Weed Science, 52:297–301. 2004

Combined effects of *Aceria malherbae* and herbicides on field bindweed (*Convolvulus arvensis*) growth

Rick A. Boydston
Corresponding author. USDA-ARS, 24106 North Bunn Road, Prosser, WA 99350;
boydston@pars.ars.usda.gov

Martin M. Williams, II
USDA-ARS, 1102 South Goodwin Avenue, Urbana, IL 61801

The effects of a gall mite (*Aceria malherbae*) and sublethal doses of either 2,4-DB or glyphosate on field bindweed growth were evaluated under laboratory conditions. Mite feeding reduced field bindweed shoot biomass 37 to 48% and root biomass 46 to 50%. 2,4-DB at 0.07 to 0.14 kg ae ha^{-1} or glyphosate at 0.14 to 0.28 kg ai ha^{-1} reduced field bindweed root biomass 25 to 52%. Combining *A. malherbae* feeding with either 2,4-DB or glyphosate application reduced root biomass of field bindweed plants more than mites or either herbicide alone. Live *A. malherbae* were present on field bindweed 3 wk after treatment with either herbicide. Combination of *A. malherbae* with sublethal herbicide doses may allow for field bindweed suppression while reducing potential herbicide injury to crops and maintaining *A. malherbae* populations.

Nomenclature: 2,4-DB; glyphosate; field bindweed, *Convolvulus arvensis* L. CONAR.

Key words: Biocontrol, biological control, gall mite, integrated pest management.

Field bindweed is an aggressive perennial weed that is difficult to manage in annual row crops, perennial tree and vine crops, and pastures and along roadsides. It is native to Europe and Asia and was first reported in the United States in 1739 (Mitich 1991). The plant is listed as one of the 10 most serious weeds in the world, prospering in numerous cropping systems worldwide (Holm et al. 1991). Field bindweed has an extensive underground root system that makes it particularly difficult to control (Swan and Chancellor 1976). Most herbicides and cultivation only suppress or partially control field bindweed (Ogg 1975; Westra et al. 1992).

Glyphosate is used to suppress field bindweed during fallow or dormant periods in numerous crops but seldom eliminates regrowth from adventitious buds on rhizomes (Wiese and Lavake 1985). In peppermint (*Mentha peperita* L.), 2,4-DB suppresses field bindweed growth but seldom kills the weed when used at rates that do not injure the crop (R. A. Boydston, unpublished data).

A gall-forming eriophyid mite, *Aceria malherbae* (Acari: Eriophyidae), was introduced in the United States from the Mediterranean region in 1987 and has established on field bindweed in several states, including Texas, Montana, and Washington (Boldt and Sobhian 1993; McClay et al. 1999; Rosenthal and Platts 1990; R. A. Boydston, unpublished data). *Aceria malherbae* feeding results in formation of small galls and malformed growth of leaf, stem, and bud tissue. Severely infested plants usually fail to flower, and aboveground growth is greatly stunted. Most research on *A. malherbae* has focused on plant host selectivity, establishment, and dispersion, whereas a few studies have quantified the response of field bindweed growth or plant populations to *A. malherbae* infestation (Boldt and Sobhian 1993; Craemer 1995; McClay et al. 1999).

Classical biological control of weeds with arthropods has been most successful in uncultivated land and perennial cropping systems, such as rangeland and forest (Harris 1991). The relatively slow nature of biological control, when used alone, may result in excessive early-season weed competition and crop yield loss, which cannot be tolerated in most annual cropping systems (Zimdahl 1980). Integration of biological and chemical control may result in improved weed control with lower doses of herbicides (Harris 1991; Stoyer and Kok 1987). Relatively few studies have focused on integrating biological control using arthropods with herbicides for weed management (Andres 1982; Charudattan 1986; Lym and Nelson 2002). The focus of arthropod–herbicide studies has often been on the effects of the herbicide on arthropod populations rather than on the weed response (Campbell 1988; Messersmith and Adkins 1995; Paynter 2003; Trumble and Kok 1980). Successful integration of biological control with the use of herbicides could allow increased implementation in annual and perennial cropping systems, pastures, and noncrop areas.

These studies were conducted to quantify the response of field bindweed growth to *A. malherbae* feeding alone and in combination with low doses of 2,4D-B or glyphosate.

