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Review Article

The ladybird predator *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae): current status and future perspectives

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ABSTRACT: Whiteflies have been causing extensive damage for almost a century and continue to be destructive pests of several agricultural crops in much of the world. Biological control is recognized as the best alternative to the use of insecticides for controlling insect pests. *Serangium parcesetosum* Sicard (Col., Coccinellidae) is a specialist, oligophagous and efficient predator that has demonstrated a potential for biological control of many whitefly species. Concomitantly, this paper reviews the morphology, phenology and biology of *S. parcesetosum*. In addition, studies conducted during the last decade on the predator's predation potential and preferences are summarized. Furthermore, *S. parcesetosum* releases against some whitefly species are herein presented. Finally, this paper presents the current efforts in biological control of whiteflies using *S. parcesetosum* in greenhouses and open fields, and highlights research gaps and directions deserving further development to create a better understanding of *S. parcesetosum* on different agricultural crops to control whiteflies. The available data indicate that long survival of *S. parcesetosum* adults accomplished by their voracious feeding is a great feature that resulted in successful control of whiteflies. An additional positive feature of *S. parcesetosum* is that it could establish and disperse throughout citrus fields. In conclusion, *S. parcesetosum* could develop, survive, reproduce and prey upon whiteflies, and build up its population successfully. Consequently, it is likely that *S. parcesetosum* could effectively function as a sole biological control agent or in conjunction with other natural enemies to develop new management strategies to provide a great level of suppression of whiteflies worldwide.

KEY WORDS: *Serangium parcesetosum*, predator, whiteflies, biology, predation, preference, population dynamics, biological control

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INTRODUCTION

Coccinellidae (Coleoptera) is a wellknown beetle family, worldwide distributed (Almeida *et al*., 2011), and divided into six subfamilies: Coccidulinae, Coccinellinae, Scymninae, Chilocorinae, Sticholotidinae and Epilachninae (Vandenberg, 2002). The predaceous insects of family Coccinellidae are commonly known variously as ladybirds, ladybugs, lady beetles or coccinellid beetles (Sharma and Joshi, 2010). Predaceous ladybird beetles occur within the first five subfamilies whereas the Epilachninae are phytophagous (Hodek and Honek, 1996; Dixon, 2000). The coccinellids are of extremely diverse habits, predators of a variety of pests such as aphids, leafhoppers, scale insects, mealybugs, whiteflies, thrips and mites in all parts of the world (Majerus, 1994; Omkar and Bind, 1996; Al-Zyoud, 2007, 2008, 2012). The introduction of the Vedalia ladybird, *Rodolia cardinalis* Mulsant from Australia into California in 1888 to control the cottony cushion scale, *Icerya purchasi*, which threatened the citrus industry, is widely regarded as the most successful instance of biological pest control by coccinellids (Majerus, 1994). About 6000 species of Coccinellidae are known Worldwide (Vandenberg, 2000) with over 300 species known from the Indo-Pakistan subcontinent (Rahatullah *et al.,* 2010). Poorani (2002) has given an annotated checklist of the family Coccinellidae for the Indian sub-region, which lists 400 species, under 79 genera, 22 tribes and five subfamilies. Thirty one species were identified, of which 19 species were recorded for the first time within the Haridwar district of India (Joshi and Sharma, 2008). Fourteen species from 12 genera belonging to 4 subfamilies were listed in Pakistan (Rahatullah *et al.,* 2011). Also, Khan *et al*. (2007) have recorded 12 species of coccinellid beetles from Chitral district of Pakistan. Shah (1985) studied the coccinellids of Peshawar valley and recorded 16 species along with geographical distribution and host plants. Singh and Singh (1990) have reported 16 species of aphidophagous coccinellids from Mizoram state, a north eastern state of India. In addition, Omkar and Pervez (2000, 2002) have reported 17 more species of coccinellids from the same region. Also, in India, 8 species of ladybird beetles belonging to 6 genera were recorded (Sharma *et al.,* 2011). Similarly, Usman and Puttarudriah (1955) recorded 48 species of predaceous coccinellids from the Mysore state, to which Kapur (1972) further added 17 species. Furthermore, 30 coccinellid species belonging to 18 genera (Pajni and Singh, 1982) and 25 coccinellid species from 15 genera from the Chandigarh region (Pajni and Varma, 1985) were recorded.

Biological control of whiteflies through the release of natural enemies has been attempted for at least 30 years (Goolsby *et al.,* 2000), and many attempts have ended in complete success. Some species of fungi such as *Aschersonia aleyrodis*, *Verticillium lecanii*, *Paecilomyces fumosoroseus* and *Beauveria bassiana* have been developed as microbial agents against whiteflies (Mor *et al.,* 1996; Chen and Feng, 1999; James and Jaronski, 2000), but, the development of fungi as control agents of whiteflies is still at a fairly early stage. However, extensive listed fauna of parasitoids were used to control whiteflies of various species of the genera *Eretmocerus* and *Encarsia* (DeBarro *et al.,* 2000; Hu *et al.,* 2003; Urbaneja and Stansly, 2004). Nevertheless, the required releases of *Er. eremicus* (Rose and Zolnerowich) were 27-fold more expensive than the use of insecticides (Driesche *et al.,* 1999). Moreover, *En. formosa* Gahan was unable to build-up its populations on *B. tabaci* and its activity is reduced during winter (Arno and Gabarra, 1996). Nevertheless, in spite of whiteflies being hosts of many parasitoids, it seems that the control of these pests by parasitoids is not achieved due to the extensive host range and mobility of the pests (Gerling and Steinberg, 2003). Thus, biological control strategies should include the release of additional natural enemies.

Predators play a key role in regulating pest populations (Jazzar and Hammad, 2004). Predators range from generalists that require additional food and specialists whose metabolism is adjusted to a specific biochemical composition of food. Hundreds of predators have been reported to prey upon whiteflies including arthropods belonging to 9 orders and 31 families. Heteropteran predators are usually polyphagous and prey specificity is rare (Fauvel, 1999). The predatory mirid bug, *Dicyphus tamaninii* Wagner (Lucas and Alomar, 2002) and *Nesidiocoris tenuis* Reuter (Calvo *et al.,* 2009), and the anthocorid bugs, *Orius laevigatus* (Fieber) and *O. majusculus* (Reuter) (Montserrat *et al.,* 2000) were used to control whiteflies. However, plant feeding by some species of predatory Heteroptera may cause economic injury (Sanchez and Lacasa, 2008) making their use controversial. The green lacewing, *Chrysoperla carnea* (Stephens) (Abd-Rabou and El-Naggar, 2003), and the phytoseiid predatory mites, *Euseius scutalis* (Athias-Henriot) and *Typhlodromips swirskii* (Athias-Henriot) appear to be promising biological control agents of whiteflies (Nomikou *et al.,* 2003). Many species of Coccinellidae are considered important natural enemies of whiteflies and may exhibit various degrees of oligophagy (Obrycki and Kring, 1998). *Delphastus catalinae* (Horn) feeds on immature whitefly but there are conflicting reports on prey consumption rates (Heinz and Parrella, 1994a).

The genus *Serangium* (Coleoptera: Coccinellidae) was erected by Blackburn (1889) with *Serangium mysticum* Blackburn from Australia as the type species. The name Serangiini was introduced by Blackwelder (1945) in his checklist and was validated by Pope (1962). *Serangium* is the largest genus of Serangiini with 45 described species, mostly occurring in the Oriental Region (Slipinski and Burckhardt, 2006). Wang *et al.* (2011) reviewed and described 12 species of *Serangium* from China. *Serangium* spp. are widely distributed in the World and known to be useful predators of many whitefly species. *Serangium parcesetosum* Sicard is a specialist, oligophagous and efficient predator that has demonstrated a potential for the biological control of many whitefly species. *S. parcesetosum* was firstly found in India and described by Sicard (1929) and reported there to be a very host specific on the cotton whitefly, *Bemisia tabaci* (Genn.) (Kapadia and Puri, 1992) and on the sugarcane whitefly, *Aleurolobus barodensis* Mask. (Shah *et al.,* 1986; Patel *et al.,* 1996). This predatory species was originally collected from India in 1929 for the release as a bio-agent of the citrus whitefly, *Dialeurodes citri* (Ashmead) in the Union of Soviet Socialist Republic (Timofeyeva and Nhuan, 1979). According to field studies carried out in Turkey, *S. parcesetosum* has successfully adapted in citrus growing areas to control *D. citri* (Ulusoy *et al.,* 1996). *S. parcesetosum* was introduced into Georgia in 1974 and into France from Georgia in 1985 for the biological control of *D. citri* (Malausa *et al.,* 1988). This ladybird was released to control the wooly whitefly, *Aleurothrixus floccosus* Maskell in Israel (Argov, 1994), and *B. tabaci* and *D. citri* in Syria (Abboud and Ahmad, 1998 Ahmad and Abboud, 2001). In addition, *S. parcesetosum* was investigated as a predator of the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (*B. tabaci* biotype B) in the USA (Ellis *et al.,* 2001; Legaspi *et al.,* 2001). *S. parcesetosum* release was evaluated in grapefruit orchard to control the citrus blackfly, *Aleurocanthus woglumi* Ashby (Legaspi *et al.,* 2001). The biological and ecological parameters of

S. parcesetosum have thoroughly been investigated on *B. tabaci* (Al-Zyoud and Sengonca, 2004; Al-Zyoud *et al.,* 2004, 2005b, 2006; Sengonca *et al.,* 2004, 2005; Al-Zyoud, 2007, 2008). According to Al-Zyoud *et al.* (2005a), *S. parcesetosum* was found to be a promising predator of the greenhouse whitefly, *Trialeurodes vaporariorum* Westwood. *S. parcesetosum* releases were evaluated to control *B. tabaci* on cotton and cucumber (Al-Zyoud *et al.,* 2007; Al-Zyoud, 2012), and *B. argentifolii* on poinsettias (Ellis *et al.,* 2001) under greenhouse conditions.

Concomitantly, this paper reviews the morphology, phenology and biology of *S. parcesetosum*. In addition, the studies conducted during the last decades on the predator's predation potential and preferences are summarized. Finally, *S. parcesetosum* releases against some whitefly species are herein presented. Also, this paper presents the current efforts in biological control of some whiteflies using *S. parcesetosum* in greenhouses and open fields, and highlights research gaps and directions deserving further development to create a better understanding of this predator on different agricultural crops to control whiteflies.

