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HOST SPECIFICITY OF *CHAETORELLIA AUSTRALIS* (DIPTERA: TEPHRITIDAE) FOR BIOLOGICAL CONTROL OF YELLOW STARTHISTLE (*CENTAUREA SOLSTITIALIS*, ASTERACEAE)

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Abstract.—The flower head tephritid fly *Chaetorellia australis* Hering was studied to determine its host specificity for biological control of *Centaurea solstitialis* L. (yellow starthistle) in the United States. Flies from flower heads of *C. cyanus* L. collected in northern Greece were tested for oviposition and development on nine plant species in no-choice host tests during the summers of 1986–87 in Albany, California. Oviposition and development occurred on only two species: flies damaged 93.7% (1986) and 79.6% (1987) of the heads of *C. solstitialis* and 85.8% of the heads of *C. cyanus*. No evidence of oviposition and development occurred on the other test plant species: *Centaurea americana* Nutt., *Centaurea rothrockii* Greenm., *Carthamus tinctorius* L., *Cirsium occidentale* (Nutt.) Jeps., *Helianthus annuus* L., *Zinnia elegans* Jacq., and *Lactuca sativa* L.. More than 92% of the pupal fly-yielding flower heads produced only one pupal fly, while less than 8% of these flower heads had two pupal flies, indicating that the fly is not particularly gregarious.

Key Words: biological control, weed, rangeland, insect

Yellow starthistle (*Centaurea solstitialis* L., Asteraceae) is a winter annual that is a naturalized weed primarily in the western United States. Surveys indicate that it occurs in 208 counties in 23 states within the U.S. (Maddox et al. 1985), and infestations in California alone have reached an estimated 3.25 million gross hectares (Maddox and Mayfield 1985). The weed is a pioneering species that is especially invasive on disturbed lands. Its primary economic impact is on rangelands where it reduces livestock productivity because of its unpalatability, competitiveness, and toxicity to horses (Maddox et al. 1985). Yellow starthistle is believed to be native to the eastern Mediterranean Basin and western Asia (Prodan 1930). Multiple introductions have probably occurred in the U.S. (Maddox and Mayfield 1985). An analysis of seeds contained in adobe bricks from early buildings in California indicates that yellow starthistle was introduced in the nineteenth century after 1824 (Hendry 1931, Hendry and Bellue 1936, Maddox and Mayfield 1985).

A search for natural enemies of yellow

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starthistle and other weedy members of the thistle tribe (Cardueae) was begun in Europe in the late 1950's (Zwolfer et al. 1971). In 1985 the flower head weevil, *Bangasternus orientalis* (Capiomont) (Coleoptera: Curculionidae), was introduced from northern Greece for biological control of yellow starthistle and is now successfully established in several western states (Maddox et al. 1986). Sobhian and Zwolfer (1985), in their studies of the yellow starthistle flower head–insect host system, show that the larvae of about 20 phytophagous insect species utilize the flower heads of yellow starthistle in the Mediterranean Basin and regions in the northern half of the Balkan Peninsula. *Chaetorellia australis* Hering is one of those flower head insects that offers promise as a biological control agent. Tephritid fly species, including *C. australis,* are considered to be one of the most important elements within the guild of insects utilizing the flower heads (Sobhian and Zwolfer 1985). They are important flower head feeders on asteraceous species in general, and are often either strongly monophagous or stenophagous on their host plants. Flower head feeders may be especially important as biological control agents because yellow starthistle is an annual weed that relies solely on seed production to reproduce. This fly has previously been referred to as *Chaetorellia hexachaeta australis* Hering (White and Marquardt 1989).

