

**Biological Control of Noxious Weeds at the
Fort Carson Military Reservation, Fort Carson,
Colorado.**



2001 Progress Report

**BIOLOGICAL CONTROL OF SPOTTED KNAPWEED AND CANADA THISTLE
AT THE FORT CARSON MILITARY RESERVATION,
FT. CARSON, COLORADO**

2001 PROGRESS REPORT

by

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Introduction

This program continues the release, colonization, and redistribution of biocontrol agents to reduce or eliminate noxious weeds infestations at Ft. Carson. According to the original and subsequent plans of work, some Phase I release and colonization efforts continue on Canada thistle, musk thistle, field bindweed, and spotted knapweed. These release efforts focus on the establishment of biocontrol agents that were released in previous years, but are not yet established at our release sites. Phase II redistributions of established biocontrol agents are ongoing for spotted knapweed and musk thistle. In addition, we continue to map noxious weed infestations and record plant parameters at each site. These data will be invaluable to Phase III economic and environmental analyses which will take place in the future.

PROGRAMATIC ENHANCEMENTS AND INITIATIVES

In order to facilitate the intensive data collection planned at our Ft. Carson biocontrol sites in 2001 we hired two student aides to work full time in the program. The students, Abigail Appleton and Claire Zimmerman, recent graduates of Colorado College, assisted us in georeferencing and mapping weed infestations, collecting plant data (density, height, numbers of seed heads, etc.), collecting biocontrol agents for new releases at Ft. Carson and redistributing insects from previously-established sites (Cover page).

The program at Ft. Carson is the focus of an extended and expansive project for biological control of noxious weeds at military and other federal installations along the Colorado and Wyoming Front Range. The overall program now encompasses projects at the United States Air Force Academy at Colorado Spring, CO, the USDA Monument Fire Center at Monument, CO, the Department of Energy's Rocky Flats Environmental Technology Site near Golden, CO, and in 2002, the United States Air Force F. E. Warren Base at Cheyenne, WY. The Ft. Carson program acts as a focus for the redistribution of established biological control agents, development and fine-tuning of methods and techniques for noxious weed biological control, and benefits from the expanded program as a

recipient of new biological control agents as they become available in reciprocal distributions among the various sites.

In the ensuing years since the initiation of this program at Ft. Carson, some aspects of biological control of noxious weeds have been questioned in regard to the potential impact biocontrol agents may have on native plants, primarily native thistle species. In order to address these concerns, and continue with a program that blends noxious weed control with good environmental stewardship, a risk assessment was developed in cooperation with Robin Romero (DECAM), and is included in this report. It is our opinion that none of the native thistles found at Ft. Carson are at risk from the biocontrol agents we have released. In addition, any impact on native thistle species by biological control agents must be assessed in light of what would happen to native thistles if noxious thistles, which often occupy the same habitat, were not controlled, and what impact other forms of control, such as chemical and mechanical, would have on native species. Although two insects established at Ft. Carson, *Rhinocyllus conicus* on musk thistle and *Larinus planus* on Canada thistle, have been found to infest native thistles, to date it has not been shown that biological control agents released for Canada and musk thistle control reduce the density of native thistles. In fact, *Rhinocyllus conicus* was established at Ft. Carson long before the current biocontrol program began, perhaps for as long as 10-15 years, however there are still healthy stands of native thistles found on the post. In the future we will monitor native thistle populations as well as the noxious thistle species we are attempting to control.

PROGRAM ACCOMPLISHMENTS BY WEED SPECIES

CANADA THISTLE

Canada thistle is in Colorado's top ten state-listed noxious weeds.

Ceutorhynchus litura, the Canada thistle stem weevil, is very small and extremely difficult to find. We used a vacuum made from a modified leaf blower to aid in the collection of these small insects, however to date, no recoveries have been made.

Larinus planus was apparently recovered at ARA. A student of Dr. Svata Louda recovered one beetle in a wavy leaf thistle head. However, we were unable to find another beetle to retain as a voucher specimen. We will continue to monitor Canada thistle sites where *L. planus* was released to determine establishment and spread, as well as any possible damage that may occur to native thistles. Harris (2001) stated that although *L. planus* was found on the native thistles *C. undulatum* (wavy leaf thistle) and *C. flodmanii* (Flodman's thistle) the adults became entangled in the pappus and were unable to emerge because the heads on native thistles of the United States are too large for *L. planus* to breed and complete its life cycle. Harris (2001) also commented that *L. planus* could displace *R. conicus* and help restrict *R. conicus* to *Carduus spp.*, thus benefiting the native *Cirsium spp.* where *R. conicus* is a concern. In researching the literature regarding the growing concern of native thistles being attacked by biocontrol agents, there is one major factor that is not addressed:

what impact does the noxious weed in question have on the natives? If left unchecked, the noxious weed will no doubt continue to spread and eliminate not just native thistles, but disrupt the entire native ecosystem. Chemical applications are not target specific and will destroy natives as well as the intended noxious weed and are not usually effective without continued applications. Regardless, we will be monitoring all native thistles found within the release areas.

Although *C. rubiginosa* was recovered in 1999 on Canada thistle at ARA, no other specimens were observed and no obvious damage recorded since its recovery.

We collected naturally occurring rust (*Puccinia* spp.) infecting Canada thistle at ARA site and brought it back to Bushland, TX greenhouses to see if we could infect healthy Canada thistle with the rust.

New releases and sites

Two hundred *C. rubiginosa* were released on Canada thistle at the ARA release site in June 2001 (Table 1, Fig. 1). A population of wavy leaf thistle (*C. undulatum*), a native thistle, located close to the ARA Canada thistle site, was recorded and the area mapped (Fig. 1). We will monitor this native thistle population closely for potential impact by biocontrol agents released at ARA site.

Table 1. Summary of Insects Released for Biological Control of Canada Thistle 1997-2001.

| 2001 Releases in RED BOLD | Date | Release | | Total |
|----------------------------|---|-------------------|-----------------------|-------------------|
| | | Site ¹ | Number Cage / Open | |
| <u>AGENCY</u> | <u>Thistle feeding shield beetle - <i>C. rubiginosa</i></u> | | | |
| Penn.Dpt.of Agric. | 7/3/1997 | 4 | 25 / 3 | 25 |
| | 7/8/1998 | 3 | 15 / 0 | 25 |
| Biol. Control of Weeds, MT | 6/23/1999 | 3 | 105 / 0 | 105 |
| | 6/23/1999 | 4 | 0 / 105 | 105 |
| | 6/23/1999 | 6 | 0 / 75 | 75 |
| Penn.Dpt.of Agric. | 6/28/2001 | 3 | 0 / 200 | 200 |
| | <u>Canada thistle bud weevil - <i>L. planus</i></u> | | | |
| Penn.Dpt.of Agric. | 7/3/1997 | 3 | 47 / 0 | 47 |
| | 7/8/1998 | 3 | 0 / 150 | 150 |
| Colo.Dpt.of Agric. | 7/14/1999 | 8 | 0 / 400 | 400 |
| | <u>Thistle stem gall fly - <i>U. cardui</i></u> | | | |
| Forestry Sci Lab, MT | 1/28/1998 | 6 | 0 / 77 | 539 ² |
| | 1/28/1998 | 7 | 0 / 92 | 644 ² |
| | 1/15/1999 | 3 | 0 / 1 | 1000 ³ |
| | 1/15/1999 | 4 | 0 / 1 | 1000 ³ |
| | 1/15/1999 | 6 | 0 / 1 | 1330 ³ |
| | 1/14/1999 | 7 | 0 / 1 | 1670 ³ |
| | 1/12/2000 | 7 | 0 / 2000 | 2000 ³ |
| | 1/12/2000 | 10 | 0 / 2600 | 2600 ³ |
| | <u>Canada thistle stem weevil- <i>C. litura</i></u> | | | |
| Forestry Sci Lab, MT | 6/3/1999 | 3 | 120 / 0 | 120 |
| | 6/3/1999 | 4 | 60 / 0 | 60 |
| | 6/3/1999 | 7 | 60 / 0 | 60 |

¹Sites: 1-Cantonment I; 2-Turkey Creek; 3-ARA; 4-Reservoir; 5-Cantonment II; 6-Outdoor Recreation; 7-Duck Pond; 8-Gate 5; 9-Wildlife Reserve
10-Hwy115Rt11; 11-Range Control; 12-Prairie dog town

²Released galls, approximately 7 larvae/gall, in small screened cages to prevent rodent predation.

³Galls rated on a scale of 1-4; class 1 = 80 galls/1000 live larvae; class 4 = 200 galls/1000 live larvae; in screened cages

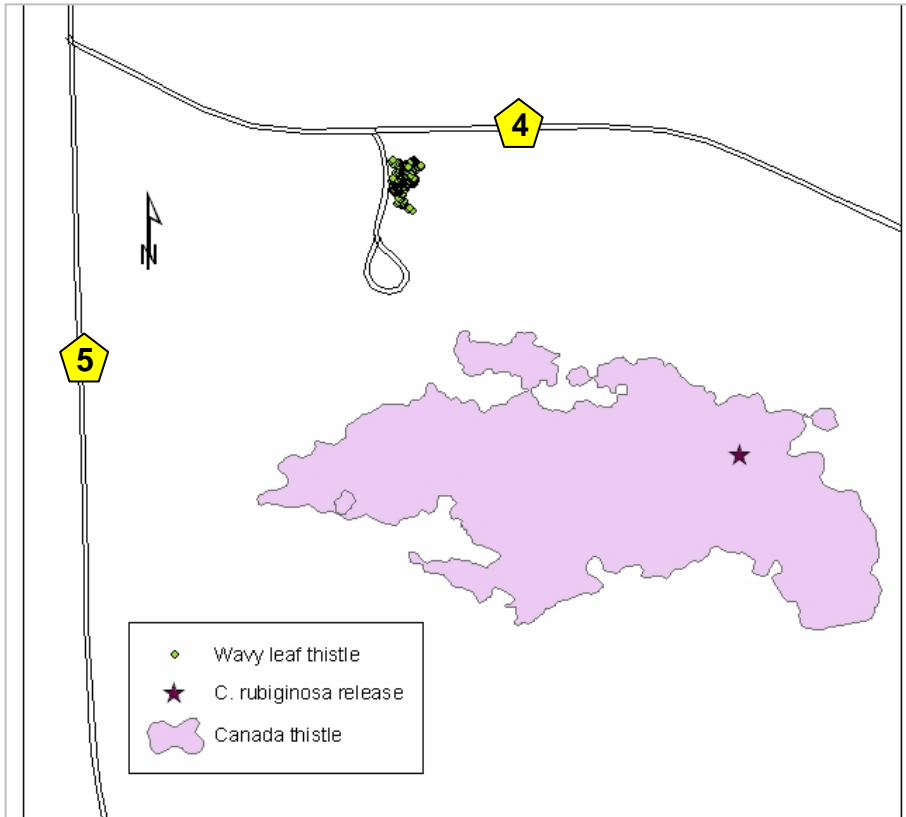


Fig. 1. *Cassida rubiginosa* released on Canada thistle at the ARA release site in 2001. *Cirsium undulatum*, wavy leaf thistle, was located close to the ARA Canada thistle site in 2001.

Redistributions

Urophora cardui galls were searched for, georeferenced, then collected from the Duck Pond site on February 20, 2001, and redistributed the following day to a Canada thistle site at the Air Force Academy (Fig. 2). We also sampled Canada thistle for *U. cardui* galls at ARA and Reservoir sites. Galls were found at the Reservoir site, but not in high enough densities to collect and redistribute.



Fig. 2. One of several *Urophora cardui* galls collected February 2001 from Duck Pond and released at a Canada thistle site at Air Force Academy, CO.

