

AN EVALUATION OF POST-EMERGENCE HERBICIDES TO CONTROL *PANICUM REPENS* L. (TORPEDOGRASS) IN UP-COUNTRY TEA FIELDS*

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Abstract: Glyphosate, Sethoxydim, Fluazifop-P and Haloxyfop-methyl, applied as single post-emergence applications, were evaluated for the control of *Panicum repens* L. (torpedograss), under both glasshouse and field conditions. Each herbicide spray solution was incorporated with the non-ionic surfactant (Agral-90) at 0.1% (v/v). All four herbicides controlled *P. repens* to varying degrees. In general, glyphosate and sethoxydim at 2.0 and 4.0 kg a.i./ha achieved the highest level of control, suppressing 90-95% of weed regrowth 30 days after treatment and killing 90-95% rhizome buds. The performance of fluazifop and haloxyfop, as measured by ability for regrowth suppression was significantly less at these rates, although these herbicides also caused 90-95% kill of rhizome buds. At < 1.0 kg/ha the four herbicides produced insufficient regrowth suppression and bud kill and could not adequately control well-established field infestations. Of the four herbicides tested, haloxyfop-methyl was the least phytotoxic to *P. repens*.

Key words: Fluazifop, Glyphosate, Haloxyfop, *Panicum repens*, Sethoxydim, torpedograss

INTRODUCTION

Panicum repens (torpedograss) is a major perennial rhizomatous grass known to be troublesome in many tropical regions of the world in orchards, field crops, pastures and non-crop lands such as along canal banks, water bodies and roadsides.^{1,2} It has been described as the most significant competitor of young citrus groves in Florida,³ sugarcane in Taiwan,⁴ and as a serious weed in open water habitats, upland rice, plantations of tea, sugarcane, cocoa and coconut in Indonesia.^{5,6} It is widely regarded as the biggest problem weed in the tea estates of Sri Lanka, particularly at high altitudes.⁷ It is also considered to be a troublesome weed in the low-country, in coconut estates, rice-field bunds, playing fields, home gardens and derelict lands, particularly in areas where drainage is poor.^{8,9}

A main feature that contributes to the success of this perennial grass is its extensive rhizome system which contains high levels of carbohydrate reserves.^{7,8,9} The nature of these rhizomes, its regenerating ability and relationship to the general biology of the plant have been reported to some extent previously.^{5,8-10} Since vegetative reproduction is the main mode of perennation, perpetuation and spread, control of *P. repens* requires the destruction of the underground rhizome system and rhizome buds, a task that cannot be achieved by mechanical methods alone.⁷ It is generally accepted that for the control of this highly noxious grass-weed, the most effective method is the use of a systemic herbicide which will translocate inside the plant and kill the rhizome apices and buds. One of the basic problems of *P. repens* control in Sri Lanka has been the lack of a range of herbicides that are consistent in field performance and effective in their intrinsic action on the rhizome system and rhizome buds.

* Publication of this article does not constitute an endorsement by NARESA of any of the products described.

Research at the Tea Research Institute (TRI) in the 1970's showed that dalapon (2,2-dichloropropionic acid) at 5.6 kg/ha, sequentially followed by paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) at 0.26-0.28 kg/ha, could give up to 80% control of *P. repens*.¹¹ Subsequently, it was found that *P. repens* control in tea estates could be most effectively achieved using glyphosate [N-(phosphonomethyl) glycine],¹² a systemic, non-selective herbicide with little or no persistence in soil. As a result, the TRI released its main recommendation for *P. repens* control in tea estates as 4.4 kg/ha of glyphosate in 600 l/ha of water,¹³ a relatively high dose. Chandrasena¹⁴ re-examining *P. repens* control with glyphosate with a view to achieving this task at a reduced cost, found superior control by split, sequential applications of glyphosate within the range 0.2-2.0 kg/ha, compared to one full application. A split application of a dose of 1.5 or 2.0 kg/ha of glyphosate completely inhibited regrowth and achieved 85-95% rhizome bud-kill in these studies.¹⁴ He also emphasized the need to incorporate a non-ionic surfactant at 0.1-0.5% (v/v) with all glyphosate applications in order to make its performance consistent.

A recent development in chemical weed control has been the use of selective, post-emergence grass-killing herbicides ("graminicides"), which combine high selectivity with systemic action.¹⁵ This fact is very significant when it comes to comparing the overall suitability of a chemical to control *P. repens* with that of glyphosate, since the latter is non-selective and potentially very harmful to the tea bush. There is little doubt that despite being highly toxic to tea, glyphosate was recommended with precautions for *P. repens* control in 1980, due to the lack of suitable alternatives.