MORPHOLOGY AND PHENOLOGY OF *SERANGIUM PARCESETOSUM*

The adult of *S. parcesetosum* is small, hemispherical, shiny, and yellow-brown. The fronts' mouthparts and legs are usually slightly lighter, and the eyes are black. The head is sub-merged into pronotum, and directed downward. Antennae have 9 segments, where the 4th-8th segments are equal. Legs are covered with hairs and the femur strongly broadened and tarsi conceitedly 4 segmented. The abdomen is semicircular. Adult's body length is 2.0–2.1 mm, width of 1.7–1.8 mm and depth of 1.1 mm (Timofeyeva and Nhuan, 1979; Poorani, 1999). The last larval instar is 4.0–5.3 mm in length, fusiform in shape, and widest on the metathorax. Larval head has indistinct brownish spots, and has 3 black ocelli on each side, and the antenna is short with 3 segments. The larval 1st – 8th abdominal segments are almost of identical length, following segments gradually narrowing to the end. Larval body is densely covered with setae surrounded by pigmented areas, and legs are long and slender with sparse hairs, and brown claw. The pupa is 2.3–2.4 mm long, 1.8 mm wide, white yellowish, covered with dense long gray hairs on prothoracic segment (Timofeyeva and Nhuan, 1979).

The predator, *S. parcesetosum* overwinters as adult in dry rolled up leaves and underneath bark, congregating in large groups. *S. parcesetosum* emerges from its winter hibernation at early April. Thereafter, *S. parcesetosum* feeds actively for 40–50 days on its prey eggs and larvae, after which it started egg laying, and continues to lay eggs until end of June. *S. parcesetosum* has 4–5 generations/year (Timofeyeva and Nhuan, 1979). The predator lays its eggs singly or in groups on the under surface of the leaf among the whitefly eggs (Ahmad and Abboud, 2001; Al-Zyoud *et al.,* 2005b). The first larval instar (L_1) to hatch frequently consumes the eggs on their own egg batch. Newly hatched L_1 are relatively immobile and feed on whitefly eggs and larvae over a limited leaf surface. The L_2 and L_3 move rapidly over the leaves, like the adults, they feed on all development stages of the host (Patel *et al.,* 1996; Ellis *et al.,* 2001; Al-Zyoud and Sengonca, 2004). Males of *S. parcesetosum* follow females, feeding on the remains of the prey of the females and rarely feeding independently. Having attached themselves, pupae frequently become the victims of cannibalism by older larvae (Timofeyeva and Nhuan, 1979).

Prey species of *Serangium parcesetosum*

The predator, *S. parcesetosum* feeds successfully upon many whiteflies in the family Aleyrodidae (Hom.), including *B. tabaci* (Al-Zyoud *et al.,* 2006, 2007; Al-Zyoud, 2008), *A. barodensis* (Kapadia and Butani, 1997; Patel *et al.,* 1996), *D. citri* (Yigit, 1992b; Uygun *et al.,* 1997; Yigit *et al.,* 2003), *B. argentifolii* (Ellis *et al.,* 2001; Legaspi *et al.,* 2001), *A. floccosus* (Argov, 1994), *T. vaporariorum* (Al-Zyoud *et al.,* 2005a), *A. woglumi* (Kalidas, 1995), the castor bean whitefly, *Trialeurodes ricini* (Misra) (Al-Zyoud, 2007), the spiraling whitefly, *Aleurodicus dispersus* (Russell) and the arecanut whitefly, *Aleurocanthus arecae* David (Legaspi *et al.,* 1996). From the family Coccidae (Homoptera), *S. parcesetosum* has been reported to feed on the brown soft scale, *Coccus hesperidum* L. (Yigit *et al.,* 2003), the citrus soft scale, *C. pseudo-magnoliarum* (Kuwana) (Abboud *et al.,* 2009), and the striped mealybug, *Ferrisia virgata* (Cockerell) (Legaspi *et al.,* 1996).

Biology of *Serangium parcesetosum*

In order to use a predator in biological control programs against a pest species, it is important to investigate its biology, which is considered one of the most important features that should be taken into account. However, the biology of *S. parcesetosum* has been affected by temperature, prey's host plant species or cultivar, and prey species or even strain (Abboud and Ahmad, 1998, 2006; Al-Zyoud *et al.,* 2004, 2005a, b; Al-Zyoud, 2008). Summarizing the data available on biology of *S. parcesetosum* may enhance the options for using this specialized predator in pest management programs to control whiteflies in both greenhouses and open fields.

Development

The predator, *S. parcesetosum* is able to complete its development on many whitefly species i.e. *B. tabaci* (Al-Zyoud, 2008), *A. barodensis* (Patel *et al.,* 1996), *D. citri* (Yigit *et al.,* 2003), *B. argentifolii* (Ellis *et al.,* 2001), *A. floccosus* (Argov, 1994), *T. vaporariorum* (Al-Zyoud *et al.,* 2005a), *A. woglumi* (Legaspi *et al.,* 2001), *T. ricini* (Al-Zyoud, 2007), *A. dispersus* and *A. arecae* (Legaspi *et al.,* 1996). The development of *S. parcesetosum* consists of an egg stage, four larval instars and a pupal stage (Patel *et al.,* 1996; Abboud and Ahmad, 1998; Sengonca *et al.,* 2004; Al-Zyoud *et al.,* 2005a; Al-Zyoud, 2008). Klausnitzer and Klausnitzer (1997) mentioned that most of the well-known coccinellids have four larval instars during development. However, prey species, temperature, prey's host plant species and predatory sex influence the developmental duration of *S. parcesetosum* as shown in Table 1. Data indicate that males develop faster than females do in all studies undertaken (Sengonca *et al.,* 2004; Al-Zyoud *et al.,* 2005a; Al-Zyoud, 2008). At the same temperature and prey species, *S. parcesetosum* develops faster on cotton than cucumber (Sengonca *et al.,* 2004), and on cabbage than eggplant. This indicates that plant species plays a key role in the development of the predator. The shortest developmental duration (13.2 days) was recorded when the predator reared at 27°C on sugarcane infested with *A. barodensis* (Patel *et al.,* 1996), while the longest development was reported at 18°C on cucumber infested with *B. tabaci* (45.2 days). Besides, this also indicates that temperature plays a vital role in the development of *S. parcesetosum* since the developmental duration is 3-fold at 18°C than at 27°C.

Table 1. Mean developmental duration from egg to adult emergence of *Serangium parcesetosum* fed on different whitefly species reared on different plants and temperatures

Temp (°C)	Prey species	Plant species	Predator Sex	Developmental duration (days)	Reference
18	*Bemisia tabaci*	Cotton	Male	43.4	Sengonca*et al.* (2004)
18	*B. tabaci*	Cotton	Female	42.4	Sengonca *et al.* (2004)
18	*B. tabaci*	Cucumber	Male	45.2	Sengonca *et al.* (2004)
18	*B. tabaci*	Cucumber	Female	43.4	Sengonca *et al.* (2004)
21	*B. tabaci*	Cabbage	–	23.8	Ahmad and Abboud (2001)
25	*B. tabaci*	Cabbage	–	15.8	Abboud and Ahmad (1998)
25	*Aleurothrixus floccosus*	Cabbage	–	17.3	Abboud and Ahmad (1998)
25	*Dialeurodes citri*	Cabbage	–	17.9	Abboud and Ahmad (1998)
25	*Bemisia tabaci*	Cucumber	Male	20.0	Al-Zyoud (2008)
25	*B. tabaci*	Cassava	–	21.0	Asiimwe *et al.* (2007)
25	*B. tabaci*	Cotton	–	22.9	Vatanesever *et al.* (2003)
25	*B. tabaci*	Egg plant	–	28.0	Vatanesever *et al.* (2003)
23–33	*B. tabaci*	Cucumber	Male	17.4	Al-Zyoud (2008)
27	*Aleurolobus barodensis*	Sugarcane	–	13.2	Patel *et al.* (1996)
27	*Bemisia tabaci*	Cabbage	–	15.7	Ahmad and Abboud (2001)
27–32	*B. tabaci*	Cabbage	–	12.9	Ahmad and Abboud (2001)
30	*B. tabaci*	Cotton	Male	17.2	Sengonca*et al.* (2004)
30	*B. tabaci*	Cotton	Female	16.2	Sengonca *et al.* (2004)
30	*B. tabaci*	Cucumber	Male	15.9	Sengonca *et al.* (2004)
30	*B. tabaci*	Cucumber	Female	15.1	Sengonca *et al.* (2004)
30	*Trialcurodes vaporariorum*	Cucumber	Male	17.4	Al-Zyoud *et al.* (2005a)
30	*T. vaporariorum*	Cucumber	Female	16.9	Al-Zyoud *et al.* (2005a)
32	*Bemisia tabaci*	Cabbage	–	14.3	Ahmad and Abboud (2001)

Mortality

Mortality occurs during all developmental stages of *S. parcesetosum*. Mortality in L_1 instar was the highest as compared to other larval instars, and the mortality in the pupal stage was the highest compared to other immature stages (Sengonca *et al.,* 2004; Al-Zyoud *et al.,* 2005a; Al-Zyoud, 2008). Temperature influences the mortality of *S. parcesetosum*, of which it was higher at 18°C (33 and 31%) than at 30°C (24 and 21%) on cotton and cucumber infested by *B. tabaci*, respectively (Sengonca *et al.,* 2004). Abboud and Ahmad (1998) stated that mortality of *S. parcesetosum* fed on *B. tabaci* was 40, 22, 20% and 10% at 32, 27, 21°C and 27-32°C, respectively. In addition, plant species influenced the predator's mortality, that is, it was higher on cotton than cucumber (Sengonca *et al.,* 2004). According to Ahmad and Abboud (2001), the mortality was 100, 30, 18% and 5%, when *S. parcesetosum* fed on *B. tabaci* on bean, cabbage, eggplant and okra at 27°C, respectively. In addition, mortality was the lowest on cotton (21%) and the highest on eggplant (49%) at 25°C (Vatanesever *et al.,* 2003). It was suggested that hair density on plant leaves helps positively in reducing the predator's mortality (Ahmad and Abboud, 2001; Sengonca *et al.,* 2004). Furthermore, mortality is affected by prey species, given that it was higher when *S. parcesetosum* fed on *T. vaporariorum* (26%) (Al-Zyoud *et al.,* 2005a) than on *B. tabaci* (21%) (Sengonca *et al.,* 2004) reared on cucumber at 30°C. Furthermore, mortality might be affected by the combination of plant-whitefly-predator (tritrophic) interaction.

Sex ratio

Sex ratio (female : male) of *S. parcesetosum* fed on *B. tabaci* is affected by temperature and plant species. It was 1:0.9 and 1:0.8 at 18°C, and 1:1.1 at 30°C on cotton and cucumber under laboratory conditions, respectively (Sengonca *et al.,* 2004). Kapadia and Puri (1992) reported a sex ratio of 1:0.8 and 1:1 under field and laboratory conditions, respectively.

