# Host Specificity of *Bangastemus orientalis* Capiomont (Coleoptera: Curculionidae) Introduced into the United States for Biological Control of Yellow Starthistle (*Centaurea solstitialis* L., Asteraceae: Carduae)

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**ABSTRACT** The weevil *Bangasternus orientalis* Capiomont was selected as a candidate for the biological control of *Centaurea solstitialis* L. (yellow starthistle) in the United States. Its potential host range was studied during 1982, 1983, and 1984 in Rome, Italy, using populations collected from *C. solstitialis* in Thermi near Thessaloniki and Kozani in northern Greece. Adults laid eggs only on members of the genus *Centaurea* and the thistle *Onopordum acanthium;* eggs laid on *O. acanthium* hatched but 1st instars died before entering buds. There was no significant difference in the number of eggs laid on various U.S. and Italian strains of *C. solstitialis* included in the tests. Eggs were not deposited on plant species of economic importance such as *Cynara scolymus, Helianthus annuus, Carthamus tinctorius,* and *Lactuca sativa.* Larvae completed their larval development only on *C. solstitialis* from Greece and on U. S. and Italian populations of *C. solstitialis* among the 60 plant species, varieties, and strains (in 7 families) tested. This restricted host range suggested introduction of this weevil as a biological control agent against yellow starthistle in the United States. Releases of *B. orientalis* were made in California, Washington, Idaho, and Oregon in 1985 and it became established in all states in 1989.

**KEY WORDS** Coleoptera, *Bangasternus orientalis*, yellow starthistle, weed, weevil, biological control

YELLOW STARTHISTLE, *Centaurea solstitialis* L., is an herbaceous plant of Eurasian origin that is adventive in many parts of the world, including the United States of America, where it reaches high densities in several climatic and vegetational zones, especially in California (3,200,000 ha infested), Idaho (81,000 ha), Oregon (400,000 ha), and Washington (54,000 ha) (Maddox and Mayfield 1985, Maddox et al. 1985, Roché and Roché 1988, Callihan et al. 1989). This weed is a serious pest of rangelands, recreational areas, and abandoned croplands, and it is spreading at an alarming rate into new areas (Callihan et al. 1989). Yellow starthistle displaces native vegetation, its spiny capitulae deters grazing by livestock, it is a nuisance to people working or playing on infested lands, and it is poisonous to horses (Cordy 1978). Yellow starthistle is typically a winter annual that propagates only by seeds that usually germinate in the fall, depending on rainfall. Floral buds undergo a series of maturation stages before they terminate in yellow inflorescences (Maddox 1981) that typically open June through August in southern Europe.

Researchers have surveyed the entomofauna of yellow starthistle in southern Europe since 1950 for potential biological control candidates (Zwölfer 1965, 1969; Zwölfer et al. 1971; Sobhian and Zwölfer 1985; Clement and Mimmocchi 1988; Clement et al. 1988). Approximately 23 capitulum infesting insect species, including the weevil *Bangasternus orientalis* Capiomont (Sobhian and Zwölfer 1985), and 7 species associated with other parts of yellow starthistle were discovered in the Mediterranean region (Clement 1990). Five insect species, *Urophora sirunaseva* (Hering) (Diptera: Tephritidae), *Chaetorellia australis* Hering (Diptera: Tephritidae), *Eustenopus villosus* (Boheman) (Coleoptera: Curculionidae), *Larinus curtus* Hochhuth (Coleoptera: Curculionidae), and *B. orientalis,* have been released in the United States to control yellow starthistle (Maddox et al. 1986, White and Clement 1987, Maddox et al. 1990, Turner et al. 1996) and all are established. The biology and phenology of *B. orientalis* reported by Sobhian et al. (1992) was based on studies in northern Greece. Overwintered adults appear on bolting yellow starthistle during mid-May. Oviposition starts at the end of May and lasts ≈3 mo. Eggs are laid singly, on or near young buds, and are covered with a protective cap of frass produced by the females. Newly hatched larvae mine into flower heads from eggs laid on branch tips. Adults do minimal damage to yellow starthistle by feeding on leaves, but the larvae consume developing seeds. A single larva is capable of destroying the entire contents of a yellow starthistle flower bud, completing its development inside the bud. Females oviposit and feed on buds of sizes categorized by Maddox (1981) as stages Bu 1, Bu 2, and Bu 3; a few eggs are found on

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bud stage Bu 4 and flower bud stages F-1 and F-2. Two species of egg parasitoids, *Pterandrophysalis levantina* Nowicki (Trichogrammatidae) and an unidentified species of Mymaridae, emerged from eggs collected in the field near Thermi in northern Greece (Sobhian et al. 1992). High eggs and larval mortality (up to 98.7 and 84%), largely the result of predation, does not allow the weevil to build up large populations in its natural environment.

