REDISTRIBUTION AND ESTABLISHMENT OF *ACERIA MALHERBAE* FOR BIOLOGICAL CONTROL OF FIELD BINDWEED (*CONVOLVULUS ARVENSIS*)

By

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REDISTRIBUTION AND ESTABLISHMENT OF

ACERIA MALHERBAE FOR BIOLOGICAL

CONTROL OF FIELD BINDWEED

(*CONVOLVULUS ARVENSIS*)

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INTRODUCTION

This thesis is a manuscript to be submitted for publication in Weed Technology, a Weed Science Society of America publication.

Redistribution and Establishment of *Aceria malherbae* for Biological Control of Field Bindweed (*Convolvulus arvensis*)[1]

KENNETH A. HOLLON[2]

Abstract: A cooperative field bindweed biological control program was initiated in the spring of 1999 in Oklahoma. *Aceria malherbae* N.-infested field bindweed foliage was hand collected near Bushland, TX. Foliage (50 to 100 g) was placed in each of 200 27 by 28 cm polyethylene bags with closures and transported to Oklahoma for distribution the next day to interested wheat producers at the annual North Central Research Station field day on May 15, 1999. Producers provided detailed information on their normal farming practices prior to obtaining one bag of *A. malherbae*-infested field bindweed foliage. Producers also agreed to allow to their property to periodically inspect the release sites. Producers were instructed to release the mites the day they received them onto growing field bindweed in winter wheat (*Triticum aestivum* L.) on their property. *A. malherbae* infested foliage was also released at undisturbed sites at the North Central Research Station, the Stillwater Agronomy Research Station, and the Oklahoma Panhandle Research and Extension Center, to establish *A. malherbae* nurseries. This process was repeated on May 19, 2000. During October and November

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each year, all sites were inspected for *A. malherbae* feeding damage. Of 106 cooperative release sites established in 1999, 2 had *A. malherbae* feeding damage when inspected in November 1999. These were located in Harper and Beaver Counties in the Oklahoma Panhandle. During October and November 2000 all 1999 release sites were revisited as well as the 48 cooperative release sites established on May 19, 2000. At this time the only site with visible *A. malherbae* feeding damage was the site from Harper County. Of the three nursery sites, *A. malherbae* became established only at the Oklahoma Panhandle Research and Extension Center.

Nomenclature: Field bindweed, *Convolvulus arvensis* L., *Aceria malherbae* N.

Additional index words: Bindweed mite, galling mite.

Abbreviations: CRP, conservation reserve program, GPS, global positioning system.

INTRODUCTION

Field bindweed is native to Eurasia, but has become a serious problem throughout much of the world between 60°N and 45°S latitudes (Holm et al. 1977). Field bindweed was introduced into the U.S. in the late 18th century on the Atlantic coast and was firmly established in the western U.S. by the early 1900's (Phillips 1978). Field bindweed has become a serious problem in all areas of the United States except the Southeastern states (Zamora 1991).

Field bindweed is a warm-season perennial that reproduces sexually and asexually by rhizomes and root buds. It belongs to the morning-glory family (Convovulaceae) and is a prostrate growing plant in agronomic settings that can twine around crop plants and form a dense mat of vegetation (Gleason and Cronquist 1963). A pure stand of field bindweed can produce 50,000 to 20 million seeds/ha/yr (Weaver and Riley 1982). Field bindweed spreads up to ten feet in diameter in one growing season and can store up to 953 kg/ha of food reserves in its roots (Baake et al. 1939; Best 1963). Consequently, removing the above ground portion of bindweed by tillage or mowing does little to deplete plant reserves (Swain 1980). Several herbicides effectively control field bindweed, but repeated annual applications for up to five years may be necessary to adequately reduce populations (Schweizer et al. 1978).

Conservation of soil water is very important in the Great Plains where rainfall is erratic and undependable. Field bindweed is extremely competitive for moisture, with roots up to 6 m deep (Best 1963). Competition from dense field bindweed can reduce crop yields 50-60% (Callihan et al. 1990). Consequently, controlling it can significantly increase available soil water (Wiese et al. 1996).

A. malherbae (Acari: Eriophyidae) was imported from Greece in 1988 to USDA APHIS quarantine facilities (Boldt and Sobhian 1993). The adult mites are approximately 0.02 mm long and are yellow with two pairs of legs found on the joined head and thorax.

In 1986, host specificity tests were conducted at the USDA quarantine facility in Albany, CA on 48 plant species in 21 families with emphasis on commercially important North American Convolvulaceae (Rosenthal and Platts 1990). They fed only on field bindweed and *Calystegia* spp., of which hedge bindweed (*Calystegia sepium*) is a member.

The mites attack the leaf mid-ribs and stems of the host plants and produce galls, in which they lay eggs, leading to deformed, curled leaves and stunted plant growth (Reese et al. 1996). Mites are active from May to November depending on the geographic location (Reese et al. 1996) and over-winter on the root buds. *A. malherbae* was first released near Bushland, Texas in 1989 (Boldt and Sobhian 1993).

Dowdy and Michels (unpublished data) conducted cooperative *A. malherbae* release studies in the Texas panhandle in 1999 and 2000. They collected *A. malherbae*-infested field bindweed foliage in 18 by 20cm transparent polyethylene bags with closures each containing approximately 6000 mites. In 1999 *A. malherbae* became established at 36 of 72 release sites in 15 counties. They found that success depended largely on farming practices and location of release. For example, in 1999 11% establishment occurred at cultivated sites, while 73% establishment occurred on mowed sites, and 80% establishment occurred on undisturbed sites.

In year 2000 cooperative releases by Dowdy and Michels (unpublished data), *A. malherbae* became established at 34 of 42 release sites in 20 counties. Cultivated sites had 19% establishment, while 58% establishment occurred on mowed sites and 88% establishment occurred on undisturbed sites.

The objectives of this study were to establish *A. malherbae* nurseries on three research stations in Oklahoma to expedite the further collection and redistribution of *A. malherbae* throughout the state. A second objective was to coordinate the release of *A. malherbae* on field bindweed throughout western

Oklahoma and to define factors that contribute to the successful establishment of *A. malherbae*. These factors included identification of weather conditions adequate for the establishment of *A. malherbae*, identification of farming practices that may affect their establishment, and influence of release time on establishment.