Among the new generation of graminicides, Fluazifop-butyl [butyl 2-4-(5-trifluoromethyl-2-pyridyloxy) phenoxy propionate], Haloxyfop-methyl [methyl 2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl] oxy] phenoxy] propanoic acid] and Sethoxydim {2-[1-(ethoxyimino) butyl]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one} are highly effective, post-emergence, systemic herbicides that provide efficient and selective control of a wide range of annual and perennial grasses in many dicotyledonous crops.¹⁶⁻¹⁹ In addition to their main mode of action which is through foliar uptake, all three herbicides are known to possess some useful soil component of activity as well.^{15,16} Fluazifop-butyl is known to provide excellent control of perennial grasses such as quackgrass [*Elymus repens* (L.) Gould]^{20,21}, Johnsongrass [*Sorghum halepense* (L.) Pers.] and a range of annual grasses²², despite the fact that a number of other tropical grasses including Illuk [*Imperata cylindrica* (L.) Beauv] have been found to be resistant to it.²²

Parker²⁴ found that the activity of fluazifop-butyl and sethoxydim on *P. repens* was superior to that of glyphosate, but noted that rates of approximately 3.0 kg/ha were needed for satisfactory control. Contrary to this, the TRI in Sri Lanka found that fluazifop-butyl was inefficient in *P. repens* control compared with glyphosate.²⁵ Chandrasena²⁶ obtained 89-98% of regrowth suppression and 84-96% kill of rhizome buds of *P. repens* with fluazifop-butyl, applied at rates of 1.0-2.0 kg/ha and suggested that fluazifop could be developed as a potential weapon against

the weed as an alternative to glyphosate. Subsequently, he showed that the performance of Fluazifop-P (the active R enantiomer of fluazifop-butyl) against *P. repens* could be further improved and made consistent by using additives such as a non-ionic surfactant (Agral 90) or a petroleum oil (Atplus 411F).²⁷

With the above background, the present study was conducted with the objective of comparing the relative performance of glyphosate, fluazifop-P haloxyfop-methyl and sethoxydim in field control of *Panicum repens*.

METHODS AND MATERIALS

Location and Experimental Conditions: This research was carried out in the St. Coombs Estate of the Tea Research Institute of Sri Lanka, Talawakele (1200 m above mean sea level), and the Wooton Estate, Kotagala, during February to September, 1991. During this period the temperature varied between 24-26°C (day) and 7-18°C (night). The average relative humidity during the study period was 65-80% and sunlight was received generally between 0700 and 1700 h.

Spray applications and Herbicide Formulations: The following formulations of the four herbicides were studied for efficacy in controlling *P. repens*: (a) Glyphosate, available as the formulated commercial product, "COUNTER" (35.5% e.c. of acid, Monsanto); (b) Fluazifop-P (experimental samples of the R-enantiomer of fluazifop, 13% e.c., ICI, U.K.); (c) Haloxyfop-methyl (experimental samples, 12.5% e.c., Dow Chemicals Ltd.); and (d) sethoxydim (experimental samples, 12.5% e.c. Nippon Soda Ltd.). The required spray solutions were prepared in tap water. A non-ionic surfactant, "AGRAL-90" (ICI, U.K.) at a rate of 0.1% v/v was incorporated into all herbicide spray solutions.

All applications were done using a Baur's "IRIS" V-L-V knapsack sprayer fitted with a "flat-fan V-L-V nozzle". The sprayer operated at a pressure of 2.5-3.0 kg/cm², with a flow rate of 300 ml/min over an even swathe width of 1 m. The diluent volume used for spraying was 600 l/ha.

Assessment of Phytotoxic Effects: Phytotoxicity on the weed was generally estimated by three methods: (a) visual effects on the plant foliage 10 days after treatment (DAT), using the following scale: 0 = no injury; 1 = slight injury; 2 = 25% of tissues necrosed; 3 = 25-50% of tissues necrosed; 4 = 50-75% of tissues necrosed and 5 = all shoots completely dead. (b) measurement of regrowth inhibition: by cutting-off the aerial shoots of treated plants at soil level 3-4 days after spray applications, allowing for regrowth to take place for the next 30 days, and determining the regrowth dry weight after drying in an oven at 80°C for 24h. (c) measurement of rhizome bud-kill: by taking samples of rizomes of treated plants at specific times after applications, fragmenting the rizomes into 1- or 2-node containing pieces and planting these in trays containing soil, in order to determine whether new shoot regeneration occurs from the lateral buds on the rhizome pieces.