Materials and Methods

Field bindweed rhizomes were collected from a field at the Irrigated Agriculture Research and Extension Center near Prosser, WA. Rhizomes were cut into 3-cm segments containing one node and planted in a Warden loamy sand soil (coarse-silty, mixed, mesic Xerollic Camborthids) in a 15-cm-diam by 20-cm-high plastic pot. Field bindweed plants were staked to prevent lodging and to facilitate measurement of plant height. Plants were grown in a growth chamber at 25 and 18 C (day and night, respectively) with a 14-h photoperiod and 340-μmol m^{-2} s^{-1} photosynthetically active photon flux density light intensity.

Aceria malherbae was obtained from the USDA-ARS Grassland, Soil and Water Research Laboratory in Temple, TX, and a colony was established and maintained on greenhouse-grown field bindweed plants during the course of the study. When test plants reached a height of 15 cm, *A. mal-*

TABLE 1. Significance (P) of *Aceria malherbae*, 2,4-DB, and glyphosate dose factors and the interaction in determining total number of observed galls on field bindweed, plant height, shoot biomass, and root biomass.

		P			
Herbicide	Factor	Gall number	Plant height	Shoot biomass	Root biomass
2,4-DB	*A. malherbae*	< 0.001	0.044	0.005	< 0.001
	Dose	0.124	< 0.001	< 0.001	< 0.001
	A. malherbae by dose	0.124	0.167	0.873	0.863
Glyphosate	*A. malherbae*	< 0.001	0.011	< 0.001	< 0.001
	Dose	0.013	< 0.001	< 0.001	< 0.001
	A. malherbae by dose	0.013	0.100	0.063	0.543

herbae was introduced to plants by tying a mite-infested field bindweed plant to the uninfested plants with twist ties and enclosing the entire pots and plants in a clear plastic bag for 1 wk. Plants were then removed from the bag and separated. Newly formed leaves on plants usually contained leaf galls after exposure to *A. malherbae*. If no leaf galls were observed, plants were discarded. Plants in mite-free treatments also were placed in plastic bags for 1 wk.

At 1 to 2 d after removal from bags, plants were treated with 2,4-DB at 0, 0.07, and 0.14 kg ha^{-1} or glyphosate at 0, 0.14, and 0.28 kg ha^{-1}. To assess the combined effects of herbicide use and *A. malherbae* feeding on field bindweed growth, herbicide doses that were sublethal to field bindweed were selected based on preliminary trials. Herbicides were applied with a bench sprayer equipped with an 80015 even flat-fan nozzle delivering 270 L ha^{-1}.

To quantify the response of field bindweed to *A. malherbae* feeding, every malformed, fused, and folded leaf was counted and referred to as one gall. Initial plant height and number of galls per plant were recorded at the time of herbicide treatment. At 3 wk after herbicide treatment, the number of galls per plant and plant height were recorded with the exception of Trial 2 with glyphosate, where galls were not recorded on glyphosate-treated plants. Galls were randomly sampled from herbicide-treated plants and dissected under a microscope to determine if live *A. malherbae* were present. Plants were severed at the soil surface, and shoot biomass was determined by weighing. Roots were washed to remove soil, patted dry, and weighed to determine biomass.

The experimental design was a completely randomized design with a factorial arrangement of treatments. Factor 1 was "*A. malherbae*" with two levels: present or absent. Factor 2 was "herbicide" with three levels: 0, 0.07, and 0.14 kg ae ha^{-1} for 2,4-DB and 0, 0.14, and 0.28 kg ai ha^{-1} for glyphosate. Each treatment was replicated six times with a single plant as the experimental unit. Experiments with 2,4-DB were conducted three times, and experiments with glyphosate were conducted twice.

Number of galls, plant height, shoot biomass, and root biomass were subjected to analysis of variance (ANOVA). Within a trial, data were rank transformed to equalize variance. A combined ANOVA did not indicate trial effects; therefore, data were pooled among trials within each herbicide tested. When ANOVA was significant, treatment means were separated by Fisher's Protected LSD at a $P = 0.05$ level. Results of mean separation on rank-transformed data are included.

Results and Discussion

Within a week after introducing *A. malherbae* to field bindweed plants, symptoms began appearing on all newly emerging leaves. Symptoms consisted of malformed leaves and rough calluslike tissue on the adaxial surface of the leaf veins similar to those described by Craemer (1995). Severity of symptoms on mite-infested leaves continued to increase as the leaves aged, but leaves did not senesce during the experiment.