MATERIALS AND METHODS

Nursery Establishment. Field bindweed clippings infested with *A. malherbae* were hand collected at Bushland, Texas in 1999 (Table 1). Only field bindweed foliage showing symptoms of *A. malherbae* feeding, such as galls and deformed leaves, was collected. The field bindweed foliage was separated into 200 samples, each with 50 to 100 g of foliage, and placed into 27 by 28 cm transparent polyethylene bags with closures. The bags were closed and placed into insulated boxes to maintain a temperature of 20 ± 5 C during transport. This process was repeated in 2000.

An experiment was established one day after collection to determine how long the mites could survive under different conditions. Treatments were 1) closed bags placed in windowsill in direct sunlight with temperature ranging from 28.8 to 37.7 C, 2) closed bags stored at 3.3 to 6.1 C, 3) open bags at room temperature (20 to 23.3 C) not in direct sunlight, 4) closed bags at room temperature in closed metal cabinet, and 5) closed bags stored at -10 to -4 C. These samples were observed for mite presence using 20x magnification four days after collection.

A. malherbae was released at the OSU Agronomy Research Station in Stillwater, The North Central Research Station near Lahoma, and the Oklahoma Panhandle Research and Extension Center near Goodwell to establish them on controllable research station sites. In May 1999 and May 2000,10 to 15 bags of mite-infested foliage were emptied onto growing field bindweed at each site. Each bag of mite-infested foliage was placed in an area less than 10 m in diameter to concentrate a large population of mites in a single area so that *A. malherbae* could become established quickly and increase rapidly.

GPS coordinates (Appendix A) and measurements from permanent landmarks were recorded for each nursery site. Field bindweed was the dominant vegetation at each site. All three sites were mowed to suppress other weeds during the summers of 1999 and 2000, beginning not earlier than one month after release, and were not otherwise disturbed during 1999 or 2000.

Leaves and stems from each site were visually inspected monthly from June to November 2000 and in April 2001 for mite-feeding damage and for the presence of mites using 20x magnification when mite damage was visible. Height of ten field bindweed plants was measured in the mite-affected areas as well as the unaffected areas. Soil samples were also collected in April 2001 for pH analysis to determine whether pH had an affect on mite establishment.

Cooperative Release Program. Mites not used for nursery establishment were used in a cooperative release program. A press release (Appendix B) was sent to all Oklahoma State University County Extension Educators explaining how interested producers could participate in the release program along with a questionnaire (Appendix C) for interested producers to complete. Several OSU County Extension Educators placed the press release in their respective local newspapers. The completed questionnaires were used to determine the field conditions of each release site and obtain the legal land description of the release site for later mapping and inspection. Field conditions of each cooperative release site at the time of mite release are in table 2.

At the North Central Research Station field day, cooperators exchanged their questionnaires for one bag of *A. malherbae*-infested field bindweed foliage. They also received two wire flags with instructions to place one flag at the release site and the other at the fence or road nearest the release site so that Oklahoma State University personnel could easily locate the site for mapping. Cooperators were instructed to release the mites on the same day they received them and empty the bag of mite-infested field bindweed foliage into actively growing field bindweed. Following release of the mites, the cooperator was instructed to walk in a straight line back to the nearest fence or road and place the second flag in the fence or roadside. They were also instructed to continue with their present management practices as if the mites were not there so that we could determine whether the mites would establish under normal conditions. The cooperators in 2000 were asked to release the mites in an uncultivated area such as a fencerow or roadside to establish *A. malherbae* in areas that would have growing field bindweed all summer. Of the 48 cooperator release sites established in 2000, 41 were located in fencerows and roadsides with the other 7 located in cultivated winter wheat.

Mites were released in 23 western Oklahoma counties at 106 sites in 1999, and in 15 western Oklahoma counties at 48 sites in 2000. During the later half of May 1999 and July 2000 all of the release sites were mapped in relation to distance from two semi-permanent structures. The coordinates of each site were also recorded using a hand-held GPS unit.

During October and November 1999 and 2000 all sites were visually inspected for damage caused by *A. malherbae* feeding. All plants exhibiting symptoms of stress were inspected using 20x magnification for the presence of *A. malherbae* or it's symptoms.

The Harper and Beaver County sites were revisited in April 2001. The field bindweed at these sites was inspected for mite feeding damage and soil samples were collected. Field bindweed density was also measured at five random places within the affected area and five random places outside of the affected area if visual symptoms of mite feeding were present. The dominant species of vegetation were recorded and field bindweed plant height was measured from ten random places in mite-affected areas and unaffected areas. Field bindweed with visible symptoms of mite feeding was inspected using 20x magnification for the presence of *A. malherbae*.

Time-of-Release Experiments. Experiments were initiated at the Stillwater Agronomy Research Station and the North Central Research Station near Lahoma to determine the effect of month of release on *A. malherbae* establishment. A completely randomized design with a factorial arrangement of treatments was used with three replications. Treatments were time of year of release. Each plot was the area < 1 meter in diameter where the *A. malherbae* infested field bindweed foliage was placed.

Using the same methods previously described in the cooperative release program, mites were released on April 27, May 19, and June 28, 2000. Lack of *A. malherbae* infested foliage from the Bushland, Texas site prevented additional releases.

All treatments were inspected in November 2000 and April 2001. Soil samples were also collected in April 2001 for pH analysis.

RESULTS AND DISCUSSION

Nursery Establishment. The foliage samples that were stored open at room temperature away from direct sunlight had live mites on the field bindweed foliage in all four replications. The samples stored in closed bags at 3.3 to 6.1 C also had live mites on the foliage in all four replications. No live mites were found in any of the frozen, windowsill, and closed cabinet treatments. These results confirmed mites were present on the field bindweed foliage that was used in the release programs. Death of the mites in the closed bag-closed cabinet treatment may have been associated with heavy accumulation of condensation in the bags.

As of April 2001, the only mite nursery that was successfully established was at the Oklahoma Panhandle Research and Extension Center near Goodwell. This site is in a patch of field bindweed approximately 20 meters in diameter. The dominant species of vegetation within this area is field bindweed. Symptoms of *A. malherbae* feeding damage were visible at this site by May 2000. In April

2001, the entire area had mite-feeding damage and live mites were observed on the foliage. The mean height of ten mite-affected field bindweed plants was 3 cm, which was 4 cm shorter ($t < .0001$) than the mean height in nearby unaffected areas.

No symptoms of mite-feeding damage were seen at any time at the Stillwater Agronomy Research Station nursery. The dominant species of vegetation on this site were field bindweed and Bermudagrass (*Cynadon dactylon* L.).

