

Host-specificity Studies of *Chaetorellia australis* (Diptera: Tephritidae), A Prospective Biological Control Agent for Yellow Starthistle, *Centaurea solstitialis* (Asteraceae)

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Abstract

Chaetorellia australis (Diptera: Tephritidae) is a potential biological control agent for yellow starthistle (*Centaurea solstitialis*; Asteraceae), a naturalized weed of rangelands and crop lands in North America. The larvae of this fly are internal flowerhead feeders. This paper reports the results of two studies that were carried out to assay the host-specificity of the fly. A field host range study of Greek flowerhead insects, including *C. australis*, was undertaken in which natural thistle populations were sampled throughout mainland Greece. In 1985 a total of 164 population samples of flowerheads were taken from a diverse array of thistle species of 10 genera from four thistle subtribes, and kept for the emergence of adult flowerhead insects. The results of this study were that *C. australis* emerged only from the flowerheads of *C. solstitialis* and *Centaurea cyanus*. These results are congruent with previous host records for the fly. A laboratory no-choice host-specificity study of the fly was carried out in 1986 and 1987 with the test plants *C. solstitialis*, *C. cyanus*, *Centaurea americana*, *Centaurea rothrockii*, *Cirsium occidentale*, two varieties of *Carthamus tinctorius* (safflower), *Helianthus annuus* (sunflower), *Lactuca sativa* (lettuce), and *Zinnia elegans*. The results of this study were that next generation adult flies emerged only from *C. solstitialis* and *C. cyanus*, and that only the flowerheads of these hosts were attacked by the fly as evidenced by the presence of frass, larvae, pupae and pupal cases in the flowerheads. The fly attacked 80% (1987) to 94% (1986) of the flowerheads of *C. solstitialis*, and 86% of the flowerheads of *C. cyanus*. None of the flowerheads of the other test plant species were attacked by the fly. These studies support the conclusion that *C. australis* has a very narrow host range, where the only demonstrated hosts are *C. solstitialis* and *C. cyanus*.

Introduction

Yellow starthistle (*Centaurea solstitialis* L.; Asteraceae) is a naturalized weed of rangelands and crop lands in the western United States, where it is most problematical in the States of California, Idaho, Oregon and Washington (Reed and Hughes 1970, Maddox *et al.* 1985). In California alone the gross infestation area of yellow starthistle exceeds three million ha (mostly in northern California), and it increased more than 640% between 1958 and 1985 (Maddox and Mayfield 1985), an average increase of *ca.* 24% per year. The spiny flowerheads of yellow starthistle are unpalatable to livestock, and yellow starthistle is poisonous to horses in which it causes a potentially lethal neurological disorder called nigropallidal encephalomalacia or "chewing disease" (Cordy 1954, Cordy 1978). Yellow starthistle is also a weed in fields of alfalfa and cereal grains (Reed and Hughes 1970, Robbins *et al.* 1970). Yellow starthistle populations are often very dense and, because of the long stout spines on the flowerheads, are a nuisance on recreational lands. This weed is native to Eurasia, and is a member of the thistle tribe Cardueae and the subtribe Centaureinae.

The flowerhead weevil *Bangasternus orientalis* (Capiomont) (Coleoptera: Curculionidae) is the only biological control agent presently established in the U.S.A. for control of yellow starthistle. This weevil was first introduced from Greece in 1985 (Maddox *et al.* 1986), and is presently established in California, Idaho, Oregon and Washington. Adult *B. orientalis* females oviposit on the small leaves arising from the stem below the flowerhead buds. The larvae feed, develop and pupate inside the flowerhead, where they feed primarily on receptacle tissue. The weevil is univoltine in Greece and California (Sobhian and Zwölfer 1985, Maddox *et al.* 1986). It is too early to know what impact *B. orientalis* will have on yellow starthistle in the U.S.A., but it is expected that additional natural enemies will

supplement the effect of *B. orientalis* and further contribute to biological control of yellow starthistle.