One of the most important criteria determining the introduction into a new country of phytophagous organism for the biological control of weeds is that they should be safe, sufficiently host specific to pose no threat to any cultivated or socially important plant. The objective of this article is to provide background information of specific laboratory tests that were conducted at the overseas laboratory with *B. orientalis* prior its introduction and release in the United States.

## Materials and Methods

**Host Specificity Tests.** Tests were conducted during 1982, 1983, and 1984 with 60 plant species or varieties in 7 families (Table 1). The plants included genera and families closely related to *Centaurea* (order Asterales), plants in other orders of the superorder Rosidae, and plants attacked by other species of *Bangasternus*, such as *C. diffusa* DeLamarck, *C. calcitrapa* L., *C. paniculata* L., *C. scabiosa* L., and *C. maculosa* DeLamarck. Engler (1964) and Heywood (1978) were used as guides in constructing our list of test plants. Native American *Cirsium*, and *Centaurea* species such as *Cirsium undulatum* (Nuttal) Spreng, *C. douglasii* Decandolle, *C. andrewsii* (Gray) Jepson, and *Centaurea americana* Nuttall were included in the tests. Adults for host specificity tests were collected in Thermi (Thessaloniki) and Kozani in northern Greece during May. The weevils were sexed and kept in a refrigerator at 8–10°C until collections in Greece were completed. They were transported from Greece to Rome, where they were caged separately on young bolting plants of *C. solstitialis*, allowing them to feed on fresh plant material for 48 h to recover from the stress of the travel to Rome. Healthy adults were used to conduct the various host specificity tests.

**Single Plant, No-Choice Oviposition Tests: 1982–1984.** The experiments were conducted in a quarantine greenhouse (shaded on the top) under natural light during June and July 1982–1984. For the tests, mean temperature was 24.8 ± 5.9°C (range, 16–36°C), mean relative humidity was 65.6 ± 19.6% RH (range, 32–91%), and a photoperiod ≈16:8 (L:D) h. The insects were confined on potted plants covered with a transparent plastic cylinder (20 cm diameter, 70 cm high) that had 4 holes (10 cm diameter) covered with organdy on the side of each cylinder to allow air circulation. Each cage was capped with organdy cloth held in place by a rubber band. Experiments were conducted from late May to late July each year. Five replicates of each plant species were caged with 2 pairs of *B. orientalis* adults. Weevils were allowed to feed and oviposit on test plants until they died. All exposed buds of test plants, including the control, were checked to record the number of eggs laid. Longevity of caged adults also was recorded. Host specificity data were analyzed by analysis of variance (ANOVA) and means were separated by a Student–Newman–Keuls a posteriori test.

**First Instar Survival Test.** These trials were conducted in a shaded quarantine greenhouse under natural light between May and June 1982–1984. For the tests, mean temperature was 24.9 ± 6.2°C (range, 15–35°C); mean relative humidity was 65.7 ± 18.9% RH (range, 30–92%); and a photoperiod of 16:8 (L:D) h. The 1982 test was from 2 June to 30 July; 1983, 1 June to 31 July; and 1984, 3 June to 31 July. Infested buds were dissected and the numbers of larvae were recorded. Eggs for 1st-instar survival tests were obtained from 10 females each year. Males and females were caged with *C. solstitialis* (bearing young buds of categories Bu 1 and Bu 2) (Maddox 1981). Each day, newly laid eggs were recorded and removed from the plants and placed in hatching containers (Rizza 1977). Instead of using cotton as described by Rizza, the authors used plaster of paris as a hatching surface to avoid injury to neonate larvae. Egg development was monitored daily using a stereoscope. When the head capsule was visible through the mature eggs they were transferred to test plants with a moistened camel's-hair brush. Each test plant received 20 mature eggs distributed over 10 flower buds (2 eggs per flower bud), each bud serving as a replicate. We observed in the field that only 1 larva can develop in 1 flower bud. We decided that no more than 2 eggs per bud were necessary to avoid competition and stress between 1st instars using the same flower bud. Infested buds were marked to facilitate reexamination and to allow us to record the number of hatching eggs. Data of larval survival test are expressed with means and standard deviation.