MUSK THISTLE

Last year we noticed harvester ants were present in very high numbers on the thistles, tending leafhoppers (Membracidae). When disturbed, the ants attack all arthropods on the plants including spiders, bees, and each other. Ant specimens were collected and sent to USDA ARS – Systematic Entomology Laboratory in Beltsville, MD for identification. The specimens submitted were identified as *Formica obscuripes* Forel, which are known to be predatory. If they are disturbed when releases are made, they may attack and destroy the bioagents. We initiated a study to investigate this hypothesis at the Wildlife Refuge site. We removed the ants, aphids, and membracids using a pesticide application. This was done by DECAM personnel using Dursban™ at labeled rates. After the allotted reentry time had elapsed, we released *Trichosirocalus horridus* in both the treated and untreated areas (Table 2, Figs. 3 & 4).

Table 2. Summary of Insects Released for Biological Control of Musk Thistle 1997-2001.

| 2001 Releases in RED BOLD | Date | Release | | |
|---------------------------|------------------|--|-----------------------|------------|
| | | Site ¹ | Number Cage / Open | Total |
| AGENCY | | <u>Rosette weevil - <i>T. horridus</i></u> | | |
| Colo.Dpt.of Agric. | 7/14/1999 | 8 | 0 / 400 | 400 |
| | 7/14/1999 | 9 | 0 / 400 | 400 |
| | 6/21/2000 | 9 | 0 / 200 | 200 |
| | 6/28/2001 | 9 | 0 / 200 | 200 |

¹Sites: 1-Cantonment I; 2-Turkey Creek; 3-ARA; 4-Reservoir; 5-Cantonment II; 6-Outdoor Recreation; 7-Duck Pond; 8-Gate 5; 9-Wildlife Reserve; 10-Hwy115Rt11; 11-Range Control; 12-Prairie dog town

Ant, aphid, spider, and membracid density counts were taken after treatment (Table 3, Fig. 5). There was a definite correlation between ant density and membracid/aphid density. It is also interesting to note the increase in the spider densities when the ants had been removed (Fig. 6). The effectiveness of the treatment in aiding establishment of *T. horridus* will be evaluated in the Spring 2002.

New releases and sites

In June 2001, two hundred *T. horridus* were released at Wildlife Refuge site (one hundred per treated and untreated areas) (Table 3, Fig. 4). The Hwy115Rt11 site was expanded to include a musk infestation in a large area near Gate 6 (Fig. 7).

Redistributions

T. horridus were collected at Gate 5 site and brought back to Texas for musk research being conducted at Friona, TX. An additional two hundred *T. horridus* were collected near Denver, CO. and were released at Friona, TX (Fig. 8).

Table 3. Insect densities at Wildlife release site before and after chemical application in 2001.

| Insects | Numbers/Treated m ² | | | | | | | | | | Total | Average | Std dev | Std err |
|-------------------|----------------------------------|-----|----|-----|-----|-----|----|----|----|-----|-------|---------|---------|---------|
| | 0 | 4 | 18 | 0 | 118 | 32 | 34 | 24 | 12 | 4 | | | | |
| Ants | 0 | 4 | 18 | 0 | 118 | 32 | 34 | 24 | 12 | 4 | 246 | 24.6 | 35.16 | 3.52 |
| Aphids | 0 | 14 | 0 | 14 | 6 | 6 | 2 | 2 | 16 | 16 | 76 | 7.6 | 6.72 | 0.67 |
| Membracid Adults | 0 | 6 | 6 | 0 | 18 | 8 | 6 | 2 | 6 | 8 | 60 | 6 | 5.16 | 0.52 |
| Membracid Nymphs | 0 | 2 | 2 | 4 | 16 | 2 | 12 | 10 | 0 | 0 | 48 | 4.8 | 5.75 | 0.58 |
| <i>R.conicus</i> | 0 | 0 | 4 | 4 | 6 | 6 | 8 | 0 | 4 | 0 | 32 | 3.2 | 3.01 | 0.30 |
| <i>T.horridus</i> | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| Spiders | 4 | 24 | 46 | 78 | 8 | 20 | 48 | 8 | 26 | 18 | 280 | 28 | 23.06 | 2.31 |
| Flies | 0 | 6 | 14 | 46 | 2 | 2 | 18 | 6 | 36 | 36 | 166 | 16.6 | 16.84 | 1.68 |
| Other | 2 | 0 | 12 | 2 | 8 | 10 | 6 | 10 | 0 | 12 | 62 | 6.2 | 4.85 | 0.48 |
| Insects | Numbers/Untreated m ² | | | | | | | | | | Total | Average | Std dev | Std err |
| | 188 | 256 | 54 | 40 | 202 | 158 | 20 | 60 | 58 | 348 | | | | |
| Ants | 188 | 256 | 54 | 40 | 202 | 158 | 20 | 60 | 58 | 348 | 1384 | 138.4 | 109.59 | 10.96 |
| Aphids | 2 | 0 | 4 | 4 | 0 | 0 | 2 | 0 | 2 | 0 | 14 | 1.4 | 1.65 | 0.16 |
| Membracid Adults | 8 | 40 | 18 | 10 | 18 | 10 | 20 | 22 | 18 | 18 | 182 | 18.2 | 9.02 | 0.90 |
| Membracid Nymphs | 160 | 552 | 52 | 100 | 270 | 216 | 2 | 38 | 56 | 556 | 2002 | 200.2 | 204.26 | 20.43 |
| <i>R.conicus</i> | 0 | 8 | 2 | 12 | 4 | 18 | 0 | 2 | 0 | 0 | 46 | 4.6 | 6.19 | 0.62 |
| <i>T.horridus</i> | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| Spiders | 20 | 12 | 6 | 8 | 6 | 12 | 0 | 12 | 16 | 4 | 96 | 9.6 | 5.95 | 0.59 |
| Flies | 4 | 2 | 10 | 8 | 10 | 6 | 8 | 4 | 0 | 0 | 52 | 5.2 | 3.79 | 0.38 |
| Other | 0 | 0 | 2 | 2 | 2 | 8 | 0 | 4 | 0 | 0 | 18 | 1.8 | 2.57 | 0.26 |



Fig. 3. Pesticide-treated area at the Wildlife Refuge site. The orange flag marks the location of the *T. horridus* release.

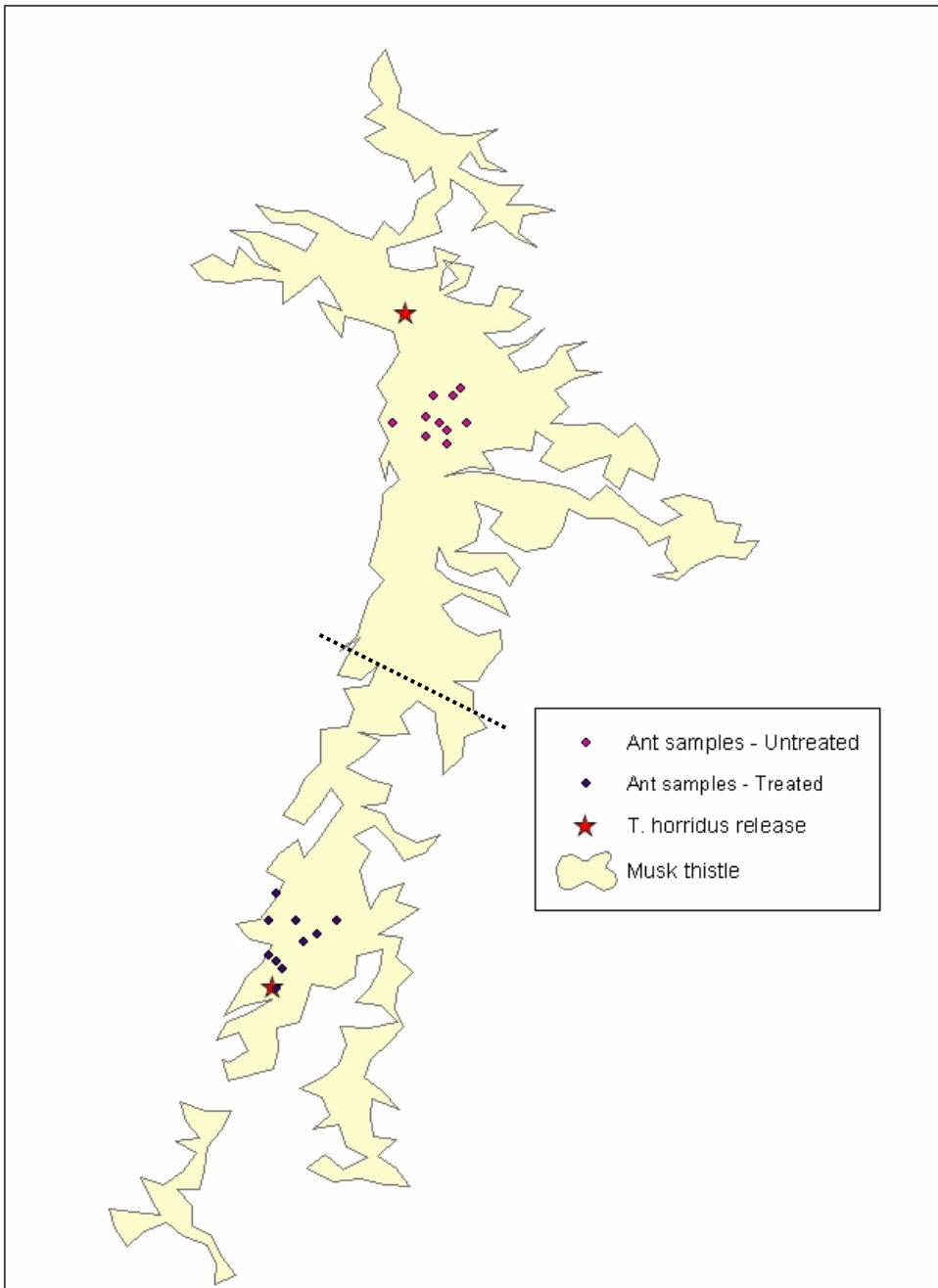


Fig. 4. Chemical research prior to release of bioagents in 2001 at the Wildlife reserve site. One hundred *T. horridus* were released in both the treated and untreated areas. The black line denotes the division of the treated and untreated areas.

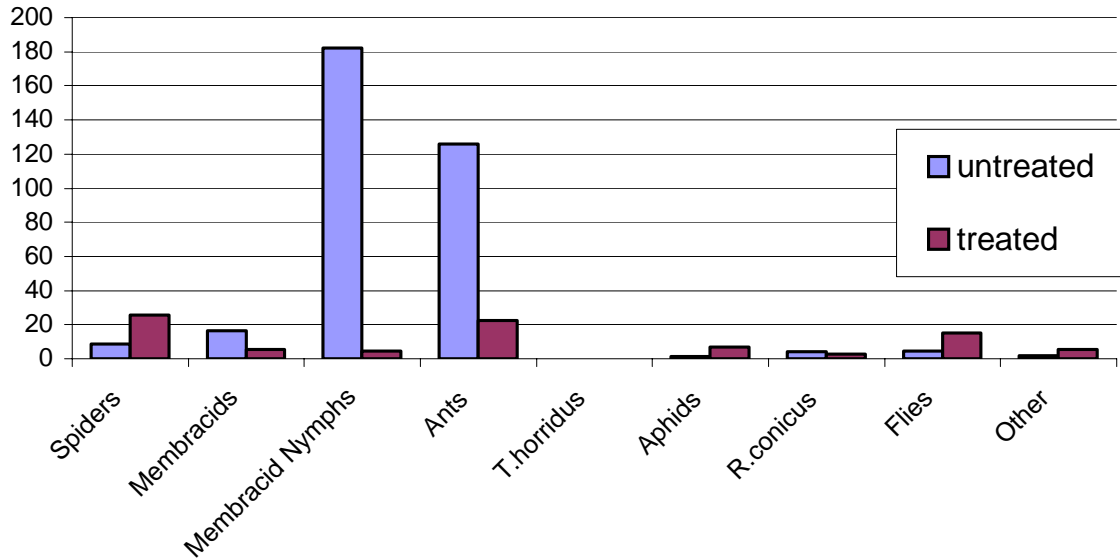


Fig. 5. Average arthropod densities per m² at Wildlife Refuge site in pesticide-treated vs. untreated areas.

