trial data show reduction of waterhyacinth stand by over 50% from control levels, the treatment regime necessary for maintenance of such levels over a long period is yet to be worked out. This can be expected to vary according to the type of waterhyacinth plant as evidenced by the higher effectiveness of the treatment regime on free floating plants when compared to rooted plants.

ACKNOWLEDGEMENTS

This work forms a part of an M. Phil project of University of Kelaniya (NPL) and was carried out under a research grant (RG/83/71) awarded by NARESA, Sir Lanka. The authors thank M/s Hayles Ltd, Sri Lanka for provoding the herbicide , and Mr. S. C. Kodagoda for technical assistance and photographs.

LITERATURE CITED

1. Charudattan, R. 1984. Role of *Cercospora rodamanii* and other pathogens in the biological and integrated control of waterhyacinth. Proceedings of the International Conference on Waterhyacinth, Hyderabad, India, ed. G. Thyagarajan, United Nations Environment Programme, 834-859.
2. Conway, K. E., T. E. Freeman, and R. Charudattan. 1978 . Development of *Cercospora rodmanii* as a biological control for *Eichhornia crassipes*. Proceedings EWRS 5th Symposium on Aquatic Weeds, Waganingen, Netherlands, 225-230.
3. Conway, K. E., R. E. Cullen, T. E. Freeman, and J. A. Cornell. 1979. Field evaluation of *Cercospora rodmanii* as a biological control of Waterhyacinth, Inoculum rate studies. Misc. Paper. A-79-6, US Army Waterways Experiment Station, Vicksburg, MS, 46 pp.
4. Freeman, T. E., R. Charudattan, K. E. Conway, R. E. Cullen, R. D. Martyn, E. E. McKinney, M. T. Olexa, and D. F. Reese. 1981. Biological control of aquatic plants with pathogenic fungi. Tech. Rep. A-81-1, US Army Waterways Experiment Station, Vicksburg, MS, 47 pp.
5. Hettiarachchi, S., S. A. Gunasekera, and I. Balasooriya. 1983. Leaf spot diseases of waterhyacinth in Sri Lanka. J. Aquat. Plant Manage. 21:62-65.
6. Joshi, N. C. 1974. Suggested control measures for common aquatic weeds. Manual of weed control, Researchco Publication, Delhi : 305-307.
7. Liyanage, N. P. 1987. Studies on integrated control of waterhyacinth with *Myrothecium roridum* and 2,4-D. M Phil Thesis, University of Kelaniya, Sri Lanka. 159 pp.
8. Parker, R. E. 1973. Introductory statistics for Biology, Edward Arnold Ltd, London.
9. Ponnappa, K. M. 1970. On the pathogenicity of *Myrothecium roridum—Eichhornia crassipes* isolate. Hyacinth Contr. J. 8(2):18-20.
10. Ponnappa, K. M. 1971. A highly virulent strain of *Myrothecium roridum* on *Trapa hispinosa*. Indian Journal of Mycology and Plant Pathology, 1:90-94.
11. Rakvidyasastra, V., M. Iemwimangsa, and V. Petcharat. 1978. Host range of fungi pathogenic to waterhyacinth (*Eichhhornia crassipes* (Mart) Solms). Kasetsart Journal, 12(2):114-118.
12. Sokal, R. R. and F. J. Rohlf. 1969. Biometry, W. H. Freeman & Company, San Francisco, 775 pp.

J. Aquat. Plant Manage. 27: 20-23

Control of Common Cattail with Postemergence Herbicides[1]

R. D. COMES AND A. D. KELLEY[2]

ABSTRACT

Field studies were conducted to determine the effect of herbicide rate, spray volume, and plant growth stage on the control of common cattail (*Typha latifolia* L.) with glyphosate. Control was best when the 3.3 kg ae/ha was applied to mature cattail about 1 week before the first autumn frost (96% stand reduction). Control of common cattail was equal when glyphosate at 3.3 kg/ha was applied in 280, 560, or 1120 L/ha (30, 60, 120 gpa) water plus 0.5% v/v surfactant. Treatments applied when common cattail was in mid to full bloom (early July) were much less effective than when applied later in the season (August-September). A single application of dalapon at 22 kg ae/ha was much less effective than glyphosate at 3.3 kg/ha, whereas control with amitrole plus ammonium thiocyanate at 8.8 + 7.3 kg ai/ha (92% stand reduction) was similar to glyphosate. The year following treatment, redtop (*Agrostis alba* L.) and horsetail rush (*Equisetum* spp.) dominated many plots that had been treated with amitrole plus ammonium thiocyanate and glyphosate, respectively.

