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Response of black swallowwort (*Vincetoxicum nigrum*) to herbicides plus mowing

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Research Article

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Abstract

The invasive vine black swallowwort [*Vincetoxicum nigrum* (L.) Moench = *Cynanchum louiseae* Kartesz & Gandhi, Apocynaceae] is difficult to control, and herbicide studies are lacking. This long-lived perennial species is primarily found in high-light environments in natural areas and perennial cropping systems in northeastern North America. We conducted a 3-yr herbicide efficacy study, with or without mowing, in an old-field site infested with *V. nigrum* in Dutchess County, NY, USA. Experimental plots were either herbicide treated in early July or mowed in early July and subsequently herbicide treated in late August for 2 yr with the potassium salt of glyphosate (2.02 kg ae ha^{-1}), the isopropylamine salt of glyphosate (1.35 kg ae ha^{-1}), or the butoxyethyl ester of triclopyr (1.79 kg ae ha^{-1}). Both glyphosate formulations were effective in reducing *V. nigrum* aboveground biomass, although they were somewhat less effective in reducing cover or stem densities of *V. nigrum* plants >10-cm tall after 2 yr compared with untreated plots. Mowing did not always enhance the efficacy of foliar glyphosate applications. Triclopyr, with or without mowing, was generally not effective against *V. nigrum* in our study. The only significant effect of triclopyr was to increase the cover of grasses in the plots. While annual applications of glyphosate can be useful for management of *V. nigrum* infestations, higher rates and more frequent applications of triclopyr need to be investigated to determine its usefulness for *V. nigrum* control.

Introduction

Black swallowwort [*Vincetoxicum nigrum* (L.) Moench = *Cynanchum louiseae* Kartesz & Gandhi, Apocynaceae], a herbaceous viny perennial plant, was first introduced into North America in the mid-1800s (Sheeley and Raynal 1996). Originating in southwestern Europe, *V. nigrum* is currently reported from 21 U.S. states and the Canadian provinces of Ontario and Quebec (USDA-NRCS 2022). Within the United States, the primary infestations occur in northeastern states, with increasing populations in some midwestern states (Alred et al. 2022). As previously noted, the one reported infestation of *V. nigrum* in California has likely disappeared (Milbrath and Biazzo 2016). Along with its congener pale swallowwort [*Vincetoxicum rossicum* (Kleopow) Barb. = *Cynanchum rossicum* (Kleopow) Borhidi] from southeastern Europe, it has invaded a variety of habitats ranging from open field to forest, including both unmanaged and managed lands (DiTommaso et al. 2005). Infestations of *V. nigrum* primarily occur in open-field habitats, whereas forest invasion is much less common for this species. *Vincetoxicum nigrum* spreads through its wind-dispersed seeds, and stem densities also increase over time via tillering from root crown buds (Averill et al. 2011).

Mechanical control such as digging rootstocks may be suitable for small patches, but hand-pulling stems or mowing must be done repeatedly within a season to prevent seed production (Milbrath et al. 2016) and, in the case of *V. rossicum*, for several years to suppress populations (Biazzo and Milbrath 2019). Long-term control with the biological control agent *Hypena opulenta* (Christoph) (Lepidoptera: Erebidae), the only agent released to date, is uncertain given the vigorous growth of *Vincetoxicum* species under full sun conditions and the preference of the moth for shaded environments (Livingstone et al. 2020; Milbrath et al. 2016). At present, broad-spectrum herbicides remain the most effective control for *Vincetoxicum* species. Previously published herbicide studies have only involved *V. rossicum.* These studies have primarily focused on the systemic herbicides glyphosate and triclopyr, usually alone or in combination with some form of cutting (Averill et al. 2008; Cain and Irvine 2011; Christensen 1998; DiTommaso et al. 2013; Lawlor and Raynal 2002; Mervosh and Boettner 2009; Mervosh and Gumbart 2015). Results using various formulations and rates of glyphosate and triclopyr have varied from poor to excellent control of *V. rossicum.* In many cases, glyphosate provided higher control (e.g., Mervosh and Gumbart 2015), although triclopyr has the advantage of selectively