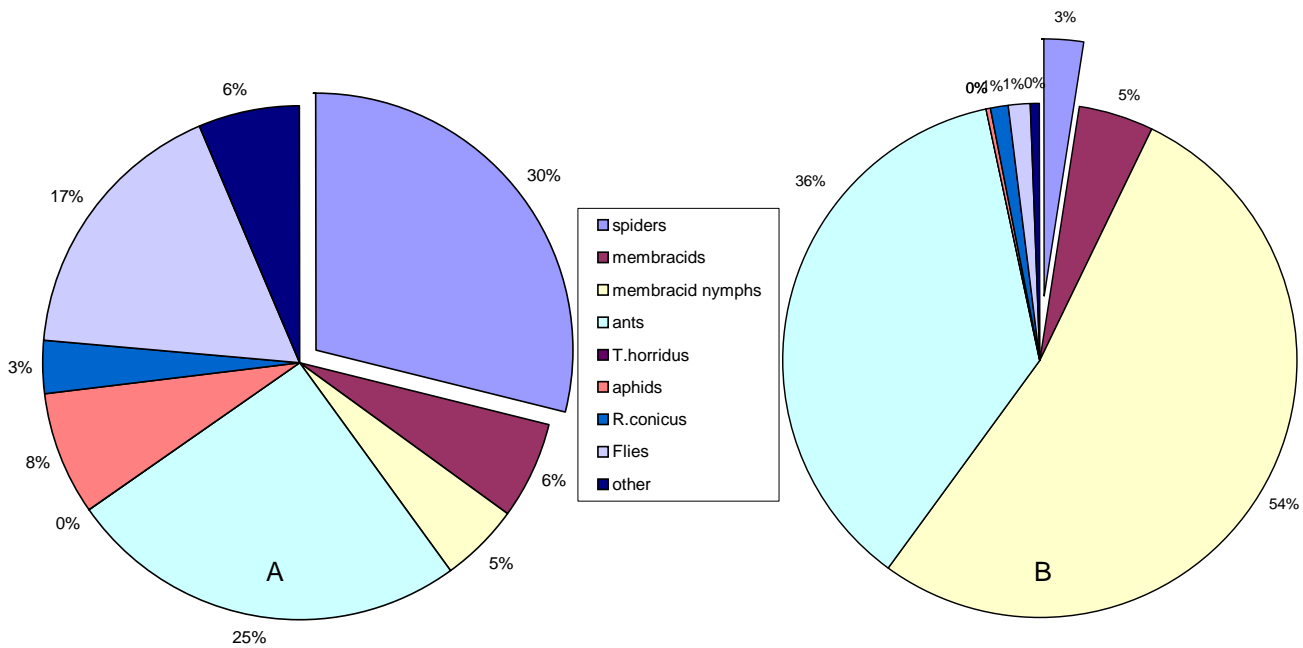


Fig. 6. Percentage of arthropods at Wildlife Refuge site in A) pesticide-treated vs. B) untreated areas.

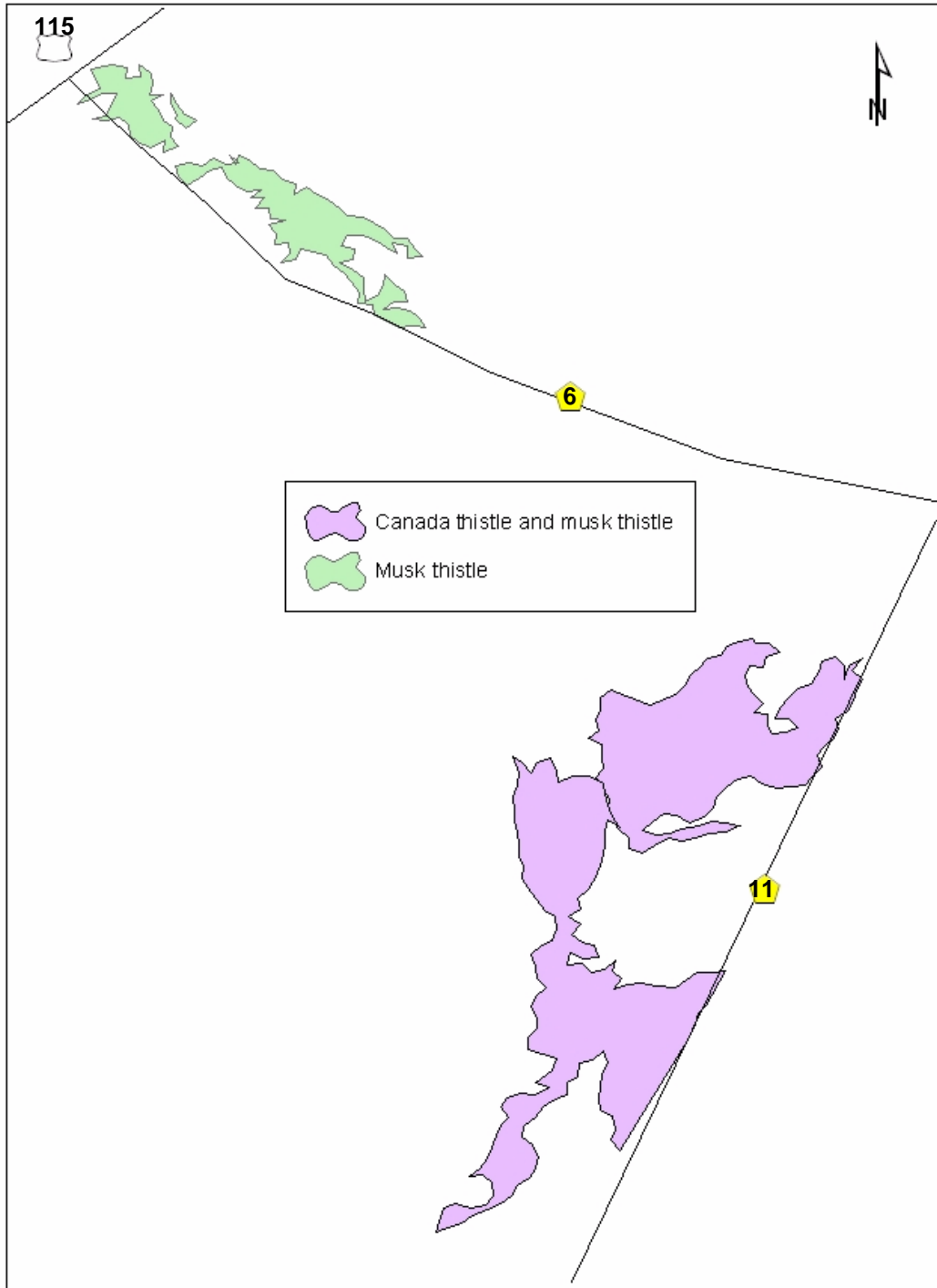


Fig. 7. Hwy115Rt11 musk and Canada thistle release site in 2001.

SPOTTED KNAPWEED

Spotted knapweed biological control program is progressing. At Turkey Creek site, *Larinus minutus* and *Cyphocleonus achates* are abundant and will be used for collecting and redistribution next year.



Fig. 8. TAES employees releasing *T. horridus* in Friona, TX. The insects were collected from Gate 5, Fort Carson and Denver, CO. 2000.

Turkey Creek site spotted knapweed height and densities for 2001 was compared with data collected in 1998 and 2000 (Figs. 9 & 10).

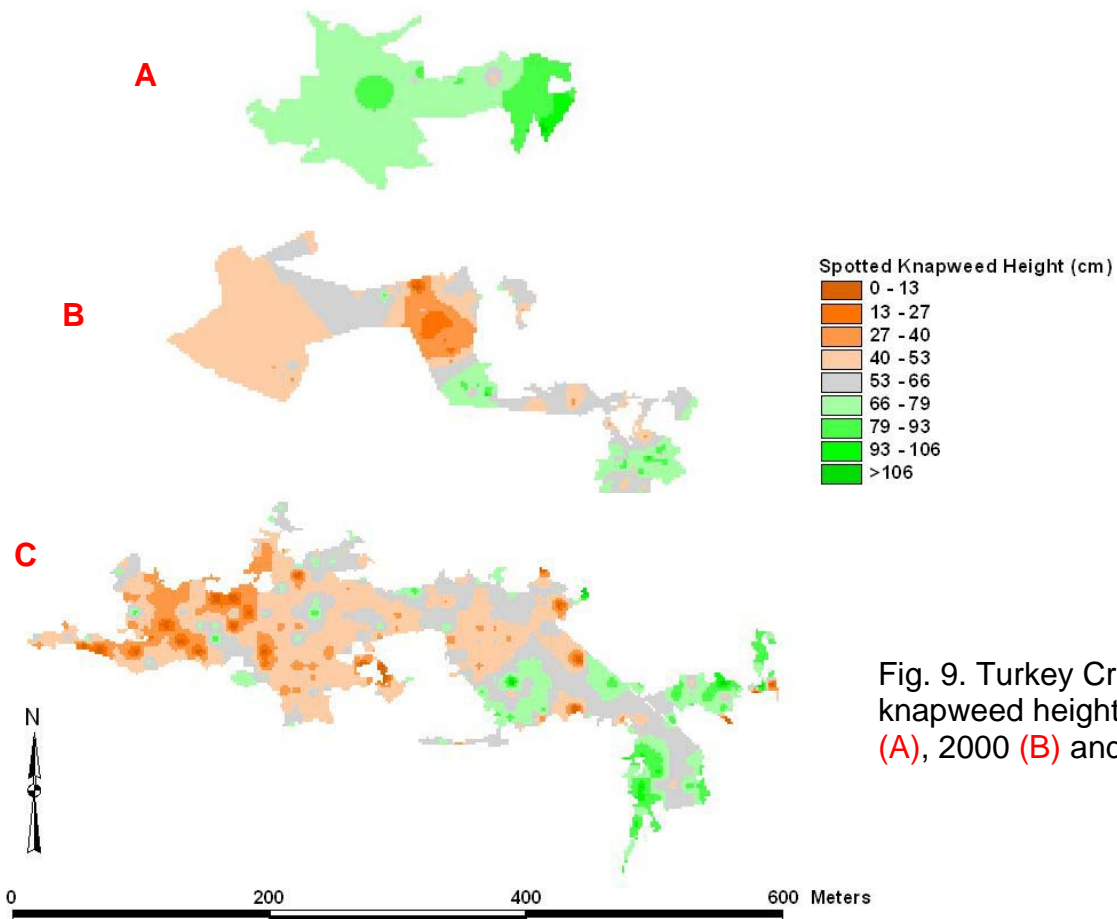


Fig. 9. Turkey Creek site spotted knapweed height (cm) in 1998 (A), 2000 (B) and 2001 (C).

