M. euphorbiae, M. persicae* and *A. spiraecola*

Species	Cucumber		Tomato	
	C. septempunctata/ A. bipunctata		*C. septempunctata/ A. bipunctata*	
F. occidentalis	-7.97		-3.50	
T. tabaci	-5.49		-4.58	
T. vaporariorum	-8.78		-6.23	
M. persicae	+0.1			
M. euphorbiae	-2.74		-3.93	
A. spiraecola	11.33	9.29	18.14	5.06
* Significant differences at 0.05 level for percentage over ±3%				

Table 4. The b-slope values estimated for the two predators *C. septempunctata* and *A. bipunctata* on all prey species: *T. tabaci, F. occidentalis, T. vaporariorum, M. euphorbiae, M. persicae* and *A. spiraecola*

Species	*C. septempunctata*	*A. bipunctata*
F. occidentalis	3.13	5
T. tabaci	1	0.93
T. vaporariorum	1.3	1.4
M. persicae	2.33	1.6
M. euphorbiae	0.33	0.75
A. spiraecola	1.43	1.07

Discussion

In real cultivation conditions in a glasshouse, plant protection is essential in order to ensure a satisfactory economic result (van Lenteren and Woets 1988). Deligeorgidis et al. (2005a,b,c; 2011) presented theoretical models (and their use) that are summarized below:

The new equation describing predatory effect of *C. septempunctata* on *A. spiraecola* was found $y = -0.038x^2 + 2.289x - 8.412$ ($r^2 = 0.65$). The second equation, describing predatory effect of *A. bipunctata* on *A. spiraecola* is $y = 0.033x^2 - 1.472x + 29.219$ ($r^2 = 0.75$). For *M. euphorbiae* $y = 0.0329x^2 - 0.4403x + 1.82$ ($r^2 = 0.979$). For large insects *T. tabaci* model was $y = 0.078x^2 - 1.9x + 47.425$ ($r^2 = 1$) and for *T. vaporariorum* $y = 0.082x^2 - 2.1x + 38.108$ ($r^2 = 1$).

There were significant differences between realized and theoretical data. Negative deviations and lower effectiveness showed for almost all species of prey. Especially for aphid species there were very low and non-significant deviations but in case of *A. spiraecola* there were a strong positive deviation for both predators, indicating that the Coccinellids used were underestimated in previous studies and in cultivations (real conditions) they may be much more effective than it is expected, especially *C. septempunctata*. These Coccinellidae have been proved to be very capable predators and many b-values have been estimated near 1, indicating that ideal population index (predator to prey) was fulfilled (Deligeorgidis 2005a,b), but even then deviations were found present especially for larger insects. Thus, prediction model must be used as a guide for practical purposes and not for theoretical modeling. Triltsch and Roßberg (1997) reported that predation rate of *C. septempunctata* on aphids was higher when aphid density was higher and was depended on temperature conditions. Ahmed et al. (2016) reported an increased reliability of biological control of insect pests and a successful integration of integrated pest management. In another study on predator-prey relationship Inayat et al. (2011) showed an almost linear relationship and they concluded that species specific biological control can be implemented against targeted pests. They used the major coleopteran predators *C. septempunctata*, *Coccinella undecimpunctata*, *Cheilomenes sexmaculata* (Fabricius, 1781), *Hippodamia variegata* (Goeze, 1777) and *Calosoma maderae* (Fabricius, 1775), and hemipteran prey *Schizaphis graminum* (Rondani), *Aphis maidis* (Fitch, 1856), *Macrosiphum miscanthi* (Takahashi, 1921), *Aphis gossypii* (Glover, 1877) and *Diuraphis noxia* Kurdjumov from mixed crop agro-ecosystems.

In our study, the two species exhibited different predatory efficiency and *C. septempunctata* was usually a better predator. This differentiation is common to coccinellids and depends also on the local abundance of a species (Finlayson et al.2010). Also, small prey like aphids was more easily consumed by the two predators.

As a conclusion, prediction model must be used as a guide for practical purposes and not for theoretical modeling. The choice of a predator species must be a result of extensive testing on the prey because differentiation of predatory effect is common to coccinellids and depends also on the local abundance of a species. *C. septempunctata* was usually a better predator in almost all measurements. The model predictions were in accordance only for *M. persicae* and *M. euphorbiae* measurements and predators-prey relationships were different on different plant leaves.

Compliance with Ethical Standards

There are no potential conflicts of interest and this paper is based on biological protection procedures.

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