Chaetorellia (Diptera: Tephritidae) is a Palearctic genus of nine known species in the tribe Terelliini (I.M. White, unpubl. rep., CAB Int. Inst. of Ent.). The flowerhead fly *Chaetorellia hexachaeta* ssp. *australis* Hering is a potential biological control agent for yellow starthistle. A forthcoming revision is expected to give full specific rank to *C. australis* Hering; the true application of the name *C. hexachaeta* is uncertain. For convenience, the species in question is hereafter called *C. australis*. Females oviposit on the inner surface of the involucre bracts on the host flowerhead shortly before anthesis. Hatched larvae burrow into the host flowerhead where they feed on ovules and developing seeds. The larvae tunnel through many ovules/seeds while feeding, and have the potential to destroy most of the seeds in a flowerhead. *C. australis* is apparently multivoltine, with perhaps three generations per year in northern Greece. In Greece, the overwintering generation passes the winter in yellow starthistle flowerheads as late instar larvae, and pupate to emerge as adults the following spring.

The known host plants of all *Chaetorellia* species are species of the genera *Centaurea*, *Carthamus* and *Chartolepis* in the subtribe Centaureinae; and the known host plants of all *Chaetorellia* species in the *jaceae* species group (which includes *C. australis*) are species of *Centaurea* (I. M. White, unpubl. rep., CAB Int. Inst. of Ent.). The reported records for *C. australis* prior to the work reported here include yellow starthistle in Greece, Turkey, Hungary and Moldavian SSR, and *Centaurea cyanus* L. in Greece and Hungary (I. M. White, unpubl. rep., CAB Int. Inst. of Ent.). (*C. cyanus* also is a naturalized weed in North America [Robbins *et al.* 1970], where it occurs as scattered weedy populations throughout most of the yellow starthistle areas.) A field host range study and a laboratory host-specificity experimental study were carried out to assay further the host-specificity of the fly.

Methods and Materials

Field Host Range Study

The purpose of this study was to sample a diverse array of thistles to derive a comprehensive database of the field host range of Greek thistle flowerhead insects, including *C. australis*. Natural populations of thistles (Asteraceae: Cardueae) were sampled for flowerhead insects throughout mainland Greece in July and September 1985, and in June, August and September 1986. Each sample consisted of flowerheads collected at a stage just after anthesis and before seed dissemination from a number of different plants scattered throughout the population. A mean of 95.4 flowerheads ($s = 14.19$) were collected from a mean of 18.5 plants ($s = 8.97$) per sample population in 1985. All arthropods on the exterior of the sampled flowerheads, including ants, spiders and other potential predators, were removed immediately. The flowerhead samples were then shipped to the USDA-ARS quarantine facility in Albany, California. Here the flowerheads were again checked for potential predators, put into cardboard cartons with a mesh screen at one end, and kept for emergence of adult insects, including *C. australis*. All *Chaetorellia* flies that emerged were sent to I.M. White for determination. Only the material from the 1985 survey has been processed so far.

In 1985 a total of 164 samples were taken from ten thistle genera from all four thistle subtribes: Centaureinae - *Carthamus*, *Centaurea*; Carduinae - *Carduus*, *Cirsium*, *Cynara*, *Onopordum*, *Ptilostemon*; Carlininae - *Carlina*, *Xeranthemum*; Echinopsidinae - *Echinops* (Table 1). The genera *Centaurea*, *Carthamus*, and *Cirsium* were emphasized in the 1985 sample because of their availability and for the following reasons. *Centaurea* (77 samples) contains the known hosts which serve as a "control" for this study, and samples of other *Centaurea* were necessary to ascertain whether other *Centaurea* spp. are also hosts for the fly. *Carthamus* (29 samples) contains safflower (*C. tinctorius* L.), the only commercially-significant plant within the same subtribe as the host plants. Two common *Carthamus* species, *C. dentatus* (Forsk.) Vahl and *C. lanatus* L., were sampled; safflower itself was not seen in Greece. *Cirsium* (27 samples) is important for the large number of native species in North America (Turner 1985, Turner *et al.* 1987).

Table 1. Results of emergence of *Chaetorellia australis* Hering from flowerheads of natural populations of thistles (Asteraceae: Cardueae) sampled in Greece in 1985.

Thistle genus	Thistle subtribe	No. of samples ¹	Emergence of <i>C. australis</i>
<i>Carduus</i>	Carduinae	9	No
<i>Carlina</i>	Carlininae	5	No
<i>Carthamus</i>	Centaureinae	29	No
<i>Centaurea</i>	Centaureinae	77	Yes ²
<i>Cirsium</i>	Carduinae	27	No
<i>Cynara</i>	Carduinae	1	No
<i>Echinops</i>	Echinopsidinae	5	No
<i>Onopordum</i>	Carduinae	3	No
<i>Ptilostemon</i>	Carduinae	2	No
<i>Xeranthemum</i>	Carlininae	6	No

¹ A mean of 95.4 flowerheads ($s = 14.19$) from a mean of 18.5 different plants ($s = 8.97$) per population sample.