Glasshouse Experiment: Fresh *P. repens* rhizomes dug out from soil were cut into 2.5-3.0 cm fragments each containing a single, central node. The immature apical tip region and the basal ends where the nodes were too close to each other were avoided. These fragments were planted 2.5 cm deep in plastic trays (35 x 22 x 4 cm) containing an ordinary garden loam soil. When new plants had emerged, usually in two weeks, these were selected for uniformity and transplanted singly into 15 cm diameter plastic pots filled with the same soil. On a weekly basis 40 ml of a soluble fertilizer (2 g/l of a mixture containing urea, superphosphate and muriate of potash; 22.5% N, 22.5% P₂O₅ and 22.5% K₂O) was added to each pot. Plants which had grown for 12-weeks, and had well-developed rhizomes and 7-8 tillers, were selected for the experiment.

Plants were treated with the four herbicides, each at rates of 0, 0.125, 0.25, 1.0 or 2.0 kg/ha using diluent volume of 600 l/ha of water. The experimental design used was the randomized complete block design (RCBD) with a factorial arrangement of treatments. Each treatment was replicated three times with groups of 7-8 plants representing each replicate. Plants were sprayed outside and returned to the glasshouse bench after allowing 20 minutes to dry. Phytotoxicity evaluation was done using three plants for visual injury and 4-5 plants for regrowth inhibition, from each group of replicates. The experiment was repeated, and all results are the average of the two experiments.

Field Experiments: The initial field experiment was carried out in an area heavily infested with *P. repens* in the Wootoon tea estate, Kotagala. One m² plots which were covered 100% with *P. repens*, were established in between the tea bushes. The total experimental area was about 1 ha. The soil was a clay loam. The experiment was of a complete randomized design (CRD) with three replicates. Each herbicide was applied at rates of 0, 1.0, 2.0 or 4.0 kg a.i./ha. Spray operations were done in a rain-free period. Control of the weed was evaluated by all three methods as follows: visual evaluation of foliage injury was done at 10 DAT. For the evaluation of regrowth inhibition, two square quadrats (15 cm x 15 cm) were selected randomly within each one m² area of a plot and all the plant foliage within the quadrats clipped off at soil level at 7 DAT. Regrowth which occurred in the quadrats over the next 30 days was harvested and compared with the regrowth made by the untreated control plots. Thirdly, at 7 DAT, two soil cores (each of 15 cm x 15 cm) were obtained randomly from each plot and the rhizomes within it washed free of soil. These rhizomes were then fragmented into 1- or 2-node bearing 3 cm pieces, whose ability to produce new shoots was determined. The field experiment was repeated in a similar area of the St. Coombs estate of the TRI, and the data of the two experiments combined for analysis.

Statistical Analyses: Regrowth dry weights were analysed by analyses of variance (ANOVA) using the statistical package INSTAT (Statistical Services Centre, University of Reading, U.K), and their means compared by the LSD. Plant injury scores (binomial data) were analysed using non-parametric statistics and the mean comparison was done according to the Wilcoxon rank sum test. The binomial rhizome bud viability data were subjected to logit regression with

binomial errors²⁸ and an analysis of deviance, to determine the significance of factors using the statistical package GLIM (Royal Statistical Society, London).

RESULTS

Glasshouse Experiment

Visual ratings of injury (Fig. 1), indicated the manner in which the phytotoxicity symptoms developed. In general, the overall visual injury caused at 10 DAT by 0.125 and 0.25 kg/ha rates of fluazifop, haloxyfop and sethoxydim was greater than that produced by similar rates of glyphosate at 10 DAT. This difference was still visible at 10 days even at the rate of 1.0 kg/ha. However, all four herbicides at the highest rate of 2.0 kg/ha caused similar and very heavy shoot injury to *P. repens*, by 10 DAT, indicating that they may be equally effective in killing the aerial growth.

Plants which received higher doses glyphosate and sethoxydim showed chlorotic symptoms from the third day onwards and within a week the foliage was completely yellowed and withered. Not very different to this, phytotoxicity symptoms caused by fluazifop and haloxyfop also appeared first as marked chlorosis of youngest leaves 3-5 days after spraying. In all treatments these symptoms gradually spread to other leaves as well.