***Aceria malherbae* and 2,4-DB**

Gall number per plant, plant height, shoot biomass, and root biomass were all significantly affected by *A. malherbae* feeding (Table 1). Dosage of 2,4-DB did not affect gall number per plant, but 2,4-DB significantly reduced plant height, shoot biomass, and root biomass (Table 1). Moreover, there were no statistical interactions between *A. malherbae* and 2,4-DB dose for any of the measured parameters (Table 1).

Addition of *A. malherbae* significantly increased the number of galls per plant. Plants receiving *A. malherbae* contained an average of 24.5 galls, whereas no galls or symptoms of feeding were evident on plants that did not receive *A. malherbae* (Table 2). Although 2,4-DB dose did not significantly affect the number of galls per plant, gall number tended to decrease with increasing dose of 2,4-DB, perhaps because field bindweed was severely stunted by 2,4-DB and fewer leaves were available for *A. malherbae* to infest (Table 2). Random inspection of galls from 2,4-DB–treated plants revealed an average of 27 live *A. malherbae* per leaf gall, regardless of the herbicide dose.

Plant height, shoot biomass, and root biomass were significantly reduced by *A. malherbae* feeding. Field bindweed plants treated with *A. malherbae* were 28% shorter than plants without the mite (Table 2). Shoot biomass and root biomass were reduced 48 and 46%, respectively, in *A. malherbae*–infested plants, compared with the control.

Plant height, shoot biomass, and root biomass also were reduced by 2,4-DB dose. Plant height declined from 57.1 to 30.5 cm as 2,4-DB dose increased from 0 to 0.14 kg ha^{-1} (Table 2). Shoot biomass was reduced 56 and 86%, whereas root biomass was reduced 25 and 50% with 0.07 and 0.14 kg ha^{-1} 2,4-DB, respectively (Table 2). Field bindweed root biomass was reduced to 1.5 g $plant^{-1}$ when treated with 0.14 kg ha^{-1} 2,4-DB plus *A. malherbae*. Depletion of root biomass of field bindweed may result in lower fitness and reduced ability to spread and regrow after multiple control measures.

TABLE 2. Mean number of galls, plant height, shoot biomass, and root biomass of field bindweed after treating with 2,4-DB and *Aceria malherbae*.[a]

Dose	*A. malherbae*	Galls	Plant height	Shoot biomass	Root biomass
kg ae ha^{-1}		no. plant^{-1}	cm	g plant^{-1}	
0	−	0.0 (0.0)	74.2 (8.0)	11.4 (1.8)	5.3 (0.7)
0	+	30.4 (7.1)	40.0 (3.9)	5.1 (0.9)	2.7 (0.3)
0.07	−	0.0 (0.0)	41.9 (5.3)	4.4 (0.6)	4.0 (0.6)
0.07	+	26.3 (3.7)	34.6 (3.5)	2.9 (0.6)	2.1 (0.3)
0.14	−	0.0 (0.0)	30.5 (2.2)	1.5 (0.3)	2.4 (0.3)
0.14	+	16.7 (2.1)	30.4 (3.0)	0.9 (0.2)	1.5 (0.2)
Factor	Level				
A. malherbae	−	0.0 b	48.9 a	5.8 a	3.9 a
	+	24.5 a	35.0 b	3.0 b	2.1 b
Dose	0.00	15.2 a	57.1 a	8.2 a	4.0 a
	0.07	13.2 a	38.3 b	3.6 b	3.0 a
	0.14	8.4 a	30.5 c	1.2 c	2.0 b

[a] Standard errors of simple effects are in parentheses. For each factor, means within a column followed by the same letter do not differ at the 5% level.

Aceria malherbae and Glyphosate

Gall number per plant, plant height, shoot biomass, and root biomass were all significantly affected by *A. malherbae* feeding and glyphosate dose (Table 1). There were no interactions between *A. malherbae* and glyphosate dose for plant height, shoot biomass, or root biomass, but there was an *A. malherbae* by glyphosate dose interaction for gall number per plant (Table 1).

No galls or symptoms of feeding were evident on plants that did not receive *A. malherbae* (Table 3). However, in the presence of *A. malherbae*, the numbers of galls per plant for the 0.14 and 0.28 kg ha^{-1} glyphosate doses were approximately twice that on untreated plants. Arthropod population densities have been observed to increase on herbicide-treated plants (Campbell 1988; Oka and Pimentel 1976), although reasons for the variation in gall number among *A. malherbae*–treated plants are not clear. Random inspection of galls from glyphosate-treated plants revealed live *A. malherbae* present in galls.

