

Efficacy of 10 Broadcast Foliar-Applied Herbicide Treatments on Emergent Hygrophila (*Hygrophila polysperma*)

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INTRODUCTION

Hygrophila [*Hygrophila polysperma* (Roxb.) T. Anders.], also known as “East Indian hygrophila,” “Indian swampweed,” or “Miramarweed,” is an herbaceous perennial plant that grows emersed or submersed in slow-moving waters or as a terrestrial plant in saturated soils (Ramey 2001). Native to the East Indies (Les and Wunderlin 1981), hygrophila was introduced into the United States in 1945 as an aquarium plant (Innes 1947) and was found growing in natural waters in Lee County, Florida, in 1965 (Les and Wunderlin 1981). Hygrophila has subsequently spread throughout south Florida, and by 1985 it was commonly found in canals throughout Broward, Hillsborough, and Palm Beach counties (Spencer and Bowes 1985). In addition to those counties, hygrophila is currently present in Alachua, Leon, Levy, Pasco, Pinellas, and Sarasota counties (USDA-NRCS 2008) and is included on the United States Federal Noxious Weed list (USDA-APHIS 2006) and Florida State Noxious Weed list (FDEP 2005). Kay and Hoyle (2001) conducted research on the availability of invasive aquatic weeds for purchase on commercial websites. Hygrophila was found to be available for purchase from 30 vendors, which was greater than the number of vendors found for 11 other invasive species (Kay and Hoyle 2001). Based on the research of Kay and Hoyle (2001), new introductions of hygrophila will likely continue and additional plants will be released in currently infested regions.

Several inherent characteristics of hygrophila contribute to its invasiveness. Hygrophila readily reproduces from vegetative fragments (Vandiver 1980), and Spencer and Bowes (1985) reported that 50 and 100% regrowth occurred from hygrophila stem fragments that contained one and three

nodes, respectively. Hygrophila has multiple growth forms, depending on whether the plant is submersed or emersed (Botts et al. 1990), and hygrophila leaves are capable of drawing CO₂ from water and the atmosphere (Bowes 1987). Furthermore, the plant has relatively low light saturation and compensation points (Spencer and Bowes 1985), which allow it to fix CO₂ at low light levels. Van Dijk et al. (1986) reported that hygrophila grew more aggressively in flowing water compared to static water, and that hygrophila may become competitive with hydrilla [*Hydrilla verticillata* (L.f. Royle)] in flowing water. Fast et al. (2008) reported that hygrophila growth was greater in water that was flushed twice per week (to simulate the water replacement that would occur in canals and rivers) compared to water that was static or continuously circulated. This information helps explain why canals and rivers in south Florida are an ideal environment for the growth and spread of hygrophila.

Hygrophila is included on the list of weeds controlled by the dipotassium and dimethylalkylamine formulations of the herbicide endothall (Cerexagri-Nisso 2007, United Phosphorus 2008). Sutton (1995) reported that endothall provided excellent control of hygrophila for 4 to 8 weeks after treatment, but an additional application was needed 8 to 10 weeks after the initial treatment to control regrowth. No other hygrophila control data were found in the literature, and labels of the other 10 herbicides registered for use in aquatic sites (carfentrazone, copper, diquat, fluridone, glyphosate, imazamox, imazapyr, penoxsulam, triclopyr, and 2,4-D) did not include hygrophila on their lists of weeds controlled. Fast et al. (2008) reported that hygrophila fragments had to be emergent or in saturated soil to establish new plants, which indicates that hygrophila plants become established on banks or at the edges of canals and rivers before spreading into deeper water to grow as submersed plants. Early control of hygrophila with broadcast foliar-applied herbicides is needed to control emergent hygrophila before it becomes established and begins growing submersed in deeper water, which would likely require treatment of the entire water col-

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umn with an herbicide such as endothall. The potential for continued spread of hygrophila, severity of hygrophila as a weed problem, lack of published hygrophila control data, and need to control emergent hygrophila before it begins growing as a submersed plant indicate an immediate need for information on control of this weed. The objective of this research was to evaluate the efficacy of 10 broadcast foliar-applied herbicide treatments on hygrophila.