**Multiple Choice Test: 1984.** Plants for this test were those that received eggs from tests of no-choice oviposition conducted in 1982, 1983, and 1984. The objectives were to see if *B. orientalis* adults would select nonhost plants for oviposition and to determine the degree of larval development. The degree of preference between American and European strains of yellow starthistle was also measured. Selected groups of test plants, each containing a control plant, were potted together in large plastic pots (80 cm diameter, 70 cm high). Each group of plants in a pot was covered by a cylinder cage as described previously. Four groups of plants were prepared, and each group was replicated 3 times. Ten pairs of *B. orientalis* were placed in each cage. Weevils ($n$ = 180) collected in Thermi, Greece, in mid-May 1984 were used for this test. The experiment was carried out in a shaded quarantine greenhouse under natural light from 15 May to 30 July. All buds per test plant, with and without eggs, were recorded. During the test, the mean temperature was 24.4 ± 6.3°C (range, 16–36°C), the mean relative humidity was 65.3 ± 19.8% RH (range, 33–91%), and a photoperiod of 16:8 (L:D) h. The longevity of weevils used in these tests was recorded. Multiple choice

**Table 1. Results of *B. orientalis* oviposition–no–choice host specificity tests, 1982, 1983, 1984 (mean ± SD followed by range)**

| Test plant species | No. replicates | Total exposed floral buds per plant | | Total floral buds attacked per plant | | Total eggs laid per plant | | Adult Longevity Days | |
|---|---|---|---|---|---|---|---|---|---|
| **1982** | | | | | | | | | |
| *Centaurea solstitialis* Greece (Control) | 5 | 55.00 ± 4.74 | 49–61 | 51.60 ± 4.04 | 46–56 | 82.60 ± 4.93a | 78–90 | 46.6 ± 4.83 | 39–51 |
| *Centaurea solstitialis* Goldendale (WA) | 5 | 46.00 ± 12.24 | 27–61 | 42.00 ± 12.51 | 24–59 | 61.60 ± 5.41b | 56–70 | 41.8 ± 3.35 | 39–47 |
| *Centaurea solstitialis* Walla Walla (WA) | 5 | 40.00 ± 12.21 | 22–53 | 39.60 ± 12.22 | 21–52 | 63.40 ± 15.95b | 43–80 | 46.4 ± 5.46 | 37–51 |
| *Centaurea solstitialis* Yakima (WA) | 5 | 39.80 ± 15.45 | 17–59 | 31.40 ± 8.96 | 17–39 | 51.40 ± 15.63c | 35–75 | 44.8 ± 5.26 | 38–52 |
| *Centaurea solstitialis* Concord (CA) | 5 | 44.00 ± 5.91 | 37–51 | 38.00 ± 6.52 | 30–46 | 48.00 ± 11.36d | 35–65 | 40.8 ± 2.39 | 38–44 |
| *Centaurea solstitialis* Bracciano (Italy) | 5 | 50.00 ± 4.18 | 45–56 | 39.60 ± 2.41 | 37–43 | 47.80 ± 7.73c | 40–58 | 38.0 ± 4.64 | 32–44 |
| *Centaurea solstitialis* Salerno (Italy) | 5 | 4.00 ± 9.43 | 46–67 | 42.00 ± 2.74 | 38–45 | 62.00 ± 5.52e | 54–69 | 42.4 ± 5.37 | 37–51 |
| *Centaurea solstitialis* Bari (Italy) | 5 | 47.00 ± 5.43 | 39–53 | 44.00 ± 5.79 | 37–50 | 97.80 ± 0.84f | 97–99 | 46.4 ± 4.39 | 39–50 |
| *Centaurea solstitialis* var. *schowii* (Italy) | 5 | 57.00 ± 2.73 | 54–61 | 44.40 ± 2.70 | 40–47 | 48.00 ± 2.92g | 44–51 | 44.2 ± 4.55 | 37–48 |
| *Centaurea diffusa* Greece | 5 | 54.40 ± 1.22 | 52–55 | 5.00 ± 2.45 | 2–8 | 6.00 ± 2.74h | 2–9 | 28.2 ± 2.39 | 25–31 |
| *Centaurea jacea* Italy | 5 | 44.0 ± 2.91 | 39–46 | 20.60 ± 2.30 | 18–24 | 28.60 ± 5.59i | 24–38 | 44.0 ± 4.36 | 39–49 |
| *Centaurea maculosa* Italy | 5 | 48.00 ± 6.85 | 39–57 | 4.60 ± 0.55 | 4–5 | 6.00 ± 2.92l | 2–9 | 25.2 ± 3.03 | 21–29 |