Key words: Typha latifolia, glyphosate, dalapon, amitrole, plant-succession.

INTRODUCTION

Common cattail grows throughout most of the United States and northward to Alaska in drainage ditches, sluggish irrigation canals, shallow bays and marshes, and in the margins of ponds, lakes, and streams (6). Common cattail is the principal emersed species that interferes with the flow of water in irrigation canals and drainage ditches in the west (16). It is a nuisance in waterfowl management areas in many parts of the country, because stands of cattail encroach upon shallow water marshes and eliminate plants that provide food and cover for wildlife (1).

One goal of irrigation district personnel is to control all or most of the cattail in drainage and delivery channels to facilitate water movement, whereas wildlife managers desire to manage cattail populations at specific ratios to open

[1]Received for publication September 19, 1988, and in revised form January 23, 1989. Contribution of Agric. Res. Serv., U.S. Dep. Agric., in cooperation with the Washington State University Coll. of Agric. and Home Economics Res. Ctr., Agronomy and Soils Dept. No. 8802-17.

[2]Res. Agron. and Biol. Res. Tech., respectively, Agric. Res. Serv., U.S. Dep. Agric., Irrigated Agric. Res. and Ext. Ctr., Prosser, WA 99350.

water and to other species. Weller (20) recommends a 1:1 ratio of open water to cover for optimum bird use and production.

Control of common cattail with herbicides applied postemergence was researched thoroughly in the western U.S. about three decades ago (17, 18). Methods of control developed during that era were based on the proper use of dalapon (2,2-dichloropropanoic acid), amitrole (1*H*-1,2,4-triazol-3-amine), and 2,4-D (2,4-dichlorophenoxy)acetic acid). Dalapon at 22 kg/ha and amitrole at 8.8 to 13.2 kg/ha were most effective when applied in late summer or early fall when cattail plants were fully headed to nearly mature. A single application of 2,4-D at 4.4 to 6.6 kg/ha in an oil-water emulsion was ineffective, especially when applied after cattail had bloomed, but two or three repeated applications at the late boot to early flower stage were very effective.

Glyphosate [*N*-(phosphonomethyl)glycine], a translocated herbicide, was evaluated for the control of numerous emersed species during the 1970s and was registered for aquatic weed control in the early 1980s. However, literature concerning the control of cattail with glyphosate is scarce and inconclusive. Mueller and Lembi (11) reported 40 to 60% control of cattail when treated at flowering with glyphosate at 3.3 and 6.6 kg/ha, respectively. Apparently these rates were completely ineffective when applied before cattail had flowered. In later studies, Lembi (8) reported 100% control of common cattail with glyphosate at 1.5 kg/ha, but the time of application was not specified.

The objectives of this study were a) to compare the efficacy of glyphosate, dalapon, and amitrole plus ammonium thiocynate for control of common cattail; b) to determine the effect of growth stage at the time of treatment on susceptibility of cattail to glyphosate; and c) to determine the effect of spray volume on the phytotoxicity of glyphosate to cattail.

MATERIALS AND METHODS

A natural, dense (44 shoots/m^2) infestation of common cattail growing in a shallow drainage ditch on the Washington State University research farm near Othello, Washington, was used for the study. Cattail was well established and attained heights up to 3 m. Water flowed through the drainage ditch from late March until November, and the soil remained saturated throughout the remainder of the year.

Plots 15 m by 3.6 m were arranged end-to-end in the drainage ditch in a randomized block design with four replications. Two sets of plots were established; one set was treated in 1983 and the other was treated in 1984.

