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Biological Aspects of *Galeruca circassica* Reitter, 1889 (Coleoptera: Chrysomelidae: Galerucinae) in Relation to the Weed *Cephalaria procera*, Fish. and Lall. (Dipsacaceae) in Anatolia[1]

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Abstract. Biological aspects of *Galeruca circassica*, a herbivore feeding on *Cephalaria procera*, were studied in Turkey. In the laboratory, adults oviposited on *Cephalaria procera* from 9 days after emergence and laid an average of 198 eggs per female. Development of eggs and larvae proved to be temperature dependant. Larvae passed through four instars and pupated in a pupal case in the soil. Pupal stage lasted 48 days. Laboratory tests indicated that this species can complete its development on several *Cephalaria* species and on *Salvia staminea* and *Centaurea solstitialis*. Only on *Cephalaria procera* and *C. hirsute* a substantial percentage reached the adult stage. *Galeruca circassica* should be preserved in Eastern Anatolia because it most probably contributes in regulating the abundance of *Cephalaria procera* and because it might be used in biocontrol. The biology and host specificity of *G. circassica* indicates that it has a potential to be an agent for the biological control of *C. procera* in situations where this plant species occurs as an invasive plant.

Key words. Chrysomelidae, leaf beetle, *Galeruca circassica*, *Cephalaria procera*, biological control, weeds

1. INTRODUCTION

Cephalaria procera Fisch and Lall., 1840 (Dipsacaceae) is distributed in North Iran, Armenia and Turkey (DAVIS 1972). It is a perennial plant with subglabrous or sparsely pilose stems up to two meters. The flowers are pale yellow or cream. *Cephalaria procera* is very close to *C. gigantea*, possibly it has to be reduced to a subspecies of *C. gigantea* (DAVIS 1972). The Turkish name of *Cephalaria procera* is "Gevrek". *Cephalaria* plants root deep and the roots are strong which can be problematic in cultivating the ground (ploughing). In Eastern Anatolia "Gevrek" is regarded an important weed in meadows and pastures. Therefore a study was conducted of one of the herbivorous species associated with this plant and attempts were made to determine the influence of this species on *Cephalaria*.

Cephalaria is associated with several leaf beetle species. MEDVEDEV & ROGINSKAJA (1988) mention *Galeruca pomonae* (Scopoli) and *G. tanaceti* (L.) (Galerucinae) as polyphagous species feeding on *Cephalaria*. DOGUET (1994) mentions the polyphagous *Longitarsus luridus* (Scopoli) (Alticinae) feeding on *Cephalaria mauritanica* in Northern Africa and *Cephalaria syriaca* in Israel. In Turkey *Galeruca* is the only leaf beetle genus associated with *Cephalaria* (ASLAN pers. obs.).

The subfamily of Galerucinae comprises six tribes and approximately 5800 species (WILCOX 1971-1975) distributed throughout the world but predominantly in the tropics. In Turkey, this subfamily is known with 14 genera and 52 species (ASLAN 1998; ASLAN et al. 2000). In this subfamily, larvae feed on leaves or on plant roots in the soil, rarely on fruits. The biology of most species in this subfamily is unknown, except for the biology of pest species such as *Agelastica alni* (L.), *Aulacophora foveicollis* (Lucas) and *Xanthogaleruca luteola* (Müller) (ASLAN et al. 2000). On the other hand, there have been some attempts to study the biology of *Galerucella calmariensis* (L.) and *G. pusilla* in order to use them as biocontrol agents for management of *Lythrum salicaria* in the United States and some other countries (MCFAYDEN 1998).

The genus *Galeruca* is represented in Turkey by approximately 10 species (ASLAN et al. 2000). The genus is currently revised (BEENEN 1999, 2002, 2003) and possibly this will affect the number of Turkish species.

2. MATERIAL AND METHODS

2.1. Taxonomy

The specimens of *Galeruca* observed in this study belong to the *Galeruca pomonae*-group. From this species-group ASLAN et al. (2000) include *G. fuliginosa* (Joannis) and *G. pomonae* in their preliminary list of Turkish species. The inclusion of *G. fuliginosa* is based only on the type specimen collected in "Grece et Caucase". BEENEN (1999) concluded that *G. fuliginosa* is to be treated as a junior synonym of *G. littoralis* (F.) and

[1] Paper included here, but not presented to the 6th International Symposium on the Chrysomelidae, Bonn, Germany, May 7, 2004.

that it is unlikely that it has been captured in the Caucasian mountains. The other species, *G. pomonae*, is a widely distributed and variable species. Many local forms have been described as different species and subsequent authors have synonymised these with *G. pomonae*. One of these, *G. circassica* Reitter, has been synonymised with *G. pomonae* by IABLOKOFF-KHNZORIAN (1968). ASLAN (1998) followed IABLOKOFF-KHNZORIAN in this respect. BEENEN (2005) gives arguments to remove *G. circassica* from synonymy and re-established it as a valid species. The results presented in the next paragraphs are based on the study of Turkish specimens of *G. circassica*.