| *Centaurea calcitrapa* Italy | 5 | 54.60 ± 13.37 | 39–75 | 14.00 ± 2.45 | 11–17 | 15.80 ± 2.68m | 13–19 | 24.8 ± 4.97 | 19–30 |
| *Centaurea calcitrapa* Greece | 5 | 58.00 ± 6.12 | 49–66 | 20.00 ± 3.16 | 17–25 | 20.60 ± 3.51m | 17–26 | 29.6 ± 3.65 | 24–34 |
| *Centaurea cyanus* Italy | 5 | 54.00 ± 10.01 | 42–65 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 17.4 ± 2.30 | 15–21 |
| *Centaurea paniculata* Italy | 5 | 46.00 ± 7.68 | 37–55 | 0.40 ± 0.89 | 0–2 | 0.40 ± 0.89n | 0–2 | 20.2 ± 1.48 | 18–22 |
| *Centaurea cineraria* Italy | 5 | 66.00 ± 5.70 | 59–72 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 16.2 ± 3.11 | 13–21 |
| *Centaurea americana* USA | 5 | 5.80 ± 1.30 | 4–7 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 17.6 ± 1.67 | 15–19 |
| *Centaurea scabiosa* Italy | 5 | 42.00 ± 2.91 | 39–46 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 17.0 ± 2.24 | 14–20 |
| *Helianthus annuus* USA | 5 | 1.80 ± 0.83 | 1–3 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 17.2 ± 1.48 | 15–19 |
| *Helianthus tuberosus* USA | 5 | 3.80 ± 1.92 | 2–7 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 16.8 ± 2.17 | 15–20 |
| *Zinnia elegans* Italy | 5 | 9.40 ± 5.45 | 0–14 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 18.4 ± 1.95 | 16–21 |
| *Carthamus tinctorius* USA | 5 | 7.00 ± 3.53 | 4–13 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 16.0 ± 1.58 | 14–18 |
| *Cynara scolymus* USA | 5 | 4.00 ± 1.00 | 3–5 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 16.0 ± 1.58 | 14–18 |
| *Cynara scolymus* Italy | 5 | 3.00 ± 1.58 | 1–5 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00n | 0–0 | 15.8 ± 1.92 | 13–18 |
| **1983** | | | | | | | | | |
| *Centaurea solstitialis* Greece (control) | 5 | 82.00 ± 8.24 | 69–89 | 82.00 ± 8.25 | 69–89 | 142.00 ± 34.02 | 99–190 | 49.0 ± 7.84 | 39–60 |
| *Centaurea alba* Italy | 5 | 45.80 ± 3.03 | 42–50 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 17.0 ± 1.22 | 15–18 |
| *Carduus nutans* USA | 5 | 15.00 ± 3.16 | 10–18 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 16.0 ± 2.35 | 12–18 |
| *Carduus pycnocephalus* Italy | 5 | 35.00 ± 6.67 | 28–45 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 18.6 ± 2.30 | 15–21 |
| *Carduus acanthoides* USA | 5 | 44.20 ± 13.64 | 29–64 | 0.00 ± 0.00 | 0–0 | 0,00 ± 0,00 | 0–0 | 14.8 ± 2.77 | 12–19 |
| *Carduus thoermeri* USA | 5 | 22.00 ± 4.84 | 15–26 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 16.0 ± 2.35 | 13–18 |
| *Cirsium lanceolatum* Italy | 5 | 2.00 ± 0.70 | 1–3 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 17.6 ± 2.30 | 14–20 |
| *Cirsium undulatum* USA | 5 | 2.40 ± 1.14 | 1–4 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 17.4 ± 2.88 | 13–21 |
| *Cirsium douglasii* USA | 5 | 2.20 ± 0.83 | 1–3 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 15.2 ± 1.30 | 14–17 |
| *Cirsium andrewsii* USA | 5 | 2.60 ± 1.34 | 1–4 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 17.6 ± 1.67 | 15–19 |
| *Onopordum acanthium* USA | 5 | 7.00 ± 3.08 | 4–11 | 0.00 ± 0.00 | 0–0 | 1.4 ± 0.55 | 1–2 | 21.0 ± 4.53 | 17–28 |
| *Onopordum illyricum* Italy | 5 | 4.20 ± 2.28 | 2–8 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 17.6 ± 1.95 | 15–20 |