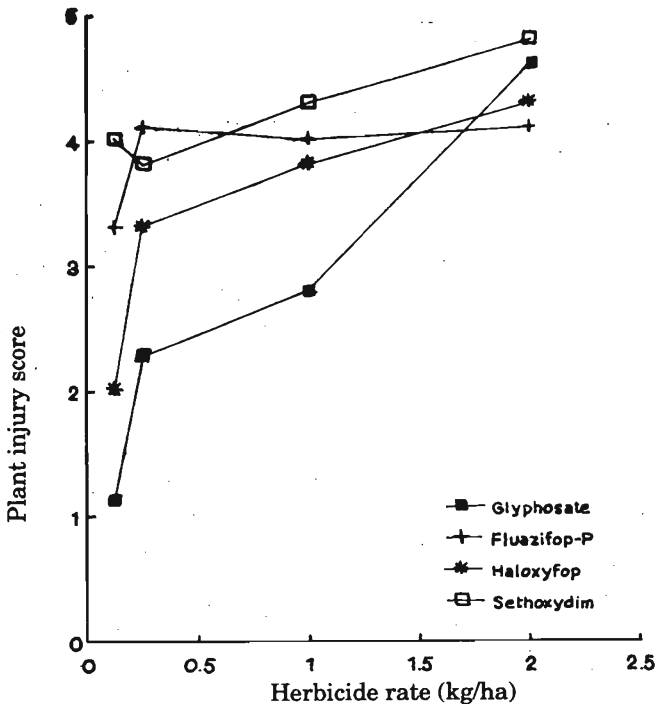


Figure 1: Visual injury caused by a range of post-emergence herbicides on torpedograss (*Panicum repens*)

Glyphosate at rates of 0.125 and 0.25 kg/ha, caused approximately 70-88% reduction in regrowth, while the rates 1.0 and 2.0 kg/ha consistently caused 85% or more regrowth reduction (Fig. 2). Sethoxydim was slightly less effective at the lowest rate of 0.125 kg/ha, but showed a significant dose-dependent effect, with rates of 1.0 and 2.0 kg/ha attaining 82 and 93% regrowth reduction, respectively. Fluazifop-P, caused 71 to 90% regrowth reduction across this dose range. Haloxyfop, on the other hand, was the least effective at lower rates, but at the two higher rates also gave approximately 80% regrowth reduction of the grass. These results therefore, indicated that with glasshouse-grown plants, glyphosate, sethoxydim and fluazifop were superior in activity against *P. repens*, relative to haloxyfop.

Field Experiment

Results of the field trials were expected to be somewhat different to that of the glasshouse experiments, since in the fields *P. repens* infestations were very heavy and much of the above-ground stand quite old. Data on regrowth dry weight (Fig. 3) showed that the dose-effect was highly significant. A lower rate of 1.0 kg/ha of any herbicide achieved only 60 to 68% regrowth inhibition and left many plants relatively poorly controlled. Glyphosate and sethoxydim achieved 90% and 100% reduction of regrowth at 2.0 and 4.0 kg/ha rates, respectively, indicating highly effective control of the field infestation. Both fluazifop and haloxyfop attained 90% regrowth reduction only with the high rate of 4.0 kg/ha; the intermediate rate of 2.0 kg/ha of these two herbicides caused only 74-77% regrowth reduction, suggesting relatively less effective field performance.

The assessment of rhizome bud-kill carried out in the field plots confirmed these findings. The analysis of deviance carried out on the bud-viability data indicated that the effect of herbicide type was not significant. However, the effects of herbicide rate (dose-effect) and herbicide type versus rate interaction, were found to be highly significant (Table 1). Untreated control plots had 68% bud viability as indicated by their ability to regenerate following fragmentation. All herbicide treatments significantly reduced this bud viability. Even the lower rates of all the herbicides gave a high degree of bud kill, although a few buds of some of these low-rate treatments did produce new shoots indicating that they were not completely dead. Fluazifop and haloxyfop, in particular, left about 10% viable buds in the plots at a rate of 1.0 kg/ha, and 2-3% viable buds even at the high rate of 4.0 kg/ha. However, all these new shoots showed varying degrees of chlorosis and growth abnormalities, indicating that the herbicides had reached the rhizome system and had accumulated in the buds. Glyphosate and sethoxydim at the high rate of 4.0 kg/ha, did not leave any viable buds, thus demonstrating a very high kill of the underground rhizome system. Even their lower rates of 1.0 and 2.0 kg/ha, caused significantly greater bud-kill than fluazifop and haloxyfop.

Foliage injury scores, indicated that at the three rates tested, both fluazifop and haloxyfop caused relatively less visible injury to the heavy field-infestation compared to the injury caused by glyphosate and sethoxydim (Table 1).