2.2. Development

Adults and larvae of *G. circassica* were collected from Gölyurt Pass (İspir, Erzurum), Olur (Erzurum) and Aşkale (Erzurum). The altitudes in the localities differed between 1000 m. and 2450 m. The collected specimens were used to start laboratory studies. Larvae and adults were placed in cages (50 x 45 cm) and kept at 20 (± 3) ^{0}C and 45 (± 10) % humidity. Fresh leaves of *Cephalaria procera* taken from the same localities were placed in the cages. In order to keep the leaves fresh their petioles were dipped in glass vials (15 ml) filled with tap water. The leaves were replaced every four days. The bottom of the cages was covered with a layer of soil (three cm) in which larvae could pupate. Cages with pupal cases were retained in laboratory, under natural photoperiod (during July approximately 12 hours dark). Eggs were removed every 24 hours.

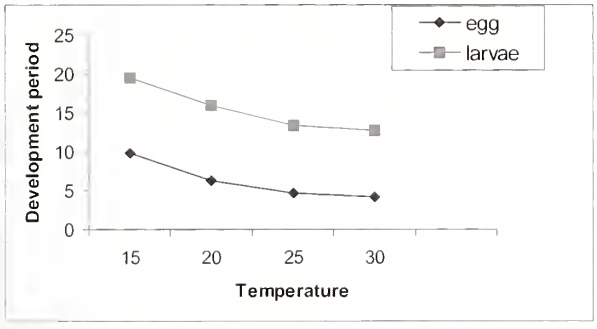

Fig. 1. Development period of larvae and egg in different temperature.

To determine the effect of temperature on egg development, eggs less than 24 hours old were placed, still attached to *C. procera*, on moist filter paper in petri dishes in each of four constant environment chambers at 15 ^{0}C (n= 25), 20 ^{0}C (n= 25), 25 ^{0}C (n=25) and 30 ^{0}C (n=25) (RH 65 ± 5 %; 12h L: 12 h D). Twice every day, at 8:30 and 19:30, newly hatched larvae were counted and removed.

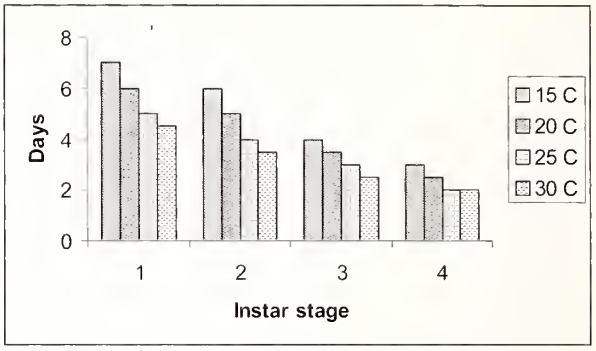

Fig. 2. Days taken for each instar stage to develop at 15, 20, 25 and 300C.

To determine the effect of temperature on larval development newly hatched larvae were kept in constant environment chambers at 15 ^{0}C (n= 20), 20 ^{0}C (n= 20), 25 ^{0}C (n=20) and 30 ^{0}C (n=20) (RH 65 ± 5 %; 12h L: 12 h D). Each larva was placed on a fresh leave. In order to keep the leaves fresh their petioles were dipped in glass vials (15 ml) filled with tap water. Larvae were monitored twice daily at 8:30 and 19:30. Leaves were replaced every other day. After the final moult, the bottom of each cage was covered with soil as above.

2.3. Foodplants

In the province of Erzurum the vegetation was studied in Ispir, Pasinler, Olur, Aşkale and Oltu. Plant species of the genera *Cephalaria*, *Salvia*, *Centaurea*, *Cirsium* and *Scabiosa* were intensively examined for the presence of *G. circassica* eggs, larvae, and adults. Each plant species, regardless the number of individuals, was examined for 15 minutes.

In addition also laboratory tests were conducted. Five species of *Cephalaria* including *C. procera*, two species of *Centaurea* and *Salvia* and one species of *Cirsium* and *Scabiosa* were tested in no-choice tests for feeding.

Adults manually removed from pupal cases 25 to 35 days after pupation were used in tests for feeding. Six adults (3 males and 3 females) were placed on each leaf for the above mentioned species. In larval test three first instar larvae were placed on each plants leaf. In order to keep the leaves fresh their petioles were dipped glass vials filled with tap water. The leaves were replaced every four days. The no-choice tests were carried out in the laboratory under natural light condition at 20 ± 3 ^{0}C and a relative humidity of 45 ± 10%. All plants were tested separately using three replicates.