Management Implications

Black swallowwort (*Vincetoxicum nigrum*) is a European twining vine that was introduced into eastern North America. Herbicidal control is a potentially effective management approach, but herbicide control studies have only been published for the related pale swallowwort (*Vincetoxicum rossicum*). We evaluated different herbicides, combined with mowing or not, applied over 2 yr to a moderate- to high-density population of *V. nigrum* in Dutchess County, NY, USA. *Vincetoxicum nigrum* in plots was either sprayed at flowering in early July or mowed in early July followed by a herbicide application in late August after plants had flowered again. We tested the potassium salt of glyphosate (2.02 kg ae ha^{-1}), the isopropylamine salt of glyphosate (1.35 kg ae ha^{-1}), and the butoxyethyl ester of triclopyr (1.79 kg ae ha^{-1}). Both glyphosate formulations reduced *V. nigrum* aboveground biomass by 83% to 98% after 2 yr, although reductions in *V. nigrum* cover or stem densities of plants >10-cm tall were not as large relative to untreated plots. Mowing did not always enhance the efficacy of foliar glyphosate applications. In contrast, triclopyr, with or without mowing, was generally not effective against *V. nigrum*, although grass cover did increase. Repeated single applications of glyphosate can be useful for the management of *V. nigrum*, but higher rates and possibly more frequent applications of triclopyr will need to be assessed to determine if triclopyr can be used for the control of *V. nigrum*.

controlling dicot species, an important consideration if dealing with grass-dominated habitats. The cutting or mowing of plants several weeks before foliar herbicide applications is often done to reduce interfering vegetation, promote good regrowth of the targeted weed species with subsequent greater coverage by the herbicide, and potentially diminish carbohydrate reserves by forcing regrowth (Brandsaeter et al. 2017; Delabays et al. 2008; DiTommaso et al. 2013; Håkansson 2003; Hewett 1985; Ringselle et al. 2015). Also, applying herbicides for at least 2 yr has usually been recommended to control escapes and seedlings (Averill et al. 2008; Cain and Irvine 2011). The efficacy of herbicides for *V. nigrum* control has not yet been quantified and may differ from herbicide efficacy for its congener due to biological differences. For example, root-to-shoot ratios are much lower for *V. nigrum* (typically <1) compared with *V. rossicum* (1.4 or higher), potentially affecting the potential of regrowth (DiTommaso et al. 2021; Milbrath 2008).

The main objective of this study was to determine *V. nigrum* control efficacy of different herbicide treatments that were labeled for use against *Vincetoxicum* species in New York State, with or without a prior mowing, applied over two growing seasons. We hypothesized that (1) glyphosate would have more consistent and better efficacy than triclopyr and (2) a previous mowing would enhance the efficacy of foliar-applied herbicides relative to not mowing.

Materials and Methods

Field Site

The experiment was conducted on the grounds of the Cornell University Cooperative Extension Office, Millbrook, Dutchess County, NY, USA (41.7805°N, 73.7388°W). We did not have access to other large infestations of *V. nigrum* where herbicides were allowed. However, it is standard practice for land managers to reapply herbicides to the same area in subsequent years when managing invasive species, including *Vincetoxicum*. Our study therefore assessed annual repeated treatments. A 0.25-ha grassy area was used that had not been mown for 17 yr before our study. It included a moderate to high-density (65 to 150 stems m^{-2}), open-field stand of *V. nigrum* still in early stages of succession to woody plant species. The soil was a Hoosic gravelly loam (sandy-skeletal, mixed, mesic Typic Dystrudepts). Common grass species were Kentucky bluegrass (*Poa pratensis* L.), smooth brome (*Bromus inermis* Leyss.), quackgrass [*Elymus repens* (L.) Gould], and orchardgrass (*Dactylis glomerata* L.). Common broadleaf species included smooth bedstraw (*Galium mollugo* L.), rough goldenrod (*Solidago rugosa* Mill.), common speedwell (*Veronica officinalis* L.), and yellow toadflax (*Linaria vulgaris* Mill.), whereas spotted St. Johnswort (*Hypericum punctatum* Lam.), rough fleabane (*Erigeron strigosus* Muhl. ex Willd.), and other species were much sparser. Woody species included common buckthorn (*Rhamnus cathartica* L.), Japanese zelkova [*Zelkova serrata* (Thunb.) Makino], and Morrow's honeysuckle (*Lonicera morrowii* A. Gray).