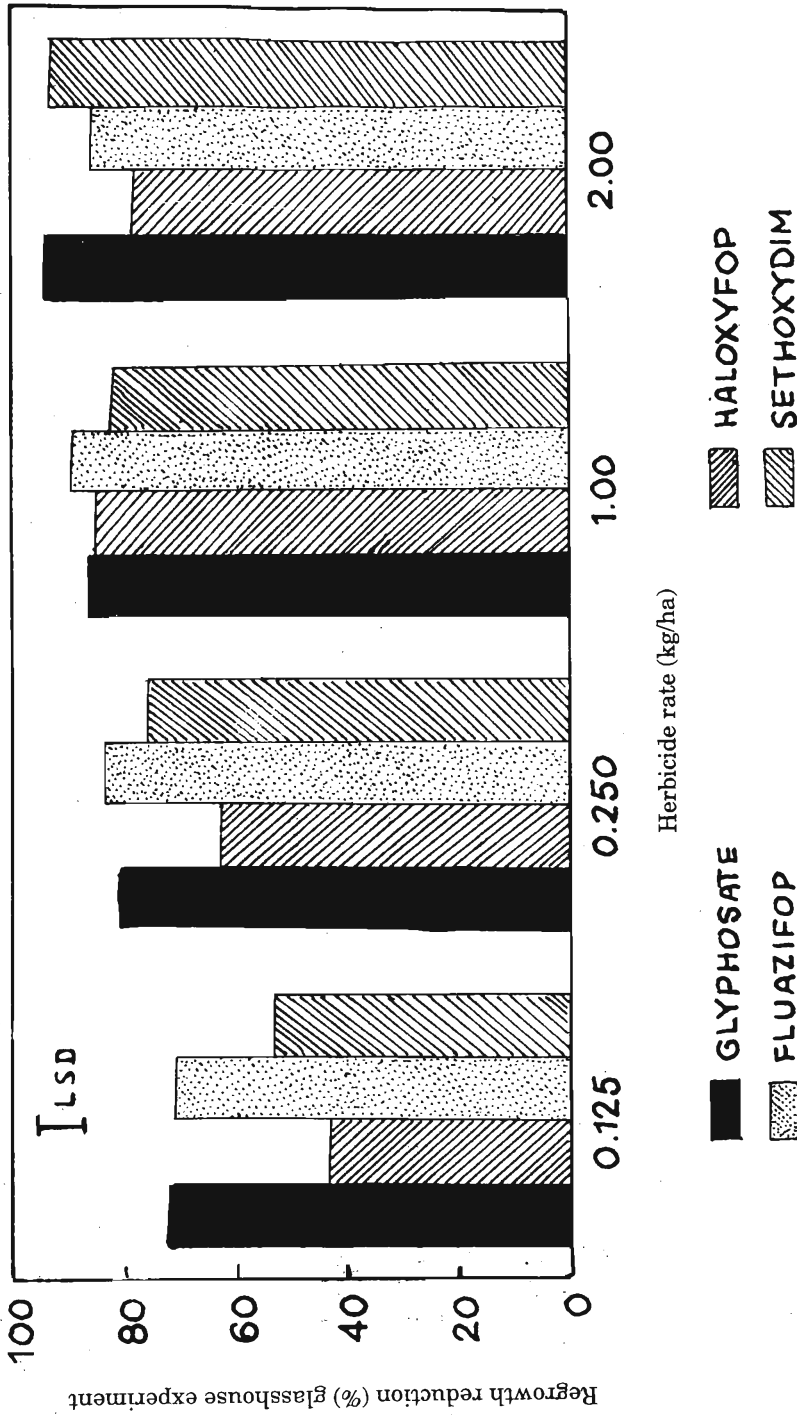


Figure 2: Rate response of torpedograss to a range of post-emergence herbicides, measured by suppression of regrowth, in a glasshouse study.