No symptoms of mite-feeding damage were seen at any time at the North Central Research Station nursery. The dominant species of vegetation on this site were field bindweed, downy brome (*Bromus tectorum* L.), and cheat (*Bromus secalinus* L.).

Cooperative Release Program. The 106 cooperative release sites established in 1999 were located in 22 counties in Oklahoma indicating widespread interest in field bindweed control. *A. malherbae* feeding was obvious in November 1999 at two sites, one in Beaver and one in Harper County (Figure 1).

Beaver County Site. Mite-feeding damage was visible in November 1999, but no symptoms were visible in November 2000 or April 2001. The site was located in a cultivated winter wheat field. The wheat forage was grazed at the time of mite release in 1999. During the summer months of 1999 this site was cultivated for weed control and winter wheat was seeded in September. When inspected in November 1999, the wheat was approximately 7 cm tall and the field bindweed within a 0.25 m diameter around the release area had galling and deformed foliage evident of *A. malherbae* feeding. The mean height of ten mite-affected field bindweed plants was 6 cm, which was 9 cm shorter (t<.0001) than unaffected plants. Field bindweed plants from the affected area were visually inspected using 20x magnification, but no mites were found on the foliage.

The wheat forage was grazed during the winter and spring months of 1999-2000 until May and cultivated during the summer months. Winter wheat was seeded in September 2000. When inspected in November 2000, the wheat was approximately 3 cm tall and no symptoms of mite feeding were seen on field bindweed. When inspected in April 2001, again, no symptoms of mite feeding were seen.

It is unknown at this time why the symptoms of *A. malherbae* disappeared from this site. Results from Dowdy and Michels' release program (Unpublished data) suggest lower rates of establishment under cultivated conditions.

Harper County Site. When visually inspected in November 1999 mite-feeding damage was present in an area 0.25 m in diameter. The mean field bindweed plant height from ten mite-affected field bindweed plants was 6 cm, which was 4 cm shorter (t<.0001) than unaffected plants. Samples of the affected field bindweed foliage were inspected using 20x magnification, but no mites were found on the foliage. This site is located in CRP land and the dominant species of vegetation are field bindweed, common yarrow (*Achillea millefolium* L.), and downy brome.

In November 2000 the mite-affected area had grown to 15 m in diameter. The mean height of ten mite-affected field bindweed plants was 2.5 cm, which was 12.5 cm shorter (t<.0001) than unaffected plants. Samples of the affected field bindweed foliage were examined using 20x magnification, but no mites were found on the foliage. The entire field this site is located in was sprayed in October 2000 with 2,4-D, but only the 15 m diameter area around the release area had severe damage and galls representative of *A. malherbae* feeding.

When inspected in April 2001, the mite-affected area was 5 m in diameter. The field bindweed density in the affected area was 56 $\pm$ 4.5 stems/m^2. The affected stems in this area were scattered among healthy stems. Of these, only 2 $\pm$ 0.7 stems/m^2 were mite-affected. The mean height of ten mite-affected field bindweed plants was 5 cm, which was 5 cm shorter ($t<.0001$) than unaffected plants. Affected field bindweed plants were inspected using 20x magnification, but no mites were found.

No other sites from the 1999 or the 2000 cooperative release program were ever found to exhibit symptoms of *A. malherbae* feeding. There are many variables that could have affected the establishment of *A. malherbae* including climatic factors such as temperature, precipitation, humidity, and also site and soil conditions, as well as the possibility of natural enemies and diseases.

The results from Dowdy and Michels' release program (unpublished data) suggests that *A. malherbae* tends to show better rates of establishment under uncultivated conditions; however, establishment was not successful at any uncultivated sites east of the Oklahoma panhandle. It is also possible that the mites prefer higher soil pH. Soil pH at established sites ranged from 6.9 to 8.1. There are currently not enough established sites in Oklahoma to correlate soil pH with the success of *A. malherbae*.

Lower rainfall and humidity in the Oklahoma panhandle versus other release sites may have contributed to the success of *A. malherbae* establishment in the panhandle. Weather conditions in the Oklahoma Panhandle are very similar to conditions in the Texas Panhandle where Dowdy and Michels had 50% and 80% establishment in 1999 and 2000 respectively (unpublished data). The average daily evapotranspiration rates at the Oklahoma Panhandle Research and Extension Center and the North Central Research Station from January 1, 2000 to December 31, 2000 were 44 mm/day and 35 mm/day respectively, measured from cool season sod and 29 mm/day and 23 mm/day respectively, measured from warm season sod. Higher evapotranspiration rates correspond to lower humidity. Evapotranspiration rates at Goodwell indicate drier conditions.

The mean monthly temperature at these two locations for 1999 and 2000 differed less than 4 C with the Oklahoma Panhandle Research and Extension Center being consistently cooler than the North Central Research Station (Appendix D). It is unknown whether temperature affects survival of *A. malherbae* and if so, what the optimum temperature range for survival is.

With nearly identical methods used for mite collection and release as those used in Texas (Dowdy and Michels unpublished data) and far superior establishment results in Texas, relatively heavy precipitation in Oklahoma following mite release may have had a negative impact on the establishment of *A. malherbae*. Comparing the monthly precipitation totals for the North Central Research Station, Slapout, OK (the closest weather station to the successfully established site in Harper County), and Amarillo, TX reveals that the North central Research Station received approximately 30 cm more precipitation than Slapout, OK and Amarillo, TX during the summer months of 1999 (Appendix E).

Of the 48 cooperator releases made in May 2000, 41 were located in fencerows and roadsides (Table 2). These areas should have been relatively undisturbed and stable for the establishment of *A. malherbae* when compared to a tilled wheat field, yet as of November 2000 none of them had shown any signs of *A. malherbae* feeding.

Time-of-Release Experiments. The effect of month of release could not be determined because none of the releases were successful.

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Table 1. Timeline of activities associated with nursery establishment and cooperative release program.