Experimental Design and Treatments

The study was conducted from June 2018 to June 2020, with mowing and herbicide treatments applied in 2018 and 2019. Based on an initial assessment of *V. nigrum* stem densities and cover in June 2018, plots were arranged in a completely randomized design. The experiment included two factors in a repeated-measures design: seven management treatments in a one-way treatment structure with repeated measures on years. Each treatment was replicated seven times for a total of 49 experimental units measured up to three times. Treatments were applied to 4 by 1.9 m plots marked with labeled PVC pipes and separated by 2-m buffer zones and included an unmanaged control, three treatments involving herbicide applications at flowering (early July), and three treatments in which plants were cut at flowering (early July) followed by a herbicide application at reflowering (late August). Comparisons of herbicides alone to a single mowing alone (or other mechanical method of control) were not done, because pulling or cutting stems one to two times per year has not been shown to be effective for *Vincetoxicum* species (Averill et al. 2008; DiTommaso et al. 2013; Mervosh and Gumbart 2015; Milbrath et al. 2016).

Herbicides were applied using a CO_2-pressurized backpack sprayer (R & D Sprayers, Opelousas, LA) equipped with a four-nozzle boom (XR80015 TeeJet® nozzles, Glendale Heights, IL) to provide a 2-m-wide spray pattern. Nozzle pressure was 172 kPa (25 psi), and applications were timed to deliver an equivalent rate of 187 L ha^{-1} (20 gal ac^{-1}). The herbicides used included the potassium salt of glyphosate (Roundup ProMax®, 48.7% ai, Monsanto, St Louis, MO), the isopropylamine salt of glyphosate (Ranger Pro®, 41.0% ai, Monsanto), and the butoxyethyl ester of triclopyr (Garlon 4 Ultra®, 60.45% ai, Corteva Agriscience, Johnston, IA). We used 2% solutions of the two glyphosate products based on specific Federal Insecticide, Fungicide, and Rodenticide Act 2(ee) supplemental label concentrations for *V. nigrum* in New York State that were available as of 2017 (NYS DEC 2017). We also chose to use a similar 2% solution of triclopyr (equivalent to 3.74 L ha^{-1} or 1.6 qt ac^{-1}) that was within the 2(ee) label of 2.34 to 18.71 L ha^{-1} (1 to 8 qt ac^{-1}) (NYS DEC 2017). A previous study with *V. rossicum* showed that a similar low dosage of triclopyr could be very effective (Averill et al. 2008). Glyphosate solutions included a 0.5% by volume of an organosilicone surfactant

(Kinetic®, Helena Chemical, Collierville, TN) and the butoxyethyl ester of triclopyr included a 1.25% by volume of the surfactant (equivalent to 2.34 L ha^{-1} or 1 qt ac^{-1}) based on specific label recommendations. Herbicide rates applied were glyphosate at 2.02 kg ae ha^{-1} (1.80 lb ae ac^{-1}, Roundup ProMax®) and 1.35 kg ae ha^{-1} (1.20 lb ae ac^{-1}, Ranger Pro®), and butoxyethyl ester of triclopyr at 1.79 kg ae ha^{-1} (1.60 lb ae ac^{-1}).

Herbicide-only treatments were applied July 10, 2018, and July 9, 2019. Mowing-herbicide treatments included mowing on July 10, 2018, and July 9, 2019, with a rotary mower (Husqvarna HD 800HW, Husqvarna Professional Products, Charlotte, NC) throughout the entire plot to a height of 8 cm, which is a typical mowing height for land managers. Herbicides were then applied 7 wk later on August 28, 2018, and August 28, 2019, when plants were at flowering and early follicle production stages, that is, similar to when the first herbicide applications occurred in July.

