The release and establishment of the tansy ragwort flea beetle in the northern Rocky Mountains of Montana

J.L. Littlefield¹, G.P. Markin², K.P. Puliafico³ and A.E. deMeij⁴

Summary
The flea beetle, *Longitarsus jacobaeae* (Waterhouse) (Coleoptera: Chrysomelidae), has successfully suppressed tansy ragwort [*Senecio jacobaea* L. (Asteraceae)] in mild, mid-latitude climates of western North America. Attempts to establish this flea beetle in more continental climates, such as those found in the interior of the Pacific Northwest, have failed. With the recent incursion of tansy ragwort in northwestern Montana, a biological control program was implemented. Two populations of *L. jacobaeae* from Oregon (collected from low and high elevation sites) and cold-adapted populations from Switzerland were released between 1997 and 2006. Several release techniques using flea beetle eggs, larvae or adults were tried, and those using eggs or larval flea beetles were less successful than those using adults. Subsequent surveys indicate that the Oregon low-elevation population failed to establish and that the Oregon high-elevation and Swiss populations have established and are dispersing from their original release sites.

Keywords: tansy ragwort, ragwort flea beetle, *Longitarsus jacobaeae*.

Introduction
The Eurasian weed species, tansy ragwort, *Senecio jacobaea* L. (Asteraceae), readily invades disturbed rangelands, pastures, open forests and other natural areas in areas of the western USA. Montana was considered tansy ragwort-free until several infestations were located in Lincoln and Flathead Counties after the 1994 Little Wolf Fire (USFS, 1996). By 1997, despite extensive treatments with herbicides, the plant was found to be too widely distributed and well established to be eradicated or economically controlled. Several biological control agents were initially introduced by the US Forest Service from established sites in Oregon (Markin and Birdsall, 2002); including the cinnabar moth, *Tyria jacobaeae* L. (Lepidoptera: Arctiidae), the tansy ragwort seed fly, *Botanophila seneciella* (Meade) (Diptera: Anthomyiidae), and the tansy ragwort flea beetle, *Longitarsus jacobaeae* (Waterhouse) (Coleoptera: Chrysomelidae). An additional population of the flea beetle was later introduced from Switzerland. This paper reports on the release and successful establishment of two populations of the flea beetle in Montana.

Methods
Flea beetle populations
Three populations of the tansy ragwort flea beetle were introduced into Montana. Our initial attempt to establish *L. jacobaeae* used beetles from established populations in western Oregon. These flea beetles (referred to as the Oregon low-elevation population) were collected from the Willamette Valley (elevation, 75 m) or along the Oregon coast near Florence. This population was established from the Italian strain of the flea beetle collected near Rome, Italy in 1968 by K. Frick (USDA-ARS) and initially introduced into northern California in 1969 and in Oregon in 1971 (Frick, 1970; Hawkes, 1980). This population has been very effective in controlling tansy ragwort in coastal areas of...
Oregon, Washington and northern California (Hawkes and Johnson, 1978; McEvoy et al., 1991). The seasonal life cycle of the Italian strain has been reported by Frick and Johnson (1973) and Windig and Vrielin (1996). Key aspects of this phenology are (1) the adults emerge during the summer and undergo a summer aestivation, (2) adults re-emerge in the autumn with the onset of seasonal rains and begin to oviposite, (3) oviposition continues through the winter months, (4) eggs do not have a diapause and hatch within 10 days and (5) both eggs and early instar larvae can be observed during the winter months. This phenology, although well suited to milder, mid-latitude climates, is ill-adapted to colder, drier, continental climates. Previous introductions of L. jacobaeae in the interior portions of the Pacific Northwest, east of the Cascade Mountains, have not been successful (Coombs et al., 1996), and we suspected that results for Montana would be similar.

A second population of the Italian strain was also introduced from Oregon. This population (referred to as the Oregon high-elevation population) was collected from Mt. Hood, Oregon (elevation, 1100 m), and differs in phenology from the Oregon low-elevation population in that adults emerge in late summer and eggs are the primary overwintering stage (Hawkes, 1980; Markin and Birdsal, 2002). Although it has adapted to colder climates found on Mt. Hood, population density of this flea beetle appear to be less than at lower elevation sites (Markin and Birdsal, 2002).

A third population of L. jacobaeae from Switzerland was investigated, as it had been reported to be better adapted to continental climates (Frick, 1971). The life history and biological attributes that would make this population more cold-adapted were investigated by Frick (1971), Frick and Johnson (1972) and Puliafico (2003). The phenology of the Swiss population of L. jacobaeae differs from that of the Italian population in that (1) adults emerge in the later part of the summer (e.g. starting in mid-July) and do not aestivate, (2) oviposition occurs after 2 weeks and the beetles overwinter as eggs in a semi-diapaused state and (3) larvae hatch the following spring and complete their development by mid-summer. Host-specificity testing of Senecio and Packera species endemic to northwestern Montana indicated no significant non-targets impacts associated with the Swiss populations of L. jacobaeae (Puliafico, 2003), and therefore, the beetle could be introduced safely into Montana. Flea beetles were collected in 2002 to 2004 by U. Schaffner (CABI-Europe) from St. Imier and Mettembert, Switzerland, from elevations of 820 and 640 m, respectively.