Longevity

One of the most important features for a successful predator is to survive for a long period and feed continuously on the prey species. Long survival of *S. parcesetosum* adults (Sengonca *et al.,* 2004) accomplished by voracious feeding (Sengonca *et al.,* 2005) is a great feature that results in a successful control of *B. argentifolii* (Ellis *et al.,* 2001) and *B. tabaci* (Sengonca *et al.,* 2004; Al-Zyoud, 2008). However, *S. parcesetosum* longevity varies according to temperature, prey's host plant species or cultivars, prey species or even strains and predatory sex as shown in Table 2. The longest longevity (6 months)

Table 2. Mean longevity of *Serangium parcesetosum* fed on different whitefly species reared on different plants and temperatures

Temp (°C)	Prey species	Plant species	Predator Sex	Longevity period (days)	Reference
18	*Bemisia tabaci*	Cotton	Male	175.4	Sengonca *et al.* (2004)
18	*B. tabaci*	Cotton	Female	144.5	Sengonca *et al.* (2004)
18	*B. tabaci*	Cucumber	Male	122.2	Sengonca *et al.* (2004)
18	*B. tabaci*	Cucumber	Female	94.3	Sengonca *et al.* (2004)
30	*B. tabaci*	Cotton	Male	92.4	Sengonca *et al.* (2004)
30	*B. tabaci*	Cotton	Female	52.5	Sengonca *et al.* (2004)
30	*B. tabaci*	Cucumber	Male	63.4	Sengonca *et al.* (2004)
30	*B. tabaci*	Cucumber	Female	50.3	Sengonca *et al.* (2004)
30	*Trialcurodes vaporariorum*	Cucumber	Male	70.8	Al-Zyoud *et al.* (2005a)
30	*T. vaporariorum*	Cucumber	Female	59.9	Al-Zyoud *et al.* (2005a)
25	*Bemisia tabaci*	Cucumber	Male	79.9	Al-Zyoud (2008)
23–33	*B. tabaci*	Cucumber	Male	95.1	Al-Zyoud (2008)
25	*B. tabaci*	Cucumber	Female	65.2	Al-Zyoud (2008)
23–33	*B. tabaci*	Cucumber	Female	71.5	Al-Zyoud (2008)
23.7	*B. tabaci*	Egg plant	Male	50.5	Kapadia and Puri (1992)
23.7	*B. tabaci*	Egg plant	Female	22.6	Kapadia and Puri (1992)
27	*Aleurolobus barodensis*	Sugarcane	–	29.8	Patel *et al.* (1996)
20–23	*Bemisia argentifolii*	Hibiscus	–	44.2	Legaspi *et al.* (1996)
20–23	*B. argentifolii*	Cucumber	–	24.5	Legaspi *et al.* (1996)
20–23	*B. argentifolii*	Cantaloupe	–	27.6	Legaspi *et al.* (1996)
20–23	*B. argentifolii*	Tomato	–	27.8	Legaspi *et al.* (1996)
20	*B. argentifolii*	Cantaloupe	–	79.2	Legaspi *et al.* (1996)
30	*B. argentifolii*	Cantaloupe	–	26.9	Legaspi *et al.* (1996)
40	*B. argentifolii*	Cantaloupe	–	1.40	Legaspi *et al.* (1996)

was reported on cotton infested by *B. tabaci* at 18°C (Sengonca *et al.,* 2004), while the shortest (1.4 days) was recorded on cantaloupe infested by *B. argentifolii* at 40°C (Legaspi *et al.,* 1996). Moreover, within the same temperature *S. parcesetosum* survives longer on cotton than cucumber (Sengonca *et al.,* 2004), and on hibiscus than cucumber, cantaloupe and tomato (Legaspi *et al.,* 1996). In all studies, females survive longer than males do. It is worth mentioning that the extremely high longevity on cotton may partly be explained by that *S. parcesetosum* was reared on *B. tabaci* using cotton as a host plant. Therefore, it might be that the predator has adapted itself on cotton plants and lived much more on it (Legaspi *et al.,* 1996; Al-Zyoud *et al.,* 2004). Additionally, the morphological characteristics of the host plant and the interaction of the plant-whitefly-predator (tritrophic) may have a major effect on the longevity of the predator, suggesting a high degree of specialization of *S. parcesetosum* on a plant species. *S. parcesetosum* lived longer when the predator fed on *T. vaporariorum* than on *B. tabaci* (Al-Zyoud *et al.,* 2005a), *B. argentifolii* (Legaspi *et al.,* 1996), and *A. barodensis* (Patel *et al.,* 1996).

The periods of pre-oviposition, oviposition and post-oviposition are affected by temperature, prey and plant species as shown in Table 3. Range of periods of pre-oviposition, oviposition and post-oviposition were 6.8-26.3, 24.3-121.1 and 8.6-59.7 days, respectively.

The ability of a natural enemy to survive on alternative nutritional sources may have an advantage in stabilizing its population dynamics (Lalonde *et al.,* 1999). However, a major stumbling block to use biological control on a large scale is that it has been difficult to produce adequate numbers of predatory insects to effect reduction of large outbreaks of pest populations. For example, predators have been used successfully for decades to control insect pests however, the scale of their use has been limited because of inadequate methods to artificially produce these predatory insects. In case of *S. parcesetosum,* a growth medium composed of a mixture of an adherent and fibrous retention substrate, a protein-lipid paste, and a liquid was successfully used to rear the predator for three generations (Hodek and Honek, 2009). In addition, it was found that *S. parcesetosum* adults survive on honey emulsion for 27 days at 18°C, and for 14 days at 30°C (Al-Zyoud *et al.,* 2006).

Fecundity

The ability of a predator to oviposit successfully on the host plant on which its prey lives is one of the major factors in determining its ability to successfully control the pest. Prey's host plant species or even cultivar temperature and prey species influence the daily and total fecundity of *S. parcesetosum*. The maximum number of eggs laid per day by *S. parcesetosum* was 4.7 eggs/female (fed on *B. tabaci* Sengonca *et al.,* 2004) and 1.5 eggs/female (fed on *T. vaporariorum* Al-Zyoud *et al.,* 2005a) on cucumber at 30°C. A maximum daily laid eggs of 8.7 and 6.6 eggs/female was reported when *S. parcesetosum* fed on *B. tabaci* at 25°C and 23-33°C, respectively (Al-Zyoud, 2008). The highest total fecundity of *S. parcesetosum* (443.9 eggs/female) was recorded on cabbage when the predator fed on *B. tabaci* at 27°C (Ahmad and Abboud, 2001) as shown in Table 4. This was followed by 354.7 eggs/female when the predator fed on *B. tabaci* on cotton at 25°C (Vatanesever *et al.,* 2003). It seems that temperature ranges from 25°C to 27°C is the most preferred for the predator. Within the same temperature and plant species, the fecundity is 3-fold higher when *S. parcesetosum* fed on *B. tabaci* (98 eggs/female) (Sengonca *et al.,* 2004) than on *T. vaporariorum* (28 eggs/female) (Al-Zyoud *et al.,* 2005a). In addition, when *S. parcesetosum* kept together with 5 different plant species infested with *B. tabaci*, the predator laid more eggs on cucumber (115 eggs) than on tobacco (42 eggs), cotton (33 eggs), tomato (30 eggs),

Table 3. Mean pre-oviposition, oviposition and post-oviposition periods of *Serangium parcesetosum* fed on different whitefly species reared on different plants and temperatures

Temp (°C)	Prey species	Plant species	Pre-ovip.	Ovip.	Post-ovip	Reference
18	*Bemisia tabaci*	Cotton	18.8	121.1	35.5	Sengonca *et al.* (2004)
18	*B. tabaci*	Cucumber	26.3	36.2	59.7	Sengonca *et al.* (2004)
30	*B. tabaci*	Cotton	07.7	28.0	56.7	Al-Zyoud *et al.* (2004)
30	*B. tabaci*	Cucumber	12.1	40.6	10.7	Al-Zyoud *et al.* (2004
30	*Trialcurodes vaporariorum*	Cucumber	08.8	46.0	16.0	Al-Zyoud *et al.* (2005a)
23.7	*Bemisia tabaci*	Eggplant	16.3	24.3	08.6	Kapadia and Puri (1992)
23–33	*B. tabaci*	Cucumber	06.8	52.5	35.8	Al-Zyoud (2008)
25	*B. tabaci*	Cucumber	08.2	42.3	29.5	Al-Zyoud (2008)

Table 4. Mean total fecundity of *Serangium parcesetosum* fed on different whitefly species reared on different plants and temperatures

Temp (°C)	Prey species	Plant species	Fecundity	Reference
18	*Bemisia tabaci*	Cotton	52	Sengonca *et al.* (2004)
18	*B. tabaci*	Cucumber	25	Sengonca *et al.* (2004)
30	*B. tabaci*	Cucumber	98	Sengonca *et al.* (2004)
30	*B. tabaci*	Cotton	31	Sengonca *et al.* (2004)
30	*Trialeurodes vaporariorum*	Cucumber	28	Al-Zyoud *et al.* (2005a)
25	*Bemisia tabaci*	Cucumber	228	Al-Zyoud (2008)
23–33	*B. tabaci*	Cucumber	143	Al-Zyoud (2008)
23.7	*B. tabaci*	Eggplant	22.7	Kapadia and Puri (1992)
27	*B. tabaci*	Cabbage	443.9	Ahmad and Abboud (2001)
20–23	*Dialeurodes citri*	Citrus	135–185	Timofeyeva and Nhuan (1979)
25	*B. tabaci*	Eggplant	135.2	Vatanesever *et al.* (2003)
25	*B. tabaci*	Cotton	354.7	Vatanesever *et al.* (2003)

and sweet pepper (only 3 eggs) (Al-Zyoud *et al.,* 2004). Host plant and prey species have a major impact on natural enemies by influencing their searching success and the quality of their dietary resources, and consequently their biology (Coll and Ridgway, 1995). Several researchers have stated that plant architecture and surface texture influence the search behavior of coccinellid predators (Kareiva and Sahakian, 1990). Sweet pepper has overly smooth leaf surfaces which may have a negative effect on the oviposition of the predator (Carter *et al.,* 1984). The other four plants are characterized by hairiness leaf surfaces therefore, it might be that leaf pubescence helps positively increase the probability of more eggs being laid enhacing the protection of eggs by the pubescence of the host plant of *S. parcesetosum*. Vatanesever *et al.* (2003) reported that cotton infested with *B. tabaci* constitutes more suitable plant species for mass rearing due to short development time, low mortality rate and high fecundity of *S. parcesetosum*. In addition, *B. tabaci* is an insect that is easily reared under laboratory conditions and suitable for rearing *S. parcesetosum* (Yigit, 1992a). The data also show that the interaction between *S. parcesetosum* and its prey influences not only by prey species but also by the suitability of the food plants used by the prey that serves as food for the predator. In conclusion, *S. parcesetosum* seems to prefer a number of whiteflies host plant species for oviposition and can complete its full development successfully on them.