| *Sylibum marianum* Italy | 5 | 4.20 ± 2.49 | 2–8 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 15.6 ± 1.95 | 13–18 |
| *Chrysanthemum leucanthemum* Italy | 5 | 25.80 ± 3.56 | 20–29 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 16.0 ± 1.87 | 14–19 |
| *Achillea millefolium* Italy | 5 | 27.80 ± 10.18 | 17–39 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 17.8 ± 2.95 | 13–21 |
| *Tanacetum vulgare* Italy | 5 | 30.00 ± 3.80 | 26–36 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 15.0 ± 1.22 | 14–17 |
| *Anthemis tinctoria* Italy | 5 | 26.40 ± 6.02 | 21–36 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 15.2 ± 2.28 | 13–18 |
| *Artemisia vulgaris* Italy | 5 | 34.20 ± 7.69 | 25–45 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 18.0 ± 2.35 | 14–20 |
| *Senecio jacobea* Italy | 5 | 10.00 ± 4.63 | 6–17 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 18.0 ± 2.65 | 15–22 |
| *Lactuca sativa* Italy | 5 | 34.00 ± 7.34 | 25–44 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 15.2 ± 1.30 | 14–17 |
| *Lactuca sativa* var. Great Lakes USA | 5 | 26.80 ± 8.10 | 14–35 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 15.4 ± 1.14 | 14–17 |
| *Leontodon crispus* Italy | 5 | 5.40 ± 3.78 | 2–10 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 15.4 ± 2.70 | 11–18 |
| *Taraxacum officinalis* Italy | 5 | 7.60 ± 3.50 | 2–11 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 18.4 ± 1.52 | 16–20 |
| *Tagetes erecta* Italy | 5 | 5.00 ± 2.34 | 3–9 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 16.6 ± 1.14 | 15–18 |
| *Calendula officinalis Italy* | 5 | 15.00 ± 4.47 | 10–21 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 18.8 ± 2.28 | 15–21 |
| **1984** | | | | | | | | | |
| *Centaurea solstitialis* Greece (control) | 5 | 135.60 ± 21.96 | 99–156 | 146.00 ± 12.35 | 128–160 | 181.80 ± 7.19 | 173–190 | 54.8 ± 3.89 | 49–59 |
| *Antirrhinum majus* Italy | 5 | 24.40 ± 7.20 | 15–35 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 18.4 ± 1.14 | 17–20 |
| *Linaria vulgaris* Italy | 5 | 15.00 ± 4.18 | 10–21 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 20.0 ± 2.12 | 18–23 |
| *Linaria dalmatica* USA | 5 | 9.00 ± 2.35 | 6–11 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 20.8 ± 2.16 | 19–24 |
| *Silene vulgaris* Italy | 5 | 25.40 ± 4.62 | 19–32 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 17.8 ± 2.58 | 14–21 |
| *Viola bertolinii* Italy | 5 | 14.00 ± 3.94 | 11–20 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 17.2 ± 0.83 | 16–18 |
| *Ranunculus auricomus* Italy | 5 | 44.80 ± 12.15 | 27–56 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 17.0 ± 1.58 | 15–19 |
| *Papaver somniferum* Italy | 5 | 1.00 ± 0.00 | 1–1 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 16.4 ± 1.51 | 14–18 |
| *Euphorbia esula* Italy | 5 | 5.40 ± 1.52 | 4–8 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 15.4 ± 0.89 | 14–16 |
| *Euphorbia lathyris* Italy | 5 | 4.20 ± 2.28 | 2–8 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 14.8 ± 1.48 | 13–17 |
| *Euphorbia characias* Italy | 5 | 2.60 ± 0.89 | 2–4 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 18.8 ± 1.48 | 17–21 |
| *Euphorbia virgata* USA | 5 | 3.00 ± 1.22 | 2–5 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | 20.8 ± 2.28 | 18–24 |