Release methods and monitoring

Several different release techniques were used to establish L. jacobaeae in Montana. Adults were used for the releases of the Oregon low-elevation population. Beetles were collected from sites in Oregon in early September and were field-released within large cages (2 x 4 x 2 m) or smaller cages (1 x 1 x 1 m). L. jacobaeae collected from Switzerland were screened before release for possible parasites, pathogens and other flea beetle species at the Montana State University Biological Control Containment Facility. Eggs obtained from field-collected adults were used for initial releases and for maintaining a laboratory colony for subsequent releases. Initial releases of the Swiss population used eggs. Eggs were harvested and placed in groups of 25 eggs on a strip of filter paper, which was placed next to the root crown of tansy ragwort plants at field sites and held in place by moistened peat moss or soil. Eggs were placed in the field in early November and, after cold treatment, in late April or early May, June and July.

In subsequent years, we also inoculated plants with newly hatched larvae, or adults were released uncaged or into cages (2 x 4 x 2 m). The Oregon high-elevation populations were released as adults in cages and also as larvae transplanted into the field in infested plants from a laboratory colony or as larvae in infested plant material, which was placed on tansy ragwort in the field. The success of releases was determined by the collection and dissection of plants throughout the summer to look for larvae or to determine larval feeding. This was conducted during the year of release and the following year. Adults were vacuumed sampled on a yearly basis using a modified leaf blower. Sites were sampled from late July through late October or early November. Due to uneven plant densities, adult counts were expressed as adults per 100 plants.

Results

Oregon low elevation population

Releases were made in 1997 and 1998, with a total of 435 adults released at six sites in Flathead County. Approximately 170 to 280 adults were released per site, although numerous smaller releases of 10–15 adults were also made. Adults were recovered at low levels for 2 or 3 years after release. Flea beetle feeding was observed in early September, and adults were observed from mid-September to mid-October. By 2005, no adults were recovered at release sites. During this time, the tansy ragwort density at sites significantly declined due to cinnabar moth feeding (Markin and Littlefield, 2006). This decline may have impacted any flea beetle populations remaining at these sites. To our knowledge, no long-term establishment of this population has occurred in Montana.

Oregon high elevation population

Before the release of the Swiss population, a second population of L. jacobaeae was located on the slopes of
The release and establishment of the tansy ragwort flea beetle in the northern Rocky Mountains of Montana

Mt. Hood, Oregon. Releases were made starting in 1999 and continued through 2001. An estimated 410 adults and 2905 larvae were released at 20 sites in Flathead and Lincoln Counties. Releases made in 1999 were inadvertently sprayed with herbicides, and no recoveries of the flea beetle have been made from these sites. Based on observations of the flea beetle habitats on Mt. Hood, releases in 2001 occurred in more mesic habitats along the Little Wolf drainage in Lincoln County. By 2002, larvae were recovered at four sites where either adult or transplanted infested plants were placed. In 2006, we determined that the Oregon high-elevation population had increased in numbers and dispersed several hundred metres from the initial releases in the Little Wolf drainage. Flea beetles were most evident in moist micro-habitats. At one site, adults were sampled along a moisture gradient, starting at a wet seep (the site of release), then progressing out 60 m into a drier habitat. The number of adults was higher along the wet seep (92 beetles per 100 plants) but decreased rapidly (two to nine beetles per 100 plants) as one moved into drier areas. We are not certain if the presence of adults in the wet area was due to available water, greater plant density or if moisture conditions are favourable for egg laying and/or survival.

Swiss population

A total of 27,560 eggs, 16,435 larvae and 2937 adults have been released at field sites from 2002 to 2006. Several release techniques were used in our effort to establish flea beetles. Our initial releases (2002–2004) were made using eggs obtained from our rearing colony. As large numbers of eggs could be collected, we thought this would be an efficient way to release the insect. This technique did not appear to be successful due to low establishment. In 2005, we switched tactics by releasing larvae that had just hatched and eggs that were about to hatch. Larvae or eggs were placed on tansy ragwort rosettes or at the base of developing stems. This technique proved more difficult, as timing of the larval hatch was critical and a large number of larvae had to be placed on plants within a short time span.

With improvements in our flea beetle rearing, we were also able to release adequate number of adults for the first time in 2005 and 2006. Adult releases have several advantages in that they are less time consuming, adults are less vulnerable to handling damage and they are more likely to select oviposition sites that maximize offspring survival.