Glyphosate (Rodeo[3,4] formulation) at 2.2, 3.3, and 4.4 kg ae/ha was applied in 280 l/ha (30 gpa) water at 207 kPa (30 psi) at three stages of cattail growth as follows: (a) mid to full bloom (early July); (b) post anthesis, spikes up to 3 cm in diam. (mid August); and (c) seed mature, leaf tips yellow (mid September). The 3.3 kg/ha rate also was applied in a volume of 560 and 1120 l/ha (60 and 120 gpa) in mid September. On the mid-August treatment date, dalapon at 22 kg ae/ha and amitrole plus ammonium thiocyanate (hereafter referred to as amitrole+T) at 8.8 + 7.3 kg ai/ha were applied in a volume of 1120 l/ha (120 gpa). The surfactant X-77[4,5] (mixture of alkylarylpolyoxyethylene glycol, fatty acids, and isopropanol) was added to all herbicide solutions at a concentration of 0.5% (v/v). Herbicides were broadcast with a CO_2 pressurized sprayer equipped with seven flat fan nozzles spaced 51 cm apart. The sprayer was mounted on an amphibious tracked vehicle whose speed was calibrated and maintained with an engine tachometer and locking hand throttle (3).

Injury, based on the percent necrosis and chlorosis of the leaves and stems, was estimated visually in mid- to late September of the treatment year. Stand reduction, as a percent of the untreated plots, was estimated by two independent observers in mid June and mid August of the year following treatment. Estimates were averaged before the data were subjected to analysis of variance. Results were similar both years and all data are averages of two years. Means were separated using Fishers' Protected LSD Test at the 5% level of significance.

RESULTS AND DISCUSSION

Glyphosate injury to common cattail was only slight to moderate on plants treated in July or August, and was never perceptible on plants treated in September. The first frost of the season occurred 7 to 10 days after the September treatments in both years and masked any herbicide symptoms. In mid September of the treatment year, necrosis/chlorosis was similar on plants treated with glyphosate in July and August and averaged 10, 18, and 30% for 2.2, 3.3, and 4.4 kg/ha, respectively. Dalapon at 22 kg/ha and amitrole+T at 8.8 + 7.3 kg/ha caused 70 and 22% necrosis/chlorosis, respectively. No herbicide symptoms were evident the year after treatment with the exception that about 20% of the cattails growing above the waterline on plots treated with amitrole+T had bleached shoots, which is typical of amitrole injury.

Data collected in mid June of the year following treatment was not a reliable estimate of the effect of glyphosate on the control of common cattail, Figure 1. At that time all treatments except 2.2 and 3.3 kg/ha applied in July had reduced the stand of cattail at least 96%. However, by August the stand had increased significantly on all plots except those treated with 3.3 kg/ha in September and 4.4 kg/ha in either August or September. Stand density increased most dramatically on plots that had been treated with 3.3 kg/ha in July and 2.2 kg/ha in August of the previous year (from 17 to 80% and from 3 to 75%, respectively). These data suggest that glyphosate inhibits the emergence of cattail in the spring or early summer of the year after treatment when applied at less than the optimum rate and stage of plant development.

[3]Tradename of Monsanto Agricultural Products Co., 800 N. Lindbergh Blvd., St. Louis, MO 63166.

[4]Mention of a trademark, proprietary product, or vendor does not constitute a guarantee of the product by the U.S. Dep. of Agric., or Washington State Univ., and does not imply their approval to the exclusion of other products or vendors that may also be suitable.

[5]Tradename of Chevron Chemical Company, 575 Market Street, San Francisco, CA 94105.