PREDATION POTENTIAL OF *SERANGIUM PARCESETOSUM*

A successful biological control of a pest species depends on the fact that the predator destroys, kills or consumes a sufficient number of the pest to keep its population bellow the economic threshold level (Sengonca *et al.,* 2005). *Serangium parcesetosum* are common in the Mediterranean region and both adults and larvae are predaceous stages (Santos *et al.,* 2009). Despite their polyphagy, coccinellid adults tend to feed more on certain types of food (Iperti, 1999) and the beneficial effect that food has on individual predators leads to increased rates of growth, development and fertility, and decreased rates of mortality (Begon *et al.,* 1996). Moreover, larvae are the most voracious stages of coccinellids requiring great amount of food to grow up rapidly (Stathas, 2000). However, predation potential data reveal that *S. parcesetosum* larvae and adults exhibit the ability to prey voraciously upon many whitefly species.

Predation potential of larval instars

The larvae of *S. parcesetosum* are able to prey successfully upon different whitefly species reared on different plants at different temperatures. The larvae consume 310 and 261 of *B. tabaci* immatures/day at 25°C and 23–33°C, respectively on cucumber (Al-Zyoud, 2008). Sengonca *et al.* (2005) mentioned a maximum daily predation of 161 nymphs and 27 puparia at 18°C, and 235 nymphs and 36 puparia of *B. tabaci* at 30°C on cotton. Predation potential of the separate larval instars of *S. parcesetosum* at 18°C indicated that L_1 instar consumes a total of 115 nymphs or 27 puparia of *B. tabaci*. The mean total predation increased with the progress of development until it was the highest by the L_4 instar with 964 nymphs or 152 puparia. At 30°C, L_1 instar fed on 79 nymphs or 18 puparia, while L_4 instar consumed 676 nymphs or 102 puparia of *B. tabaci* (Sengonca *et al.,* 2005). Asiimwe *et al.* (2007) reported that L_1 instar consumed only 51 nymphs, while L_4 feeds on 551 nymphs of *B. tabaci* on cassava, indicating that L_4 consumes 10-fold higher than L_1. The L_1 consumed a total of 44 nymphs or 18 puparia of *T. vaporariorum*, while L_4 instar consumed 722 nymphs or 110 puparia *B. tabaci* (Al-Zyoud *et al.,* 2005b). Means total of 122 and 75 (L_1), and 924 and 733 (L_4) *B. tabaci* immatures were consumed at 25°C and 23-33°C, respectively (Al-Zyoud, 2008).

However, *S. parcesetosum* during its entire larval development consumed more prey at 18°C (1566 nymphs or 280 puparia) than at 30°C (1119 nymphs or 188 puparia) (Sengonca *et al.,* 2005). This may be explained by that the larval developmental period at 30°C was only a half of that one at 18°C (Sengonca *et al.,* 2004). *S. parcesetosum* consumed 1012 nymphs or 184 puparia of *T. vaporariorum* during its development (Al-Zyoud *et al.,* 2005b). The predatory larvae consumed more *B. tabaci* at 25°C (1542) than at 23–33°C (1095 immatures) (Al-Zyoud, 2008). Timofeyeva and Nhuan (1979) reported that *S. parcesetosum* larval instars consumed a total of 900–1000 eggs of *D. citri* at 20–23°C. In addition, *S. parcesetosum* consumed during its larval duration 1678 eggs or 195 puparia of *B. tabaci* on cabbage at 27°C (Ahmad and Abboud, 2001), 1055 nymphs of *B. tabaci* on cassava (Asiimwe *et al.,* 2007), and 671 nymphs and puparia of *A. barodensis* on sugarcane at 27°C (Patel *et al.,* 1996) respectively. Differences in the results might be due to the fact that different prey stages or species, host plants and temperatures used in the different studies.

Predation potential of adults

The available data from prior studies on the predation potential of *S. parcesetosum* adults indicated that predatory females and males feed on 15 and 13 nymphs or 10 and 9 puparia of *B. tabaci* on the 1st day after adult emergence, and reach a peak of 49 and 44 nymphs or 22 and 18 puparia/day at 18°C, respectively. While at 30°C, 41 and 23 nymphs or 24 and 23 puparia were consumed on the 1st day, and consumption reached a peak of 74 and 71 nymphs or 40 and 33 puparia/day by females and males, respectively (Sengonca *et al.,* 2005). *S. parcesetosum* females and males fed on 31 and 30 nymphs or 20 and 18 puparia of *T. vaporariorum* on the 1st day after adult emergence, and reached a peak of 84 and 71 nymphs or 34 and 29 puparia/day, respectively (Al-Zyoud *et al.,* 2005a). At 25 and 23-33°C, adults consumed 84 and 92 immatures of *B. tabaci* on the 1st day after adult emergence and reached a peak of 144 and 130 immatures/day, respectively (Al-Zyoud, 2008). *S. parcesetosum* adults consumed daily 99 nymphs and puparia of *A. barodensis* and 170-200 eggs and immature stages of *B. argentifolii* at 27°C (Patel *et al.,* 1996), and 271 eggs or 23 puparia of *B. tabaci* (Ahmad and Abboud, 2001).

Within 60 days of longevity, *S. parcesetosum* adults consumed 2188 (males) and 1994 (females) nymphs or 727 (males) and 625 (females) puparia at 18°C, and 3948 (males) and 3577 (females) nymphs or 1601 (males) and 1449 (females) puparia of *B. tabaci* at 30°C (Sengonca *et al.,* 2005), as well as 3842 (males) and 3507 (females) nymphs or 1482 (males) and 1368 (females) puparia of *T. vaporariorum* (Al-Zyoud *et al.,* 2005a). While over 80 days of longevity, the predator consumed 7805 and 7502 of *B. tabaci* immatures at 25°C and 23–33°C, respectively (Al-Zyoud, 2008). The maximum cumulative lifetime predation was measured at >10,000 of *B. argentifolii* consumed in the most long-lived individuals (Legaspi *et al.,* 1996). The daily predation rate of adults increased with increasing temperature, where it was 139, 181, and 187 of *B. argentifolii* immatures at 20°C, 30°C and 40°C on cantaloupe, respectively (Legaspi *et al.,* 1996). In all the studies, females consumed more prey than males, which justifies a stronger need for nutrients for egg laying by females. Differences in predation rate among the different studies could be attributed to different prey species, prey stages, plant species, temperatures and feeding periods used in the different studies. It can be concluded that *S. parcesetosum* successfully developed, survived, reproduced and fed upon many whitefly species. Consequently, this ladybird seems to have a potential to be a bio-agent of whiteflies, which could be employed in biological control programs against these pests under greenhouses and open field conditions.

Predation potential by changing prey number

The prey's population available in the agro-ecosystem for a natural enemy will never be constant and fluctuates in relation to many factors. To be considered as an efficient natural enemy, a predator is expected to be able to adapt itself to such a fluctuation in prey availability. However, *S. parcesetosum* was smoothly able to adapt itself to prey availability fluctuation. A range of 3–5, 6–9, 14–17 and 25–30 of *B. tabaci* puparia/day was consumed by *S. parcesetosum* when 5, 10, 20 and 50 puparia were offered/day, respectively (Sengonca *et al.,* 2005). Thus, daily predation rate became higher when more prey was offered, in contrast, most of prey individuals offered were consumed when the daily prey offer was only 5 puparia. These results are going along with a conclusion made by Alvarado *et al.* (1997) who reported a considerable increase in the daily predation rate in relation to prey density.

Density-dependent response of *Serangium parcesetosum*

It is of vital importance in biological control to find the predator response to prey because it may contribute to stability of predator-prey system (Taylor, 1984). The predator, *S. parcesetosum* imposes positive density dependent with *B. tabaci* (type III functional response). The functional response of *S. parcesetosum* can be simulated by Hollings disc equation and expressed as $Ne=0.82N/1+0.0016N$, and by the reciprocal linear transformation of Hollings equation as $y=1.2218x-0.0019$. The estimated search rate is 5.74 cm and the handling time is 3 min (Araj *et al.,* 2012). Predators having such a type of response allow long-term population persistence (Pech *et al.,* 1992), and in turn will effectively stabilize their prey population. *S. parcesetosum* causes higher mortality levels at moderate whitefly densities. So, it is recommended to use the predator at a moderate infestation of whiteflies'.

PREFERENCES OF *SERANGIUM PARCESETOSUM*

Before considering a predator in biological control, it is important to investigate its affinity toward a certain developmental stage of the target pest or even the pest species to be controlled and a possible interaction with other natural enemies. This is true especially when it is taken into account that under greenhouses and open field conditions there are naturally several pest species that might serve as potential prey for the predator, in addition, there are several natural enemies that could interact with it.

Prey stage preferences

Investigating the preferred prey stage would be useful in determining which developmental stage of the prey is the most predated, and this will facilitate further laboratory rearing of the predator, which is a prime objective in biological control (Sahayaraj and Paulraj, 2001). However, *S. parcesetosum* L_2, L_4 instars and adults prefer puparia and nymphs to the eggs of *B. tabaci* on cotton (Al-Zyoud and Sengonca, 2004). Patel *et al.* (1996) reported that the predator to be highly specific and feeds voraciously on eggs, nymphs and puparia of *A. barodensis*. *S. parcesetosum* predates eggs and puparia of *A. barodensis* (Shah *et al.,* 1986). According to Ahmad and Abboud (2001), *S. parcesetosum* could feed on all *B. tabaci* developmental stages. In general, predation and preference depend mostly on the characteristics of the prey's tegument (Honda and Luck, 1995), relation between size of predator and prey, and prey's nutritional quality (Roger *et al.,* 2000). However, regardless of the whitefly species used in the different studies, *S. parcesetosum* has the ability to feed on all developmental stages of whiteflies offered.