Aceria malherbae reduced plant height, shoot biomass, and root biomass. In the presence of *A. malherbae*, plant height was reduced by 12% compared with plants with no mites (Table 3). Field bindweed shoot biomass and root biomass were reduced 37 and 50%, respectively, when *A. malherbae* was present, compared with the control. We suspect that such reductions in shoot and root growth would reduce the capacity of field bindweed to compete with a crop and reduce the capacity of field bindweed to spread by both seed and underground root and rhizome production.

Glyphosate significantly reduced field bindweed growth. Plant height, shoot biomass, and root biomass were reduced by 52% or more when glyphosate was applied at 0.28 kg ha^{-1}. Similarly, glyphosate reduced shoot and root growth of field bindweed in greenhouse studies by Flint and Barrett (1989). However, glyphosate application seldom results in complete control of field bindweed in field situations (Westra et al. 1992). Root biomass was least in plants subjected to both *A. malherbae* feeding and an application of 0.28 kg ha^{-1} glyphosate.

Management Implications

Combining *A. malherbae* with low doses of 2,4-DB or glyphosate greatly reduced field bindweed shoot and root biomass. The lack of an interaction between mite feeding and herbicides on field bindweed shoot and root biomass

TABLE 3. Mean number of galls, plant height, shoot biomass, and root biomass of field bindweed after treating with glyphosate and *Aceria malherbae*.[a]

Dose	*A. malherbae*	Galls	Plant height	Shoot biomass	Root biomass
kg ai ha^{-1}		no. plant^{-1}	cm	g plant^{-1}	
0	−	0.0 (0.0)	111.1 (3.7)	23.9 (1.8)	9.7 (1.0)
0	+	51.8 (12.0)	90.3 (6.9)	12.3 (1.5)	3.9 (0.3)
0.14	−	0.0 (0.0)	73.6 (4.4)	17.2 (1.5)	5.8 (0.5)
0.14	+	105.8 (21.5)	76.2 (5.8)	14.0 (1.9)	3.6 (0.5)
0.28	−	0.0 (0.0)	50.7 (3.1)	10.8 (1.0)	4.2 (0.4)
0.28	+	105.2 (30.6)	40.6 (2.9)	6.3 (0.9)	2.3 (0.2)
Factor	Level				
A. malherbae	−	0.0 b	78.5 a	17.3 a	6.6 a
	+	87.6 a	69.0 b	10.9 b	3.3 b
Dose	0.00	25.9 b	100.7 a	18.1 a	6.8 a
	0.14	52.9 a	74.9 b	15.6 a	4.7 b
	0.28	52.6 a	45.7 c	8.5 b	3.3 c

[a] Standard errors of simple effects are in parentheses. For each factor, means within a column followed by the same letter do not differ at the 5% level.

suggests that mite feeding and herbicides affected field bindweed growth independently. Increasing mite density or herbicide dose beyond levels used in this study could possibly reduce field bindweed growth further. If mite and herbicide damage to field bindweed are independent, combining mite feeding with herbicides in situations, where poor translocation of herbicide to roots may be occurring, may help reduce root growth and provide additional suppression of field bindweed.

If similar results can be demonstrated in the field, several benefits could be realized. Field bindweed suppression may be enhanced by combining *A. malherbae* with reduced herbicide doses. In the case of the selective herbicide 2,4-DB, herbicide injury to crops such as peppermint could be lessened while possibly improving suppression of field bindweed. In addition, using sublethal herbicide doses may help sustain *A. malherbae* populations by not eliminating the host plant, therefore eliminating the need for reintroduction of the biological control agent.

Further research will determine how this study relates to larger scales in space and time. McClay et al. (1999) found that at 15 release sites in Alberta, Canada, and Montana, damage by *A. malherbae* was slight 1 yr after introduction, with only a few galled leaves. Greater damage to field bindweed, as measured by the number of galls and extent of stunting, was observed at two sites 3 to 4 yr after release of *A. malherbae*. However, no plant mortality was observed at any of the release sites. Boldt and Sobhian (1993) reported *A. malherbae* establishment on field bindweed in Texas, but even severely galled plants were sometimes hidden under a canopy of healthy leaves. They suggested that biological control of field bindweed might be more effective if combined with more than one organism. These studies suggest that combining biological control with herbicides also may improve effectiveness.