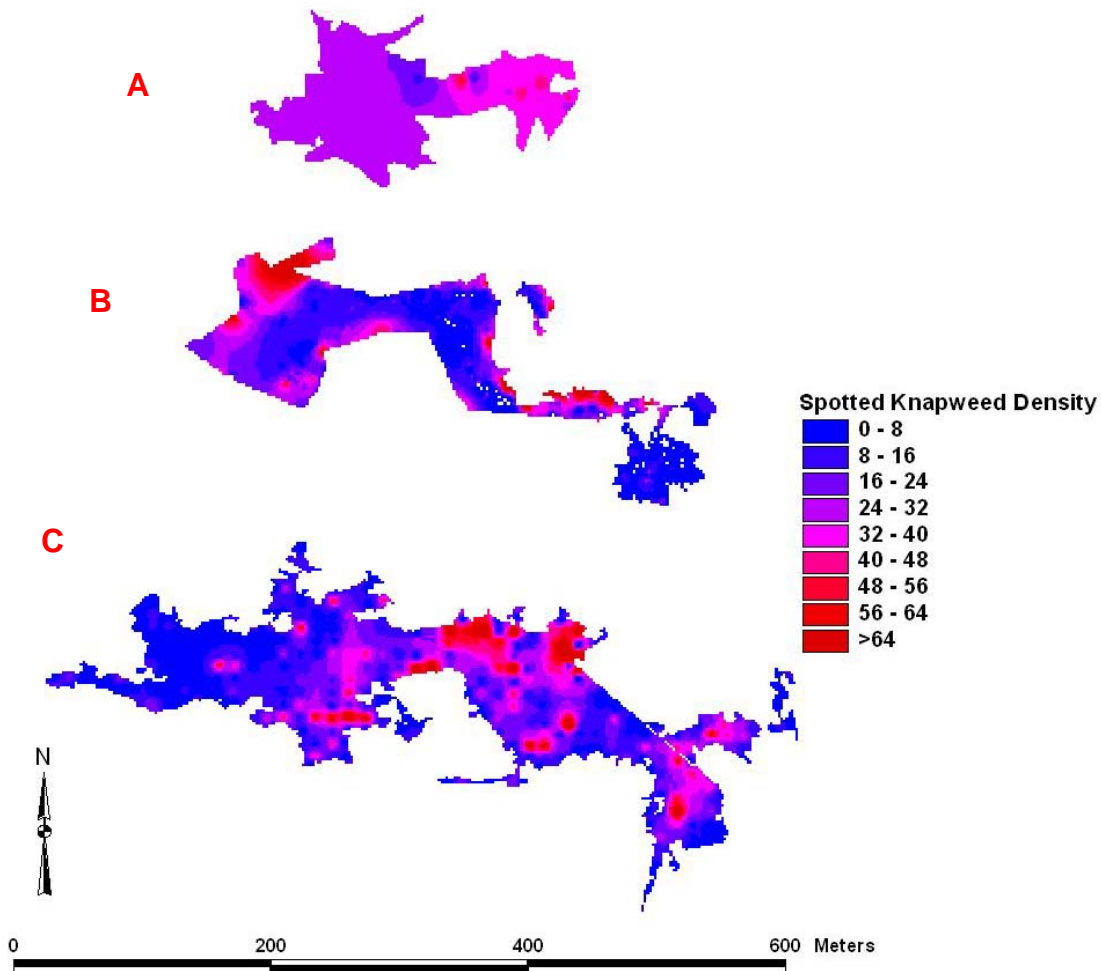


Fig. 10. Turkey Creek site spotted knapweed densities / m^2 in 1998 (A), 2000 (B) and 2001 (C).

Although the spotted knapweed infestation has spread at the site, plant height and densities are decreasing over time. Efforts are underway to control knapweed at the the perimeters to prevent further spread and allow the bioagents to work more effectively. Pictures of Turkey Creek Site from 1997 and 2001 illustrate the changes in the spotted knapweed infestation that have taken place since the establishment of the bioagents (Figs. 11 & 12).

C. achates, recovered at Cantonment II on August 25, 1999, was increasing and populations were expected to be high enough for redistributing this year. However, due to construction at the site, insect numbers have declined and collections are not expected from this site for at least another year. Adults of *Sphenoptera jugoslavica* or *Metzneria paucipunctella* from releases in 2000 have not been recovered.

New releases and sites

On July 10th and 11th, approximately two hundred *S. jugoslavica* were collected at Chatfield Reservoir near Denver, CO and released at Cantonment I on July 13, 2001 (Table 4, Fig. 13). On July 10, 2001, three hundred thirty *L. minutus* were received from the Colorado Dept. of Agriculture, Palisade, CO. Two hundred *L. minutus* were released at Cantonment I and one hundred thirty released at Cantonment II (Table 4, Figs.13 & 14).



Fig. 11. Picture of Turkey Creek spotted knapweed site in 1997 prior to establishment of biocontrol agents.



Fig. 12. Picture of Turkey Creek spotted knapweed site 2001 after establishment of biocontrol agents

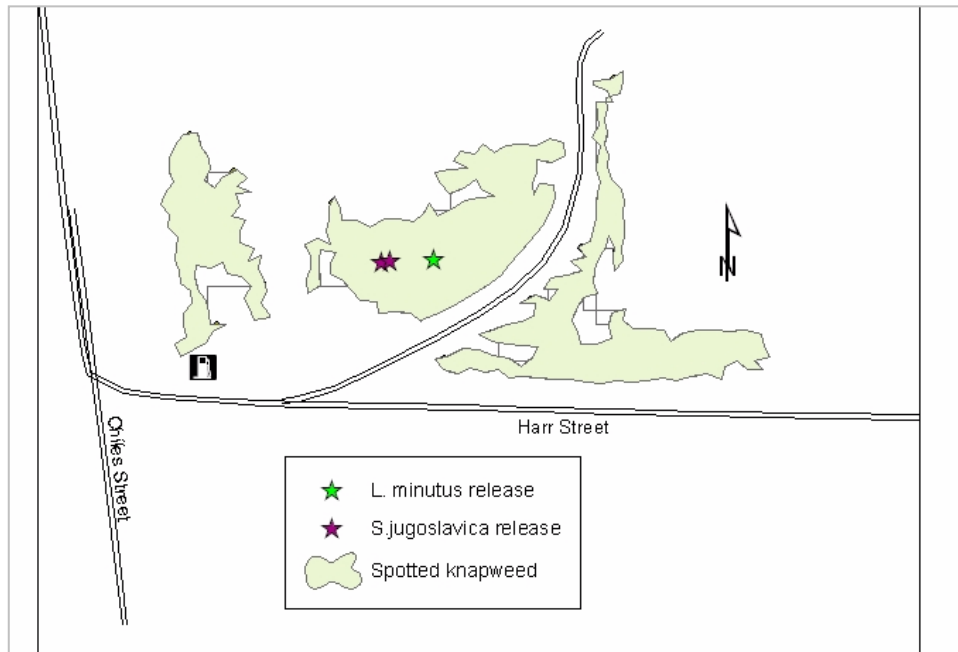


Fig. 13. *S. jugoslavica* and *L. minutus* releases on spotted knapweed at Cantonment I in 2001.

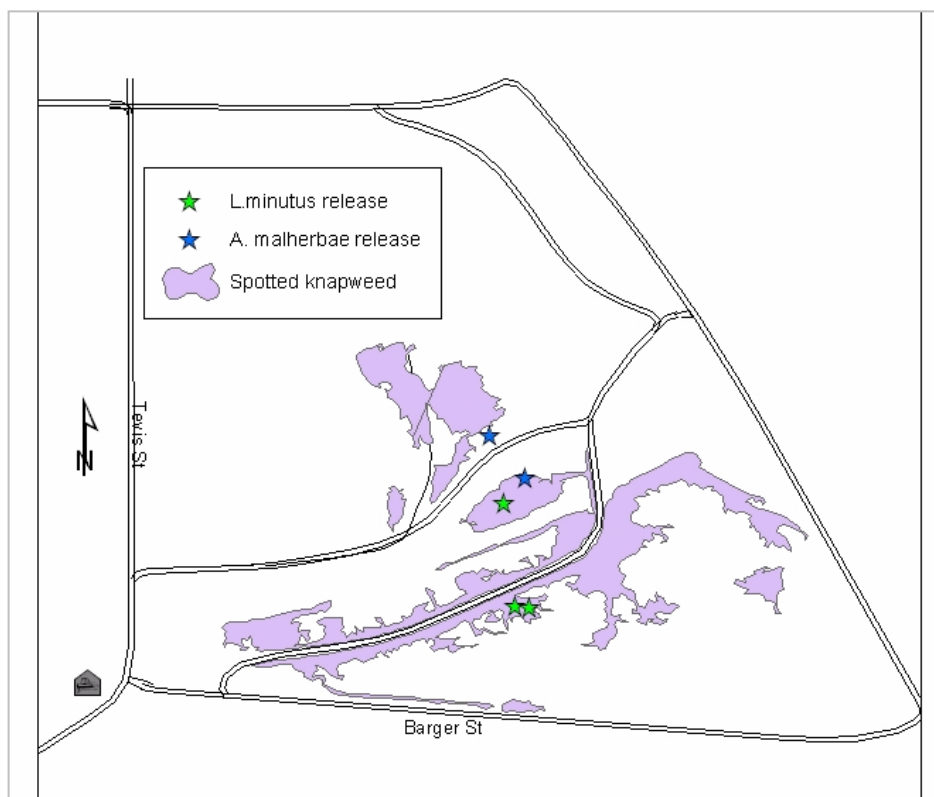


Fig. 14. *L. minutus* and *A. malherbae* releases in 2001 at Cantonment II.

Table 4. Summary of Insects Released for Biological Control of Spotted Knapweed, 1997-2001.

| 2001 Releases in RED BOLD | Date | Release | | |
|---------------------------|-----------------|--|----------------|---------------------|
| | | Site ¹ | Number | Total |
| AGENCY | | | Cage / Open | |
| | | <u>Lesser knapweed flower weevil - <i>L. minutus</i></u> | | |
| USDA/APHIS, MT | 06/05/97 | 1 | 50 / 50 | 100 |
| | 06/05/97 | 2 | 50 / 50 | 100 |
| Colo.Dept. Of Agric | 07/14/99 | 1 | 0 / 250 | 250 |
| | 07/14/99 | 5 | 0 / 500 | 250 |
| | 07/12/00 | 5 | 0 / 250 | 250 |
| | 06/19/01 | 5 | 0 / 200 | 200 |
| | 07/10/01 | 5 | 0 / 130 | 200 |
| | 07/20/01 | 1 | 0 / 200 | 200 |
| Colo.Dept. Of Agric | 08/05/98 | 1 | 50 / 0 | 50 |
| | 08/26/99 | 1 | 75 / 0 | 75 |
| Colo.Dept. Of Agric | 07/02/98 | 2 | 250 / 250 | 500 |
| Colo.Dept. Of Agric | 08/06/97 | 5 | 50 / 200 | 250 |
| | 08/04/98 | 5 | 50 / 150 | 200 |
| | 08/26/99 | 2 | 0 / 150 | 150 |
| USDA/APHIS, MT | 06/05/97 | 1 | 0 / 1 | 4800 ² |
| | 06/05/97 | 2 | 0 / 1 | 4800 ² |
| USDA/APHIS, WA | 04/28/98 | 2 | 0 / 2 | 3456 ³ |
| | 04/28/98 | 7 | 0 / 2 | 3456 ³ |
| | 04/28/98 | - | 0 / 1 | 1728 ^{3,4} |
| | 05/07/99 | 1 | 0 / 1 | 3000 ⁵ |
| | 05/07/99 | 2 | 0 / 1 | 3000 ⁵ |
| | 05/07/99 | 5 | 0 / 1 | 4000 ⁵ |
| | 04/18/00 | 1 | 0 / 1 | 4320 ⁶ |
| | 04/18/00 | 2 | 0 / 0 | 4320 ⁶ |
| | 04/18/00 | 5 | 0 / 1 | 4320 ⁶ |
| | 07/12/00 | 5 | 0 / 104 | 104 |
| Colo.Dept. Of Agric | 07/14/99 | 5 | 0 / 100 | 100 |
| | 07/14/99 | 5 | 0 / 100 | 100 |
| | 07/13/01 | 1 | 0 / 200 | 200 |

¹Sites: 1-Cantonment I; 2-Turkey Creek; 3-ARA; 4-Reservoir; 5-Cantonment II; 6-Outdoor Recreation; 7-Duck Pond; 8-Gate 5; 9-Wildlife Reserve

²Released in bouquets of dead spotted knapweed with approximately 1200 larvae/bouquet.

³Released in screened cages containing 2400 seedheads/cage with approx. 1728 larvae/cage (72% infestation).