Date	Activity
May 1, 1999	Press releases and questionnaires were sent to OSU County Extension Educators
May 14, 1999	Mites were collected near Bushland, TX
May 15, 1999	Mites were distributed at field day
May 15, 1999	Mites released at nursery sites
May 20 to June 6, 1999	All sites visited and mapped
Oct 25 to Nov 6, 1999	All sites inspected for *A. Malherbae* feeding
May 1, 2000	Press releases sent to OSU County Extension Educators
May 18, 2000	Mites collected near Bushland, TX
May 19, 2000	Mites distributed at field day
May 19, 2000	Mites released at nursery sites
May 22 to June 1, 2000	Year 2000 sites visited and mapped
Oct 31 to Nov 15, 2000	All sites inspected for *A. malherbae* feeding
Apr 10 and 11, 2001	Nursery sites inspected and soil samples collected
Apr 10 and 11, 2001	Harper and Beaver County sites inspected and soil samples collected

Table 2. Number of cooperative release sites and field conditions at those sites at time of release.

County	Year	Field conditions at time of release[a]								
		1	2	3	4	5	6	7	8	9
Alfalfa	1999	6	0	0	2	0	0	0	1	2
Beaver	1999	1[b]	0	0	0	0	0	0	0	0
Blaine	1999	4	4	0	1	0	0	0	0	0
Blaine	2000	1	0	0	0	0	0	0	0	0
Caddo	1999	1	0	2	0	0	0	0	0	0
Caddo	2000	0	0	0	0	0	0	1	0	0
Canadian	1999	3	2	1	0	0	0	0	0	0
Canadian	2000	1	0	0	0	0	0	0	0	0
Cotton	1999	1	0	0	0	0	0	0	0	0
Custer	1999	3	1	0	0	0	0	0	0	0
Custer	2000	0	0	0	0	0	0	1	0	0
Dewey	1999	1	0	0	0	0	0	0	0	0
Dewey	2000	1	0	0	0	0	0	0	0	0
Garfield	1999	3	7	1	1	0	0	0	0	0
Garfield	2000	0	0	0	0	0	0	20	0	0
Grant	1999	4	0	1	0	0	0	0	0	0
Grant	2000	0	0	0	0	0	0	4	0	0
Harmon	1999	1	0	0	2	0	0	0	0	0

Table 2. Continued.

Harper	1999	4	2	0	0	0	1[c]	0	0	0
Jackson	1999	0	5	0	0	0	0	0	0	0
Kay	1999	0	1	0	0	0	0	0	0	0
Kay	2000	0	1	0	0	0	0	0	0	0
Kingfisher	1999	4	5	0	2	0	0	0	0	0
Kingfisher	2000	1	0	0	0	0	0	7	0	0
Logan	1999	2	1	0	0	0	0	1	0	0
Major	1999	2	6	0	1	0	0	1	0	0
Major	2000	0	0	0	0	0	0	3	0	0
Noble	1999	4	0	0	0	1	0	0	0	0
Noble	2000	0	1	0	0	0	0	2	0	0
Payne	1999	0	1	0	0	0	0	0	0	0
Payne	2000	0	0	0	0	0	0	1	0	0
Tillman	1999	1	0	0	0	0	0	0	0	0
Washita	1999	1	0	0	0	0	0	0	0	0
Washita	2000	0	0	0	0	0	0	1	0	0
Woods	1999	0	5	0	1	0	0	0	0	0
Woods	2000	0	0	0	0	0	0	1	0	0
Woodward	1999	0	0	0	2	0	0	0	0	0
Woodward	2000	0	1	0	0	0	0	0	0	0

[a] Field conditions at time of release:

1 = Wheat forage was grazed, cattle were removed by March 15, wheat grain

Table 2. Continued.

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was harvested. 2 = Wheat forage was not grazed, wheat grain was harvested. 3 = Wheat forage was grazed, cattle were removed by March 15, then wheat forage was harvested for hay. 4 = Wheat forage was grazed throughout the season, wheat grain was not harvested. 5 = Wheat was planted no-till, wheat grain was harvested. 6 = Conservation Reserve Program site (CRP). 7 = A roadside or fencerow. 8 = Site had no field bindweed present when inspected. 9 = Site was planted to rotational crop of soybeans (*Glycine max*. L.) or sorghum (*Sorghum bicolor* L.).