² Emerged only from *Centaurea cyanus* and *C. solstitialis*.

Laboratory No-Choice Host-Specificity Study

Host-specificity no-choice tests were carried out in the USDA-ARS quarantine facility at Albany, California during 1986 and 1987 (D.M. Maddox, A. Mayfield and C. E. Turner, unpubl. data). Test plant taxa were chosen on the basis of taxonomic affiliation, commercial significance, and place of origin (Table 2). The test plant taxa were *Centaurea solstitialis*, *Centaurea cyanus*, *Centaurea americana* Nutt., *Centaurea rothrockii* Greenm., *Carthamus tinctorius* var. "4440", *C. tinctorius* var. "Hartman", *Cirsium occidentale* (Nutt.) Jeps., *Helianthus annuus* L., *Lactuca sativa* L., and *Zinnia elegans* Jacq. Because field host data indicated a very narrow host range, all test plant species were in the Asteraceae, and most were in the subtribe Centaureinae. The known hosts *C. solstitialis* and *C. cyanus* served as controls for the experiment. Two varieties of safflower (*C. tinctorius*) were tested: variety "4440" represented varieties grown in California; and variety "Hartman" represented varieties grown in more northerly latitudes in the U.S.A. *Centaurea americana*, *C. rothrockii*, and *Cirsium occidentale* are thistles native to the U.S.A. The remaining test plant species are outside the thistle tribe. Sunflower (*H. annuus*) is an oilseed crop, lettuce (*L. sativa*) is a leafy food crop, and zinnia (*Z. elegans*) is an ornamental.

The tests were carried out under natural light conditions in the quarantine glasshouse, where the photoperiod ranged between 14.5 and 16 h, and the temperatures averaged 24°C during the day and 13°C at night. The test plants were placed on wooden platforms under 1 m³ screen cages, one test plant taxon/cage, and 13 - 25 test plants/taxon. Flowerheads of *C. cyanus* were field-collected in Greece and shipped to Albany, where adult *C. australis* flies emerged and were used in the tests. Newly-emerged adult flies were put into the test cages at the rate of one male-female pair per individual test plant. Thus, for example, in the 1986 test with yellow starthistle, 25 males and 25 females were released into a cage with 25 plants of

Table 2. Plant species for *Chaetorellia australis* Hering no-choice host tests, 1986-7.

Test plant species	Family, Tribe	Cardueae Subtribe	Common Name	U.S.A. Status
<i>Centaurea solstitialis</i> L.	Asteraceae, Cardueae	Centaureinae	yellow starthistle	naturalized target weed
<i>Centaurea cyanus</i> L.	Asteraceae, Cardueae	Centaureinae	cornflower, bachelor button	ornamental, naturalized weed
<i>Centaurea americana</i> Nutt.	Asteraceae, Cardueae	Centaureinae	American knapweed	native knapweed
<i>Centaurea rothrockii</i> Greenm.	Asteraceae, Cardueae	Centaureinae	Rothrock's knapweed	native knapweed
<i>Carthamus tinctorius</i> L. var. "4440"	Asteraceae, Cardueae	Centaureinae	safflower	oilseed crop
<i>C. tinctorius</i> var. "Hartman"	Asteraceae, Cardueae	Centaureinae	safflower	oilseed crop
<i>Cirsium occidentale</i> (Nutt.) Jeps.	Asteraceae, Cardueae	Carduinae	western thistle	native thistle
<i>Helianthus annuus</i> L.	Asteraceae, Heliantheae	-	sunflower	oilseed crop, native plant
<i>Lactuca sativa</i> L.	Asteraceae, Lactuceae	-	lettuce	leafy food crop
<i>Zinnia elegans</i> Jacq.	Asteraceae, Heliantheae	-	zinnia	ornamental

yellow starthistle. Because the flies were released into cages containing only one test plant taxon per cage, these were no-choice host tests. After the next generation adult flies began to emerge from the known host plants, the post-anthesis flowerheads were removed from all test plants and examined for any evidence of host use. Dissected flowerheads were checked for the presence of frass, larvae, pupae, or pupal cases from emerged flies.