Pre- and Posttreatment Data Collection

A pretreatment assessment of plant cover and *V. nigrum* stem densities was made on June 20, 2018. Two posttreatment assessments were made on June 26, 2019, and June 29, 2020, each approximately 1 yr after treatment. A 1 by 1 m quadrat was placed in the middle of each plot, and two opposite corners were permanently marked with PVC pipes. Percent cover of *V. nigrum*, grasses, other herbaceous dicots, woody species, and bare ground in each 1-m^2 subplot was visually estimated by the same observer in all years. All *V. nigrum* stems >10-cm tall (consisting of larger vegetative juveniles and flowering plants) were counted in each 1-m^2 subplot. Stems <10-cm tall (seedlings and young vegetative juveniles) were counted from two separate 0.0625-m^2 quadrats placed at opposite corners of a 1-m^2 subplot. After cover and density data collection in June 2020, *V. nigrum* aboveground dry biomass was determined by cutting plants in each subplot at soil level, oven-drying tissues at 70 C for 48 h, and weighing. We did not quantify seed output posttreatment, because our June data collection occurred before most follicle production had begun.

Statistical Analyses

A mixed model was used including a repeated-measures analysis with an autoregressive covariance structure (PROC MIXED, SAS v. 9.4, SAS Institute, Cary, NC) for the dependent variables stem density (<10-cm tall, average of two counts per subplot) and percent cover. Dependent variables were transformed using the logarithmic or logit transformations to fit the assumptions of the model. For the stem density (>10-cm tall) data, a generalized linear mixed model with a negative binomial distribution, a log link, and an error term for repeated measures was used (PROC GLIMMIX, SAS v. 9.4, SAS Institute). In all analyses, management treatment and year were fixed effects. Logarithmic-transformed biomass data were analyzed with a mixed model with management treatment as a fixed effect (PROC MIXED). Stepwise removal of nonsignificant interaction terms was done to determine the best model for each parameter. Preselected groups of means were compared using Fisher's protected LSD test with the SLICE option and a modified Bonferroni correction (based on the actual number of comparisons being made for each parameter rather than all possible comparisons) (SAS v. 9.4, SAS Institute).

Results and Discussion

Pretreatment *V. nigrum* densities and percent cover of different plant groups (year 2018) did not differ among the various management treatment plots (Figures 1 and 2). Temperatures (lows and highs) did not vary substantially among the 3 yr of the study or from the 30-yr average at the site (data not shown; CLIMOD 2021). Precipitation was more variable, with a wetter than normal summer in 2018 and a dry spring in 2020.

Density, Cover, and Biomass of Vincetoxicum nigrum

Posttreatment stem densities of *V. nigrum* (>10-cm tall) varied to a limited degree among treatments over time (treatment by year interaction, $F(12, 84) = 5.07$, $P < 0.001$). None of the treatments differed from the unmanaged control at 1 yr after treatment (2019), although stem densities were significantly reduced (approximately 75%) for the mowing plus glyphosate-isopropylamine treatment (14 stems m^{-2}) compared with glyphosate-isopropylamine alone (62 stems m^{-2}; Figure 1). After two seasons of treatment (2020), most treatments again did not differ from the control plots (75 stems m^{-2}; Figure 1), with the exception of the mowing plus glyphosate-isopropylamine treatment (12 stems m^{-2} or 84% reduction; Figure 1).

Changes in percent cover of *V. nigrum* also varied among years (treatment by year interaction: *V. nigrum* $F(12, 89.7) = 4.81$, $P < 0.001$) and were comparable to results for stem densities (>10-cm tall). Specifically, mowing plus either glyphosate formulation generally had the lowest percent cover in 2019 and 2020 with 85% reductions compared with the control plots (Figure 2A). Percent cover of *V. nigrum* after foliar sprays of glyphosate alone or triclopyr with or without mowing were not significantly less than cover in untreated plots, although trends toward lower percent cover were evident for some herbicide treatments after 2 yr (Figure 2A).

Significant reductions in aboveground dry mass per square meter of *V. nigrum* at 2 yr after treatment were present for several herbicide treatments ($F(6, 42) = 20.11$, $P < 0.001$). Specifically, dry mass of *V. nigrum* was reduced by 83% with foliar sprays of glyphosate and 93% to 98% with mowing plus glyphosate sprays (Figure 3). The two formulations of glyphosate gave similar levels of dry mass reduction, but the addition of mowing did not always enhance the efficacy of foliar applications alone. In contrast, triclopyr alone did not reduce the dry mass of *V. nigrum*, although a nonsignificant trend toward greater *V. nigrum* suppression was evident with the addition of mowing (Figure 3). As noted by Lawlor and Raynal (2002) for *V. rossicum*, the stunting and proliferation of stems from herbicide damage can complicate stem density and percent cover measurements, whereas biomass can give a more accurate picture of herbicide impact. Our biomass results are somewhat similar to the stem density and percent cover results but clearly indicate strong efficacy for glyphosate and a lack of efficacy for triclopyr (Figures 1 and 2A). Our initial hypothesis that glyphosate would provide more consistent and better efficacy than triclopyr was met, although we had not necessarily expected such poor results with triclopyr.