Prey species preferences

Al-Zyoud and Sengonca (2004) offered five different prey species to *Serangium parcesetosum* Sicard separately on cotton, and it is found that predatory larvae and adults have prey preference toward the whitefly species used (*B. tabaci* and *T. vaporariorum*) consuming very few individuals from the non-whitefly species *Aphis gossypii*, *Frankliniella occidentalis* and *Tetranychus urticae*. In addition, the predator had more preference for *B. tabaci* rather than *T. vaporariorum*. In addition, when *S. parcesetosum* offered five different prey species together or separately on cucumber, the predator also preferred the whitefly species tested *B. tabaci* and *T. ricini* rather than *T. urticae*, *A. gossypii* and *Liriomyza huidobrensis* (Al-Zyoud, 2007). Legaspi *et al.* (1996) mentioned that when *S. parcesetosum* was simultaneously offered the eggs of *Helicoverpa zea* and *Manduca sexta*, and *B. argentifolii* reared on poinsettia, cantaloupe and cucumber respectively, the predatory adults did not feed on *H. zea* and *M. sexta*, indicating a preference for *B. argentifolii.* Abboud and Ahmad (1998) in a study conducted on the preference of *S. parcesetosum* for different whitefly species observed that the whitefly, *Paraleyrodes minei* Laccarino is not suitable prey for *S. parcesetosum*, while *B. tabaci*, *D. citri* and *A. floccosus* were found to be suitable for the predator. In addition, they found that *S. parcesetosum* prefers *B. tabaci* more than *D. citri* and *A. floccosus*. Legaspi *et al.* (2001) noted that *S. parcesetosum* is not as voracious on *A. woglumi* eggs as on *B. argentifolii* nymphs. However, the degree of preference of *S. parcesetosum* for one whitefly species upon another might be due to size of the whitefly, thickness and hardness of the cuticle, and many other physical and chemical factors. Moreover, it might be that nutrient differences among prey species have a substantial impact on predator choice. Concomitantly, *S. parcesetosum* is a specialist predator of whiteflies.

Interaction and combined use of natural enemies

The predator, *S. parcesetosum* L_2, L_4, adult females and males tend to avoid parasitized *B. tabaci* puparia by *En. formosa* and feed instead on unparasitized ones. The predator consumed daily 8.7 and 0.2 (L_2), 11.1 and 0.6 (L_4), 12.1 and 1.0 (male), and 10.5 and 0.2 (female) unparasitized and parasitized *B. tabaci* puparia, respectively (Al-Zyoud and Sengonca, 2004). In addition, larvae and adults of *S. parcesetosum* significantly tend to avoid parasitized puparia and feed instead on unparasitized puparia of *B. tabaci* by *Er. mundus*, i.e. 8.3 and 1.3 (L_4) and 8.5 and 1.3 (adult) unparasitized and parasitized puparia, respectively (Al-Zyoud, 2007). Furthermore, *S. parcesetosum* survivorship has not affected by the rates of the entomopathogenic fungi, *B. bassiana* and *P. fumosoroseus*, and cumulative predation showed that *S. parcesetosum* sprayed with *P. fumosoroseus* consumes prey at a rate similar to that in the control (Poprawski *et al.,* 1998). Overall, these results enhance the options for the use of *S. parcesetosum* in pest management programs in conjunction with parasitoids and pathogens. The results suggest that because the parasitized whiteflies by *En. formosa* and *Er. mundus* are currently in use worldwide to control whiteflies (Abd-Rabou, 1999) from one hand and on the other hand these parasitoids are avoided by *S. parcesetosum*. There is a feasible potential for integration of these natural enemies into whiteflies management programs in order to provide a great level of the pest suppression. In this regard, Zapata *et al.* (2003) mentioned that release of *Er. mundus* in combination with *Macrolophus caliginosus* provides a great level of whitefly suppression.

EGG LAYING BEHAVIOUR OF *SERANGIUM PARCESETOSUM*

Studying of egg-laying behaviour and oviposition strategy of a natural enemy is of a great value that leads to a better understanding of its ecological characteristics and helps positively in using it in a biological control program against a pest species. A female insect must take at least two decisions to oviposit on a host where to lay its eggs and how many *eggs* to lay in each site. The answers to these questions could explain the oviposition strategy, which determines the insect fitness of offspring and growth rate in the population (Danho and Haubruge, 2003). However, Al-Zyoud *et al.* (2005b) investigated the egg-laying behaviour of *S. parcesetosum* in the absence and presence of *C. carnea*, one of the main predators associated with *B. tabaci* population, on cucumber and cotton infested with *B. tabaci*. They found that *S. parcesetosum* prefers to lay its eggs between the veins and close to the veins in the absence of *C. carnea*, while in its presence more eggs were deposited close to veins and petiole on cucumber leaves. In contract, on cotton leaves S. *parcesetosum* prefers to deposit its eggs close to the veins and petiole in the absence and presence of *C. carnea*. Timofeyeva and Nhuan (1979) stated that *S. parcesetosum* fed on *D. citri* lays its eggs on the under surface of citrus leaves. *S. parcesetosum* deposits its eggs singly on the under surface of eggplant leaves infested with *B. tabaci* (Kapadia and Puri, 1992). According to Patel *et al.* (1996), *S. parcesetosum* fed on *A. barodensis* lays its eggs singly. While, Ahmad and Abboud (2001) mentioned that *S. parcesetosum* fed on *B. tabaci* deposits its eggs singly or in irregular groups on the plant leaves near the prey stages. It appears that *S. parcesetosum* could lay its eggs singly or in groups. Also, the results indicate that the presence of *C. carnea* and plant species influence the distribution of eggs on the leaves.

RELEASES OF *SERANGIUM PARCESETOSUM*

The predator, *S. parcesetosum* is a promising bio-agent against many whitefly species because of its voracity and preference. Both larvae and adults of *S. parcesetosum* could feed on all developmental stages of whiteflies (Kapadia and Puri, 1992; Ahmad and Abboud, 2001; Al-Zyoud *et al.,* 2005a.). However, because of the success of *S. parcesetosum* in the laboratory and in order to be considered as an efficient predator for a biological control program and to be successfully used to control whiteflies, it has been evaluated to check its effectiveness in reducing the population of some whitefly species under more natural conditions such as greenhouses and open fields. However, when *S. parcesetosum* introduced 1 and 2 weeks after infestation with *B. tabaci* as well as a control treatment on cotton plants under glasshouse conditions, the number of *B. tabaci* was 75, 123 and 685 (1 predator: 25 whiteflies) in the last experimental week (7th week), respectively (A-Zyoud *et al.,* 2007). On cucumber plants, the number of *B. tabaci* was significantly higher in the control treatment compared with 1- and 2-week treatments when *S. parcesetosum* was introduced at densities of 1:30 and 1:20. Initial whitefly release rates (1:30 or 1:20) greatly affected the final population density of the whitefly. This effect was most evident when whitefly populations were left uncontrolled, in which *B. tabaci* numbers in the last experimental week were 955, 336 and 364 (1:30) as well as 670, 253 and 267 (1:20) in control, 1 and 2 weeks after *S. parcesetosum* introduction, respectively (Al-Zyoud, 2012). It could be concluded that release rate of 1 predator: 20 whiteflies would be more efficient in suppressing the pest than 1:30. A single release of one adult *S. parcesetosum* beetle was effective at stopping the growth of *B. tabaci* populations on cucumber and cotton for 7 weeks. In general, *S. parcesetosum* was able to successfully feed, reproduce and consume *B. tabaci* infested cotton and cucumber under greenhouse conditions. In addition, the number of whitefly was lower when the predator introduced one week rather than two weeks after the whitefly infestation (A-Zyoud *et al.,* 2007; Al-Zyoud, 2012). In similar fashion, Ellis *et al.* (2001) found that introduction of *S. parcesetosum* adults was extremely effective at stopping the growth of *B. argentifolii* population on poinsettias under greenhouse conditions for 10 weeks. They further mentioned that after six weeks of introducing *S. parcesetosum*, *B. argentifolii* population densities were dramatically lower in the cages with *S. parcesetosum* than in the control cages. An early introduction of *S. parcesetosum*, while the density of *B. tabaci* population is still low, would be more effective in its control. On eggplants infested by *B. tabaci*, followed by the introduction of *S. parcesetosum* within three weeks at weekly intervals at rates of 0, 3, 6 adults/plant, the number of whiteflies increased in treated cages until the 3rd week, and then began to decrease 7 weeks later. Whereas, the density of whitefly population in the control treatment increased 3-fold during the same period (Abboud *et al.,* 2006).

Reductions in *B. tabaci* population of 65 and 62% (1:30) as well as 62 and 60% (1:20) on cucumber plants, and 89 and 82% (1:25) on cotton plants were reported in the last experimental week (7th week) when the predator was introduced 1 and 2 weeks, respectively (A-Zyoud *et al.,* 2007; Al-Zyoud, 2012). *B. tabaci* population in cages receiving 2 and 4 *S. parcesetosum* adults/plant showed 56 and 53% reductions on eggplants, respectively (Kutuk *et al.,* 2008). In addition, when 1 *S. parcesetosum* was released in cages filled with *A. woglumi* eggs on grapefruit, it was found that predation by *S. parcesetosum* for 12 days reduced egg hatch by 12.5% (Legaspi *et al.,* 2001). Variation among the different studies might be due to differences in prey species or strain, temperature, host plant and release rate used in the different studies.

However, it is to be mentioned that even without a reproductive success, introducing *S. parcesetosum* prevents *B. tabaci* population from increasing over a 7-week-period (Al-Zyoud *et al.,* 2007 Al-Zyoud, 2012) and *B. argentifolii* population over a 10-week-period (Ellis *et al.,* 2001). This can be explained by the fact that laboratory studies up to date show that the ladybird's adults could survive for 2-6 months (Sengonca *et al.,* 2004) and 3 months (Legaspi *et al.,* 1996 Al-Zyoud *et al.,* 2007). In addition, the predator's adults are voracious feeders capable for consuming large numbers of whiteflies, where they reached just over 80 days of longevity to 7805 whiteflies (Al-Zyoud, 2008), and >10,000 *B. argentifolii*/lifetime (Legaspi *et al.,* 1996). Therefore, depending on these results, it appears that this success in controlling whiteflies was primarily, in addition to the feeding of the larvae, due to the prolonged survival and continuous feeding of *S. parcesetosum* adults.