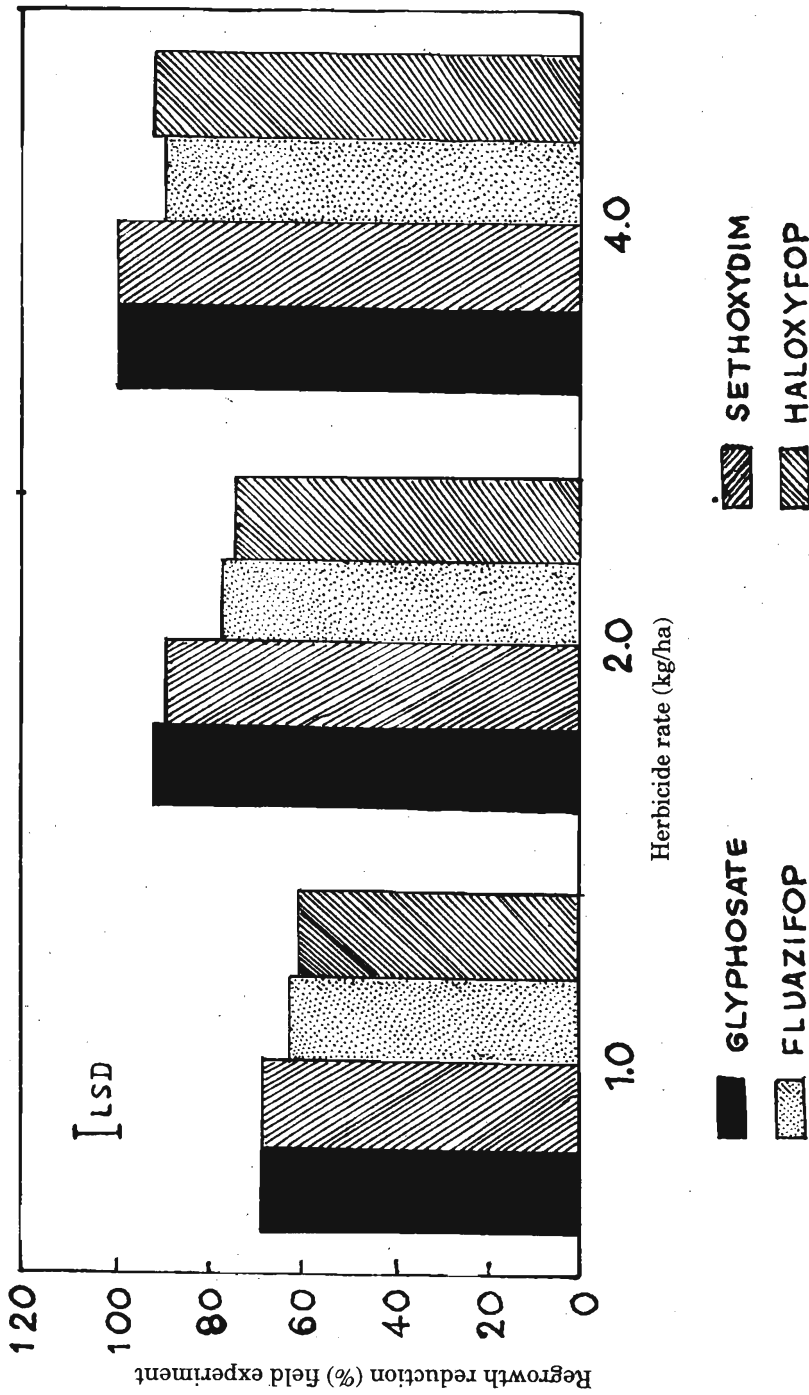


Figure 3: Rate response of torpedograss to a range of post-emergence herbicides, measured by suppression of regrowth, in a field study.

Table 1: Rate response of post-emergence, systemic herbicides on torpedograss (*Panicum repens*) under field conditions

Herbicide	Rate (kg/ha)	Bud-viability (%)	Foliar Injury Score
Glyphosate	1.0	5.0	4
	2.0	3.5	4
	4.0	0	5
Fluazifop	1.0	9.1	3
	2.0	4.0	3
	4.0	1.6	3
Haloxyfop	1.0	9.6	2
	2.0	6.2	2
	4.0	2.9	3
Sethoxydim	1.0	5.7	3
	2.0	3.4	4
	4.0	0	4
Control (Untreated)	-	67.8	0

*Bud-viability data: Change in deviance due to herbicide type- not significant; herbicide rate- highly significant; herbicide type vs rate interaction- significant, according to an analysis of deviance (ANDEV).²⁸ Foliage injury scores: 0 = no injury; 5 = plants dead.

DISCUSSION

The relative performance of the four herbicides could thus be determined from the results of both the glasshouse and field experiments. Clearly, all four herbicides were phytotoxic to *P. repens*, causing moderate to severe dose-dependent foliar damage followed by inhibition in regrowth of shoots and kill of rhizome buds. Evidence that the herbicides were translocated to below ground rhizomes of *P. repens* after uptake, was shown by the extent of regrowth reduction and rhizome bud-kill. Glyphosate and sethoxydim were superior in this translocation ability and also in their inherent toxic activity against the grass than fluazifop and haloxyfop, generally at rates of 1.0 kg/ha or above. However, with both glyphosate and sethoxydim as well, rates of 2.0 kg/ha and above appear essential for the total kill of mature and well established plants of the grass. Under field conditions where heavy infestations occur, a rate close to 4.0 kg/ha with the additional non-ionic surfactant (at 0.1%), is required to achieve satisfactory control and prevent further regrowth, if only a single application is to be made. Low levels of infestations however should be easily controlled by rates in the range of 1.0-2.0 kg/ha applied as a single application or as split-applications of half the full rate.