Our results differ substantially from DiTommaso et al. (2013) in that all the different formulations and rates of glyphosate and triclopyr they used substantially reduced old-field *V. rossicum* stem density (>5 cm), cover, and dry mass by about 90% or more. However, they used 1.7 to 2.7 times higher herbicide rates than the present study. We used 2% solutions with resulting lower dosages because that was specifically indicated in the Section 2(ee)

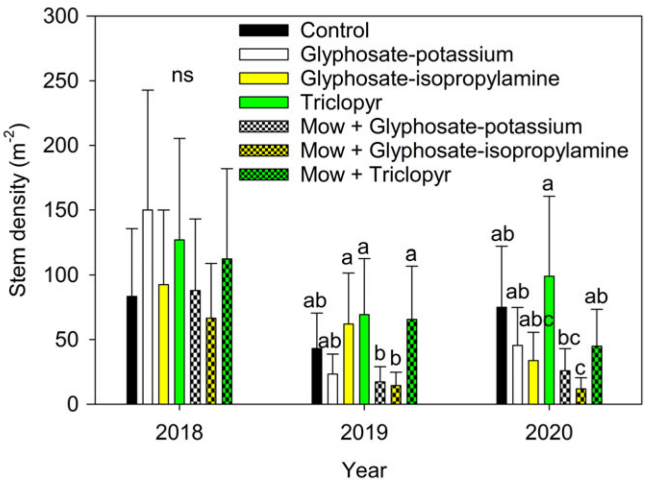

Figure 1. Mean (+SE, back-transformed, $n = 7$) stem densities per square meter for *Vincetoxicum nigrum* >10-cm tall for seven treatments during a 3-yr study. Pretreatment values were in year 2018; values in 2019 and 2020 were 1-yr post first and second herbicide treatment, respectively. Bars within each year denoted by the same letter are not different (Fisher's protected LSD test with Bonferroni correction, P > 0.05). "ns" indicates no significant differences.

labels for New York State for both glyphosate products (NYS DEC 2017). Because we chose to keep a similar 2% solution for triclopyr, the amount of product applied was on the lower end allowed in the Section 2(ee) label for triclopyr (NYS DEC 2017). Other studies have also reported a consistently high efficacy of glyphosate against the congener *V. rossicum*, whereas the efficacy of triclopyr has been more variable. Mervosh and Boettner (2009) reported similar reductions 1 yr later in seedpod mass (66% to 71%) and control ratings (7.0 to 7.8 out of 10) for single low rates of a triethylamine salt of triclopyr (1.26 kg ae ha^{-1}) or an isopropylamine salt of glyphosate (1.12 kg ae ha^{-1}). Lawlor and Raynal (2002) reported similar efficacy among single foliar applications of the isopropylamine salt of glyphosate (3.1 or 7.8 kg ae ha^{-1}) and the butoxyethyl ester of triclopyr (1.9 kg ae ha^{-1}), with average reductions 1 yr later in *V. rossicum* stem density, percent cover, and aboveground biomass of 73%, 83%, and 83%, respectively, compared with untreated plots. Averill et al. (2008) also reported excellent control of *V. rossicum* at 2 yr after a single application of butoxyethyl ester of triclopyr (1.9 kg ae ha^{-1}). They observed a 74% reduction in cover and 44% and 84% reductions in stem densities of <10-cm- and >10-cm-tall *V. rossicum*, respectively. This treatment also prevented follicle production in *V. rossicum*. In the latter two examples, the rates of triclopyr were similar to the present study (1.79 kg ae ha^{-1}).