In general, the technique of using eggs to inoculate plants proved unsatisfactory. Although larvae were recovered from plants with autumn and spring inoculations, no recoveries were made on those inoculated in June or July. It is speculated that eggs may have desiccated, were more susceptible to predation or the plants were unsuitable for larval establishment at these later dates. Of the 21 sites with egg inoculations, three have recoverable beetle populations after 4 years.

With the success of the cinnabar moth on the Flathead County side of the tansy ragwort infestation, most of the sites were abandoned due to very low tansy ragwort plant densities. However, there was indication that the flea beetle had established before the rapid decline of tansy ragwort. Two sites in Flathead County were retained, as these appeared to have persistent pockets of tansy ragwort, and adults of the Swiss population were released at these sites in 2005. In Lincoln County, where the cinnabar moth has not been as successful, at two sites that received larvae in 2005, adults were recovered, and of the ten adult releases made before 2006, adults were recovered at nine.

Thirty-two release locations (a location may be comprised of several individual release plots) were visited in August and September 2006. Flea beetle adults were observed at 23 locations (72% of the locations). Beetles were observed at all, except for one, of the 2005 releases. At selected sites in the Little Wolf drainage in Lincoln County, adult beetles were collected and returned to the laboratory to confirm their population origin. From egg hatch data, it appeared that both the Swiss and Oregon high-elevation populations (see below) are present in the Little Wolf drainage, and at some sites, both populations (and/or possible hybrids) are present. Sites in which flea beetles have been recovered ranged from seasonally moist (e.g. intermittent streams) to dry (e.g. burnt slash piles).

There has been a gradual increase in the number of adult flea beetles recovered in vacuum sampling. The mean number of adults was 2.4/100 plants in 2004 (range, 1–5), 2.4/100 plants in 2005 (range, 1–5) and 7.8/100 plants in 2006 (range, 1–42). The number of beetles collected represents only a small portion of the beetles actually present due to sampling bias (i.e. the sampling technique). Also the number of adults collected may vary due to date, time of day or weather conditions. We consider the Swiss population of the flea beetle to have become established since it has persisted for several years and increased in density, although no dispersal from the original sites has been observed.

Phenological development

Despite low flea beetle populations, a general indication of the phenological development of the three L. jacobaeae populations in Montana can be inferred. The life history of the Oregon low-elevation population appears to be similar to that reported in the literature (Frick and Johnson, 1973; Windig and Vrieling, 1996), with the exception of a longer larval developmental period. Adults emerge from pupation in mid-September. Eggs and first instar larvae were observed in mid-October and early November. During this period, soil tempera-

575
tures can drop as low as -2.5°C. These temperatures did not seem to adversely affect adults or larvae present at field sites. But by emerging in September, adults may have a reduced period of time for oviposition before the onset of colder temperatures, which may limit the subsequent population. This phenology in Montana is very similar to that reported for the Oregon high-elevation population from Mt. Hood (Markin and Birdsall, 2002). In Montana, the life history of the Oregon high-elevation population differs in that adults emerge in early August, rather than in September. This would be more advantageous to population development, as it extends the oviposition period of *L. jacobaeae*. The life history of the Swiss population in Montana is very similar to that reported by Frick (1971) and Puliafico (2003). Adults have been collected from early August to November. Oviposition occurs approximately 2 weeks after adult emergence. Eggs remain in a semidiapaused state until spring, and larvae complete their development by late July. The main disadvantage of this life history is that eggs are present in the soil during the driest time of the year and may be subjected to desiccation.

**Conclusions**

The tansy ragwort flea beetle appears to be well established in Montana. This is the first report of establishment of this beetle east of the Cascade Mountains of the United States. It is speculated that the Oregon low-elevation population failed in Montana due to low numbers released and phenological incompatibility. The Oregon high-elevation population is well established but may be environmentally limited to moist habitats. The emergence of adults of this population occurs earlier in Montana than in Oregon, giving adults time to lay larger numbers of eggs before winter. The Swiss population also appears to have established but may be less restricted in its habitat requirements, thereby making it a superior control agent. Future research will address the environmental suitability of the two *L. jacobaeae* populations in Montana and their potential impact on tansy ragwort.

**Acknowledgements**

We thank E. Reneau, Y. Wang, J. Wolfe, C. Horning, A. Schmidt and A. Hunter for assisting with field and laboratory work; A. Odor, T. Barboulatos (USFS) and W. Chalgren for locating release sites and their help with releases; U. Schaffner (CABI) for the collection of beetles in Switzerland; Kootenai and Flathead National Forests and Plum Creek Timber Company for the use of their land for study sites; Members of Tansy Ragwort Task Force for their cooperation and financial support from the Montana Noxious Weed Trust Fund, Montana Agricultural Experiment Station, US Forest Service and M.J. Murdock Charitable Fund.

**References**