Furthermore, *En. formosa* and *S. parcesetosum* were released at a rate of 1 adult/plant to control *B. argentifolii* infecting a greenhouse crop of poinsettias. Whitefly densities within the control treatments were considerably greater than those of each of the two natural enemy treatments. At the end of the study (week 13), the whitefly population was less than 1/100 and 1/150 in the greenhouse area receiving both natural enemies and *S. parcesetosum* alone, respectively from those in the control (Weaver and Ciomperlik, 2000a). Furthermore, releases of *S. parcesetosum* were evaluated for their ability to disperse throughout a greenhouse crop of poinsettias infested with *B. argentifolii*. Whiteflies were introduced at a rate of 1.25 adult/plant in week 0 into two separate greenhouses and releases of *S. parcesetosum* were made on weeks 5, 7, and 9. However, results indicated that if whitefly densities were high, the beetles did not disperse as readily as when whitefly densities were low (Weaver and Ciomperlik, 2000b). Heinz and Parrella (1994b) recovered several adult *D. catalinae* three weeks after the last release, but no evidence of successful predator reproduction was reported. In contrast, S. *parcesetosum* larvae were first observed 1 week after adults have been released (A-Zyoud *et al.,* 2007 Al-Zyoud, 2012). However, *S. parcesetosum* would be useful especially for suppressing localized pest population in the greenhouse. An additional positive feature of *S. parcesetosum* that its ability to distinguish between parasitized and unparasitized *B. tabaci* by *En. formosa* (Al-Zyoud and Sengonca, 2004) and *Er. mundus* (Al-Zyoud, 2007) and feed on more unparasitized whiteflies. In Jordan, Sharaf and Hassan (2003) mentioned a high parasitization rate when either *Er. mundus* (72.2%) or *En. formosa* (75.8%) were released against *B. tabaci* at a ratio of 1 parasitoid: 2 whiteflies. As an obligate whitefly predator with a voracious feeding potential, *S. parcesetosum* is capable for checking rapid increases in whitefly populations, thus potentially enabling whitefly parasitoid species such as *Eretmocerus* or *Encarsia* to suppress whiteflies to acceptable thresholds. Thus, there is a feasible potential for integration of the predator and the two parasitoids into a biological control program to suppress *B. tabaci*. This conclusion is supported by Heinz and Nelson (1996) who found that the specific whitefly predator, *D. catalinae* provided the greatest suppression of the silverleaf whitefly when used in conjunction with *Encarsia*. Also, Zapata *et al.* (2003) showed that releases of *Er. mundus* alone or in combination with *M. caliginosus* provided a great level of whitefly suppression. Based on these data it appears that *S. parcesetosum* might be best suited for inclusion in a multiple species biological control approach for management of whiteflies. Another positive feature which makes the predator, *S. parcesetosum* more distinguished and effective compared to other predators is that the predator is specific for whiteflies (Legaspi *et al.,* 1996 Abboud and Ahmad, 1998; Al-Zyoud and Sengonca, 2004; Al-Zyoud, 2007).

Releases of *S. parcesetosum* in citrus orchards infested with *Diaphernia citri* resulted in its establishment on citrus and dispersal throughout the citrus-growing regions in Turkey. Also, *S. parcesetosum* could tolerate large temperature intervals in the region of Turkey. The success in colonization of *S. parcesetosum* within a certain period shows its high potential of searching capacity in addition to prey suitability (Yigit and Canhalal, 2005). Antadze and Timofeyeva (1975) indicated that *S. parcesetosum* could overwinter in Georgia where the temperature was –2°C. While, Yasnosh and Chaidze (1986) mentioned that the predator overwintered as adults and could resist –6°C to –8°C. On cotton, the predator population increased in the 1st generation to 9-fold, and in cages into which 16-18 adult coccinellids were introduced, produced an average of 157 adults (Yigit, 1992a).

CONCLUSION

The ladybird, *S. parcesetosum* is a specialist, oligophagous and efficient predator that has demonstrated a potential for biological control of many whiteflies. *S. parcesetosum* is able to develop successfully on many whitefly species and it could survive for up to 6 months. *S. parcesetosum* adults survived for a period of time on artificial nutritional sources, which may have an advantage in stabilizing its population dynamics. An artificial growth medium was successfully used to rear *S. parcesetosum* for 3 generations.

Cotton infested with *B. tabaci* constituted more suitable plant species for mass rearing of *S. parcesetosum*. *S. parcesetosum* seems to occupy a number of host plant species for oviposition and can complete its development successfully on them. Data presented herein provide opportunities to better understand interactions of the plant-whitefly-predator and demonstrated that successful biological control of pests should integrate the environmental aspects of each trophic level.

The predator exhibited the ability to prey successfully upon many whitefly species. The predatory larvae could consume up to 1566 whitefly immatures/day during its entire larval development and adults feed on >10,000 *B. argentifolii* in the most long-lived individuals. In addition, *S. parcesetosum* imposes positive density dependent with *B. tabaci*, which allows long-term population persistence, and in turn will effectively stabilize its prey population. In addition, *S. parcesetosum* could feed on all developmental stages of whiteflies offered, and has a prey preference toward whitefly species used rather than the non-whitefly species. Thus, *S. parcesetosum* is a specialist predator of whiteflies. Furthermore, *S. parcesetosum* tended to avoid parasitized puparia of *B. tabaci* by *En. formosa* and *Er. mundus* and feed instead on unparasitized puparia. Moreover, *S. parcesetosum* sprayed with *P. fumosoroseus* consumed prey at a rate similar to that of the control. Thus, there is a feasible potential for integration of these natural enemies into management programs for whiteflies in order to provide a great level of suppression.

Under greenhouse conditions, *B. tabaci* population was significantly lower when *S. parcesetosum* was introduced after 1 or 2 weeks than control treatment. Also, the number of *B. tabaci* was lower when the predator was introduced after 1 week rather than 2 weeks. A single release of one *S. parcesetosum*/plant was effectively checked further increases in prey population on cotton and cucumber for up to 7 weeks, and on poinsettias for 10 weeks. It is speculated that early release of *S. parcesetosum* would be more effective in biological control of whiteflies. *S. parcesetosum* could spread out throughout cotton orchards with heavily infested by *D. citri* by forming a colony, and tolerate large temperature intervals. It is concluded that releases of the predatory beetle should preferably be done in central point in an orchard, heavily infested by the prey to spread the predator to other orchards.

Long survival of *S. parcesetosum* adults accomplished by their voracious feeding is a great feature that resulted in a successful control of whiteflies. These information will lead to enhance the options for using this specialized whitefly predator in pest management programs to control many whitefly species in greenhouses and open fields. Finally, the ladybird predator, *S. parcesetosum* showed the ability to develop, survive, reproduce and prey successfully upon and build up its population as well as cause a high reduction in whiteflies population. Consequently, it is likely that *S. parcesetosum* could function effectively as the sole biological control agent or in conjunction with other natural enemies to provide a great level of whiteflies suppression, as well as to develop new managing strategies to successfully suppress these worldwide pests. However, additional studies mentioned below are worth consideration: (1) searching behavior of *S. parcesetosum* that permits subsistence at low whitefly densities; (2) optimal exploitation of *S. parcesetosum* must consider the fact that several species may be present contemporaneously and act in a complementary way; (3) the effect of insecticides on *S. parcesetosum*; (4) the discontinuous nature of annual crops which do not provide a stable environment for the predator establishment and finally, (5) the presence of other pests that may require additional management considerations.

REFERENCES

Abboud R, Ahmad M. 1998. Effect of temperature and prey-species on development of the immature stages of the coccinellid *Serangium parcesetosum* Sicard (Col.: Coccinellidae). *Arab J Pl Prot.* **16**: 90–93.

Abboud R, Ahmad M. 2006. The effect of host plants and prey stage on feeding behavior and feeding time of the whitefly predator *Serangium parcesetosum*. *Arab J Pl Prot.* **24**: 61–66.

Abboud R, Ahmad M, Abou Kaf N. 2006. Evaluation of the efficiency of the coccinellid *Serangium parcesetosum* Sicard (Col.: Coccinellidae) for controlling *Bemisia tabaci* Genn. (Hom.: Aleyrodidae). *Arab J Pl Prot.* **24**: 107–111.

Abboud R, Mofleh M, Habak H, Alkaim F, Ahmad M. 2009. Ecological study of soft citrus scale *Coccus pseudomagnoliarum* on citrus trees in the coastal region of Syria. 7th Conference of GCSAR.

Abd-Rabou S. 1999. Biological control of the cotton whitefly *Bemisia tabaci* (Genn.) (Hom.: Aleyrodidae) in Egypt. *Shashpa* **6**: 53–57.

Abd-Rabou S, El-Naggar M. 2003. Efficacy of natural enemies in the biological control of *Bemisia tabaci* biotype “B” (Hom.: Aleyrodidae) in Egypt. 3rd Inter. *Bemisia* Workshop, Barcelona, 17–20 March, p 79.

Ahmad M, Abboud R. 2001. A comparative study of *Serangium parcesetosum* Sicard and *Clitostethus arcuatus* (Rossi) (Col.: Coccinellidae): two predators of *Bemisia tabaci* (Genn.) in Syria. *Arab J Pl Prot.* **19**: 40–44.

Almeida LM, Corrêa GH, Giorgi JA, Grossi PC. 2011. New record of predatory ladybird beetle (Col.: Coccinellidae) feeding on extrafloral nectaries. *Revista Brasileira de Entomologia* **55**: 447–450.

Alvarado P, Balta O, Alomar O. 1997. Efficiency of four heteroptera as predators of *Aphis gossypii* and *Macrosiphum euphorbiae* (Hom.: Aphididae). *Entomophaga* **42**: 215–226.

Al-Zyoud F. 2007. Prey species preference of the predator *Serangium parcesetosum* Sicard (Col.: Coccinellidae) and its interaction with another natural enemy. Pakistan *J Biol Sci*. **10**: 2159–2165.

Al-Zyoud F. 2008. Biology and predation potential of the Indian ladybird *Serangium parcesetosum* on *Bemisia tabaci*. *Jordan J Agric Sci.* **4**: 26–40.

Al-Zyoud F. 2012. Greenhouse cage evaluation of *Serangium parcesetosum* Sicard (Col.: Coccinellidae) as predator of the cotton whitefly *Bemisia tabaci* (Genn.) (Hom.: Aleyrodidae). *Jordan J Agric Sci*. (In print).

Al-Zyoud F, Blaeser P, Sengonca C. 2005a. Investigations on the biology and prey consumption of the predator *Serangium parcesetosum* Sicard (Col.: Coccinellidae) by feeding on *Trialeurodes vaporariorum* Westwood (Hom.: Aleyrodidae) as prey. *J Pl Dis Prot.* **112**: 485–496.

Al-Zyoud F, Blaeser P, Sengonca C. 2006. Longevity of the ladybird predator, *Serangium parcesetosum* Sicard (Col.: Coccinellidae) on natural and artificial nutritional sources. *Mitt Dtsch Ges allg angew Ent.* **15**: 251–256.

Al-Zyoud F, Sengonca C. 2004. Prey consumption preferences of *Serangium parcesetosum* Sicard (Col.: Coccinellidae) for different prey stages, species and parasitized prey. *J Pest Sci.* **77**: 197–204.

Al-Zyoud FC, Sengonca C, Abbadi S. 2007. Evaluation of *Serangium parcesetosum* (Col.: Coccinellidae) for biological control of *Bemisia tabaci* under greenhouse conditions. *J Pest Sci.* **80**: 85–92.

Al-Zyoud F, Tort N, Sengonca C. 2004. Influence of host plant species of *Bemisia tabaci* (Genn.) (Hom.: Aleyrodidae) on some of the biological and ecological characteristics of the entomophagous *Serangium parcesetosum* Sicard (Col.: Coccinellidae). *J Pest Sci.* **78**: 25–30.