2.4. Predators and parasites

In the province of Erzurum, eggs, larvae and pupae were observed to identify possible predators or para-

sites. Additionally eggs, larvae and pupae were collected and placed in a cage for emerging parasites.

3. RESULTS

3.1. Development

Eggs of *G. circassica* were 1.9±0.015 mm (after the ± sign the standard deviation is indicated) long 1.5±0.005 mm (n=25) wide and deposited in groups at the underside, rarely at the upper side, of the leaves. Eggs were initially translucent to dirty white, becoming darker during development. Egg development took 9.8±0.17 (n=30), 6.3±0.14 (n=30), 4.7±0.08 (n=30), and 4.2±0.04 (n=30) days at 15, 20, 25, and 30 ^{0}C, respectively (Fig. 1).

Larvae emerged (head first) and immediately started feeding on the foliage. The black larvae passed through four instars, taking 19.5±0.17 (n=30), 16±0.14 (n=30), 13.4±0.11 (n=30) and 12.7±0.08 (n=30) days from emergence to the construction of the pupal case at 15, 20, 25, and 30 ^{0}C, respectively (Figs. 1, 2). Larval mortality was lowest at 20 ^{0}C and highest at 30 ^{0}C, especially during the first instar stage. Mature larvae dropped to the ground where they pupated in a pupal case in the soil.

In the laboratory 80.5 % (145/180) of the larvae that entered the pupal stage emerged as adults. Pupal stage lasted 47.8 (±1.86) days and was independent of temperature.

On the locations were field studies were conducted active *G. circassica* adults were present mainly from the beginning of May to the end of June. *Galeruca circassica* eggs and larvae were found on *C. procera* in from mid of May to the beginning of July.

3.2. Food plants

Eggs, larvae and adults of *G. circassica* were recorded in the field on plant species of the families Dipsacaceae, Lamiaceae and Asteraceae (Table 1). The highest presence occurred on plant species of *Cephalaria*, especially *C. procera*. *Salvia staminea* and *Centaurea solstitialis* were the only species in the subfamilies Lamiaceae and Asteraceae on which *G. circassica* were registered.

Table 1. Plant species monitored in the field in Turkey for presence of *G. circassica*.

Family	Species	Sites[a]	Occasions[b]	Present[c]
Dipsacaceae	*Cephalaria aristata*	10	5	2
	C. hirsute	20	12	12
	C. speciosa	15	10	3
	C. anatolica	13	8	2
	C. procera	48	115	45
	C. syriaca	12	12	4
	C. media	8	4	1
	C. gigantean	18	9	2
Lamiaceae	*Salvia staminea*	5	4	1
	S. verticillata	4	5	0
	S. brachyantha	3	2	0
Asteraceae	*Centaurea depressa*	8	9	0
	C. solstitialis	25	55	3
	C. iberica	11	5	0
	C. virgata	9	2	0
Asteraceae	*Cirsium arvense*	38	76	0
	C. ciliatum	5	3	0
Dipsacaceae	*Scabiosa rotata*	11	5	0
	S. columbaria	4	2	0

[a]Sites monitored; [b]Occasions each site monitored; [c]Sites *Galeruca circassica* present.

No-choice tests revealed that *G. circassica* laid eggs on all plant species on which this *Galeruca* species has been observed in the field. Most eggs were laid within nine days of the adults' removal from pupal cases. Each female deposited on average 198 eggs. Although intense feeding was observed on only one species (*C. procera* showing severe damage) many adults survived for 45 days on most species tested (Table 2). Larvae completed their development on *Cephalaria* spp. and two other species, *Salvia staminea* and *Centaurea solstitialis* (Table 2).

Table 2. Plant species tested in larval and adult no-choice test.

	Larvae			Adults			
Test plants	**n[a]**	**% Pupated[b]**	**Damage[c]**	**n[a]**	**%Alive[d]**	**Eggs[e]**	**Damage[c]**
Cephalaria procera	10	85	S	9	80	250	s
C. hirsute	8	50	S	5	78	175	M
C. arsistata	5	20	M	4	70	60	M
C. speciosa	5	10	M	5	72	20	NE
C. anatolica	5	8	M	2	69	18	NE
Salvia staminea	3	2	NE	1	67	32	NE
S. verticillata	3	0	N	0	60	0	N
Centaurea depressa	3	0	N	1	69	0	N
C. solstitialis	3	3	M	2	58	29	NE
Cirsium arvense	3	0	N	0	52	0	N
Scabiosa rotata	3	0	N	0	55	0	N

[a]Number of replicates; [b]Mean percentage of larvae for replicates reaching the pupal stage; [c]Estimated damage (N, none; NE, negligible; M, moderate; S, substantial); [d]Mean percentage of adults alive for all replicates after 45 days; [e]Total number of eggs laid after 45 days.