⁴Released at HazMaterials site which was accidentally mowed at a later date, then abandoned.

⁵Released in screened cages containing 4500 seedheads/cage (approx. 3000 larvae/cage) for sites 1 and 5 and 6000 seedheads/cage (approx. 4000 larvae/cage) for site 2 (72% infestation)

⁶Released in screened cages containing 6000 seedheads/cage (approx. 4320 larvae/cage; 72% infestation).

FIELD BINDWEED

Aceria malherbae, the field bindweed mite, was recovered at ARA and Duck Pond sites. No recoveries have been made at Cantonment II or Gate 5 sites to date.

New releases and sites

A. malherbae was released at Cantonment II (Table 5, Fig. 14) and Range Control (Table 5, Fig. 15). A new bindweed mite release site was established approximately 4.5 miles north of the ARA Canada thistle site (Table 5, Fig. 16). The area was not mapped in 2001 due to strict security, however it will be mapped when restrictions are lifted. An additional release was made at the

Wildlife Headquarters (Table 5). The release was georeferenced, but was not mapped as a new release site due to the relatively small size of bindweed infestation.

Table 5. Summary of Insects Released for Biological Control of Field Bindweed 1997-2001.

| 2001 Releases in RED BOLD | Date | Release | | |
|---------------------------|------------------|-------------------|-----------------------|----------------------|
| | | Site ¹ | Number Cage / Open | Total |
| AGENCY | | | | |
| | | | | |
| Tx Agric. Exp. Sta.,TX | 7/15/1999 | 5 | 0 / 2 | 2 ² |
| | 7/14/1999 | 7 | 0 / 1 | 1 ² |
| | 7/14/1999 | 8 | 0 / 1 | 1 ² |
| | 5/31/2000 | 2 | 0 / 1 | 1 ² |
| | 5/31/2000 | 8 | 0 / 1 | 1 ² |
| | 5/31/2000 | 3 | 0 / 1 | 1 ² |
| | 5/31/2000 | 5 | 0 / 1 | 1 ² |
| | 5/31/2000 | 11 | 0 / 1 | 1 ² |
| | 7/12/2001 | 11 | 0 / 1 | 1² |
| | 7/13/2001 | 5 | 0 / 1 | 1² |
| | 7/13/2001 | 12 | 0 / 1 | 1² |

¹Sites: 1-Cantonment I; 2-Turkey Creek; 3-ARA; 4-Reservoir; 5-Cantonment II; 6-Outdoor Recreation; 7-Duck Pond; 8-Gate 5; 9-Wildlife Reserve 10-Hwy115Rt11; 11-Range Control; 12-Prairie dog town

²Released one pint-size baggie of mite-infested bindweed sprigs, approximately 10,000 mites.

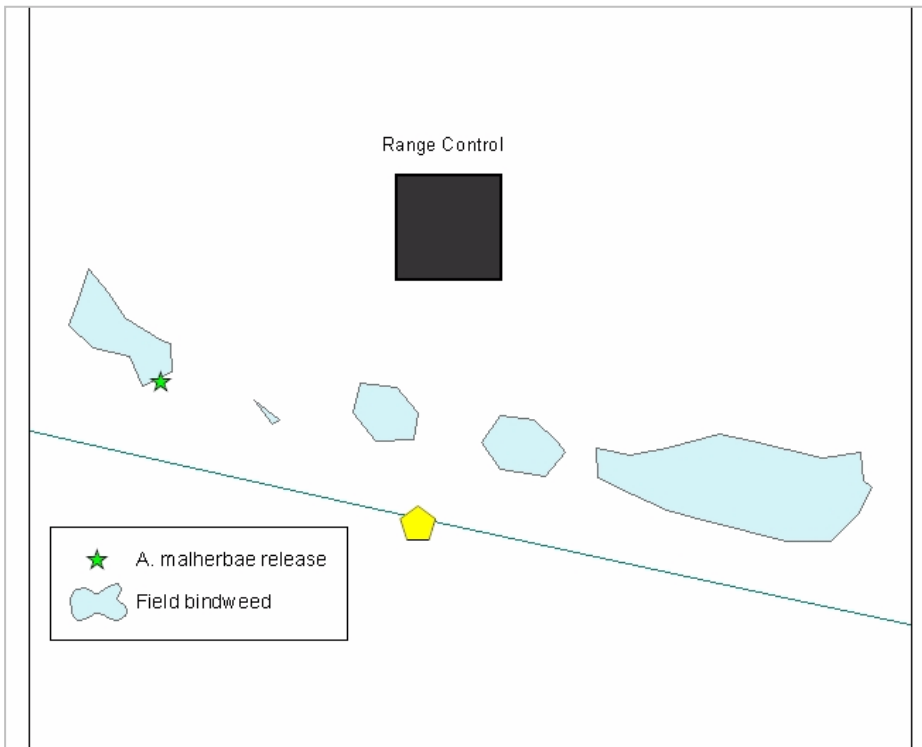


Fig. 15. The bindweed mite, *A. malherbae* release on field bindweed at the Range Control site 2001.

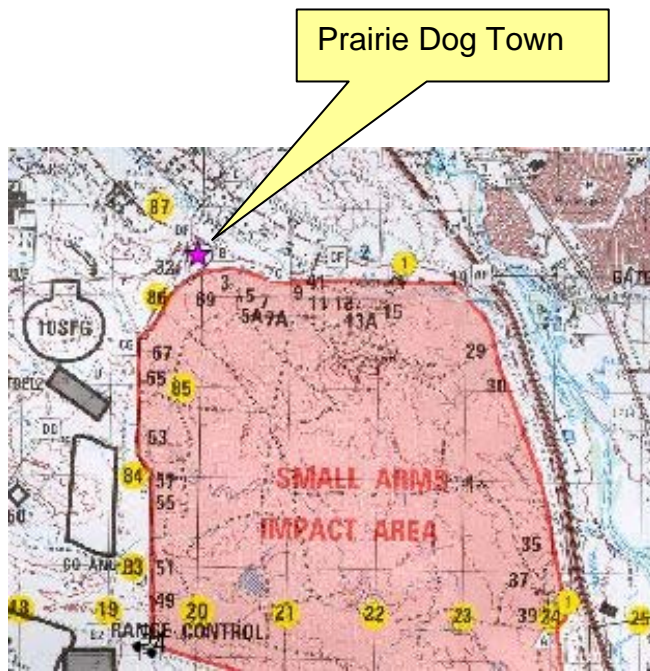


Fig. 16. Approximate location of the new bindweed mite release site known as Prairie Dog Town at Fort Carson.

ADDITIONAL PROGRAM COMPONENTS, CONCERNS AND RESULTS

Gate 5, a Canada and musk thistle site, was scraped and the land prepared for housing development, thus the effectiveness of the bioagents recovered cannot be monitored. This site is all but useless for biocontrol purposes and will be eliminated from future biological control efforts (Fig. 17).



Fig.17. Gate 5 release site land scraped in preparation for housing development at Fort Carson.

Construction of a tank trail through the Cantonment II site has caused all but the outlying areas of the original release site to be destroyed (Fig. 18). However, spotted knapweed is extensive in this area, and new areas were mapped and new releases made (Fig. 14). Signs were posted to discourage mowing, spraying, etc., however, the signs were ignored and the new release site was mowed.



Fig. 18. Construction of a tank trail in 2000 at Cantonment II site.

It is difficult to determine if last year's releases of *S. jugoslavica* and *M. paucipunctella* would have been recovered in 2001 without the aforementioned disturbances. To aid in determining which bioagents and numbers infesting the seed heads, fifty, randomly selected spotted knapweed seed heads were collected from Cantonment I and Cantonment II sites for dissection. Larvae and/or galls were counted, placed into separate containers, and labeled. The containers were kept at room temperature and emergence recorded (Table 6a). A comparative summary of spotted knapweed seed head dissections from 1997 – 2001 is included (Table 6b).

Due to heightened security and limited access to Turkey Creek site, the spotted knapweed seed head collection was delayed and will be included in next years' report.

Table 6a. Summary of Larvae Recovered from Spotted Knapweed Seed heads, 2001.

| Species | Status | Larval density ¹ | | | Emerging adults | | Larval frequency distribution ² | | | | | | | | | | | | |
|---------------------------------|--------|-----------------------------|-------------------|------------|-----------------|---------|--|----|---|---|---|---|---|---|---|---|----|---|---|
| | | total/50 seed heads | average/seed head | std. error | total | percent | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| Cantonment I | | | | | | | | | | | | | | | | | | | |
| <i>Urophora quadrifasciata</i> | Live | 39 | 0.80 | 0.10 | 38 | 97.4 | 22 | 20 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Dead | 6 | 0.12 | 0.05 | | | 45 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 45 | 0.90 | 0.14 | | | 67 | 24 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Urophora affinis</i> | Live | 2 | 0.04 | 0.03 | 2 | 100.0 | 48 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Dead | 0 | 0.00 | 0.00 | | | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 2 | 0.04 | 0.03 | | | 98 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Larinus minutus</i> | Live | 19 | 0.38 | 0.07 | * | | 31 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Dead | 0 | 0.00 | 0.00 | | | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 19 | 0.38 | 0.07 | | | 81 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cantonment II | | | | | | | | | | | | | | | | | | | |
| <i>Urophora quadrifasciata</i> | Live | 194 | 3.88 | 0.45 | 128 | 66.0 | 9 | 6 | 7 | 2 | 3 | 8 | 3 | 6 | 4 | 0 | 2 | | |
| | Dead | 0 | 0.00 | 0.00 | | | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 194 | 3.88 | 0.45 | | | 59 | 6 | 7 | 2 | 3 | 8 | 3 | 6 | 4 | 0 | 2 | | |
| <i>Larinus minutus</i> | Live | 11 | 0.22 | 0.06 | * | | 39 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Dead | 0 | 0.00 | 0.00 | | | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 11 | 0.22 | 0.06 | | | 89 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Turkey Creek³ | | | | | | | | | | | | | | | | | | | |
| <i>Urophora quadrifasciata</i> | Live | 0 | 0.00 | 0.00 | | 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Dead | 0 | 0.00 | 0.00 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 0.00 | 0.00 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Urophora affinis</i> | Live | 0 | 0.00 | 0.00 | | 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Dead | 0 | 0.00 | 0.00 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 0.00 | 0.00 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| <i>Larinus minutus</i> | Live | 0 | 0.00 | 0.00 | * | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Dead | 0 | 0.00 | 0.00 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 0 | 0.00 | 0.00 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

¹ Number of larvae in dissected seed heads.

² Seed heads containing the specified number of larvae in fifty seed head sample.

³ Due to heightened security, samples from Turkey Creek were collected too late to be included in this report.

* Adults had already emerged. Count determined by the emergence hole.

Greenhouse Studies on Noxious Weed Seedbank

To estimate the noxious weed seed bank at our release sites, soil samples were taken in July 1999, at 1 inch and 2 – 3 inch depths from each site. The samples were bagged, labeled, and brought back to Bushland, TX.