Two males and 2 females were used per test plant. Five replicates were made per each tested plant. Means followed by the same letter are not significantly different ($P < 0.05$, Student–Newman–Keuls a posteriori test).

**Table 2. Results of *B. orientalis* larval survival test, 1982, 1983, 1984 (mean ± SD followed by range)**

| Test plants | Total replicates test plants | Total eggs used | Total eggs hatched | | Total larvae found/plant species | |
|---|---|---|---|---|---|---|
| | | | 1982 | | | |
| *Centaurea solstitialis* Greece (control) | 10 | 20 | 2.0 ± 0.0 | 2–2 | 1.0 ± 0.0 | 1–1 |
| *Centaurea solstitialis* Goldendale (WA) | 10 | 20 | 1.7 ± 0.67 | 0–2 | 1.0 ± 0.0 | 1–1 |
| *Centaurea solstitialis* Walla Walla (WA) | 10 | 20 | 1.8 ± 0.63 | 0–2 | 0.9 ± 0.0 | 0–1 |
| *Centaurea solstitialis* Yakima (WA) | 10 | 20 | 1.9 ± 0.32 | 1–2 | 1.0 ± 0.0 | 1–1 |
| *Centaurea solstitialis* Concord (CA) | 10 | 20 | 1.8 ± 0.63 | 0–2 | 0.9 ± 0.0 | 0–1 |
| *Centaurea solstitialis* Bracciano (Italy) | 10 | 20 | 1.9 ± 0.32 | 1–2 | 0.9 ± 0.0 | 0–1 |
| *Centaurea solstitialis* Salerno (Italy) | 10 | 20 | 2.0 ± 0.0 | 2–2 | 0.9 ± 0.0 | 0–1 |
| *Centaurea solstitialis* Bari (Italy) | 10 | 20 | 1.9 ± 0.32 | 1–2 | 1.0 ± 0.0 | 1–1 |
| | | | 1983 | | | |
| *Centaurea solstitialis* Greece (control) | 10 | 20 | 1.8 ± 0.63 | 0–2 | 1.0 ± 0.0 | 1–1 |
| | | | 1984 | | | |
| *Centaurea solstitialis* Greece (control) | 10 | 20 | 1.8 ± 0.63 | 0–2 | 1.0 ± 0.0 | 1–1 |

Two eggs were used per test plant. Ten replicates were made per each tested plant. Only 1 larva can develop in 1 bud. Plants that did not have any larval survival are not listed in this table. For complete list of tested plants see Table 1.

test data were analyzed (ANOVA) and means were separated by a Student–Newman–Keuls a posteriori test.

**Site Preference for Oviposition: 1983.** Yellow starthistle plants, may have as many as 6 floral bud stages present at 1 time during the oviposition period of *B. orientalis*. Therefore, an experiment was conducted to determine the preferred bud stage for oviposition. We used the bud development classes of Maddox (1981) to identify the various bud stages during May and June. Potted plants of *C. solstitialis* were used for this test, and 1 pair of adults was caged on each test plant using the same plastic cylinders as in the no-choice oviposition test. Ten plants (replicates) with different bud stages were used in this trial, which was carried out from 25 May to 18 July in the same shaded quarantine greenhouse of previous tests. After 5 d floral buds were examined and eggs were recorded and removed. Data of adult oviposition site preference test are expressed with means and standard deviation.

## Results

**No - Choice Oviposition Tests: 1982–1984.** The total number of exposed floral buds, floral buds attacked, total eggs laid, and adult longevity on each plant species, varieties, and strains are presented in Table 1. Adults laid eggs only on members of the genus *Centaurea* and the thistle *Onopordum acanthium*. Significantly more eggs were laid on *C. solstitialis* plants (all populations) than on other test plants in the 1982 (Table 1). The U.S. yellow starthistle plants were readily accepted, with plants from WallaWalla, WA, receiving the highest number of eggs per replicate (63.40 ± 15.95; range, 43–80). Populations from Italy were also accepted for oviposition, and the 1 from Bari had the highest mean number of eggs per replicate (97.80 ± 0.84; range, 97–99). There was no significant difference in number of eggs laid on *C. solstitialis* from WallaWalla versus *C. solstitialis* from Goldendale, WA, or *C. solstitialis* from Yakima, WA, versus *C. solstitialis* from Bracciano, Italy (Table 1). Other species in the genus *Centaurea* (*C. diffusa*, *C. jacea*, *C. maculosa*, and *C. calcitrapa* from Italy, and *C. calcitrapa* from Greece) received fewer eggs. There was no significant difference in number of eggs laid on *C. calcitrapa* from Greece versus *C. calcitrapa* from Italy (Table 1.). The only plant outside the genus *Centaurea* to receive eggs was *O. acanthium* with a mean of (1.4 ± 0.55). Eggs were not deposited on plant species of economic importance such as *Cynara scolymus*, *Helianthus annuus*, *Carthamus tinctorius*, *Lactuca sativa*, and the U.S. endangered species of *Cirsium*, *C. undulatum*, *C. douglasii*, and *C. andrewsii*. Adults fed little or not at all on nonhost plants and were shorter lived (15–20 d) compared with weevils caged on the natural host (39–51 d).

**First Instar Survival Test: 1982, 1983, 1984.** Results of this test are summarized in Table 2. In total, 657, 509, and 530 eggs were collected in 1982, 1983, and 1984, respectively, for a total of 1,696. Mean percentage of egg eclosion was 86.5%. This egg production was sufficient for larval survival tests. Larvae completed their larval development only on *C. solstitialis* from Greece and on U.S. and Italian populations of *C. solstitialis* among the 60 plant species, varieties, and strains tested. In the 1982 test, 1st instars completed their larval development only on the different population of *C. solstitialis*. Larval survival was 95% (76 out of 80) in this test. Survival was 100% in the 1983 and 1984 tests.