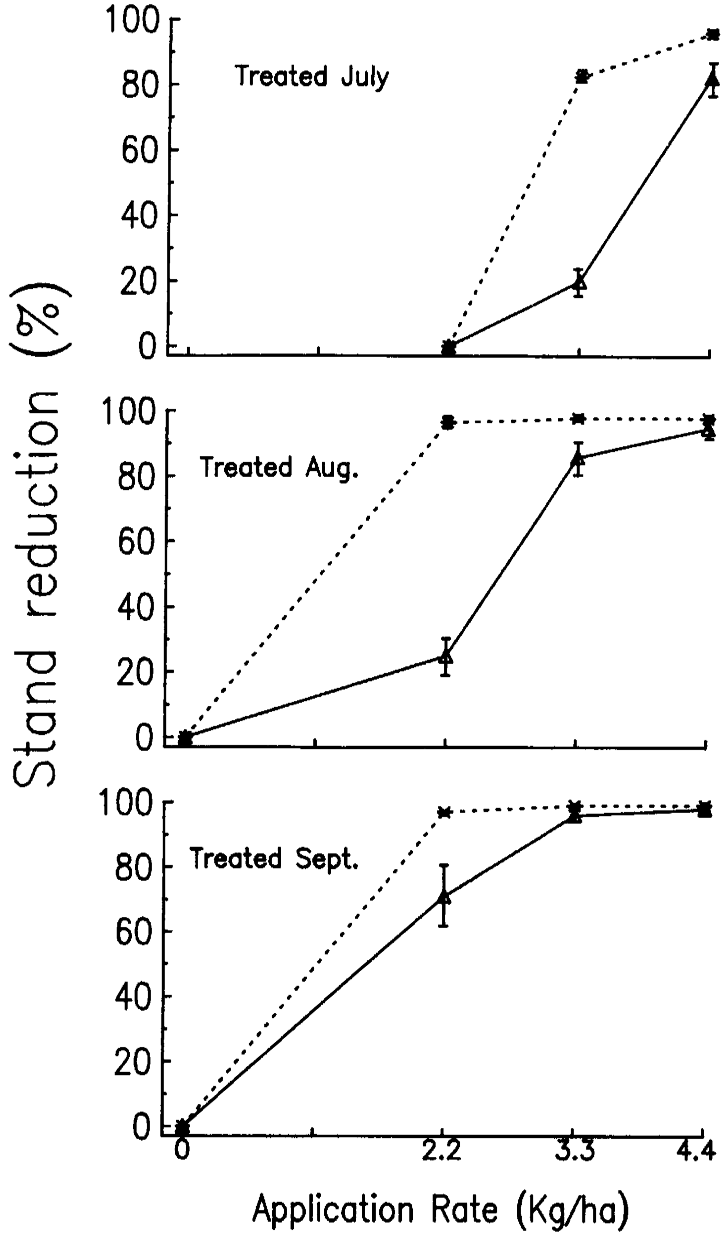

Figure 1. Stand reduction of cattail in June (---*--*--) and August (--Δ---Δ) of the year after three rates of glyphosate were applied to cattail at three different stages of growth. Vertical bars represent the standard error of the mean for each rate and date of application.

The differential response of cattail to the treatments was much more pronounced when data were collected in mid-August of the year after treatment. In general, the stand of cattail decreased as the rate of glyphosate increased and as the stage of cattail maturity at time of treatment advanced, Figure 1.

None of the tretments applied in July or at 2.2 kg/ha on any application date controlled cattail sufficiently to be commercially acceptable. There was no difference between the 3.3 and 4.4 kg/ha rates applied in August and September at the 5% level of probability, but the difference between these rates applied in August was significant at the 10% level of probability. The 2.2 kg/ha rate was much more effective when applied in September than when applied in August. Thus, under the conditions of central Washington, the 3.3 kg/ha rate applied in the fall (mid-September) is optimum for control of common cattail.

Because glyphosate is a phloem-mobile or ambimobile herbicide, its distribution in plants closely follows that of the photoassimilates (5, 21, 22). Total nonstructural carbohydrates in the rhizomes of common cattail growing in temperate climates (Utah and Wisconsin) reached a seasonal low in late June to early July when the plants were beginning to flower (9, 17). The rhizomes became a strong sink for photoassimilates during July and August, based on the accumulation of carbohydrates in rhizomes and the growth of rhizomes. These characteristics of glyphosate and common cattail suggest that applications in July and August should have been most effective if equal quantities of glyphosate were absorbed by common cattail at the different stages of growth. We could find no reference to absorption of glyphosate by common cattail, but our data suggest that uptake and/or translocation may increase with plant maturity. The effect of plant age or maturity on the uptake of glyphosate by different species of perennial plants is extremely variable (4, 10, 14).