Sethoxydim, fluazifop-butyl, haloxyfop-methyl, have all been used successfully to control many perennial grasses.^{29,30} Even at low rates, they often provide good initial control of perennial grass species, although late season shoot regrowth from surviving rhizomes has been known to occur. Miller and King³¹ reported that sethoxydim was effective against Bermudagrass [*Cynodon dactylon* (L.) Pers.] in the summer, yet the grass produced dense shoot regrowth in the autumn. Similarly, fluazifop and sethoxydim at 1.1 or 2.2 kg/ha provided excellent initial control of quackgrass, but allowed shoot regrowth from unkilld rhizomes in the low-dose treatment, 42 days after application.³² Therefore, as in the present study, at relatively low doses, the performance of these systemic herbicides may not be high or consistent enough to eliminate *P. repens* from heavily infested areas, particularly if only a single application is made. It could be that at low rates uptake of herbicide into leaves may not be adequate. Also, from the amount of herbicide taken up by the foliage, sufficiently lethal quantities may not be translocated down to the rhizome systems. It is generally known that both the above-ground shoot system and below-ground rhizome/root systems of perennial grass-weed infestations could be highly complex, if left undisturbed for long periods. The shoot system, made up of old, withered and senescing culms and leaves alongside younger culms and leaves, may not be highly amenable to uptake of a foliar-applied herbicide unless the herbicide is assisted by additional surfactants or oil-additives. An old rhizome system may also not be a highly metabolically active 'sink' that is supplied with high amounts of assimilates. Both these limitations in uptake and translocation may present problems to systemic herbicides which depend on an actively growing shoot system for uptake and metabolically strong 'sinks' for movement along with assimilates.

From these studies, it may therefore be concluded that whilst fluazifop and haloxyfop cause significant damage to *P. repens*, the toxicity and performance of both sethoxydim and glyphosate against the weed-grass, are greater. Sethoxydim, being a 'selective' graminicide which is unlikely to harm the tea plant greatly, obviously has an advantage over the relatively 'non-selective' glyphosate in areas planted with tea. Even fluazifop and haloxyfop would offer this added advantage of 'selectivity' in tea fields, combined with the ability to kill a range of other annual grasses. Further field research should evaluate more fully the potential promise of these 'graminicides' in controlling *P. repens* infestations in tea estates, as well as in the coconut estates in Sri Lanka. Particular attention needs to be paid to the control achievable with two or three sequential applications of a lower range of rates, rather than a single 'one-shot' application. Research effort needs to be also directed at finding the most appropriate additives/adjuvants which might further enhance the entry and subsequent translocation of these chemicals into the rhizome systems of *P. repens*.

Other benefits from the use of selective graminicides arise out of their useful soil component of activity. Whilst glyphosate is deactivated in contact with soil and has no soil activity, sethoxydim, fluazifop and haloxyfop have a relatively short soil persistence and residual activity.³³ Sethoxydim has a half-life of approximately 25 days in soil,³³ depending on soil types, moisture and other

environmental conditions.³⁴ Fluazifop-P and haloxyfop (the major degradation product of haloxyfop-methyl) have half-lives of ca. 21^{33,34} and 55 days³³ respectively, also depending on soil type and rainfall. Although all three herbicides do not depend on soil persistence for their activity, their ability to prevent the germination of many grasses through this residual activity³³ would be an added advantage.

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References

1. Holm L.G., Plucknett D.L., Pancho J.V. & Herberger J.P. (1977). *The World's Worst Weeds. Distribution and Biology*. University Press, Hawaii, Honolulu. pp. 609.
2. Tarver D.P. (1979). Torpedograss. *Aquatics* 1(2): 5-6.
3. Wilcut J.W., Truelove B., Davis D.E. & Williams, J.C. (1988). Temperature factors limiting the spread of cogongrass (*Imperata cylindrica*) and torpedograss (*Panicum repens*). *Weed Science* 36: 49-55.
4. Peng S.Y. & Twu L.T. (1976). Effect of competition by *Panicum repens* L. on sugarcane and eradication by herbicide. *Weed Abstract* 25: 200.
5. Siregar H. & Soemarwoto O. (1976). Studies on *Panicum repens*. *Weed Abstracts* 26:452.
6. Soerjani M., Kostermans A.J.G.H. & Tjitrosoepomo G. (1987). *Weeds of Rice in Indonesia*. Balai Pustaka, Indonesia, pp. 710.
7. Manipura W.B. & Somaratne A. (1974). Some effects of manual and chemical defoliation on the growth and carbohydrate reserves of *Panicum repens* (L.) Beauv. *Weed Research* 14: 167-172.
8. Chandrasena J.P.N.R. & Dhammika W.H.Y. (1988). Studies on the biology of *Panicum repens* L. I. Comparative morphological development of three selection from different geographical locations in Sri Lanka. *Tropical Pest Management* 34(3): 291-297.