In contrast, whereas foliar applications of isopropylamine glyphosate (2.2 kg ai ha^{-1}) resulted in a 76% reduction in *V. rossicum* cover after 2 yr of treatment, no reductions occurred with a triethylamine salt of triclopyr (1.7 kg ai ha^{-1}) (Mervosh and Gumbart 2015). Cain and Irvine (2011) also reported as low as 30% control in one trial using the butoxyethyl ester of triclopyr. Mervosh and Gumbart (2015) suggested earlier-season applications of triclopyr might provide better control than they had observed, as was demonstrated by Averill et al. (2008). DiTommaso et al. (2013) showed excellent control also could be achieved with a late-season application of triclopyr. Some authors have noted that two to three applications per season gave much better and longer-lasting control of *V. rossicum* than single applications of either glyphosate or triclopyr, although repeat applications over more than 1 yr may still be needed (Cain and Irvine 2011; Christensen 1998; Mervosh and Boettner 2009). This has not yet been studied for *V. nigrum*. Beyond *Vincetoxicum* species, glyphosate also seems to perform better than triclopyr in some, but not all, cases when used as a foliar application against other invasive or weedy plant species (Farooq et al. 2019; Knezevic et al. 2018; Meighani et al. 2021; Roth et al. 2021).

Mowing in early summer followed 7 wk later by a foliar herbicide generally did not enhance reductions in *V. nigrum* stem densities, cover, or biomass compared with an early-summer herbicide application, contrary to our initial hypothesis. We chose to wait until substantial reflowering had occurred after mowing and before applying the herbicides, as was done by DiTommaso et al. (2013), but shorter durations between mowing and herbicides could be examined. A comparison of herbicide efficacy with or without subsequent mowing has not been investigated for the related *V. rossicum*. However, Averill et al. (2008) noted that cutting *V. rossicum* plants 4 wk after spraying triclopyr gave similar results to spraying only. Cut-stem treatments, that is, immediately applying herbicides to stems of plants after they are cut, have also been effective for control of *V. rossicum*. Lawlor and Raynal (2002) reported comparable control with either an isopropylamine salt of glyphosate (3.1 kg ae ha^{-1}) or a triethylamine salt of triclopyr (1.4 kg ae ha^{-1}) cut-stem treatment. Results were also similar between the cut-stem and foliar applications of glyphosate but were less for the cut-stem compared with a butoxyethyl ester triclopyr foliar application (Lawlor and Raynal 2002). Mervosh and Gumbart (2015) also reported acceptable reductions in *V. rossicum* vigor and plot coverage with cut-stem applications of 50% solutions of an isopropylamine salt of glyphosate or triethylamine salt of triclopyr. Cut-stem treatments have not been evaluated for *V. nigrum*, and integration of mechanical, chemical, and potentially biological control should be investigated for enhancing the management of perennial plants such as *V. nigrum* (Lym and Nelson 2002; Miller 2016; Tipping et al. 2017).

Stem densities of small *V. nigrum* plants (<10-cm tall) significantly declined over each year independent of treatment (year effect, $F(2, 81.5) = 43.77$, $P < 0.001$). Densities (averaged over two 0.0625-m^2 plots) were 55.0 ± 13.9 (2018), 6.7 ± 1.7 (2019), and 2.3 ± 0.6 (2020). The lack of treatment effects on seedlings and young juveniles may have been confounded by natural annual fluctuations in seedling recruitment (Biazzo and Milbrath 2019; unpublished data) as well as the shielding of small *V. nigrum* plants from herbicide sprays by larger *V. nigrum* and other broadleaf species prevalent at the site, particularly *G. mollugo*. This interfering vegetation would have included regrown foliage in those plots that had been mown several weeks earlier. *Vincetoxicum nigrum* has a more sprawling and trailing vine growth habit than its congener *V. rossicum*, creating mats of vegetation (personal observation). Other researchers have reported variable herbicide efficacy on early-stage *Vincetoxicum* plants. Averill et al. (2008) documented *V. rossicum* seedling reductions compared with unmanaged plots from the butoxyethyl ester of triclopyr within the same growing season but not after 1 yr. DiTommaso et al. (2013) reported reductions in small *V. rossicum* (<5-cm tall) densities in an old field after 2 yr, but not after 1 yr, of various cutting plus herbicide treatments.