Spray volumes ranging from 280 to 1120 l/ha (30 to 120 gpa) did not affect the phytotoxicity of 3.3 kg/ha glyphosate applied to common cattail in mid September; all volumes provided >90% control. Many workers have reported that the phytotoxicity of glyphosate is reduced as the carrier volume is increased (2, 7, 13, 15). This relationship is especially evident with low or marginal rates of glyphosate. Such reduced phytotoxicity has been attributed to quality of the water used in the spray solution (2, 13, 15) and to differences in the dispersion pattern of the solution on leaf surfaces (19). Often the addition of surfactant to the Roundup[3,4] formulation of glyphosate increases the activity and masks the effect of spray volume, especially at low rates of glyphosate application (12, 19). This might be expected because the concentration of surfactant in a solution of Roundup is directly proportional to the rate of glyphosate and inversely proportional to the volume of diluent. In our studies the concentration of surfactant in Rodeo solutions was always 0.5% v/v. Perhaps spray volume, within the range tested in these studies, would impact control of common cattail if treatments were applied earlier in the season or at a rate of glyphosate less than 3.3 kg/ha.

Single applications of amitrole+T at 8.8 + 7.3 kg/ha and dalapon at 22 kg/ha controlled common cattail similarly to that reported by Timmons et al. (17). These treatments had reduced the stand of cattail 92 and 34 percent, respectively, in August of the year following treatment (Table 1). Dalapon was inferior to amitrole+T and to 3.3 kg/ha glyphosate applied in August or September, whereas there was no difference between amitrole+T and glyphosate applied on these dates.

Redtop, a desirable grass for stabilizing ditchbanks in temperate climates, and horsetail rush were present in and along the shallow drain. Redtop grew abundantly in several of the plots following treatment with amitrole+T, whereas glyphosate completely eliminated the redtop. Conversely, horsetail rush survived and became dominant where glyphosate had been applied. We have observed

TABLE 1. CONTROL OF COMMON CATTAIL IN A DRAINAGE DITCH WITH AMITROLE+T, DALAPON, AND GLYPHOSATE, OTHELLO, WASHINGTON.

Treatment[a]	Rate	Applic. Date	Stand reduction[b]	
			June	Aug
	(kg/ha)		(----------%----------)	
Amitrole+T	8.8 + 7.3	Aug	99	92
Dalapon	22	Aug	87	34
Glyphosate	3.3	Aug	98	87
Glyphosate	3.3	Sept	99	96
LSD (0.05)			2.3	15.9

[a]Amitrole+T and dalapon applied in 1120 l/ha; glyphosate applied in 280 l/ha; all solutions contained 0.5% v/v surfactant.
[b]Data recorded the year after application and are averages from two separate experiments conducted in 1983 and 1984.

these same trends following experimental and commercial applications of these herbicides to noncrop areas in the Pacific Northwest. The succession following application of amitrole+T is very desirable, but unfortunately this herbicide is no longer registered for control of cattail.

Although glyphosate applied at 4.4 kg/ha in August and September and at 3.3 kg/ha in September reduced the stand of cattail 95 to 98% one year after treatment, it is probable that the stand would increase significantly during the second year after treatment. Cattail has a tremendous capacity to reproduce vegetatively through rhizomes. Yeo (23) reported a single cattail seed produced a plant that had 129 emerged shoots and occupied an area 3 m in dia when cultured for 6 months in a fertile soil. Thus, two or more annual repeated applications of glyphosate would probably be necessary to prevent cattail from dominating a site within 2 to 3 years after a single treatment at 4.4 kg/ha or less.

These results show that glyphosate at 3.3 kg/ha controls cattail as well as or better than dalapon and amitrole+T, two widely used herbicides for control of cattail in the past. Treatments applied in the fall when seed was mature and leaf tips were starting to turn yellow from senescence were most efficacious, but higher rates of application earlier in the season wholly or partially compensated for more precise timing of the application. The data also emphasize the need to report dates of application and the time that data were collected in relation to the application in order to compare results from different experiments.