9. Chandrasena J.P.N.R. & Peiris H.C.P. (1989). Studies on the biology of *Panicum repens* L. II. Intraspecific competition and resource-allocation. *Tropical Pest Management* **35**(3): 316-320.
10. Bor H.L. (1960). The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, Oxford.
11. Tea Research Institute of Sri Lanka (1973). Annual Report, pp. 25-26.
12. Wettasinghe D.T. (1980). Technical Report of the Tea Research Institute for 1980 **16**: 24.
13. Tea Research Institute of Sri Lanka (1980). Circular No. W 8- The use of Glyphosate for control of couch-grass (*Panicum repens*).
14. Chandrasena J.P.N.R. (1990). Torpedograss (*Panicum repens* L.) control with lower rates of glyphosate. *Tropical Pest Management* **36**: 336-342.
15. Gilreath J.P. (1983). Post-emergence grass herbicides. *Weeds Today* **14**:3-5.
16. Anderson R.N. (1982). Comparison of four herbicides applied post-emergence for grass control. *Proceedings of the North Central Weed Control Conference* **37**: 80-82.
17. Hartzler R.G. & Foy C.L. (1983). Efficacy of three post-emergence grass herbicides for soybean. *Weed Science* **31**: 557-561.
18. Porter D.J. & Harvey R.G. (1982). Postemergence herbicides for wild proso millet control in soybeans. *Proceedings of the North Central Weed Control Conference* **37**: 87.
19. Slack C.H. & Witt W.W. (1983). Herbicide Applications with CDA *Abstracts Weed Science Society, America*: 54.
20. Chandrasena J.P.N.R. & Sagar G.R. (1984). Effects of fluazifop-butyl on shoot growth and rhizome buds on *Elymus repens* (L.) Coult. *Weed Research* **24**: 297-303.
21. Plowman R.E., Stonebridge W.C. & Hawtree J.N. (1980). Fluazifop-butyl, a new selective herbicide for the control of annual and perennial grass weeds. *Proceedings of the British Crop Protection Conference-Weeds*, 29-37.
22. Derr J.F., Monaco T.J. & Sheets T.J. (1985). Response of three grass species to fluazifop. *Weed Science* **33**: 693-697.
23. Mabb L.P. & Price C.E. (1985). Fluazifop-butyl activity on *Imperata cylindrica* (L.) P. Beauv. I. Studies on phytotoxicity, spray adhesion and herbicide uptake. *Weed Research* **26**: 301-305.

24. Parker C. (1983). The activity of some new herbicides and mixtures on tropical perennial grass weeds. *Weed Abstracts* **32**: 2844.
25. The Research Institute of Sri Lanka (1982). Annual Report, p. 19.
26. Chandrasena J.P.N.R. (1989). Fluazifop-butyl activity on perennial torpedogras (*Panicum repens* L.). *Proceedings of the 12th Asian-Pacific Weed Science Society Conference* **1**: 159-164.
27. Chandrasena J.P.N.R. (1990). Enhancement of Fluazifop-P toxicity to torpedogras (*Panicum repens* L.) by Surfactant and Oil-additive. *Proceedings symposium on Aquatic Weed Management, Bogor, Indonesia, BIOTROP Special Publication* **40**: 133-143.
28. Nelder J.A. & Wedderburn R.W.M. (1972). Generalized Linear Models. *Journal of the Royal Statistical Society (A)* **135**: 370-384.
29. Charles P.H. & Thomas N.J. (1984). Response of bermudagrass (*Cynodon dactylon*), quackgrass (*Agropyron repens*) and wirestem muhly (*Muhlenbergia frondosa*) to postemergent grass herbicide. *Weed Science* **32**: 835-841.
30. Mckeage M. (1981). Sethoxydim (Poast) EUP results for quackgrass control in soybeans. *Proceedings of the North Central Weed Control Conference* **35**: 115.
31. Miller E.M. & King J.W. (1982). Rates and timing of RO-13-8895, glyphosate and sethoxydim for eradication of bermudagrass for turf renovation. *Proceedings of the Southern Weed Science Society* **35**: 90.
32. Bhowmik P.C. (1983). Quackgrass control with postemergent herbicides. *Proceedings of the Northeast Weed Science Society* **31**: 628-633.
33. The Agrochemicals Handbook (1991). (Eds. H. Kidd & D.R. James) 3rd ed. The Royal Society of Chemistry, U.K.
34. Herbicide Handbook of the Weed Science Society of America, 5th ed. (1983). Weed Science Society of America, Illinois, U.S.A. pp. 515.