Results and Discussion

The results of the field host range study were that *C. australis* was reared only from the known hosts yellow starthistle and *C. cyanus* (Table 1). These results are congruent with the previous host records for the fly. A significant aspect of this study are the negative data, that is, the many and diverse thistles sampled but from which the fly did not emerge.

The results of the laboratory no-choice host-specificity study were as follows (D.M. Maddox, A. Mayfield and C.E. Turner, unpubl. data). Next generation adult flies emerged only from yellow starthistle and *C. cyanus*, and all test plants of yellow starthistle and *C. cyanus* had flowerheads attacked by the fly. The fly attacked 80% (1987) to 94% (1986) of the yellow starthistle flowerheads, and 86% of the *C. cyanus* flowerheads, as evidenced by the presence of frass, larvae, pupae or pupal cases in the flowerheads (Table 3). There was no evidence of host use of any of the other test plant species by the fly (Table 3). The value of no-choice host tests is that they constitute a very conservative test. If the test insect will not use a test plant species when no alternative is available, this is a very strong indicator that test plant species is not even a marginally suitable host for the test insect. Both the field host range study and the laboratory no-choice host-specificity study support the conclusion that *C. australis* has a very narrow host range, where the only demonstrated hosts for the fly are yellow starthistle and *C. cyanus*.

Table 3. Results of *Chaetorellia australis* Hering no-choice host tests, 1986-7.

Test plant species	No. plants tested	No. heads tested	% Heads with frass, larvae, pupae or pupal cases
<i>Centaurea solstitialis</i> L. (1986) ¹	25	320	94
<i>C. solstitialis</i> (1987) ¹	16	113	80
<i>Centaurea cyanus</i> L. ¹	20	268	86
<i>Centaurea americana</i> Nutt.	25	39	0
<i>Centaurea rothrockii</i> Greenm.	14	45	0
<i>Carthamus tinctorius</i> L. var. "4440"	20	107	0
<i>C. tinctorius</i> var. "Hartman"	25	72	0
<i>Cirsium occidentale</i> (Nutt.) Jeps.	25	73	0
<i>Helianthus annuus</i> L.	25	68	0
<i>Lactuca sativa</i> L.	20	800	0
<i>Zinnia elegans</i> Jacq.	13	145	0

¹ Next generation adult flies emerged from these test plant species.

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References

- Cordy, D.R. 1954. Nigropallidal encephalomalacia in horses associated with ingestion of yellow star thistle. *J. Neuropath. Exp. Neurol.* 13:330-42.
- Cordy, D.R. 1978. *Centaurea* species and equine nigropallidal encephalomalacia. In: *Effects of Poisonous Plants on Livestock*. Keeler, R.F., K.R. Van Kampen and L.F. James (eds.). Academic Press, NY, pp. 327-36.
- Maddox, D.M. and A. Mayfield. 1985. Yellow starthistle infestations are on the increase. *Calif. Agric.* 39:10-2.
- Maddox, D.M., A. Mayfield and N.H. Poritz. 1985. Distribution of yellow starthistle (*Centaurea solstitialis*) and Russian knapweed (*Centaurea repens*). *Weed Sci.* 33:315-27.
- Maddox, D.M., R. Sobhian, D.B. Joley, A. Mayfield and D. Supkoff. 1986. New biological control for yellow starthistle. *Calif. Agric.* 40: 4-5.
- Reed, C.F. and R.O. Hughes. 1970. *Selected Weeds of the United States*. USDA, ARS, Agric. Hdbk. No. 366. Washington, D.C., 463 p.
- Robbins, W.W., M.K. Bellue and W.S. Ball. 1970. *Weeds of California*. Calif. State Dep. Agric., Sacramento, 547 p.
- Sobhian, R. and H. Zwölfer. 1985. Phytophagous insect species associated with flower heads of yellow starthistle (*Centaurea solstitialis* L.). *Z. Ang. Ent.* 99:301-21.
- Turner, C.E. 1985. Conflicting interests and biological control of weeds. *Proc. VI Int. Symp. Biol. Contr. Weeds*, 19-25 August 1984, Vancouver, Canada. Delfosse, E.S. (ed.). Agric. Can., Ottawa, pp. 203-225.
- Turner, C.E., R.W. Pemberton and S.S. Rosenthal. 1987. Host utilization of native *Cirsium* thistles (Asteraceae) by the introduced weevil *Rhinocyllus conicus* (Coleoptera: Curculionidae) in California. *Environ. Ent.* 16:111-5.