3.3. Predators and parasites

In this study no natural enemies were found that were associated with *G. circassica*. However, one Miridae (Heteroptera) species, *Deraecoris serenus* Dgl, was seen feeding on the eggs of *G. circassica*, but their density was low. On the other hand, this species is zoophytophagous and feeds generally on alfalfa, some other cultivated plants and weeds.

From eggs, larvae or pupae no parasites emerged.

4. DISCUSSION

Life history tables of species of *Galeruca* (subgenus *Galeruca*), as far as known, show some remarkable similarities. The minor differences seem to be related to the exact months of summer heat and severity of winter. In the North-western part of its distribution *Galeruca pomonae* shows adult aestivation during summer (July and August) and reproduction in late summer and autumn (from September to the end of October) (BEENEN 1998). In Sardinia *Galeruca sardoa* (Gené) show summer aestivation from the end of June to the start of October. Reproduction takes place from November to January (CROVETTI & USCIDDA 1978.). In Sicily *Galeruca* species (*G. sicana* (Reiche) and *G. reichei* (Joannis)) show summer aestivation during July and August and reproduction from September to December (SINACORI & MINEO 1993). All these species show egg diapause during winter. The life history of *G. circassica*, a species hitherto confused with other *Galeruca* species, is unknown. The results of this study however show remarkable differences with the above mentioned species. *Galeruca circassica* is known to overwinter in the adult stage, mate and deposit eggs in spring and completely develops during early summer. From this study it became clear that development takes place in approximately 70 days. Eggs were seen in the field from mid May onwards, consequently adults could be seen some 70 days later: from the end of July. The results from the laboratory studies fit the results from the field. Adults of *G. circassica* overwinter and reproduce in spring. This life history table is in concordance with the observations on *Galeruca rufa* Germar by BOURDONNÉ & MALDÈS (1995). In the south of France *Galeruca rufa* deposits eggs from mid May to the end of August. Larvae are active during summer. Adults can be seen almost all year. *Galeruca rufa* is not related to *Galeruca circassica*. It is classified in the subgenus *Emarhopa*; *G. circassica* in the subgenus *Galeruca*.

From eggs, larvae or pupae no parasites emerged. Only a single predator has been observed. Most probably this subject needs some additional research. Other *Galeruca* species are known to be parasitized by Hymenoptera and Diptera parasites (COX 1994) and predated by *Zicrona* (Heteroptera), *Lebia* (Carabidae) and *Aiolocaria* (Coccinellidae) (COX 1996). It is unlikely that *Galeruca circassica* has no parasites.

The distribution of *G. circassica* is insufficiently known due to the taxonomic entanglement. This study provides information on the occurrence in eastern Anatolia. The description of *G. circassica* was based on specimens collected in Fisht in the north-western part of the Caucasian mountain range (REITTER 1889). Further study of collections and surveys in the field must provide knowledge about its distribution.

Food plants of *G. circassica* mentioned in literature are not reliable because of the uncertain taxonomic position

of this species. The same may hold true for *G. pomonae*. Records of *G. pomonae* from the Caucasian area could refer to *G. circassica*. GRUEV & TOMOV (1986) and WARCHALOWSKI (1994) indicate that *G. pomonae* could feed on *Centaurea, Salvia, Knautia, Cirsium*, and *Scabiosa*. MEDVEDEV & ROGINSKAJA (1988) mention *Mentha* and *Melissa* as possible (marked with question mark) food plants for *G. circassica*. These authors mention *Cephalaria* as food plant for *G. pomonae*.

The observation in our study show that *G. circassica* feeds primarily on *C. procera* and *C. hirsute*; plants which are widespread and abundant in eastern Anatolia. These plants are important weeds and *G. circassica* most probably contributes in regulating their abundance. However, because both *Cephalaria* and *G. circassica* are indigenous in this region it is unlikely that *G. circassica* will control this food plant completely. In situations were *Cephalaria* is introduced and causes problems, the possibility of using *G. circassica* as a biological control agent should be seriously investigated. Our study revealed that both adults and larvae of *G. circassica* feed on *C. procera* and cause important damage.

In Anatolia a decline of *G. circassica* (e.g., a decline due to the use of non-specific insecticides) should be prevented because this leaf beetle can help in restricting the nuisance caused by "Gevrek". Furthermore it is a potential agent for the biological control of *Cephalaria* in other places.

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