Al-Zyoud F, Tort N, Sengonca C. 2005b. Influence of leaf portion and plant species on the egg-laying behaviour of the predatory ladybird *Serangium parcesetosum* Sicard (Col.: Coccinellidae) in the presence of a natural enemy. *J Pest Sci.* **78**: 167–174.

Antadze AI, Timofeyeva TV. 1975. An effective predator of citrus whitefly. *Subtropicheskie Kulotury* **3**: 80–81.

Argov Y. 1994. The woolly whitefly, a new pest in Israel. *Alon Hanotea* **48**: 290–292.

Arno J, Gabarra R. 1996. Potential for biological control of mixed *Trialeurodes vaporariorum* and *Bemisia tabaci* populations in winter tomato crops grown in greenhouses. pp 523–526. *In:* Gerling, D. and R. T. Mayer (Eds.), Bemisia 1995: Taxonomy, biology, damage, control and management. Intercept Ltd., Andover, Hants, UK,

Asiimwe Ecaat JS, Guershon M, Kyamanywa S, Gerling D, Legg JP. 2007. Evaluation of *Serangium* n. sp. (Col.: Coccinellidae), a predator of *Bemisia tabaci* (Hom.: Aleyrodidae) on cassava. *J Appl Entomol*. **131**: 76–80.

Blackburn T. 1889. Further notes on Australian Coleoptera with descriptions of new species. *Trans Royal Soc South Aust.* **11**: 175–214.

Blackwelder RE. 1945. Checklist of the Coleopterous insects of Mexico, Central America, the West Indies, and South America. Part 3. Smithsonian Institution United States. *National Mus Bull.* **185**: 343–550.

Begon M, Harper JL, Townsend CR. 1996. *Ecology-individuals, populations and communities.* 3rd Edition. Blackwell Science, Oxford, pp 1092.

Calvo J, Bolckmans K, Stansly PA, Urbaneja A. 2009. Predation by *Nesidiocoris tenuis* on *Bemisia tabaci* and injury to tomato. *BioControl* **54**: 237–246.

Carter MC, Sutherland D, Dixon AFC. 1984. Plant structure and searching efficiency of coccinellid larvae. *Oecologia* **63**: 394–397.

Chen WW, Feng MG. 1999. Current status in basic and applied research on the entomopathogenic fungus *Paecilomyces fumosoroseus*. *Nat Enemies Insects* **21**: 140–144.

Coll M, Ridgway RL. 1995. Functional and numerical responses of *Orius insidiosus* (Het.: Anthacoridae) to its prey in different vegetable crops. *Ecol Popul Biol.* **88**: 732–747.

Danho M, Haubruge E. 2003. Optimal clutch size and oviposition strategy for the maize weevil *Sitophilus zeamais*. *Proceedings of the 8th International Working Conference on Stored Product Protect.* CAB International Publishing, 271–275.

DeBarro PJ, Hart PJ, Morton R. 2000. The biology of two *Eretmocerus* spp. (Haldeman) and three *Encarsia* spp. Forster and their potential as biological control agents of *Bemisia tabaci* biotype B in Australia. *Ent Exp Appl.* **94**: 93–102.

Dixon AFG. 2000. *Insect predator-prey dynamics. Ladybirds' beetles and biological control*. London, Cambridge University Press, pp 257.

Driesche RG van, Lyon SM, Hoddle MS, Roy R, Sanderson JP. 1999. Assessment of cost and performance of *Eretmocerus eremicus* (Hym.: Aphelinidae) for whitefly (Hom.: Aleyrodidae) control in commercial poinsettia crops. *Flo Entomol.* **82**: 570–594.

Ellis D, McAvoy R, Abu Ayyash L, Flanagan M, Ciomperlik M. 2001. Evaluation of *Serangium parcesetosum* (Col.: Coccinellidae) for biological control of silverleaf whitefly, *Bemisia argentifolii* (Hom.: Aleyrodidae) on poinsettia. *Flo Entomol*. **84**: 215–221.

Fauvel G. 1999. Diversity of heteroptera in agroecosystems: role of sustainability and bioindication. *Agric Ecosyst Environ*. **74**: 275–303.

Gerling D, Steinberg S. 2003. *Biological control of Bemisia tabaci using parasitoids*. 3rd Inter. *Bemisia* Workshop, Barcelona, 17–20 March, p 66.

Goolsby JA, Ciomperlik MA, Legaspi BC, Legaspi JC, Wendel LE. 2000. Laboratory and field evaluation of exotic parasitoids of *Bemisia tabaci* (Biotype 'B') in the lower Rio Grande Valley of Texas. *Biol Cont*. **12**: 127–135.

Heinz KM, Nelson JM. 1996. Interspecific interactions among natural enemies of *Bemisia* in an inundative biological control program. *Biol Cont*. **6**: 384–393.

Heinz KM, Parrella MP. 1994a. Poinsettia (*Euphorbia pulcherrima* Willd. ex Koltz.) cultivar-mediated differences in performance of five natural enemies of *Bemisia argentifolii* Bellows and Perring, n. sp. (Hom.: Aleyrodidae). *Biol Cont*. **4**: 305–318.

Heinz KM, Parrella MP. 1994b. Biological control of *Bemisia argentifolii* (Hom.: Aleyrodidae) infesting *Euphorbia pulcherrima*: evaluations of releases of *Encarsia luteola* (Hym.: Aphelinidae) and *Delphastus pusillus* (Col.: Coccinellidae). *Env Entomol*. **23**: 1346–1353.

Hodek I, Honek A. 1996. *Ecology of Coccinellidae*. Dordrecht, Kluwer Academic Publishers, pp 464.

Hodek I, Honek A. 2009. Scale insects, mealybugs, whiteflies and psyllids (Hem.: Sternorrhyncha) as prey of ladybirds. *Biol Cont.* **51:** 232–243.

Honda JY, Luck RF. 1995. Scale morphology effects on feeding behavior and biological control potential of *Rhyzobius lophanthae* (Col.: Coccinellidae). *Annals Ent Soc Am.* **88**: 441–450.

Hu JS, Gelman DB, Blackburn MB. 2003. Age-specific interaction between the parasitoid *Encarsia formosa* and its host, the silverleaf whitefly, *Bemisia tabaci* (Strain B). *J Insect Sci.* **3**: 1–10.

Iperti G. 1999. Biodiversity of predaceous coccinellidae in relation to bio-indication and economic importance. *Agric Ecosys Environ*. **74**: 323–342.

James RR, Jaronski ST. 2000. Effect of low viability on infectivity of *Beauveria bassiana* conidia toward the silverleaf whitefly. *J Inv Pathol.* **76**: 227–228.

Jazzar C, Hammad EAF. 2004. Efficacy of multiple biocontrol agents against the sweetpotato whitefly, *Bemisia tabaci* (Genn.) (Hom.: Aleyrodidae) on tomato. *J Appl Entomol.* **128**: 188–194.

Joshi PC, Sharma PK. 2008. First records of coccinellid beetles (Coccinellidae) from the Haridwar, (Uttara-khand), India. *The Natural Hist J Chulalongkorn Univ.* **8**: 157–167.

Kalidas P. 1995. Role of ecological factors on the survival and mortality of citrus blackfly. *Indian J Hort*. **52**: 117–120.

Kapadia MN, Butani PG. 1997. Record of *Serangium parcesetosum* Sicard, a predator of sugarcane whitefly in south Saurashtra (Gujarat). *Indian Sugar* **47**: 503–504.

Kapadia MN, Puri SN. 1992. Biology of *Serangium parcesetosum* as a predator of cotton whitefly. *J Maharashtra Agric Univ.* **17**: 162–163.

Kapur AP. 1972. The Coccinellidae (Coleoptera) of Goa. *Record Zool Sur Ind.* **66**: 309–320.

Kareiva P, Sahakian R. 1990. Tritrophic effects of a simple architectural mutation in pea plants. *Nature* **345**: 433–434.

Khan IS Din, Khalil SK, Rafi MA. 2007. Survey of predatory coccinellids (Col.: Coccinellidae) in the Chitral District, *Pakistan J Insect Sci.* **7**: 0–7.

Klausnitzer B, Klausnitzer H. 1997. *Marienkäfer*, Westarp Wiss. Magdeburg, pp 175.

Kutuk H, Yigit A, Alaoglu O. 2008. The effect of season on the levels of predation by the ladybird *Serangium parcesetosum* Sicard (Col.: Coccinellidae) on the cotton whitefly, *Bemisia tabaci* (Genn.) (Hom.: Aleyrodidae), a serious pest of eggplants. *J Pest Sci.* **81**: 207–212.

Lalonde R, Mcgregor R, Roitberg BD, Gillespie DR. 1999. Plant feeding by arthropod predators contributes to the stability of predator-prey population dynamics. *Oikos* **87**: 603–608.

Legaspi JC, Ciomperlik MA, Legaspi BC. 2001. Field cage evaluation of *Serangium parcesetosum* (Col.: Coccinellidae) as a predator of citrus blackfly eggs (Hom.: Aleyrodidae*). Southw Entomol Sci Note* **26**: 171–172.

Legaspi JC, Legaspi BC Jr, Meagher RL Jr, Ciomperlik MA. 1996. Evaluation of *Serangium parcesetosum* (Col.: Coccinellidae) as a biological control agent of the silverleaf whitefly (Hom.: Aleyrodidae). *Env Entomol*. **25**: 1421–1427.

Lucas E, Alomar O. 2002. Impact of the presence of Dicyphus tamaninii Wagner (Het.: Miridae) on whitefly (Hom.: Aleyrodidae) predation by *Macrolophus caliginosus* (Wagner) (Het.: Miridae). *Biol Cont.* **25**: 123–128.

Majerus MEN. 1994. *Ladybirds*. Harper Collins London, pp 359.

Malausa JC, Franco E, Brun P. 1988. Establishment on the Azur coast and in Corsica of *Serangium parcesetosum* (Col.: Coccinellidae), a predator of the citrus whitefly, *Dialeurodes citri* (Hom.: Aleyrodidae). *Entomophaga* **33**: 517–519.

Montserrat M, Albajes R, Castane C. 2000. Functional response of four heteropteran predators preying on greenhouse whitefly (Hom.: Aleyrodidae) and western flower thrips (Thys.: Thripidae). *Env Entomol*. **29**: 1075–1082.

Mor H, Gindin G, Benzeev IS, Raccah B, Geschtovt NU, Ajtkhozhina N. 1996. Diversity among isolates of *Verticillium lecanii* as expressed by DNA polymorphism and virulence towards *Bemisia tabaci*. *Phytoparasitica* **24**: 111–118.