[b] Site had A. malherbae feeding damage in November 1999

[c] Site had A. malherbae feeding damage in November 1999 and November 2000

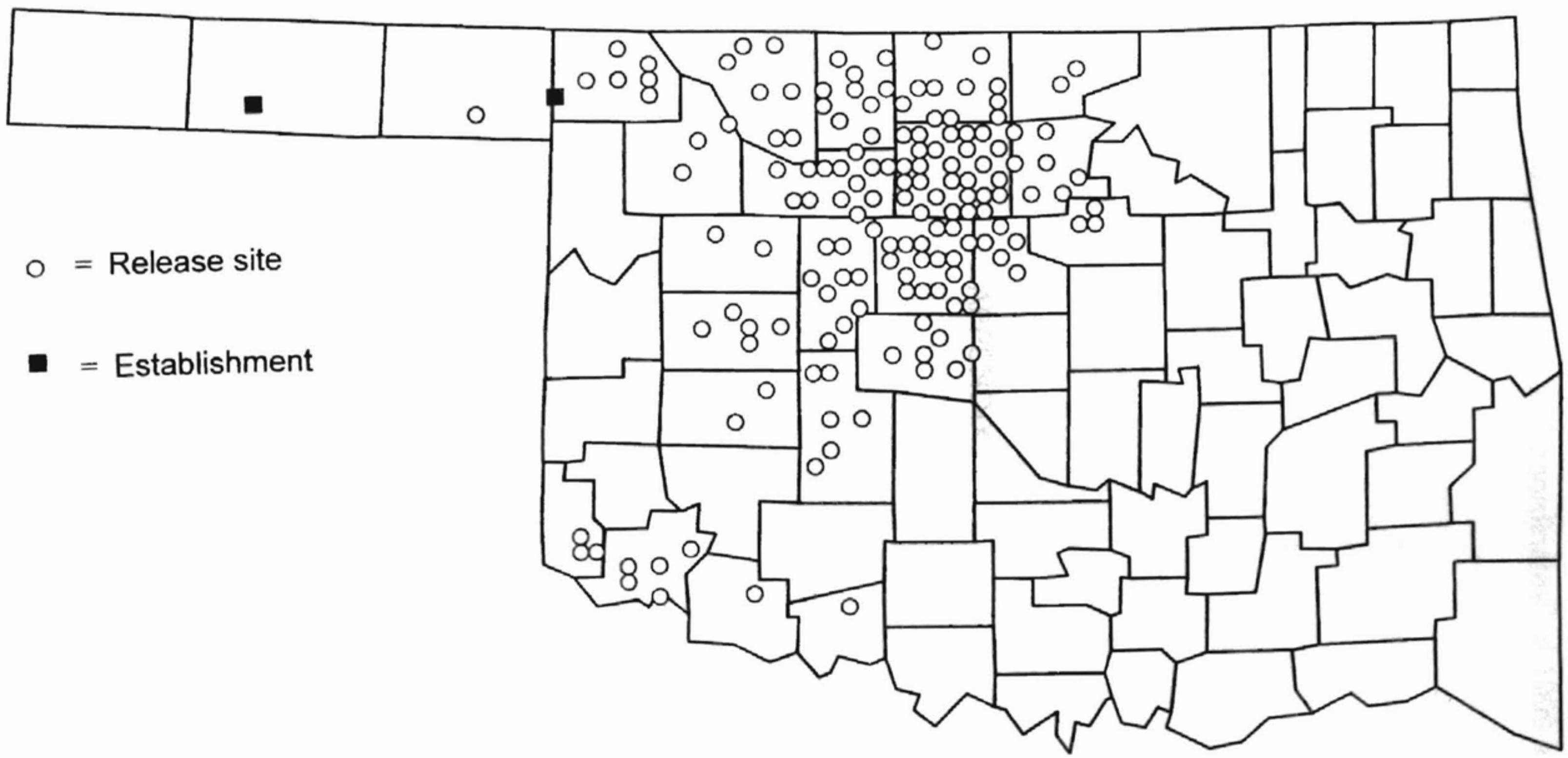

Figure 1. Locations of 1999 and 2000 cooperative release sites and nursery sites.

APPENDIX

Appendix A. Legal land descriptions and GPS coordinates[a] of 1999 and 2000 cooperative release sites.

Site	Legal Land Description	GPS Coordinates
Alfalfa 1	SW ¼, SEC 35, T29N, R12W, I.M.	N36°56.596' W98°27.728'
Alfalfa 2	NW ¼, SEC 10, T25N, R10W, I.M.	N36°39.812' W98°16.230'
Alfalfa 3	NW ¼, SEC 6, T28N, R11W, I.M.	N36°56.281' W98°25.857'
Alfalfa 4	NE ¼, SEC 15, T26N, R12W, I.M.	N36°44.216' W98°28.177'
Alfalfa 5	NE ¼, SEC 15, T26N, R12W, I.M.	N36°44.023' W98°28.194'
Alfalfa 6	NW ¼, SEC 18, T23N, R11W, I.M.	N36°33.994' W98°26.377'
Alfalfa 7	SE ¼, SEC 13, T26N, R12W, I.M.	N36°43.560' W98°26.057'
Alfalfa 8	NE ¼, SEC 9, T24N, R12W, I.M.	N36°34.700' W98°28.090'
Alfalfa 9	NE ¼, SEC 19, T28N, R11W, I.M.	N36°53.843' W98°24.839'
Alfalfa 10	NE ¼, SEC 35, T24N, R9W, I.M.	N36°31.012' W98°07.347'
Alfalfa 11	SE ¼, SEC 3, T23N, R9W, I.M.	N36°29.682' W98°08.412'
Beaver 1	NE ¼, SEC 26, T1N, R26E, C.M.	N36°31.52' W100°13.51'
Blaine 1	NW ¼, SEC 6, T14N, R12W, I.M.	N35°43.495' W98°31.171'
Blaine 2	NW ¼, SEC 6, T14N, R12W, I.M.	N35°43.091' W98°31.500'
Blaine 3	NE ¼, SEC 28, T19N, R11W, I.M.	N36°05.712' W98°22.265'
Blaine 4	NW ¼, SEC 11, T18N, R11W, I.M.	N36°03.104' W98°20.644'
Blaine 5	SW ¼, SEC 1, T18N, R11W, I.M.	N36°03.637' W98°19.963'
Blaine 6	SW ¼, SEC 29, T19N, R11W, I.M.	N36°05.186' W98°24.332'
Blaine 7	NW ¼, SEC 14, T18N, R11W, I.M.	N36°02.335' W98°20.909'
Blaine 8	NE ¼, SEC 31, T15N, R11W	N35°44.000' W98°24.179'
Blaine 9	SW ¼, SEC 31, T15N, R12W, I.M.	N35°43.598' W98°31.220'
Blaine 10	NW ¼, SEC 24, T18N, R11W, I.M.	
Caddo 1	NW ¼, SEC 9, T8N, R11W, I.M.	N35°11.369' W98°22.226'

Appendix A. Continued.

Caddo 2	NW ¼, SEC 14, T7N, R11W, I.M.	N35°11.374' W98°22.224'
Caddo 3	NW ¼, SEC 30, T5N, R11W, I.M.	N35°11.374' W98°24.177'
Caddo 4	NW ¼, SEC 6, T11N, R12W, I.M.	N36°24.295' W97°34.893'
Canadian 1	NW ¼, SEC 17, T11N, R6W, I.M.	N35°25.954' W97°51.956'
Canadian 2	NE ¼, SEC 12, T11N, R6W, I.M.	N35°26.807' W97°46.772'
Canadian 3	SW ¼, SEC 12, T12N, R7W, I.M.	N35°31.712' W97°53.602'
Canadian 4	NE ¼, SEC 13, T12N, R7W, I.M.	N35°31.325' W97°53.341'
Canadian 5	NE ¼, SEC 26, T14N, R7W, I.M.	N35°39.809' W97°54.645'
Canadian 6	NW ¼, SEC 27, T11N, R7W, I.M.	N35°24.187' W97°55.998'
Canadian 7	NE ¼, SEC 12, T11N, R6W, I.M.	
Cotton 1	SW ¼, SEC 35, T2S, R10W, I.M.	N34°20.242' W98°13.556'
Custer 1	E ½, SEC 15, T13N, R16W, I.M.	N35°35.661' W98°52.175'
Custer 2	SW ¼, SEC 35, T14N, R19W, I.M.	N35°38.503' W99°11.902'
Custer 3	S ½, SEC 23, T14N, R17W, I.M.	N35°40.809' W98°58.966'
Custer 4	NW ¼, SEC 28, T24N, R6W, I.M.	N34°52.661' W98°24.175'
Custer 5	SE ¼, SEC 6, T11N, R12W, I.M.	
Dewey 1	SW ¼, SEC 15, T18N, R20W, I.M.	
Dewey 2	NW ¼, SEC 23, T19N, R18W, I.M.	
Garfield 1	NE ¼, SEC 24, T24N, R4W, I.M.	N36°32.926' W97°34.552'
Garfield 2	SE ¼, SEC 22, T22N, R8W, I.M.	N36°21.868' W98°01.949'
Garfield 3	SW ¼, SEC 22, T24N, R3W, I.M.	N36°24.295' W97°34.893'
Garfield 4	NE ¼, SEC 31, T23N, R7W, I.M.	N36°26.057' W97°59.182'
Garfield 5	NE ¼, SEC 28, T23N, R7W, I.M.	N36°26.862' W97°56.632'
Garfield 6	SE ¼, SEC 30, T2N, R21W, I.M.	N36°26.086' W97°57.830'
Garfield 7	SW ¼, SEC 18, T21N, R8W, I.M.	N36°17.668' W98°06.212'

Appendix A. Continued.