Biology

The biology of *C. australis* in northern Greece is as follows (Sobhian and Zwolfer 1985, Sobhian and Pittara 1988): Three generations of flies occur per year. Females begin oviposition after adult emergence in the spring. Under uncrowded conditions, a female usually oviposits beneath an involucral bract one egg per host flower head. Oviposition occurs preferentially on mature, closed flower head buds. Each egg characteristically possesses a long filament, which can extend beyond the margins of a bract. Under laboratory conditions, females may oviposit up to 243 eggs during an ovipositional period of up to 60 days. Hatched larvae tunnel through the involucre into the interior of the flower head, where they tunnel through and feed on many ovaries and developing achenes. In one limited test, a single larva destroyed an average of 86.3% of the seeds in a flower head (Sobhian and Pittara 1988). According to Sobhian and Pittara (1988), the overwintering generation passes the winter as mature larvae within cocoons made of pappus hairs inside the flower heads of *C. solstitialis.* The overwintering larvae pupate and emerge as adults the following spring in April and May. The first generation larvae develop primarily on *C. cyanus* as it typically flowers earlier than *C. solstitialis*; the second and third (overwintering) generation larvae develop on *C. solstitialis.*

Taxonomy, Host Range, and Geographic Distribution

The following information is from White and Marquardt (1989) unless otherwise specified. *Chaetorellia* is a Palearctic genus of nine known species in the tribe Terellinae. *Chaetorellia australis* is one of probably five *Chaetorellia* species in the *C. jaceae* species-group. *Chaetorellia australis* was originally described by Hering (1940) as a subspecies of *Chaetorellia hexachaeta* (Loew). The known hosts of all known species of *Chaetorellia* are species of *Centaurea, Carthamus* and *Chartolepis* in the Cardueae subtribe Centaureinae. The known hosts of species of *Chaetorellia* in the *C. jaceae* species-group are species of *Centaurea.* The host records for *C. australis* include *C. solstitialis* from Bulgaria, Greece, Hungary, Turkey and Moldavian SSR; *C. cyanus* from Greece and Hungary; and *C. depressa* Bieb. from Turkey. *Centaurea solstitialis* is in the subgenus *Solstitiaria,* and *C. cyanus* and *C. depressa* are in the subgenus *Cyanus* (Dostal 1976). In an extensive field sample of natural populations of a di-

Table 1. *Chaetorellia australis* no-choice host specificity tests in Albany, California, 1986–87.

Plant Species	Year Tested	No. of Plants Tested	Total Heads Tested	% Damaged Heads (with Frass, Larvae, Pupae or Pupal Cases)	% Heads with Frass Only	% Heads with Larvae, Pupae, or Pupal Cases
Centaurea solstitialis	1986	25	320	93.7	32.2	61.5
Centaurea solstitialis	1987	16	113	79.6	15.0	64.6
Centaurea cyanus	1987	20	268	85.8	1.5	84.3
Centaurea americana	1986	25	39	0	0	0
Centaurea rothrockii	1986	14	45	0	0	0
Carthamus tinctorius ("Hartman")	1986	25	72	0	0	0
Carthamus tinctorius ("4440")	1987	20	107	0	0	0
Cirsium occidentale	1986	25	73	0	0	0
Helianthus annuus	1986	25	68	0	0	0
Zinnia elegans	1986	13	145	0	0	0
Lactuca sativa	1986	20	800	0	0	0

verse array of thistles throughout mainland Greece in 1985, *C. australis* was reared only from the flower heads of *C. solstitialis* and *C. cyanus* (Turner et al. in press).

Host Specificity Testing

Host specificity was measured in no-choice cage tests of *C. australis* oviposition and development on nine test plant species. The adult flies used in all tests were collected in northeastern Greece (by R. Sobhian) as larvae in heads of *C. cyanus* and shipped to the USDA-ARS quarantine facility of the Biological Control of Weeds Laboratory at Albany, California. Tests were carried out in this quarantine facility during the summers of 1986 and 1987.