Beginning in August 1999, the plants in each flat were counted and recorded monthly. After each count, all vegetation was removed from each flat and the soil was stirred. This process continued until germination of new plants ceased. The flats were then returned to incubators at 0° C to vernalize samples for 90 days. After vernalization, they were returned to the greenhouse and the process repeated until no new growth occurred for several months and was terminated at the end of this year

Table 6b. Summary of Larvae Recovered from Spotted Knapweed Seed heads 1997 - 2001.

| Year | Species | Status | Larval density ¹ | | | Emerging adults | |
|---------------------------------|--------------------------|--------|-----------------------------|-----------------------|---------------|--------------------|---------|
| | | | total/50 seed heads | average/ seed head | std. error | total ² | percent |
| Site: Cantonment I | | | | | | | |
| 1997 | <i>U. quadrifasciata</i> | Live | 31 | 0.41 | 0.13 | 26 | 83.87 |
| 1998 | | | 18 | 0.36 | 0.13 | 14 | 77.78 |
| 1999 | | | 41 | 0.72 | 0.15 | 33 | 80.49 |
| 2000 | | | 69 | 1.40 | 0.14 | 52 | 75.36 |
| 2001 | | | 39 | 0.80 | 0.10 | 38 | 97.44 |
| 2000 | <i>L. minutus</i> | Live | 30 | 0.60 | 0.07 | 30 | 100.00 |
| 2001 | | | 19 | 0.38 | 0.07 | 19 | 100.00 |
| 2000 | <i>U. affinis</i> | Live | 0 | 0.00 | 0.00 | 0 | 0.00 |
| 2001 | | | 2 | 0.04 | 0.03 | 2 | 100.00 |
| Site: Cantonment II | | | | | | | |
| 1997 | <i>U. quadrifasciata</i> | Live | - | - | - | - | - |
| 1998 | | | 4 | 0.08 | 0.05 | 4 | 100.00 |
| 1999 | | | 154 | 3.08 | 0.40 | 78 | 50.65 |
| 2000 | | | 124 | 2.50 | 0.40 | 67 | 54.03 |
| 2001 | | | 194 | 3.88 | 0.45 | 128 | 65.98 |
| 2000 | <i>L. minutus</i> | Live | 2 | 0.04 | 0.03 | 2 | 100.00 |
| 2001 | | | 11 | 0.22 | 0.06 | 11 | 100.00 |
| 2000 | <i>U. affinis</i> | Live | 3 | 0.10 | 0.00 | 1 | 33.33 |
| 2001 | | | 0 | 0.00 | 0.00 | 0 | 0.00 |
| Site: Turkey Creek ³ | | | | | | | |
| 1997 | <i>U. quadrifasciata</i> | Live | 76 | 1.52 | 0.19 | 57 | 75.00 |
| 1998 | | | 20 | 0.40 | 0.11 | 20 | 100.00 |
| 1999 | | | 129 | 2.58 | 0.26 | 109 | 84.50 |
| 2000 | | | 50 | 1.00 | 0.20 | 22 | 44.00 |
| 2001 | | | - | - | - | - | - |
| 2000 | <i>L. minutus</i> | Live | 28 | 0.56 | 0.07 | 28 | 100.00 |
| 2001 | | | - | - | - | - | - |
| 2000 | <i>U. affinis</i> | Live | 1 | 0.00 | 0.00 | 1 | 100.00 |
| 2001 | | | - | - | - | - | - |

¹ Number of larvae in dissected seed heads.

² Adults had already emerged. Count determined by the emergence hole.

³ Due to heightened security, samples from Turkey Creek were collected too late to be included in this report.

Plant emergence including noxious weeds and comparisons of the emergence data from 1999 to 2001 are shown in Table 7 and Figs. 19 & 20. The noxious weed emergence and 1999 to 2001 comparisons are shown in Table 8 and Figs. 20 & 21. Table 9 shows the percentage of the total plants at each site that are noxious weeds.

Table 7. Total plant emergence from 1999 soil samples.

| Sample Date ¹ | Release Site ² | | | | | | | | |
|--------------------------|---------------------------|------------|------------|------------|------------|------------|------------|-----------|-----------|
| | ARA | C1 | C2 | DP | G5 | RES | WLR | HWY | TC |
| 1" Soil Depth | | | | | | | | | |
| 1 | 21 | 20 | 35 | 11 | 17 | 11 | 8 | | |
| 2 | 38 | 37 | 93 | 17 | 56 | 1 | 88 | | |
| 3 | 14 | 41 | 28 | 20 | 51 | 11 | 9 | | |
| 4 | 5 | 10 | 7 | 4 | 8 | 3 | 4 | | |
| 5 | 98 | 66 | 141 | 29 | 81 | 121 | 45 | 36 | 10 |
| 6 | 2 | 9 | 54 | 1 | 10 | 15 | 3 | 30 | 41 |
| 7 | 1 | 15 | 7 | 6 | 7 | 7 | 4 | 0 | 1 |
| 8 | 13 | 18 | 8 | 0 | 11 | 0 | 4 | 11 | 8 |
| 9 | 5 | 5 | 4 | 2 | 7 | 6 | 16 | 10 | 4 |
| 10 | 3 | 13 | 19 | 8 | 20 | 6 | 27 | 0 | 0 |
| 11 | 2 | 6 | 4 | 0 | 8 | 2 | 2 | 3 | 3 |
| 12 | 2 | 7 | 6 | 1 | 1 | 0 | 0 | 0 | 2 |
| 13 | 1 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 14 | 1 | 0 | 5 | 0 | 0 | 0 | 2 | 0 | 0 |
| 15 | 0 | 3 | 3 | 0 | 2 | 2 | 1 | 0 | 1 |
| 16 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| Total | 206 | 252 | 419 | 100 | 280 | 185 | 213 | 90 | 70 |
| 2-3" Soil Depth | | | | | | | | | |
| 1 | 4 | 13 | 38 | 10 | 14 | 24 | 20 | | |
| 2 | 23 | 24 | 44 | 14 | 48 | 0 | 119 | | |
| 3 | 5 | 15 | 15 | 1 | 18 | 0 | 5 | | |
| 4 | 4 | 4 | 7 | 4 | 15 | 2 | 11 | | |
| 5 | 21 | 37 | 72 | 14 | 51 | 48 | 23 | 42 | 4 |
| 6 | 5 | 2 | 23 | 0 | 4 | 8 | 5 | 34 | 26 |
| 7 | 0 | 3 | 8 | 2 | 7 | 1 | 16 | 0 | 0 |
| 8 | 10 | 9 | 4 | 0 | 3 | 0 | 10 | 7 | 24 |
| 9 | 4 | 3 | 3 | 1 | 1 | 2 | 10 | 12 | 0 |
| 10 | 5 | 7 | 11 | 2 | 11 | 6 | 13 | 0 | 0 |
| 11 | 0 | 1 | 0 | 1 | 4 | 6 | 3 | 0 | 7 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 13 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 2 |
| 14 | 0 | 1 | 3 | 0 | 0 | 0 | 2 | 0 | 4 |
| 15 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 |
| 16 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 81 | 119 | 231 | 51 | 177 | 97 | 239 | 95 | 68 |

¹Sampling dates began in August 1999 and ended in December 2001.

²C1 = Cantonment I, C2= Cantonment II, DP = Duck Pond, G5 = Gate 5, RES = Reservoir, WLR = Wildlife Refuge, HWY = Hwy115Rt11, TC = Turkey Creek

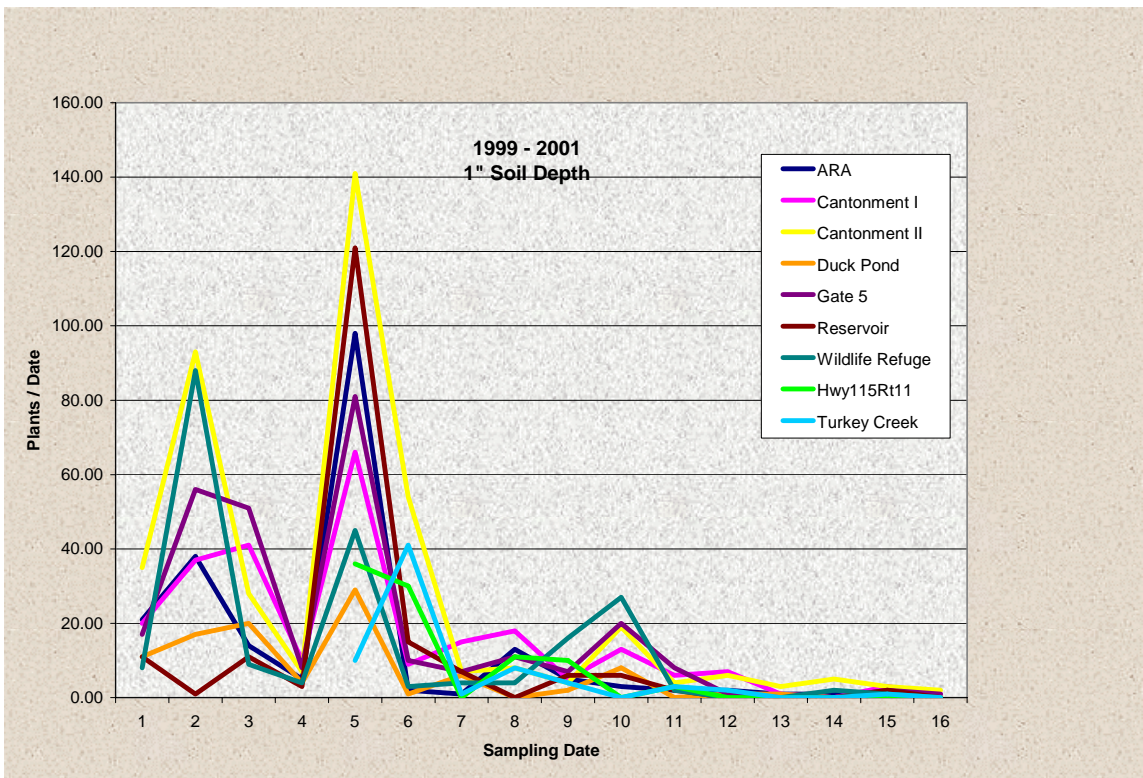


Fig. 19. Average plant emergence in soils collected from nine release sites in 1999 at 1" depths. Sampling dates began in August 1999 and ended December 2001.

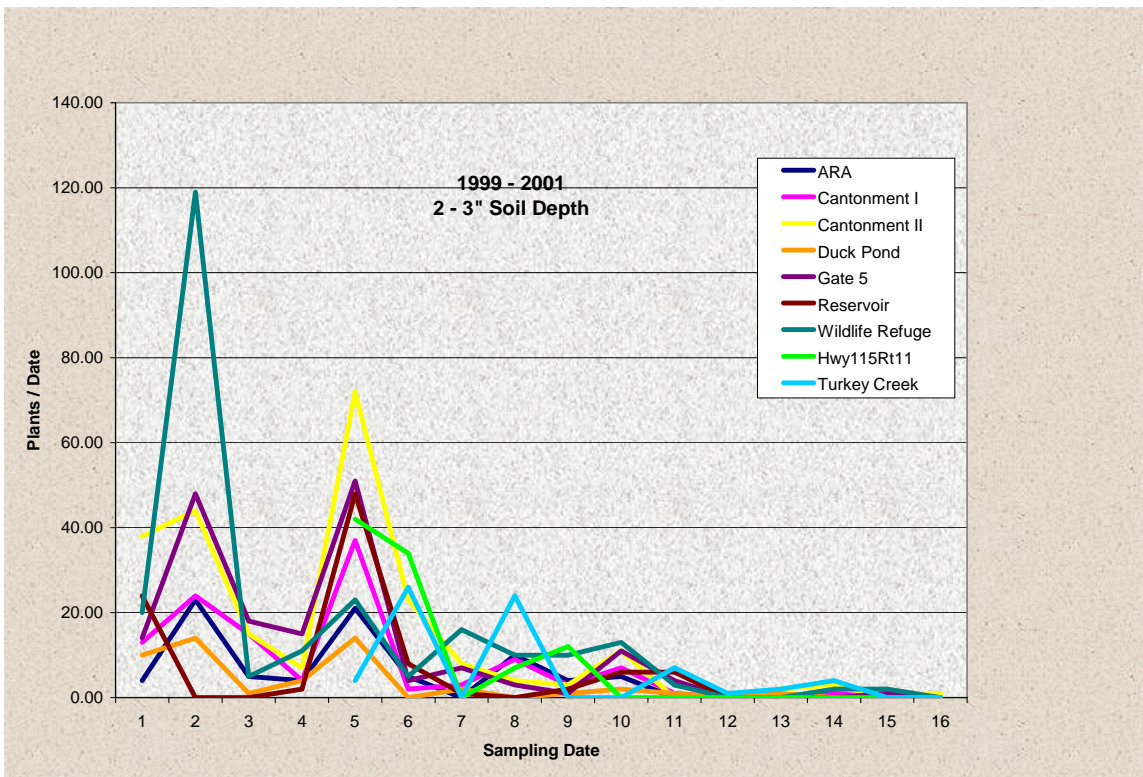


Fig. 20. Average plant emergence in soils collected from nine release sites in 1999 at 2 – 3 inch depths. Sampling dates began in August 1999 and ended December 2001.