LITERATURE CITED

1. Beule, John D. 1979. Control and management of cattails in southeastern Wisconsin Wetlands. Dept. of Natural Resources Tech. Bull. 112, Madison, WI. 41 pp.
2. Buhler, Douglas D. and Orvin C. Burnside. 1983. Effect of water quality, carrier volume, and acid on glyphosate phytotoxicity. Weed Sci. 31:163-169.
3. Comes, R. D., V. V. Vandiver, and L. W. J. Anderson. 1987. Herbicide application technology in aquatic weed control. Pages 281-296, *in* C. G. McWhorter and M. R. Gebhardt, ed. Methods of Applying Herbicides, Monograph series of the Weed Science Society of America, Champaign, IL.
4. Davis, H. E., R. S. Fawcett, and R. G. Harvey. 1979. Effect of frost and maturity on glyphosate phytotoxicity, uptake, and translocation. Weed Sci. 27:110-114.
5. Dewey, Steven A. and Arnold P. Appleby. 1983. A comparison between glyphosate and assimilate translocation patterns in tall morningglory (*Ipomoea purpurea*). Weed Sci. 31:308-314.
6. Hotchkiss, N. and H. L. Dozier. 1949. Taxonomy and distribution of North American cattails. Amer. Midl. Nat. 41:237-254.
7. Jordan, T. N. 1981. Effect of diluent volumes and surfactants on the phytotoxicity of glyphosate to bermudagrass (*Cynodon dactylon*). Weed Sci. 29:79-83.
8. Lembi, C. A. 1978. Results of 1978 aquatic herbicide trials in Indiana. Proc. North Cent. Weed Control Conf. 33:102-103.
9. Linde, Arlyn F., Thomas Janisch and Dale Smith. 1976. Cattail—The significance of its growth, phenology and carbohydrate storage to its control and management. Tech. Bull. 94. Dept. of Natural Resources, Madison, Wisconsin.
10. Lolas, P. C. and H. D. Coble. 1980. Translocation of 14C-glyphosate in johnsongrass (*Sorghum halepense* L. Pers.) as affected by growth stage and rhizome length. Weed Research 20:267-270.
11. Mueller, M. R. and C. A. Lembi. 1975. Herbicide treatments for cattails, spatterdock, and reed canarygrass. Proc. North Centr. Weed control conf. 30:169.
12. Reimer, Donald N. 1976. Long-term effects of glyphosate applications to phragmites. J. Aquat. Plant Manage. 14:39-43.
13. Sandberg, C. L., W. F. Meggitt, and D. Penner. 1978. Effect of diluent volume and calcium on glyphosate phytotoxicity. Weed Sci. 26:476-479.
14. Schultz, M. E. and O. C. Burnside. 1980. Absorption, translocation, and metabolism of 2,4-D and glyphosate in hemp dogbane (*Apocynum cannabinum*). Weed Sci. 28:13-20.
15. Stahlman, P. W. and W. M. Phillips. 1979. Effect of water quality and spray volume on glyphosate phytotoxicity. Weed Sci. 27:38-41.
16. Timmons, F. L. 1960. Weed control in western irrigation and drainage systems. Joint Rpt. U.S. Dept. Agric., Agric. Res. Serv. and U.S. Dept. Interior, Bur. Reclam., ARS 34-14. 22 pp.
17. Timmons, F. L., V. F. Bruns, W. O. Lee, R. R. Yeo, J. M. Hodgson, L. W. Weldon, and R. D. Comes. 1963. Studies on the control of common cattail in drainage channels and ditches. U.S. Dept. Agric. Tech. Bull. 1286. 51 pp.
18. Timmons, F. L., L. W. Weldon, and W. O. Lee. 1958. A study of factors which influence effectiveness of amitrol and dalapon on common cattail. Weeds 6:406-412.
19. Van, Thai K., V. V. Vandiver, Jr., and R. D. Conant, Jr. 1986. Effect of herbicide rate and carrier volume on glyphosate phytotoxicity. J. Aquat. Plant Manage. 24:66-69.
20. Weller, M. W. 1975. Studies of cattail in relation to management for marsh wildlife. Iowa State J. Res. 49:383-412.
21. Whitewell, Ted and P. W. Santelmann. 1978. Influence of growth stage and soil conditions on bermudagrass susceptibility to glyphosate. Agron. J. 653:656.
22. Wills, G. D. 1978. Factors affecting toxicity and translocation of glyphosate in cotton (*Gossypium hirsutum*). Weed Sci. 26:509-513. 23.
23. Yeo, R. R. 1964. Life history of common cattail. Weeds 12: 284-288.