Host test plant species were chosen on the basis of taxonomic affinity, economic significance, and place of origin. The test plant species were *C. solstitialis, C. cyanus, C. americana* Nutt., *C. rothrockii* Greenm., two varieties of *Carthamus tinctorius* L., *Cirsium occidentale* (Nutt.) Jeps., *Helianthus annuus* L., *Lactuca sativa* L., and *Zinnia elegans* Jacq.. All test plant species are in the Asteraceae, and all are in the thistle tribe Cardueae except *H. annuus, L. sativa* and *Z. elegans. Carthamus tinctorius* (safflower) and *H. annuus* (sunflower) are oilseed crops, and *H. annuus* is native to the United States. *Carthamus tinctorius* var. "Hartman" is grown primarily in the northern plains area, while *C. tinctorius* var. "4440" was developed primarily for California. *Zinnia elegans* (zinnia) is an ornamental, and *L. sativa* (lettuce) is a leafy food crop. *Centaurea americana, C. rothrockii* and *C. occidentale* are thistles native to the United States. *Centaurea solstitialis* and *C. cyanus,* the known hosts, served as controls.

Test plants were grown in 15 cm pots and the plants of each species were arranged on a wood base platform (ca. 1 m^2) according to a random number table. The test plants were enclosed by 1 m^3 screen cages that rested on the wooden bases. One plant species was tested per cage. Thirteen to 25 plants were tested per plant species (Table 1). One pair (1♀ 1♂) of newly emerged files were used per test plant; for example 25 plants and 25 pairs of flies (50 flies total) were enclosed by a cage in the test with *C. americana* (Table 1). The flies were released into each cage where they had free access to the test plants. Food for the adult flies was provided by a 30 ml shell vial with a wick containing a honey-water solution. The tests were conducted under natural light conditions (14.5–16 h light; average of 24°C daytime and 13°C nightime). Tests were terminated when all adult female flies were dead, the longest last-

Table 2. Number of pupae per infested flower head in *Chaetorellia australis* no-choice host specificity tests in Albany, California, 1986–1987.

Plant Host Species (Year Tested)	No. Flower Heads Infested by Pupae	% Flower Heads with 1 Fly Pupa per Flower Head[1]	% Flower Heads with 2 Fly Pupae per Flower Head[1]
Centaurea solstitialis (1986)	143	92.3	7.7
Centaurea solstitialis (1987)	55	94.5	5.5
Centaurea cyanus (1987)	198	98.7	1.3

[1] Pupal counts include intact living pupae and pupal cases from emerged flies.

ing 36 days. The flower heads were then dissected and microscopically examined for evidence of *C. australis* feeding and development (frass, larvae, pupae or pupal cases). Tests were conducted between 18 June to 10 September 1986, and 15 June to 24 July 1987.

Results and Discussion

Oviposition and larval development occurred only on *C. solstitialis* and *C. cyanus*, and these species were heavily attacked as evidenced by the presence of frass, larvae, pupae or pupal cases. Next generation adult flies emerged only in the cages containing *C. solstitialis* and *C. cyanus*. There was no evidence of host use of any of the other test plant species. For *C. solstitialis*, 93.7% of the flower heads in 1986 and 79.6% of the flower heads in 1987 were attacked by the fly, while 85.8% of the *C. cyanus* flower heads were attacked (Table 1). Our results are congruous with the known host records (White and Marquardt 1989, Turner et al. in press). All available information indicates that *C. australis* has a narrow host range with *C. solstitialis*, *C. cyanus* and *C. depressa* as the only known hosts. The restricted host range of this fly provides strong evidence that it is safe for introduction into the United States as a biological control agent for yellow starthistle.

In the course of the flower head dissections, the numbers of pupae and pupal cases (from emerged flies) per flower head were noted. *Chaetorellia australis* does not appear to be gregarious as mostly only one or sometimes two pupae were found in infested flower heads (Table 2). For *C. solstitialis*, 92.3% (1986) and 94.5% (1987) of the infested flower heads had only one pupa, and 98.7% of the infested flower heads of *C. cyanus* had only one pupa (Table 2).

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