Cover of Other Plants

Percent cover varied over time for the different plant groups or bare ground relative to different herbicide treatments (treatment by year interaction: broadleaf $F(12, 87.4) = 4.07$, $P < 0.001$;

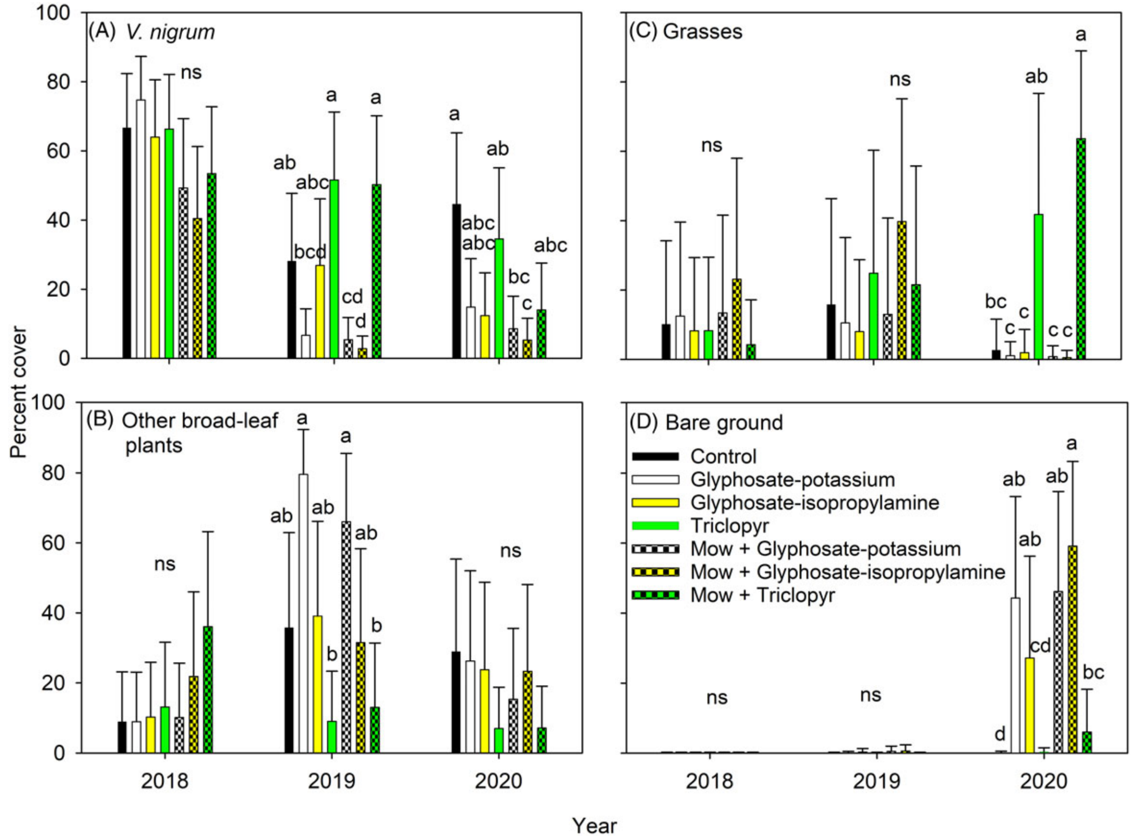

Figure 2. Mean (+95% confidence interval, back-transformed, $n = 7$) percent cover of (A) *Vincetoxicum nigrum*, (B) other broadleaf plants, (C) grasses, and (D) bare ground in 1-m^{-2} subplots for seven treatments during a 3-yr study. Pretreatment values were in year 2018; values in 2019 and 2020 were 1-yr post first and second herbicide treatment, respectively. Bars within each year denoted by the same letter are not different (Fisher's protected LSD test with Bonferroni correction, P > 0.05). "ns" indicates no significant differences.