Garfield 8	SE ¼, SEC 1, T21N, R5W, I.M.	N36°19.079' W97°40.614'
Garfield 9	SW ¼, SEC 7, T23N, R7W, I.M.	N36°29.181' W97°59.828'
Garfield 10	SW ¼, SEC 7, T22N, R4W, I.M.	N36°24.295' W97°34.893'
Garfield 11	NW ¼, SEC 28, T24N, R6W, I.M.	N36°31.954' W97°51.179'
Garfield 12	SW ¼, SEC 18, T21N, R8W, I.M.	N36°17.667' W98°06.211'
Garfield 13	NW ¼, SEC 31, T23N, R4W, I.M.	
Garfield 14	SW ¼, SEC 11, T21N, R5W, I.M.	
Garfield 15	SW ¼, SEC 19, T21N, R7W, I.M.	
Garfield 16	SE ¼, SEC 6, T23N, R7W, I.M.	
Garfield 17	SE ¼, SEC 20, 22N, R5W, I.M.	
Garfield 18	W ½, SEC 29, T22N, R5W, I.M.	
Garfield 19	SW ¼, SEC 14, T21N, R5W, I.M.	
Garfield 20	NW ¼, SEC 5, T22N, R4W, I.M.	
Garfield 21	NW ¼, SEC 28, T24N, R6W, I.M.	
Garfield 22	NE ¼, SEC 21, T22N, R6W, I.M.	
Garfield 23	NW ¼. SEC 29, T24N, R4W, I.M.	
Garfield 24	NE ¼, SEC 21, T21N, R5W, I.M.	
Garfield 25	SE ¼, SEC 26, T23N, R6W, I.M.	
Garfield 26	NE ¼, SEC 34, T23N, R10W, I.M.	
Garfield 27	NW ¼, SEC 33, T23N, R10W, I.M.	
Garfield 28	NW ¼, SEC 12, T20N, R8W, I.M.	
Garfield 29	NW ¼, SEC 2, T22N, R8W, I.M.	
Garfield 30	SE ¼, SEC 26, T23N, R8W, I.M.	
Garfield 31	SW ¼, SEC 26, T24N, R4W, I.M.	
Garfield 32	NW ¼, SEC 7, T27N, R5W, I.M.	

Appendix A. Continued.

Grant 1	NW ¼, SEC 21, T25N, R5W, I.M.	N36°37.899' W97°43.943'
Grant 2	SE ¼, SEC 30, T29N, R3W, I.M.	N36°57.388' W97°33.207'
Grant 3	NW ¼, SEC 1, T27N, R7W, I.M.	N36°51.181' W97°54.150'
Grant 4	NE ¼, SEC 31, T28N, R6W, I.M.	N36°52.036' W97°52.538'
Grant 5	SE ¼, SEC 29, T27N, R3W, I.M.	N36°47.254' W97°32.078'
Grant 6	NW ¼, SEC 3, T26N, R6W, I.M.	[illegible]
Grant 7	SE ¼, SEC 23, T29N, R3W, I.M.	
Grant 8	NW ¼, SEC 1, T27N, R7W, I.M.	[illegible]
Grant 9	NW ¼, SEC 20, T26N, R7W, I.M.	[illegible]
Harmon 1	NW ¼, SEC 1, T2N, R25W, I.M.	N34°40.630' W99°47.066'
Harmon 2	E ½, W ½, SEC 25, T2N, R24W, I.M.	N34°37.345' W99°40.707'
Harmon 3	NW ¼, SEC 1, T1N, R24W, I.M.	N34°35.622' W99°41.013'
Harper 1	NE ¼, SEC 8, T28N, R22W, I.M.	N36°55.71' W99°35.10'
Harper 2	N ½, SEC 33, T26N, R21W, I.M.	N36°41.74' W99°27.74'
Harper 3	SW ¼, SEC 5, T27N, R20W, I.M.	N36°50.56' W99°22.70'
Harper 4	NW ¼, SEC 22, T28N, R26W, I.M.	N36°54.49' W99°57.80'
Harper 5	NE ¼, SEC 14, T28N, R26W, I.M.	N36°53.44' W99°58.83'
Harper 6	NE ¼, SEC 25, T28N, R23W, I.M.	N36°53.08' W99°37.44'
Harper 7	NW ¼, SEC 11, T27N, R21W, I.M.	N36°50.35' W99°25.98'
Jackson 1	NE ¼, SEC 31, T2N, R21W, I.M.	N34°36.488' W99°26.652'
Jackson 2	NW ¼, SEC 8, T1S, R21W, I.M.	N34°29.522' W99°25.604'
Jackson 3	SW ¼, SEC 29, T2N, R21W, I.M.	N34°36.635' W99°26.332'
Jackson 4	SE ¼, SEC 30, T2N, R21W, I.M.	N34°36.581' W99°26.551'
Jackson 5	SE ¼, SEC 31, T2N, R21W, I.M.	N34°35.676' W99°26.478'
Kay 1	SE ¼, SEC 23, T26N, R1E, I.M.	N36°42.644' W97°09.544'