**Multiple Choice Test: 1984.** In all test-plant groups the plants receiving the most eggs were the *C. solstitialis* controls from Greece and the U.S. and Italian ecotypes of yellow starthistle. Significantly ($P < 0.05$) more eggs were laid on *C. solstitialis* from Greece than on any other test plant. No eggs were found on *O. acanthium* (Table 3). *B. orientalis* laid more eggs on *C. diffusa*, *C. calcitrapa*, *C. jacea*, and *C. maculosa* in this test than it did on these test plants under no-choice conditions. No large differences were noted in comparing adult longevity of *B. orientalis* caged with the various test-plant groups (Table 3).

**Adult Oviposition Site Preference: 1983.** The weevil oviposited heavily on floral buds Bu-1 and Bu-2. Stages

**Table 3. Results of *B. orientalis* oviposition–multiple–choice host specificity tests, 1984 (mean ± SD followed by range)**

| Test plants | Replicates | Total exposed floral buds per test plant | | Total floral buds attacked per test plant | | Total eggs laid per test plant | | Adult Longevity Days | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Group I | | | | | |
| *Centaurea solstitialis* Greece (control) | 3 | 100.00 ± 14.18 | 89–116 | 91.67 ± 15.53 | 79–109 | 143.33 ± 160.1a | 127–159 | 61.7 ± 3.79 | 59–66 |
| *Centaurea solstitialis* Goldendale (WA) | 3 | 106.67 ± 6.81 | 99–112 | 65.67 ± 21.57 | 41–81 | 90.00 ± 18.52b | 72–109 | | |
| *Centaurea solstitialis* Walla Walla (WA) | 3 | 96.67 ± 6.11 | 90–102 | 58.33 ± 5.86 | 54–65 | 66.67 ± 27.79b | 35–87 | | |
| *Centaurea diffusa* Greece | 3 | 95.00 ± 18.73 | 80–116 | 7.33 ± 0.58 | 7–8 | 9.00 ± 1.00c | 8–10 | | |
| *Centaurea solstitialis* Salerno (Italy) | 3 | 90.00 ± 9.85 | 79–98 | 66.00 ± 6.56 | 59–72 | 70.00 ± 16.70d | 55–88 | | |
| | | | | Group II | | | | | |
| Centaurea solstitialis Greece (control) | 3 | 100.67 ± 7.37 | 95–109 | 92.00 ± 7.21 | 86–100 | 129.67 ± 33.53a | 97–164 | 64.7 ± 6.66 | 59–72 |
| *Centaurea solstitialis* Yakima (WA) | 3 | 66.67 ± 7.09 | 59–73 | 58.67 ± 8.33 | 52–68 | 62.33 ± 6.66b | 58–70 | | |
| *Centaurea solstitialis* Concord (CA) | 3 | 70.00 ± 10.44 | 58–77 | 55.67 ± 4.51 | 51–60 | 65.67 ± 3.51c | 62–69 | | |
| *Centaurea solstitialis* Bracciano (Italy) | 3 | 68.33 ± 10.02 | 57–76 | 49.00 ± 3.61 | 46–53 | 67.00 ± 7.55d | 59–74 | | |
| *Centaurea solstitialis* Bari (Italy) | 3 | 65.67 ± 9.45 | 55–73 | 33.33 ± 16.80 | 15–48 | 59.33 ± 12.50d | 45–68 | | |
| | | | | Group III | | | | | |
| *Centaurea solstitialis* Greece (control) | 3 | 67.00 ± 31.48 | 41–102 | 56.33 ± 30.11 | 32–90 | 103.33 ± 57.85a | 54–167 | 62.0 ± 4.58 | 58–67 |
| *Centaurea solstitialis* va. *schowii* (Italy) | 3 | 66.00 ± 9.17 | 58–76 | 23.33 ± 5.51 | 18–29 | 26.33 ± 5.41b | 21–32 | | |
| *Centaurea jacea* Italy | 3 | 45.67 ± 1.53 | 44–47 | 10.00 ± 2.00 | 8–12 | 12.33 ± 3.51c | 9–16 | | |
| Centaurea maculosa Italy | 3 | 71.67 ± 5.86 | 65–76 | 9.00 ± 3.61 | 5–12 | 13.00 ± 5.29d | 7–17 | | |
| *Centaurea paniculata* Italy | 3 | 49.00 ± 9.54 | 38–55 | 1.00 ± 1.00 | 0–2 | 2.00 ± 2.00b | 0–4 | | |
| | | | | Group IV | | | | | |
| *Centaurea solstitialis* Greece (control) | 3 | 92.00 ± 14.73 | 76–105 | 78.33 ± 15.31 | 69–96 | 132.67 ± 14.84a | 120–149 | 62.0 ± 3.00 | 59–65 |
| *Centaurea calcitrapa* Italy | 3 | 85.33 ± 21.55 | 63–106 | 23.33 ± 3.21 | 21–27 | 26.67 ± 4.16b | 22–30 | | |
| *Centaurea calcitrapa* Greece | 3 | 43.00 ± 7.00 | 38–51 | 33.33 ± 7.37 | 25–39 | 34.33 ± 7.37b | 26–40 | | |
| *Onopordum acanthium* USA | 3 | 5.00 ± 2.00 | 3–7 | 0.00 ± 0.00 | 0–0 | 0.00 ± 0.00 | 0–0 | | |