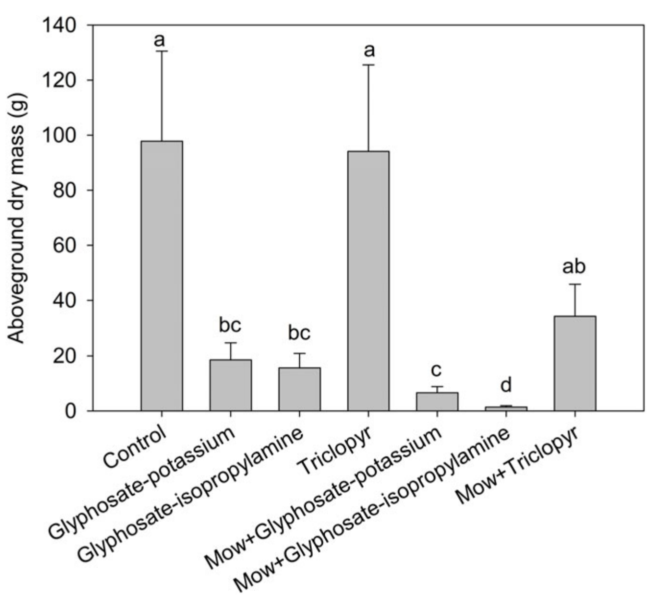

Figure 3. Mean (+SE, back-transformed, $n = 7$) aboveground dry mass of *Vincetoxicum nigrum* from 1-m^{-2} subplots after 2 yr of seven treatments. Bars denoted by the same letter are not different (Fisher's protected LSD test with Bonferroni correction, P > 0.05).

grass $F(12, 80) = 4.31$, $P < 0.001$; bare ground $F(12, 90.7) = 5.26$, $P < 0.001$). Woody species only constituted <1% cover and are therefore not shown. Cover of other broadleaf species generally did not differ over the 3 yr, except for an apparent temporary increase in a few treatments in 2019 (Figure 2B). The most abundant species besides *V. nigrum* in and around the plots was *G. mollugo*. The application timing or rates may not have been ideal for control of *G. mollugo*; many plants were already producing seeds at the July application. This species is difficult to manage with herbicides (Mersereau and DiTommaso 2003). It is also possible that *G. mollugo* grew into the plots from outside the treated area. The cover of grasses was initially 4% to 23% (Figure 2C). After 2 yr of herbicide applications, grass cover was generally the greatest for both triclopyr treatments (41% to 64%), whereas grass cover was 0.5% to 2.0% in the glyphosate plots (Figure 2C). This is not surprising due to the selectivity of triclopyr for broadleaf plants; Mervosh and Boettner (2009) and DiTommaso et al. (2013) reported similar changes in vegetation when comparing glyphosate and triclopyr treatments against *V. rossicum*. As expected, bare ground increased substantially for all glyphosate treatments but only after two seasons of application (27% to 59%; Figure 2D). While glyphosate was very effective against *V. nigrum*, active restoration of treated areas would be needed to prevent undesirable vegetation growing into the bare areas produced by glyphosate. Assuming different dosages or frequencies of application could enhance the efficacy of triclopyr toward *V. nigrum* for preserving grass species, the grasses present at our site are widespread, naturalized Eurasian species. They can be considered invasive when trying to restore natural areas to native species (DiTommaso et al. 2013). This would not be an issue for many pasture systems.

In the present study we assessed two broad-spectrum herbicides for the control of an invasive species that is primarily found in open fields of natural areas. The efficacy of annual applications of two different glyphosate formulations toward *V. nigrum* was excellent; and mowing before spraying may improve efficacy. In contrast, we did not observe control with a low rate of triclopyr even after 2 yr of application, although other studies with the congener *V. rossicum* indicate higher control with this herbicide. In part, this may be due to higher planned application rates (DiTommaso et al. 2013). However, we speculate that the effective dose may also have been greater in some studies that used a similar planned rate to ours, because they applied the herbicide with spray bottles or single-nozzle wands until the foliage was wet (Averill et al. 2008; Lawlor and Raynal 2002). In contrast, results with timed sprays of triclopyr with multi-nozzle booms have ranged from poor (Mervosh and Gumbart [2015] with a triethylamine salt; present study with a butoxyethyl ester) to good (Mervosh and Boettner [2009] with a triethylamine salt). The preservation of grasses is one advantage to using triclopyr over glyphosate, whether in natural areas or pasture systems. However, if triclopyr is to be a consistent tool for *V. nigrum* suppression, higher triclopyr rates, greater frequency of applications, and integration with other management tactics should be investigated for improved *V. nigrum* control.

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