Table 8. Total noxious weed emergence from 1999 soil samples.

| Sample Date ¹ | Release Site ² | | | | | | | | | |
|--------------------------|---------------------------|-----------|-----------|-----------|-----------|----------|----------|-----------|----|-----------|
| | ARA | C1 | C2 | DP | G5 | RES | WLR | HWY | TC | |
| 1" Soil Depth | | | | | | | | | | |
| 1 | 7 | 5 | 3 | 3 | 0 | 5 | 2 | | | |
| 2 | 12 | 6 | 21 | 1 | 36 | 0 | 3 | | | |
| 3 | 3 | 7 | 5 | 5 | 33 | 0 | 0 | | | |
| 4 | 1 | 8 | 1 | 1 | 5 | 0 | 0 | | | |
| 5 | 5 | 11 | 16 | 0 | 3 | 1 | 1 | 6 | | 4 |
| 6 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 6 | | 11 |
| 7 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 8 | 0 | 2 | 3 | 0 | 3 | 0 | 0 | 0 | | 6 |
| 9 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | | 2 |
| 10 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 11 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | | 1 |
| 12 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Total | 29 | 45 | 58 | 10 | 80 | 6 | 6 | 12 | | 25 |
| 2-3" Soil Depth | | | | | | | | | | |
| 1 | 2 | 2 | 8 | 3 | 1 | 6 | 0 | | | |
| 2 | 2 | 9 | 9 | 1 | 8 | 0 | 0 | | | |
| 3 | 0 | 5 | 6 | 1 | 6 | 0 | 0 | | | |
| 4 | 0 | 1 | 4 | 0 | 8 | 0 | 0 | | | |
| 5 | 1 | 6 | 13 | 0 | 2 | 1 | 0 | 8 | | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | | 1 |
| 7 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | | 0 |
| 8 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 0 | | 17 |
| 9 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 10 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 1 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Total | 5 | 26 | 48 | 6 | 26 | 7 | 0 | 9 | | 19 |

¹Sampling dates began in August 1999 and ended in December 2001.

²C1 = Cantonment I, C2= Cantonment II, DP = Duck Pond, G5 = Gate 5, RES = Reservoir, WLR = Wildlife Refuge, HWY = Hwy115Rt11, TC = Turkey Creek

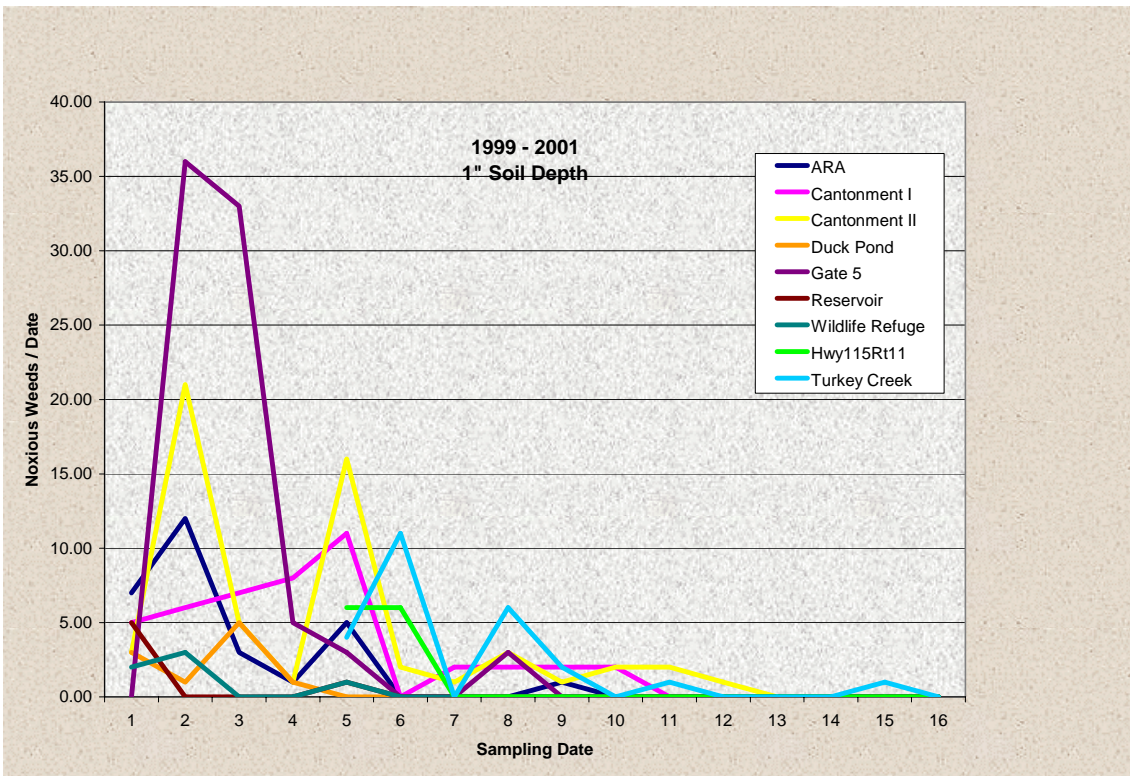


Fig. 21. Average noxious weed emergence in soils collected from nine release sites in 1999 at 1 inch depths. Sampling dates began in August 1999 and ended December 2001.

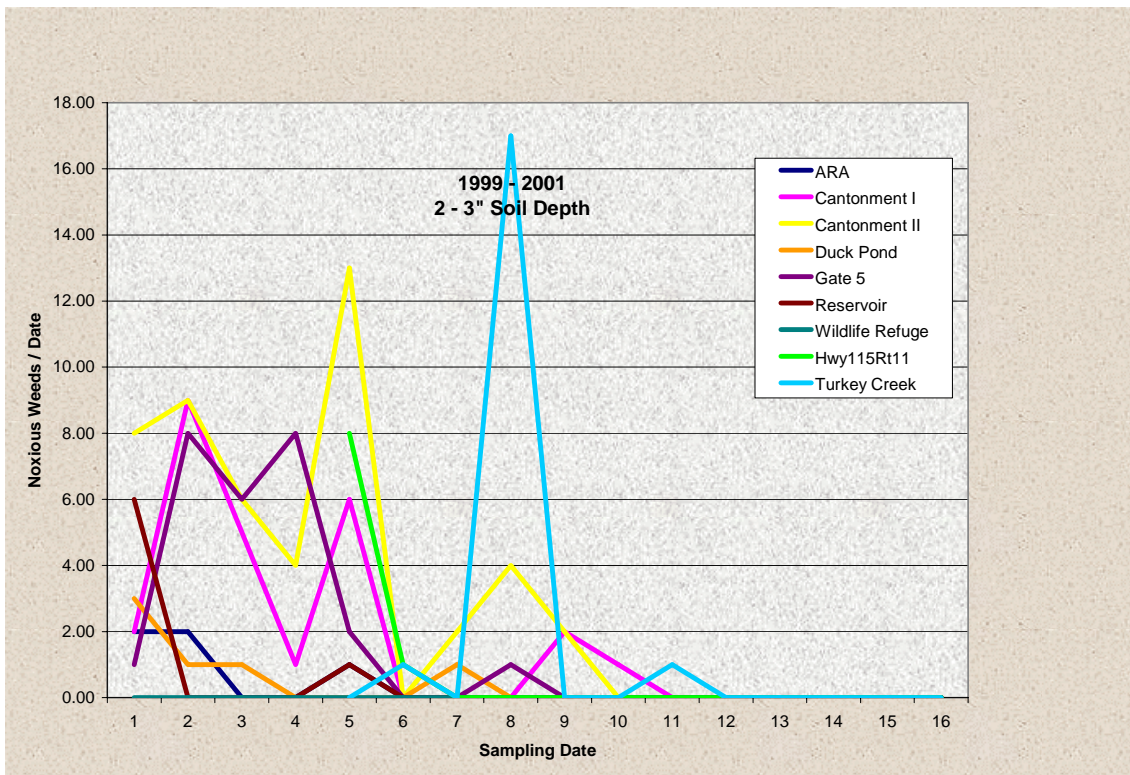


Fig. 22. Average noxious weed emergence in soils collected from nine release sites in 1999 at 2 – 3 inch depths. Sampling dates began in August 1999 and ended December 2001.

Table 9. Noxious weeds as a percentage of total plants emerging from 1999 soil samples¹

| Sampling date ² | Release Site ³ | | | | | | | | |
|----------------------------|---------------------------|-------|--------|--------|-------|-------|-------|-------|--------|
| | ARA | C1 | C2 | DP | G5 | RES | WLR | HWY | TC |
| 1" Soil Depth | | | | | | | | | |
| 1 | 33.33 | 25.00 | 8.57 | 27.27 | 0.00 | 45.45 | 25.00 | | |
| 2 | 31.58 | 16.22 | 22.58 | 5.88 | 64.29 | 0.00 | 3.41 | | |
| 3 | 21.43 | 17.07 | 17.86 | 25.00 | 64.71 | 0.00 | 0.00 | | |
| 4 | 20.00 | 80.00 | 14.29 | 25.00 | 62.50 | 0.00 | 0.00 | | |
| 5 | 5.10 | 16.67 | 11.35 | 0.00 | 3.70 | 0.83 | 2.22 | 16.67 | 40.00 |
| 6 | 0.00 | 0.00 | 3.70 | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 | 26.83 |
| 7 | 0.00 | 13.33 | 14.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 11.11 | 37.50 | 0.00 | 27.27 | 0.00 | 0.00 | 0.00 | 75.00 |
| 9 | 20.00 | 40.00 | 25.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 50.00 |
| 10 | 0.00 | 15.38 | 10.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | 0.00 | 0.00 | 50.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 33.33 |
| 12 | 0.00 | 0.00 | 16.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 100.00 |
| 16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 14.08 | 17.86 | 13.84 | 10.00 | 28.57 | 3.24 | 2.82 | 13.33 | 35.71 |
| 2-3" Soil Depth | | | | | | | | | |
| 1 | 50.00 | 15.38 | 21.05 | 30.00 | 7.14 | 25.00 | | | |
| 2 | 8.70 | 37.50 | 20.45 | 7.14 | 16.67 | 0.00 | | | |
| 3 | 0.00 | 33.33 | 40.00 | 100.00 | 33.33 | 0.00 | | | |
| 4 | 0.00 | 25.00 | 57.14 | 0.00 | 53.33 | 0.00 | | | |
| 5 | 4.76 | 16.22 | 18.06 | 0.00 | 3.92 | 2.08 | 0.00 | 19.05 | 0.00 |
| 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.94 | 3.85 |
| 7 | 0.00 | 0.00 | 25.00 | 50.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.00 | 0.00 | 100.00 | 0.00 | 33.33 | 0.00 | 0.00 | 0.00 | 70.83 |
| 9 | 0.00 | 66.67 | 66.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 10 | 0.00 | 14.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 14.29 |
| 12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 6.17 | 21.85 | 20.78 | 11.76 | 14.69 | 7.22 | 0.00 | 9.47 | 27.94 |

¹Samples consisted of 900 g of soil from 1" and 2-3" depths per site.

²Sampling dates began in August 1999 and ended in December 2001.

³C1 = Cantonment I, C2= Cantonment II, DP = Duck Pond, G5 = Gate 5, RES = Reservoir, WLR = Wildlife Refuge, HWY = Hwy115Rt11, TC = Turkey Creek.