Kay 2	NE ¼, SEC 29, T26N, R1E, I.M.	N36°23.416' W98°11.643'
Kingfisher 1	SW ¼, SEC 13, T16N, R6W, I.M.	N35°51.748' W97°47.531'
Kingfisher 2	SW ¼, SEC 2, T16N, R6W, I.M.	N35°53.261' W97°48.489'
Kingfisher 3	NE ¼, SEC 26, T16N, R6W, I.M.	N35°50.288' W97°47.925'
Kingfisher 4	SE ¼, SEC 27, T16N, R6W, I.M.	N35°49.679' W97°49.100'
Kingfisher 5	SW ¼, SEC 17, T19N, R6W, I.M.	N35°07.482' W97°52.776'
Kingfisher 6	NE ¼, SEC 17, T16N, R6W, I.M.	N35°52.186' W97°51.109'
Kingfisher 7	NW ¼, SEC 34, T16N, R6W, I.M.	N35°49.574' W97°49.653'
Kingfisher 8	SW ¼, SEC 2, T15N, R7W, I.M.	N35°48.127' W97°55.249'
Kingfisher 9	SE ¼, SEC 16, T15N, R8W, I.M.	N35°46.330' W98°03.411'
Kingfisher 10	W ½, SEC 19, T18N, R8W, I.M.	N36°01.389' W98°05.848'
Kingfisher 11	NE ¼, SEC 21, T17N, R8W, I.M.	N35°56.294' W98°03.022'
Kingfisher 12	SE ¼, SEC 28, T18N, R9W, I.M.	
Kingfisher 13	NW ¼, SEC 29, T18N, R8W, I.M.	
Kingfisher 14	SE ¼, SEC 3, T15N, R10W, I.M.	
Kingfisher 15	SE ¼, SEC 3, T15N, R10W, I.M.	
Kingfisher 16	NW ¼, SEC 21, T16N, R7W, I.M.	
Kingfisher 17	NW ¼, SEC 30, T19N, R6W, I.M.	
Kingfisher 18	NW ¼, SEC 1, T15N, R5W, I.M.	
Kingfisher 19	SW ¼, SEC 2, T15N, R7W, I.M.	
Logan 1	NE ¼, SEC 8, T19N, R4W, I.M.	N36°08.507' W97°38.629'
Logan 2	NE ¼, SEC 26, T19N, R4W, I.M.	N36°06.022' W97°35.245'
Logan 3	NE ¼, SEC 15, T19N, R4W, I.M.	N36°07.806' W97°36.473'
Logan 4	NW ¼, SEC 25, T19N, R4W, I.M.	N36°06.014' W97°35.027'
Major 1	NW ¼, SEC 9, T22N, R14W, I.M.	N36°31.064' W98°59.773'

Major 2	NE ¼, SEC 18, T22N, R9W, I.M.	N36°23.416' W98°11.643'
Major 3	SE ¼, SEC 12, T22N, R10W, I.M.	N36°23.457' W98°12.755'
Major 4	NE ¼, SEC 25, T21N, R13W, I.M.	N36°16.078' W98°32.113'
Major 5	NE ¼, SEC 25, T22N, R14W, I.M.	N36°21.216' W98°38.836'
Major 6	NW ¼, SEC 34, T23N, R10W, I.M.	N36°25.949' W98°15.871'
Major 7	NW ¼, SEC 16, T20N, R11W, I.M.	N36°12.671' W98°23.329'
Major 8	NE ¼, SEC 27, T22N, R12W, I.M.	N36°21.354' W98°27.828'
Major 9	SW ¼, SEC 32, T20N, R11W, I.M.	N36°09.801' W98°24.397'
Major 10	NW ¼, SEC 12, T20N, R13W, I.M.	N36°13.667' W98°32.393'
Major 11	SW ¼, SEC 8, T21N, R12W, I.M.	
Major 12	SE ¼, SEC 35, T22N, R13W, I.M.	
Major 13	SE ¼, SEC 8, T20N, R11W, I.M.	
Noble 1	NE ¼, SEC 3, T22N, R1W, I.M.	N36°24.973' W97°17.071'
Noble 2	SE ¼, SEC 34, T23N, R1W, I.M.	N36°25.507' W97°17.111'
Noble 3	NW ¼, SEC 5, T23N, R2W, I.M.	N36°30.084' W97°26.627'
Noble 4	NW ¼, SEC 12, T22N, R3W, I.M.	N36°24.264' W97°28.171'
Noble 5	NE ¼, SEC 7, T21N, R2W, I.M.	N36°19.063' W97°26.913'
Noble 6	NW ¼, SEC 5, T25N, R2W, I.M.	
Noble 7	SW ¼, SEC 22, T24N, R3W, I.M.	
Payne 1	NW ¼, SEC 16, T19N, R2E, I.M.	
Tillman 1	SW ¼, SEC 22, T1S, R15W, I.M.	N34°27.353' W98°45.826'
Washita 1	NE ¼, SEC 21, T10N, R19W, I.M.	N35°19.890' W99°12.377'
Washita 2	SE ¼, SEC 3, T9N, R17W, I.M.	
Woods 1	NE ¼, SEC 22, T28N, R13W, I.M.	N36°53.937' W98°34.844'
Woods 2	SE ¼, SEC 15, T28N, R13W, I.M.	N36°53.995' W98°34.989'

Appendix A. Continued.

Woods 3	SE ¼, SEC 20, T29N, R14W, I.M.	N36°58.489' W98°44.049'
Woods 4	NE ¼, SEC 1, T25N, R15W, I.M.	N36°40.454' W98°45.416'
Woods 5	NW ¼, SEC 16, T27N, R15W, I.M.	N36°49.570' W98°49.358'
Woods 6	SW ¼, SEC 8, T26N, R16W, I.M.	N36°45.021' W98°56.865'
Woods 7	SE ¼, SEC 24, T27N, R13W, I.M.	
Woodward 1	NW ¼, SEC 20, T23N, R17W, I.M.	N35°27.395' W99°02.600'
Woodward 2	SE ¼, SEC 34, T24N, R17W, I.M.	N36°31.044' W98°59.770'
Woodward 3	NE ¼, SEC 14, T22N, R19W, I.M.	

[a] Sites without GPS coordinates are from year 2000 when GPS was not used.

Appendix B. Press release to announce cooperative release program.

OSU to make available "bindweed mites" at the Lahoma station field tour.

Producers who want a natural way to control bindweed in wheat and pastures should attend the Oklahoma State University North-Central Oklahoma Research Station field tour May 19 at Lahoma.

"We will be making available so-called 'bindweed mites,' which have proven very useful in controlling the growth of bindweed," said Tom Royer.

There is no cost to attend the field tour or to receive the mites. However, producers must provide information on the release site so OSU researchers can measure establishment success of the mites in those areas.