Ten males and ten females per replication. Three replicates made per plant species. Means followed by the same letter are not significantly different ($P < 0.05$, Student-Newman-Keuls a posteriori test).

Bu-3 and Bu-4 received few eggs, whereas no eggs were laid on F-1 and F-2 floral buds. Stage Bu-1 had 31.50 ± 14.20 exposed buds per plant replicate of which 22.20 ± 11.62 were attacked, receiving 65.30 ± 47.66 eggs per replicate. Stage Bu-2 had 8.00 ± 5.70 buds per replicate and 5.80 ± 3.88 were infested, receiving 13.90 ± 7.11 eggs per replicate. Stages Bu-3 and Bu-4 were much less attacked, receiving 3.10 ± 2.69 and 0.60 ± 0.84 eggs per replicate (Table 4).

**Table 4. Bud size preference for ovipositional site of *B. orientalis* on yellow starthistle, 1983 (mean ± SD)**

| Flower bud category | No. buds/plant | No. buds attacked/plant | No. eggs laid/plant |
|---|---|---|---|
| Floral bud stage Bu-1 | 31.50 ± 14.20 | 22.20 ± 11.62 | 65.30 ± 47.66 |
| Floral bud stage Bu-2 | 8.00 ± 5.70 | 5.80 ± 3.88 | 13.90 ± 7.11 |
| Floral bud stage Bu-3 | 3.80 ± 2.74 | 1.50 ± 0.97 | 3.10 ± 2.69 |
| Floral bud stage Bu-4 | 3.10 ± 1.52 | 0.40 ± 0.52 | 0.60 ± 0.84 |
| Anthesis stage F-1 | 2.20 ± 1.14 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Anthesis stage F-2 | 1.70 ± 0.82 | 0.00 ± 0.00 | 0.00 ± 0.00 |

One male and one female used per replicate. Ten replicates made.

## Discussion

Although some adults in this study oviposited on plants from which they have not been recorded, such as *Centaurea diffusa*, *C. jacea*, *C. maculosa*, *C. calcitrapa*, and *O. acanthium*, they deposited a majority of their eggs on *C. solstitialis*. Moreover, *C. solstitialis* was the only test plant to support larval development; there was no larval survival on *C. diffusa*, *C. jacea*, *C. maculosa*, *C. calcitrapa*, and *O. acanthium*. First instars that hatched from eggs placed on floral buds of other plant species died after hatching or after feeding on the nontarget floral bud. These studies confirm the findings of 1984 open-field host specificity tests in Greece (Maddox and Sobhian 1987). Oogenesis studies showed that *B. orientalis* females were incompatible with host plants other than *C. solstitialis*, their eggs atrophying after being switched from *C. solstitialis* to safflower or native *Cirsium* species (Maddox and Sobhian 1987). While checking for adults or eggs on various plant genera (*Centaurea*, *Carduus*, *Onopordum*, *Cirsium*, and *Galactites*) in the field in northern

Greece (Campobasso, unpublished data) as well as in the laboratory, we found that *C. solstitialis* is the only host of *B. orientalis* capable of supporting larval development. The results of these 1982–1984 host specificity studies in Rome, and field studies in Thessaloniki, Greece, at the same time (Maddox and Sobhian 1987), supported release of this weevil against yellow starthistle in the United States in 1985. The weevil was released and become established in California, Oregon, Washington, and Idaho (Grossman 1989, Turner 1996).

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