The cumulative noxious weed emergence from the 1999 soil samples shows that most of the noxious weeds had emerged by the tenth sampling date (Table 10, Figs. 23 & 24). The soil samples were vernalized twice at 0° C by the tenth sampling date which would be equivalent to three growing seasons.

Table 10. Cumulative noxious weed emergence from 1999 soil samples¹.

| Sampling date ² | Release Site ³ | | | | | | | | |
|----------------------------|---------------------------|----|----|----|----|-----|-----|-----|----|
| | ARA | C1 | C2 | DP | G5 | RES | WLR | HWY | TC |
| 1" Soil Depth | | | | | | | | | |
| 1 | 7 | 5 | 3 | 3 | 0 | 5 | 2 | | |
| 2 | 19 | 11 | 24 | 4 | 36 | 5 | 5 | | |
| 3 | 22 | 18 | 29 | 9 | 69 | 5 | 5 | | |
| 4 | 23 | 26 | 30 | 10 | 74 | 5 | 5 | | |
| 5 | 28 | 37 | 46 | 10 | 77 | 6 | 6 | 6 | 4 |
| 6 | 28 | 37 | 48 | 10 | 77 | 6 | 6 | 12 | 15 |
| 7 | 28 | 39 | 49 | 10 | 77 | 6 | 6 | 12 | 15 |
| 8 | 28 | 41 | 52 | 10 | 80 | 6 | 6 | 12 | 21 |
| 9 | 29 | 43 | 53 | 10 | 80 | 6 | 6 | 12 | 23 |
| 10 | 29 | 45 | 55 | 10 | 80 | 6 | 6 | 12 | 23 |
| 11 | 29 | 45 | 57 | 10 | 80 | 6 | 6 | 12 | 24 |
| 12 | 29 | 45 | 58 | 10 | 80 | 6 | 6 | 12 | 24 |
| 13 | 29 | 45 | 58 | 10 | 80 | 6 | 6 | 12 | 24 |
| 14 | 29 | 45 | 58 | 10 | 80 | 6 | 6 | 12 | 24 |
| 15 | 29 | 45 | 58 | 10 | 80 | 6 | 6 | 12 | 25 |
| 16 | 29 | 45 | 58 | 10 | 80 | 6 | 6 | 12 | 25 |
| Total | | | | | | | | | |
| 2-3" Soil Depth | | | | | | | | | |
| 1 | 2 | 2 | 8 | 3 | 1 | 6 | 0 | | |
| 2 | 4 | 11 | 17 | 4 | 9 | 6 | 0 | | |
| 3 | 4 | 16 | 23 | 5 | 15 | 6 | 0 | | |
| 4 | 4 | 17 | 27 | 5 | 23 | 6 | 0 | | |
| 5 | 5 | 23 | 40 | 5 | 25 | 7 | 0 | 8 | 0 |
| 6 | 5 | 23 | 40 | 5 | 25 | 7 | 0 | 9 | 1 |
| 7 | 5 | 23 | 42 | 6 | 25 | 7 | 0 | 9 | 1 |
| 8 | 5 | 23 | 46 | 6 | 26 | 7 | 0 | 9 | 18 |
| 9 | 5 | 25 | 48 | 6 | 26 | 7 | 0 | 9 | 18 |
| 10 | 5 | 26 | 48 | 6 | 26 | 7 | 0 | 9 | 18 |
| 11 | 5 | 26 | 48 | 6 | 26 | 7 | 0 | 9 | 19 |
| 12 | 5 | 26 | 48 | 6 | 26 | 7 | 0 | 9 | 19 |
| 13 | 5 | 26 | 48 | 6 | 26 | 7 | 0 | 9 | 19 |
| 14 | 5 | 26 | 48 | 6 | 26 | 7 | 0 | 9 | 19 |
| 15 | 5 | 26 | 48 | 6 | 26 | 7 | 0 | 9 | 19 |
| 16 | 5 | 26 | 48 | 6 | 26 | 7 | 0 | 9 | 19 |
| Total | | | | | | | | | |

¹Samples consisted of 900 g of soil from 1" and 2-3" depths per site.

²Sampling dates began in August 1999 and ended in December 2001.

³C1 = Cantonment I, C2= Cantonment II, DP = Duck Pond, G5 = Gate 5, RES = Reservoir, WLR = Wildlife Refuge, HWY = Hwy115Rt11, TC = Turkey Creek.

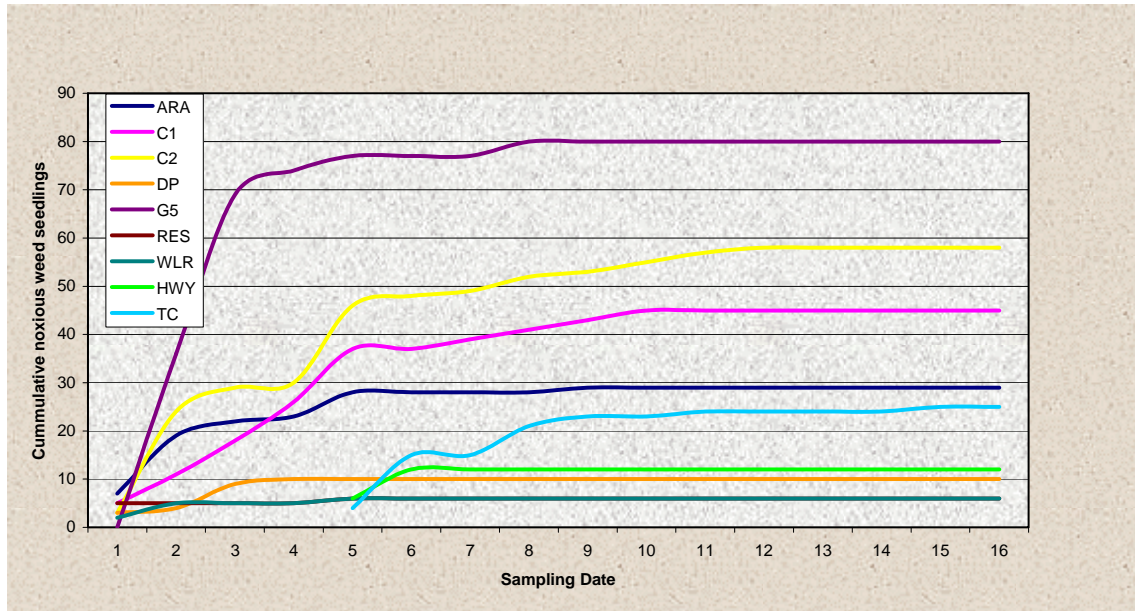


Fig. 23. Cumulative noxious weed seedling emergence from 900g soil samples at 1" depth.

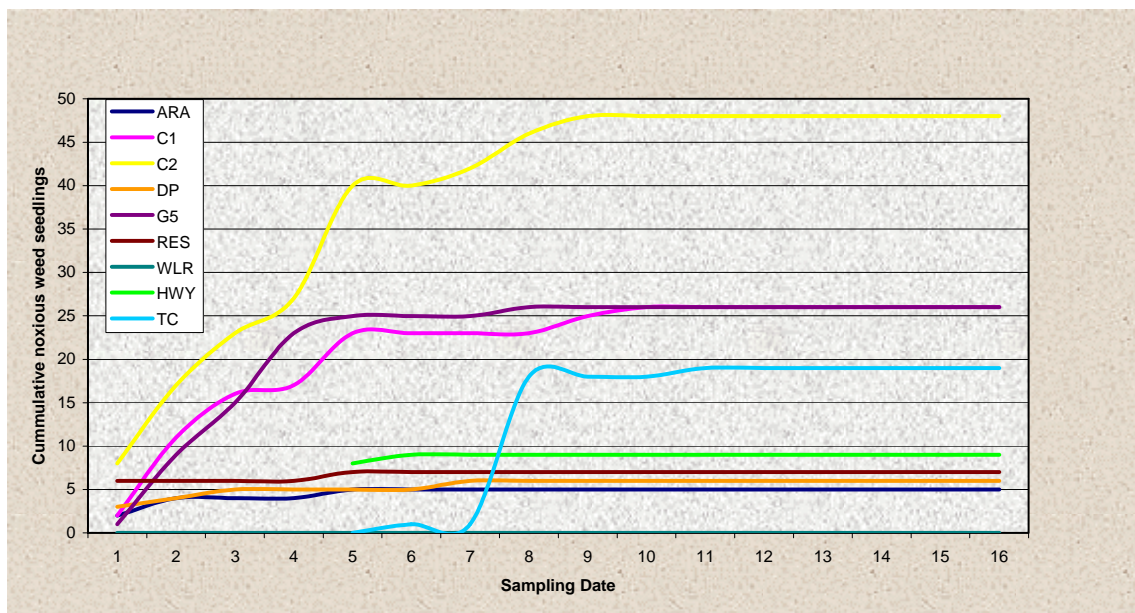


Fig. 24. Cumulative noxious weed seedling emergence from 900g soil samples at 2-3" depth.

The results indicate that noxious weeds may continue to germinate for years and can range from 1 to 80 noxious weeds per 900 g soil over a period of 3 years. Therefore, even if all noxious weeds which germinated at a site in a particular season were removed (chemical, fire, etc.), a site could continue to produce millions of noxious weeds per hectare for several years. For example, 58 spotted

knapweed plants emerged from Cantonment II soil samples taken at 1" depths. This would be equivalent to over 18 million plants per hectare (Table 11). Therefore, although seed-feeding biological control agents may not have an immediate visual impact, they are extremely important in reducing seed production. The continual presence of bioagents is vital in maintaining a constant pressure on the weeds and seedlings that emerge.

Table 11. Noxious weed density per sample, acre and hectare from 1999 soil samples.

| Total noxious weeds per | Release Site ¹ | | | | | | | | |
|-------------------------------|----------------------------|------------|------------|-----------|------------|-----------|-----------|-----------|------------|
| | ARA | C1 | C2 | DP | G5 | RES | WLR | HWY | TC |
| | 1" Soil Depth | | | | | | | | |
| Sample | 29 | 45 | 58 | 10 | 80 | 6 | 6 | 12 | 25 |
| Acre | 3,645,714 | 5,657,143 | 7,291,429 | 1,257,143 | 10,057,143 | 754,286 | 754,286 | 1,508,571 | 3,142,857 |
| Hectare | 9,004,914 | 13,973,143 | 18,009,829 | 3,105,143 | 24,841,143 | 1,863,086 | 1,863,086 | 3,726,171 | 7,762,857 |
| | 2-3" Soil Depth | | | | | | | | |
| Sample | 5 | 26 | 48 | 6 | 26 | 7 | 0 | 9 | 19 |
| Acre | 1,571,429 | 8,171,429 | 15,085,714 | 1,885,714 | 8,171,429 | 2,200,000 | 0 | 2,828,571 | 5,971,429 |
| Hectare | 3,881,429 | 20,183,429 | 37,261,714 | 4,657,714 | 20,183,429 | 5,434,000 | 0 | 6,986,571 | 14,749,429 |
| | Total (1" and 2-3" Depths) | | | | | | | | |
| Sample | 34 | 71 | 106 | 16 | 106 | 13 | 6 | 21 | 44 |
| Acre | 3,053,061 | 6,375,510 | 9,518,367 | 1,436,735 | 9,518,367 | 1,167,347 | 538,776 | 1,885,714 | 3,951,020 |
| Hectare | 7,541,061 | 15,747,510 | 23,510,367 | 3,548,735 | 23,510,367 | 2,883,347 | 1,330,776 | 4,657,714 | 9,759,020 |

¹C1 = Cantonment I, C2= Cantonment II, DP = Duck Pond, G5 = Gate 5, RES = Reservoir, WLR = Wildlife Refuge, HWY = Hwy115Rt11, TC = Turkey Creek