Nomikou M, Janssen A, Sabelis MW. 2003. Phytoseiid predator of whitefly feeds on plant tissue. *Exp Appl Acarol.* **31**: 27–36.

Obrycki JJ, Kring TJ. 1998. Predaceous coccinellidae in biological control. *Ann Rev Ent.* **43**: 295–321.

Omkar Bind RB. 1996. Records of aphid natural enemies complex of Uttar Pradesh. V. The coccinellids. *J Adv Zool.* **17**: 44–48.

Omkar Pervez A. 2000. New record of coccinellids from Uttar Pradesh. II. *J Adv Zool.* **21**: 43–47.

Omkar Pervez A. 2002. New record of coccinellids from Uttar Pradesh. III. *J Adv Zool.* **23**: 63–65.

Pajni HR, Singh J. 1982. A report on the family Coccinellidae of Chandigarh and its surrounding area (Coleoptera). *Res Bull Punjab Uni Sci.* **33**: 79–86.

Pajni HR, Verma S. 1985. Studies on the structure of the male genitalia in some Indian Coccinellidae (Coleoptera). *Res Bull Punjab Uni Sci.* **36**: 195–201.

Patel CB, Rai AB, Pastagia JJ, Patel HM, Patel MB. 1996. Biology and predator potential of *Serangium parcesetosum* Sicard (Col.: Coccinellidae) of sugarcane whitefly (*Aleurolobus barodensis* Mask.). *GAU Res J.* **21**: 56–60.

Pech RP, Sinclair ARE, Newsome AE, Catling PC. 1992. Limits to predator regulation of rabbits in Australia: evidence from predator-removal experiments. *Oecologia* **89**: 102–112.

Poorani J. 1999. A new species of *Serangium* Blackburn (Col.: Coccinellidae) with a key to species from India. *J Biol Cont*. **12**: 55–61.

Poorani J. 2002. An annotated checklist of the Coccinellidae (Coleoptera) (excluding Epilachninae) of the Indian sub-region. *Oriental Insects* **36**: 307–383.

Pope RD. 1962. A review of the Pharini (Col.: Coccinellidae). *Ann Mag Nat Hist Ser* **13**: 627–640.

Poprawski TJ, Legaspi JC, Parker P. 1998. Influence of entomopathogenic fungi on *Serangium parcesetosum* (Col.: Coccinellidae), an important predator of whiteflies (Hom.: Aleyrodidae). *Envi Entomol.* **27**: 785–795.

Rahatullah HA, Inayatullah M. 2010. M. Phil. Thesis on species diversity of coccinellidae of Dir valley.

Rahatullah FH, Mehmood SA, Saeed K, Rehman S. 2011. Diversity and distribution of ladybird beetles in District Dir Lower, Pakistan. *Int J Biodiv Conse* **3**: 670–675.

Roger C, Coderre D, Boivin G. 2000. Differential prey utilization by the generalist predator *Coleomegilla maculata lengi* according to prey size and species. *Ent Exp Appl.* **94**: 3–13.

Sahayaraj K, Paulraj MG. 2001. Rearing and life table of reduviid predator *Rhynocoris marginatus* Fab. (Het.: Reduviidae) on *Spodoptera litura* Fab. (Lep.: Noctuidae) larvae. *J Appl Entomol.* **125**: 321–325.

Sanchez JA, Lacasa A. 2008. Impact of the zoophytophagous plant bug *Nesidiocoris tenuis* (Het.: Miridae) on tomato yield. *J Econ Entomol*. **101**: 1864–1870.

Santos SAP, Pereira JA, Torres LM, Nogeira AJA. 2009. Voracity of coccinellid species on different phenological stages of the olive pest *Saissetia oleae* (Hom.: Coccidae). *Appl Ecol Environ Res.* **7**: 359–365.

Sengonca CF, Al-Zyoud, Blaeser P. 2004. Life table of the entomophagous ladybird, *Serangium parcesetosum* Sicard (Col.: Coccinellidae) by feeding on *Bemisia tabaci* (Genn.) (Hom.: Aleyrodidae) as prey at two different temperatures and plant species. *J Pl Dis Prot*. **111**: 598–609.

Sengonca CF, Al-Zyoud, Blaeser P. 2005. Prey consumption by larval and adult stages of the entomophagous ladybird *Serangium parcesetosum* Sicard (Col.: Coccinellidae) of the cotton whitefly *Bemisia tabaci* (Genn.) (Hom.: Aleyrodidae) at two different temperatures. *J Pest Sci.* **78**: 179–186.

Shah ZM. 1985. Ladybird beetles (Coccinellidae: Coleoptera) of Peshawar region. M.Sc (Hons) Thesis, Department of Entomol. NWFP Agricultural Univervisty, Peshawar, pp 109.

Shah AH, Patel MB, Patel GM. 1986. Record of a coccinellid predator (*Serangium parcesetosum* Sicard) of sugarcane whitefly in South Gujarat. *GAU Res J.* **12**: 63–64.

Sharaf N, Hassan H. 2003. The identification of two biotypes of *Bemisia tabaci* in Jordan. *Dirasat Agric Sci*. **30**: 101–108.

Sharma PK, Joshi PC. 2010. New records of Coccinellid beetles (Coccinellidae: Coleoptera) from District Dehradun, (Uttarakhand), India. *New York Sci J.* **3**: 112–118.

Sharma PK, Joshi PC, Sharma TC. 2011. Species composition and abundance of coccinellid beetles in agricultural fields of district Bijnor (U.P.), India. *J Env Bio Sci*. **25**: 53–55.

Sicard A. 1929. Par quelques especes nouvelles de Coccinellides. XXII. Descriptions de quelques especes nouvelles de Coccinellides de la faune Indo-Malaise. *Ann Nat Hist*. **10**: 179–184.

Singh T Singh VK. 1990. Four new species of genus *Epilachna* Chevrolat (Epilachninae: Coccinellidae: Coleoptera) from India. *Entomon* **15**: 27–35.

Slipinski A, Burckhard D. 2006. Revision of the Australian Coccinellidae (Coleoptera). Part 5. Tribe Serangiini. *Annals Zoologici* (Warsaw) **56**: 37–58.

Stathas GJ. 2000. *Rhyzobius lophanthae* prey consumption and fecundity. *Phytoparasitica* **28**: 1–9.

Taylor RJ. 1984. *Predation*. Chapman and Hall, New York, pp 166.

Timofeyeva TV, Nhuan HD. 1979. Morphology and biology of the Indian ladybird *S. parcesetosum* Frisch (Col.: Coccinellidae) predacious on the citrus whitefly in Azdharia. *Entomol Rev.* **57**: 210–214.

Ulusoy MR, Uygun N, Kersting U, Karaca I, Satar S. 1996. Present status of citrus whiteflies (Hom.: Aleyrodidae) in Turkey and their control. *J Pl Dis Prot*. **103**: 397–402.

Urbaneja A, Stansly PA. 2004. Host suitability of different instars of the whitefly *Bemisia tabaci* 'biotype Q' for *Eretmocerus mundus*. *BioControl* **49**: 153–161.

Usman S, Puttarudraih M. 1955. A list of the insects of Mysore including the mites. *Entomol Series Bull*. **16**: 1–189.

Uygun N, Ulusoy MR, Karaca Y, Kersting U. 1997. Approaches to biological control of *Dialeurodes citri* (Ashmead) in Turkey. *Bull IOBC/WPRS* **20**: 52–62.

Vandenberg NJ. 2000. Coccinellidae Latreille. 1807. pp 19. *In:* Arnett RH. Jr., MC Thomas and PE Skelley. (eds). *American Beetles V. 2. Polyphaga: Scarbaeoidae through Curculionidea.* CRC Press LLC, Boca Raton, FL. XIV, pp 861.

Vandenberg NJ. 2002. Coccinellidae Latreille, 1807, pp 371–389. *In*: Arnett, R.H. and M.C. Thomas (eds.). *American Beetles. Vol. 2. Polyphaga: Scarabaeoidea through Curculionoidea. Boca Raton*, CRC Press, pp 861.

Vatanesever G, Ulusoy RM, Bakircioglu LE. 2003. Improving the mass rearing possibilities of *Serangium parcesetosum* Sicard (Col.: Coccinellidae) on different host plant of *Bemisia tabaci* (Genn.) (Hom.: Aleyrodidae). *Turk J Agric For*. **27**: 175–181.

Wang XM, Ren SX, Chen XS. 2011. A review of the genus *Serangium* Blackburn (Col.: Coccinellidae) from China. *ZooKeys* **134**: 33–63.

Weaver JS, Ciomperlik MA. 2000a. Biological control of *Bemisia argentifolii* (Aleyrodidae) infesting poinsettias: evaluation of *Encarsia formosa,* Nile Delta strain, (Aphelinidae) and *Serangium parcesetosum* (Coccinellidae). USDA/ARS, pp 102.

Weaver JS, Ciomperlik MA. 2000b. Dispersal of *Serangium parcesetosum* (Coccinellidae) on poinsettia infested with *Bemisia argentifolii* (Aleyrodidae) in greenhouse trials. USDA/ARS, pp 101.

Yasnosh VA, Chaidze TA. 1986. *Serangium* against citrus whitefly in integrated pest control of citrus groves. Leaflet, Moscow, pp 6.

Yigit A. 1992a. Method for culturing *Serangium parcesetosum* Sicard (Col.: Coccinellidae) on *Bemisia tabaci* (Genn.) (Hom.: Aleyrodidae). *J Pl Dis Prot*. **99**: 525–527.

Yigit A. 1992b. *Serangium parcesetosum* Sicard (Col.: Coccinellidae), new record as a citrus whitefly predatory ladybird in Turkey. *Türk Entomol Derg.* **16**: 163–167.

Yigit A, Canhalal R. 2005. Establishment and dispersal of *Serangium parcesetosum* Sicard (Col.: Coccinellidae), a predatory beetle of citrus whitefly *Dialeurodes citri* Ashm. (Hom.: Aleyrodidae) in the East Mediterranean region of Turkey. *J Pl Dis Prot*. **112**: 268–275.

Yigit A, Canhalal R, Ekmekci U. 2003. Seasonal population fluctuations of *Serangium parcesetosum* (Col.: Coccinellidae), a predator of citrus whitefly, *Dialeurodes citri* (Hom.: Aleyrodidae) in Turkey's Eastern Mediterranean citrus groves. *Environ Entomol*. **32**: 1105–1114.

Zapata RS, Malo J, Riudavets J, Arn C Castae, Gabarra R. 2003. Biological control of *Bemisia tabaci* (Genn.) with *Eretmocerus mundus* (Mercet) and *Macrolophus caliginosus* (Wagner) in greenhouse tomatoes. 3rd Inter. *Bemisia* Workshop, Barcelona, 17–20 March, p 80.