"Producers will complete an information sheet at the field tour, and then will receive the mites," Royer said. "All information is for measurement purposes only, and will be held in the strictest confidence."

Field tour registration with refreshments will begin at 9 a.m. Lunch will be provided free of charge. The OSU research station is located one mile west of Lahoma on Highway 412.

"Participants are asked to RSVP for lunch to help ensure sufficient food is on hand for everyone," Royer said.

To RSVP, contact Roger Gribble, OSU Cooperative Extension area agronomist, at 580-237-7677 no later than May 17.

"The mites to be given away at the field tour do not feed on crops," said Tom Royer, OSU Cooperative Extension entomologist. "They feed on bindweed only, causing it to become deformed and grow very slowly. Over time, the bindweed patch will become smaller and contain fewer plants."

Tom Peeper, OSU small grains weed scientist, and graduate student Andy Hollon currently are conducting field and laboratory studies on production practices that encourage establishment and effectiveness of the *Aceria malherbae* mites ("bindweed mites") in Oklahoma.

Appendix C. Questionnaires for cooperative release program.

What tillage tools did you use last year on your wheat fields?

When was the last year your soil was tested?

What was the pH?

How much fertilizer (per acre) did you use for this year's wheat crop?

What type of fertilizer did you use?

How did you decide how much fertilizer to use?

How did you apply the fertilizer?

Do you buy seed wheat?

In the field where you will release the mites, what date did you plant wheat?

Was your field grazed this growing season?

If yes, what date were cattle put out?

What date were cattle pulled off?

Did you burn your wheat stubble last year?

Do you plan to burn in the future?

Do you combine your wheat yourself?

Was your wheat crop sprayed for greenbugs this growing season?

If yes, what insecticides were used?

Who applies insecticides on your farm?

Was your wheat sprayed for weeds this growing season?

If yes what herbicides were used?

What was your main reason for spraying weeds?

Did you walk the fields to look for weeds before deciding to apply a herbicide?

What weeds did you see growing at the time it was sprayed?

What weeds were killed by the herbicide?

Was the herbicide applied with liquid fertilizer?

Who applies fertilizers on your farm?

What weeds do you expect to have in your wheat at harvest?

Do they cause problems when combining?

If yes, how?

What herbicides do you use for weed control in wheat?

In which crops or areas is bindweed growing on your farm?

How many years has bindweed been on your property?

What date does bindweed first appear in the spring?

Is the bindweed spreading?

How fast (acres/year) is the bindweed spreading?

Is the bindweed in patches or throughout the entire field?

Which of the following best describes the growth of bindweed in your wheat fields at harvest?

Small amount of ground cover

Small amount of growth above wheat

Growth in and around wheat stems

Thick spreading growth above wheat

What percentage of your wheat acres have bindweed?

What methods have you used to control bindweed?

Appendix C. Continued.

Do you feel your control measures were successful?

Do you feel your control measures were profitable?

Does bindweed interfere with harvesting operations?

Do you cut through the bindweed or around the bindweed?

Do you attempt to control bindweed every year?

What are your estimated costs of controlling bindweed every year?

Is drift a concern when spraying for bindweed?

Appendix D. 1999 and 2000 mean monthly temperatures at the Oklahoma Panhandle Research and Extension Center (OPREC) and the North Central Research Station (NCRS).

	Site and year			
Month	NCRS 1999	NCRS 2000	OPREC 1999	OPREC 2000
	Degrees Celsius			
Jan	1.7	3.0	3.4	3.1
Feb	8.0	6.7	6.7	7.6
Mar	7.5	10.4	6.6	8.1
Apr	14.3	14.0	11.9	12.9
May	19.3	21.3	16.8	19.5
Jun	24.2	23.5	22.7	23.1
Jul	29.1	28.2	26.5	27.2
Aug	28.5	31.1	26.7	28.0
Sep	21.3	24.4	20.1	22.6
Oct	16.3	16.8	14.0	14.1
Nov	13.1	4.9	10.7	2.7
Dec	5.2	-2.5	3.8	-1.2

Appendix E. Monthly precipitation at the North Central Research Station (NCRS), Slapout, OK, and Amarillo TX.

		Site		
Year	Month	NCRS	Slapout	Amarillo
		cm		
1999	May	11.78	5.25	10.97
1999	Jun	18.36	11.37	9.16
1999	Jul	6.02	3.25	7.28
1999	Aug	11.99	2.74	5.18
1999	Sep	8.61	8.00	6.45
1999	Oct	7.24	1.32	0.96
1999	Nov	3.38	0.00	0.00
1999	Dec	9.60	1.47	4.54
2000	Jan	0.58	0.68	0.60
2000	Feb	6.17	1.67	0.10
2000	Mar	14.80	11.25	10.51
2000	Apr	6.29	4.19	1.09
2000	May	5.94	7.13	2.89
2000	Jun	9.06	10.43	14.07
2000	Jul	6.07	2.79	0.40
2000	Aug	0.00	0.05	0.73
2000	Sep	0.00	0.33	0.07
2000	Oct	16.07	21.48	10.03

Appendix E. Continued.

2000	Nov	7.57	0.33	10.03
Total for period		149.58	93.80	87.55

VITA

Kenneth A. Hollon

Candidate for the Degree of

Master Of Science

Thesis: REDISTRIBUTION AND ESTABLISHMENT OF *ACERIA MALHERBAE* FOR BIOLOGICAL CONTROL OF FIELD BINDWEED *CONVOLVULUS ARVENSIS*

Major Field: Plant and Soil Sciences

Biographical:

Education: Graduated from Woodward High School, Woodward, Oklahoma in May 1990; received a Bachelor of Science Degree in Agronomy from Oklahoma State University, Stillwater, Oklahoma in December 1994. Completed the requirements for the Master of Science Degree with a major in Plant and Soil Sciences at Oklahoma State University in May 2001.

Experience: Raised on a farm near Woodward, Oklahoma; employed as a farm laborer during high school and summers; employed by Oklahoma State University Department of Agronomy as an undergraduate research assistant, 1992 to 1994; employed by Bayer Corporation as a research technician, 1995 and 1996; employed by Woodward Lumber Company as Yard Foreman, 1995 and 1998; employed by USD 367 as a secondary agricultural education instructor, 1997 to 1998; employed as a graduate research assistant by Oklahoma State University Department of Plant and Soil Sciences 1999 to 2001.

Professional Memberships: Southern Weed Science Society, Western Society of Weed Science