MATERIALS AND METHODS

An experiment was conducted in August 2006 at the University of Florida Fort Lauderdale Research and Education Center (FLREC) to determine the efficacy of 10 broadcast foliar-applied herbicide treatments on hygrophila. Two 15-cm hygrophila sprigs were planted on 6 July 2006 in 3.8-L plastic pots containing pure sand amended with 15 g slow release fertilizer (15-9-20). Pots were placed in 900-L (219 cm long × 76 cm wide × 64 cm deep) concrete vaults and sub-irrigated with water that was continuously circulated at a rate of 44 L/min and maintained at a depth of 2.5 cm.

Herbicides commonly used to control aquatic weed species along the littoral zone were used in this research, and treatments included glyphosate (4.20 kg ae/ha), glyphosate + 2,4-D (4.20 + 4.38 kg ae/ha), imazamox (0.28 and 0.56 kg ae/ha), imazapyr (0.56 and 1.12 kg ae/ha), triclopyr (3.36 kg ae/ha), triclopyr + glyphosate (3.36 + 4.20 kg ae/ha), triclopyr + 2,4-D (3.36 + 4.38 kg ae/ha), triclopyr + glyphosate + 2,4-D (3.36 + 4.20 + 4.38 kg ae/ha), and an untreated control. Methylated seed oil (1% v/v) was used with imazamox and imazapyr, and a nonionic surfactant (0.25% v/v) was used with all other treatments. Herbicides were applied on 4 August 2006, to hygrophila plants that were 10-cm tall (10 cm above the sand surface at the top of the pots) and covered approximately 95% of the pot surface area. All treatments were applied using a CO₂-pressurized backpack sprayer calibrated to deliver 700 L/ha using a 11004VS flat fan nozzle that was travelling at 2.4 km/hr at a height of 0.46 m above the target.

Hygrophila control was visually evaluated 14, 28, and 56 days after treatment (DAT) on a scale of 0 to 100, where 0 represents no control and 100 represents complete plant death. Plant biomass was harvested 56 DAT, dried, and weighed, and the percentage biomass reduction of each treatment was calculated using the mean biomass of the untreated control (28 g/plant). The experimental design was a randomized complete block with four replications. Data were subjected to analysis of variance, and 95% confidence intervals of treatment means were calculated.

RESULTS AND DISCUSSION

We established that the minimum acceptable level of hygrophila control was a 90% control rating and a 90% biomass reduction; therefore, we concluded that a treatment provided acceptable hygrophila control if its upper 95% confidence limit was ≥90%. Widths of 95% confidence intervals were used as an indicator of the consistency of control provided by herbicide treatments. Moreover, a relatively narrow confidence interval (≤20) indicates that the mean control

provided by a treatment was consistent across the replications of that treatment. A relatively wide confidence interval (>20) indicates that the level of control provided by a treatment was highly variable across the replications of that treatment (control was inconsistent).

Glyphosate, imazamox (0.28 kg ae/ha) and imazapyr (0.56 kg ae/ha) provided unacceptable hygrophila control (<90%) at 14, 28, and 56 DAT (Table 1). At the higher rate of imazamox (0.56 kg ae/ha), control was unacceptable 14 and 28 DAT and acceptable 56 DAT. However, the confidence interval at 56 DAT was relatively wide, indicating that control was inconsistent. When the application rate of imazapyr was increased to 1.12 kg ae/ha, hygrophila control was unacceptable 14 DAT and acceptable 28 and 56 DAT. All treatments that included triclopyr (triclopyr, triclopyr + glyphosate, triclopyr + 2,4-D, and triclopyr + glyphosate + 2,4-D) provided acceptable hygrophila control at all rating timings. However, triclopyr (28 DAT), triclopyr + glyphosate (56 DAT), triclopyr + 2,4-D (28 DAT), and triclopyr + glyphosate + 2,4-D (14, 28, and 56 DAT) had relatively wide confidence intervals, which indicates that the control they provided was inconsistent at those rating timings.