Herbicide-induced alteration of plant physiology can increase the effect of arthropod-induced stress on plants (Andres 1982). Very little study has been done on the extent to which the plant stress alters the effects of biological control agents on weed populations. The physiology of weeds surviving sublethal herbicide doses may be altered and could influence arthropod food supply and habitat. In a review by Norris and Kogan (2000), glyphosate was nontoxic to several insects, but destruction of vegetation indirectly affected insect populations by altering the quantity or quality of food supply. Herbicides also can be toxic to arthropods, although in many cases they are not (Norris and Kogan 2000). Alternatively, herbicide-treated plants may support higher populations of arthropods. Oka and Pimentel (1976) reported that aphid and corn borer populations increased in corn (*Zea mays* L.) after 2,4-D application. Likewise, pea aphid (*Acyrthosiphon pisum* Harris) reproductive rate increased on broadbeans (*Vicia faba* L.) treated with 2,4-D (Maxwell and Harwood 1960).

Arthropod feeding can reduce herbicide effectiveness, as evidenced by Westra et al. (1981). In these studies, feeding damage by the weevil *Notaris bimaculatus* (Fabricius) reduced control of quackgrass (*Eltrygia repens* L.) by glyphosate.

Although few examples of weed response to combined arthropod herbivory and herbicide use can be cited, several examples of increased herbicide injury to crops infested with arthropods or nematodes have been reported. Soybean [*Glycine max* (L.) Merr.] injury from acifluorfen increased when soybean thrips (*Neohydatothrips variabilis* Beach) were present (Huckaba et al. 1988). Soybeans infested with soybean cyst nematode (*Herterodera glycines* Ichinohe) were more susceptible to acifluorfen injury and yielded less than nematode-free soybeans (Browde et al. 1994). Peanuts infested with tobacco thrips [*Frankliniella fusca* (Hinds)] were more susceptible to herbicide injury and slower to recover than uninfested plants (Brecke et al. 1996).

Although not the focus of this study, counts of live *A. malherbae* and observations taken from dissected galls on plants treated with low doses of 2,4-DB or glyphosate indicated that these herbicides did not negatively affect the mite. Similar results have been shown in other studies: 2,4-D did not adversely affect the survival of *Trichosirocalus horridus* (Panzer), a weevil used in biological control of *Carduus* spp. thistles (Trumble and Kok 1980). Development of *Neurostrota gunniella* (Busck), a caterpillar used for biological control of mimosa (*Mimosa pigra* L.), was inhibited to various degrees by three herbicides but was attributed to declining plant quality rather than toxicity of the herbicides (Paynter 2003). Glufosinate-ammonium toxicity to two predatory mite species ranged from none to moderately toxic depending on the developmental stage of the mite during exposure (Ahn et al. 2001). Other pesticides and agronomic practices used in various cropping systems may have a negative impact on the establishment and permanency of *A. malherbae* populations. Further testing of the integration of biological control with herbicides for field bindweed management should be extended to include field trials.

Acknowledgments

We acknowledge the technical support of Ray Baker and Treva Anderson. We thank Dr. Paul Boldt for supplying the initial populations of *Aceria malherbae* for these studies and the Mint Industry Research Council and Washington State Mint Commission for partial funding of these studies.

Literature Cited

Ahn, Y. J., Y. J. Kim, and J. K. Yoo. 2001. Toxicity of the herbicide glufosinate-ammonium to predatory insects and mites of *Tetranychus urticae* (Acari: Tetranychidae) under laboratory conditions. J. Econ. Entomol. 94:157–161.

Andres, L. A. 1982. Integrating weed biological control agents into a pest-management program. Weed Sci. 30(Suppl.):25–30.

Boldt, P. E. and R. Sobhian. 1993. Release and establishment of *Aceria malherbae* (Acari: Eriophydae) for control of field bindweed in Texas. Environ. Entomol. 22:234–237.

Brecke, B. J., J. E. Funderburk, I. D. Teare, and D. W. Gorbet. 1996. Interaction of early-season herbicide injury, tobacco thrips injury, and cultivar on peanut. Agron. J. 88:14–18.

Browde, J. A., L. P. Pedigo, M.D.K. Owen, and G. L. Tylka. 1994. Soybean yield and pest management as influenced by nematodes, herbicides, and defoliating insects. Agron. J. 86:968–974.

Campbell, B. C. 1988. The effects of plant growth regulators and herbicides on host plant quality to insects. Pages 205–247 *in* E. A. Heinrichs, ed. Plant Stress-Insect Interactions. New York: Wiley Interscience/J. Wiley.

Charudattan, R. 1986. Integrated control of water hyacinth (*Eichhornia crassipes*) with a pathogen, insects, and herbicides. Weed Sci. 34(Suppl. 1):26–30.