In general, biomass reduction data were in accord with visual control data. Glyphosate + 2,4-D, imazamox (0.56 kg ae/ha), imazapyr (1.12 kg ae/ha), triclopyr, triclopyr + glyphosate, triclopyr + 2,4-D, and triclopyr + glyphosate + 2,4-D provided acceptable hygrophila control 56 DAT, and mean biomass reductions caused by those treatments had upper 95% confidence limits >90%. The lower application rates of imazamox (0.28 kg ae/ha) and imazapyr (0.56 kg ae/ha) provided unacceptable hygrophila control 56 DAT, and biomass reductions caused by those treatments were 66 and 77%, respectively. Although the mean biomass reduction caused by glyphosate had an upper confidence limit >90%, control was unacceptable 56 DAT, and confidence intervals for control and biomass reduction were wide.

Based on these data and the accompanying 95% confidence intervals, we concluded that imazapyr (1.12 kg ae/ha), triclopyr, triclopyr + glyphosate, and triclopyr + 2,4-D provided the most efficacious and consistent hygrophila control of the treatments included in this research. Note that acceptable control was not achieved with imazapyr (1.12 kg ae/ha) until 56 DAT, but this was expected because imazapyr is a relatively slow-acting herbicide (Vencill 2002). Van Haaren and Vitelli (1997) reported that imazapyr was efficacious on thunbergia (*Thunbergia grandiflora* Roxb.), which is in the same family as hygrophila (Acanthaceae). The use of imazapyr for hygrophila control will be dependent on species diversity at the application site because imazapyr (at 1.12 kg ae/ha) is nonselective toward a wide range of native plants, including cattail (*Typha* spp.) and many hardwood species. Therefore, herbicide placement would require great precision, and applications would be limited to areas where damage to nontarget species was of no concern.

Triclopyr applied alone provided acceptable hygrophila control, and the addition of glyphosate or 2,4-D did not increase control. These products may, however, be used in combination with triclopyr to broaden the weed control spectrum if multiple weed species are present. Triclopyr + glyphosate + 2,4-D provided acceptable hygrophila control,

TABLE 1. HYGROPHILA PERCENT CONTROL AND BIOMASS REDUCTION WITH 95% CONFIDENCE LIMITS AFTER TREATMENT WITH BROADCAST FOLIAR-APPLIED HERBICIDES.

Treatment	Rate	Control ¹			Biomass reduction ²
		14 DAT ³	28 DAT	56 DAT	56 DAT
	kg ae/ha	----- % -----			
Glyphosate	4.20	45 (24, 66) ⁴	66 (52, 80)	41 (16, 67)	82 (61, 103)
Glyphosate + 2,4-D	4.20 + 4.38	90 (83, 97)	85 (70, 100)	70 (50, 90)	94 (85, 103)
Imazamox	0.28	28 (24, 32)	38 (23, 53)	58 (27, 89)	66 (55, 77)
Imazamox	0.56	30 (19, 41)	48 (30, 66)	82 (58, 106)	82 (67, 97)
Imazapyr	0.56	33 (26, 40)	55 (46, 64)	47 (40, 54)	79 (76, 82)
Imazapyr	1.12	43 (25, 61)	82 (66, 98)	97 (90, 104)	95 (86, 104)
Triclopyr	3.36	92 (78, 106)	91 (78, 104)	100 (100, 100)	100 (100, 100)
Triclopyr + glyphosate	3.36 + 4.20	93 (83, 103)	96 (88, 104)	93 (78, 108)	99 (97, 101)
Triclopyr + 2,4-D	3.36 + 4.38	96 (89, 103)	95 (84, 106)	95 (88, 102)	100 (99, 101)
Triclopyr + glyphosate + 2,4-D	3.36 + 4.20 + 4.38	87 (74, 100)	87 (68, 106)	73 (54, 92)	98 (96, 100)

¹Control was rated visually on a scale from 0 to 100 where 0 represents no control and 100 represents complete plant death.

²Mean biomass of the untreated control was 28 g/plant.

³Abbreviations: DAT, days after treatment.

⁴Numbers in parentheses are lower and upper 95% confidence limits of means. Means with 95% confidence intervals that do not overlap are statistically different at the 0.95 level of significance.

but control was less consistent than when triclopyr was applied alone or in combination with glyphosate or 2,4-D. Although glyphosate + 2,4-D provided acceptable hygrophylla control with a narrow confidence interval 14 DAT, control became progressively less consistent 28 and 56 DAT. This research needs to be repeated because the experiment was only conducted once. Additionally, future research should be conducted to determine if triclopyr applied alone at rates <3.36 kg ae/ha would provide acceptable hygrophylla control.

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