Craemer, C. 1995. Host specificity, and release in South Africa, of *Aceria malherbae* Nuzzaci (Acari: Eriophyoidea), a natural enemy of *Convolvulus arvensis* L. (Convolvulaceae). Afr. Entomol. 3:213–215.

Flint, J. L. and M. Barrett. 1989. Effects of glyphosate combinations with

2,4-D or dicamba on field bindweed (*Convolvulus arvensis*). Weed Sci. 37:12–18.

Harris, P. 1991. Invitation paper (C. P. Alexander fund): classical biocontrol of weeds: its definition, selection of effective agents, and administrative-political problems. Can. Entomol. 123:827–849.

Holm, L. G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1991. The World's Worst Weeds: Distribution and Biology. Malabar, FL: Krieger. Pp. 98–104.

Huckaba, R. M., H. D. Coble, and J. W. Van Duyn. 1988. Joint effects of acifluorfen applications and soybean thrips (*Sericothrips variabilis*) feeding on soybean (*Glycine max*). Weed Sci. 36:667–670.

Lym, R. G. and J. A. Nelson. 2002. Integration of *Aphthona* spp. flea beetles and herbicides for leafy spurge (*Euphorbia esula*) control. Weed Sci. 50:812–819.

Maxwell, R. C. and R. F. Harwood. 1960. Increased reproduction of pea aphids on broadbeans treated with 2,4-D. Ann. Entomol. Soc. Am. 53:199–205.

McClay, A. S., J. L. Littlefield, and J. Kashefi. 1999. Establishment of *Aceria malherbae* (Acari: Eriophyidae) as a biological control agent for field bindweed (Convolvulaceae) in the northern Great Plains. Can. Entomol. 131:541–547.

Messersmith, C. G. and S. W. Adkins. 1995. Integrating weed-feeding insects and herbicides for weed control. Weed Technol. 9:199–208.

Mitich, L. W. 1991. Intriguing world of weeds series: field bindweed. Weed Technol. 5:913–915.

Norris, R. F. and M. Kogan. 2000. Interactions between weeds, arthropod pests, and their natural enemies in managed ecosystems. Weed Sci. 48:94–158.

Ogg, A. G. 1975. Control of Canada thistle and field bindweed in asparagus. Weed Sci. 23:458–461.

Oka, I. N. and D. Pimentel. 1976. Herbicide (2,4-D) increases insect and pathogen pests on corn. Science 193:239–240.

Paynter, Q. 2003. Integrated weed management: effect of herbicide choice and timing of application on the survival of a biological control agent of the tropical wetland weed, *Mimosa pigra*. Biol. Control 26:162–167.

Rosenthal, S. S. and B. E. Platts. 1990. Host specificity of *Aceria* (*Eriophyes*) *malherbae* (Acari: Eriophyidae), a biological control agent for the weed, *Convolvulus arvensis* (Convolvulaceae). Entomophaga 35:459–463.

Stoyer, T. L. and L. T. Kok. 1987. Insect/plant interactions in integrating *Trichosirocalus horridus* (Coleoptera: Curculionidae) and 2,4-dichlorophenoxyacetic acid for *Carduus* thistle control. Environ. Entomol. 16:864–868.

Swan, D. G. and R. J. Chancellor. 1976. Regenerative capacity of field bindweed roots. Weed Sci. 24:306–311.

Trumble, J. T. and L. T. Kok. 1980. Impact of 2,4-D on *Ceuthorhynchidius horridus* (Coleoptera: Curculionidae) and their compatibility for integrated control of *Carduus* thistles. Weed Res. 20:73–75.

Westra, P., P. Chapman, P. W. Stahlman, S. D. Miller, and P. K. Fay. 1992. Field bindweed (*Convolvulus arvensis*) control with various herbicide combinations. Weed Technol. 6:949–955.

Westra, P. H., D. L. Wyse, and E. F. Cook. 1981. Weevil (*Notaris bimaculatus*) feeding reduces effectiveness of glyphosate on quackgrass (*Agropyron repens*). Weed Sci. 29:540–547.

Wiese, A. F. and D. E. Lavake. 1985. Control of field bindweed (*Convolvulus arvensis*) with postemergence herbicides. Weed Sci. 34:77–80.

Zimdahl, R. L. 1980. Weed-Crop Competition: A Review. Corvallis, OR: Oregon State University. Pp. 83–94.

Received June 3, 2003, and approved August 26, 2003.