Herbicide Combination for Controlling Glyphosate Resistant Weed

Kombinasi Herbisida untuk Mengendalikan Gulma yang Resisten terhadap Glifosat

Marulak Simarmata
Department of Agronomy, Agricultural College, The University of Bengkulu
Jln. Raya Kandang Limun Bengkulu 38371A
simarmat@msu.edu

ABSTRACT

Worldwide, rigid ryegrass is one of the grass weed species that has developed multiple resistances to numerous herbicides. Until ecenthonly glyphosate resistance has been observed in rigid ryegrass. The resistance of rigid ryegrass to glyphosate was reported as a target site basis for resistance. The resistant biotype (R) differs from the sensitive (S) due to altered site of glyphosate action. The objective of this study was to determine whether the R biotype studied in the past is also resistant to other herbicides which might be used for controlling this species. Greenhouse experiments were conducted in the Department of Crop and Soil Sciences, Michigan State University, East Lansing, Michigan, from January to June, 200. The experiments compared the control of R and S rigid ryegrass obtained with glyphosate, rimsulfuron + thifensulfuron, glyphosate combined with rimsulfuron + thifensulfuron, glufosinate, quizalofop, and glyphosate combined with quizalofop. Control with quizalofop, rimsulfuron + thifensulfuron, and glufosinate was similar, indicating that no multiple resistance was present in the R biotype and it could be controlled with herbicides with modes of action represented by the herbicide tested. Tank-mixtures of glyphosate with rimsulfuron + thifensulfuron provided synergistic control of the R biotype of rigid ryegrass.

Key words: resistance; multiple resistance; herbicide resistant weeds.

ABSTRAK

Rigid ryegrass merupakan spesies gulma yang memiliki sifat resistensi ganda terhadap beberapa jenis herbisida. Sejauh ini penilitian yang telah dilakukan hanya terfokus pada resistensi terhadap herbisida glyphosat. Hasil penelitian sebelumnya menunjukkan bahwa mekanisme resistensi glyphosat pada gulma ryegrass terjadi karena perubahan pada target site. Biotipe yang resisten (R) berbeda dengan yang sensitif (S) karena perubahan pada sisi targetnya dari aksi glyphosat. Tujuan penelitian ini mengevaluasi apakah biotipe R yang diteliti sebelumnya juga resisten terhadap jenis herbisida lain yang kemungkinan digunakan untuk mengendalikan gulma *ryegrass*. Penelitian dilakukan di rumah kaca Departemen of Crop and Soil Sciences, Michigan State University, East Lansing, Michigan, USA, untuk membandingkan hasil pengendalian gulma terhadap biotipe R dan S dengan herbisida glyphosate, rimsulfuron + thifensulfuron, kombinasi glyphosate dengan rimsulfuron + thifensulfuron, glufosinate, quizalofop, dan kombinasi glyphosate dengan quizalofop. Pengendalian gulma dengan quizalofop, rimsulfuron + thifensulfuron, and glufosinate nampak sama, menunjukkan bahwa tidak ada resistensi ganda pada biotipe R sehingga gulma *ryegrass* yang resistensi terhadap glifosat masih dapat dikendalikan dengan herbisida lain yang memiliki cara mekanisme kerja serupa seperti yang diuji pada percobaan ini. Kombinasi herbisida glifosat dengan rimsulfuron + thifensulfuron menunjukkan efek pengendalian yang synergis terhadap biotype R dari ryegrass.

Kata kunci: resistansi; multipel resistansi; gulma resisten herbisida.

INTRODUCTION

Glyphosate is one of the most important herbicide worldwide (Baylis, 2000). A broad spectrum of weed control with no residual toxicity in the environment from glyphosate is among the reasons for using glyphosate in pre-planting, land preparation, lawn, and selected weed control in orchards or fruit plantation. Introduction and adoption of glyphosate resistant crops such as glyphosate resistant corn, soybean, cotton, and canola allowed selective weed control of glyphosate. This has resulted in a massive increase of the total volume of glyphosate used worldwide, especially in North America and Canada (Baylis, 2000). From the ecological perspective, the repetitive use of a single herbicide with a single mode of action may result in the appearance of herbicide resistant weeds. Currently, at least 12 weed species including palmer amaranth, commond waterhemp, common ragweed, giant ragweed, hairy fleabane, horseweed, goosegrass, wild poinsettia, Italian ryegrass, rigid ryegrass, buchorn plantain, and johnsongrass have been reported to be glyphosate resistance (Anonymous, 2007).

Glyphosate resistant rigid ryegrass was first identified in Australia in 1996 (Powles and Preston, 2006; Wakelin and Preston, 2006). In the USA, rigid ryegrass resistant to glyphosate was found in California (Simarmata *at al*. 2001). The sites infested with the glyphosate resistant rigid ryegrass had received multiple applications of glyphosate over a period of years. Rigid ryegrass distribution in the USA includes Oregon, California, Arizona, Texas, Lousiana, and Missiouri (USDA, 2000).

Rigid ryegrass plants from California were grown from seed at Michigan State University The magnitude of glyphosate resistance of the first generation varied between 1x and 8x, where x = 1,12 kg ai ha^{-1} (Simarmata *et al.,* 2003). In the previous reports, Simarmata *et al*. (2005) concluded that glyphosate resistant traits segregated through the generations and the collected plants were the natural hybrid from two or more ryegrass species.

Uniform R and S biotypes survived and died from 8x and 0.25x glyphosate, respectively. These had been successfully separated after 8 and 5 cycles of selection, respectively. Magnitudes of glyphosate resistance calculated from the ratio of I_{50} (glyphosate rates that cause 50 percent injury) between R and S was >100-fold (Simarmata *et al*., 2005). This is the most glyphosate resistant species reported so far compared to other species including rigid ryegrass biotypes world-wide.

Table 1. Herbicide application rates used in the two greenhouse studies.

Treatements	Rates (kg ai ha^{-1})	AMS[a] (%)	MSO[b] (%)
Study I			
Control	0	0	0
Glyphosate	4,5	2	0
Glyphosate + rimsulfuron + thifensulfuron	4,5 + 0,026	2	1
Rimsulfuron +thifensulfuron	0,026	2	1
Glufosinate	0,5	3	0
Quizalofop	0,06	0	1
Glyphosate + quizalofop	4,5 + 0,06	2	1
Stdudy II			
Rimsulfuron + thifensulfuron	0,026	2	1
Rimsulfuron + thifensulfuron	0,052	2	1
Rimsulfuron + thifensulfuron	0,078	2	1
Glufosinate	0,5	3	0
Glufosinate	1,0	3	0
Glufosinate	1,5	3	0

[a] AMS = diammonium sulfate; [b] MSO = methylated seed oil (SCOIL®)

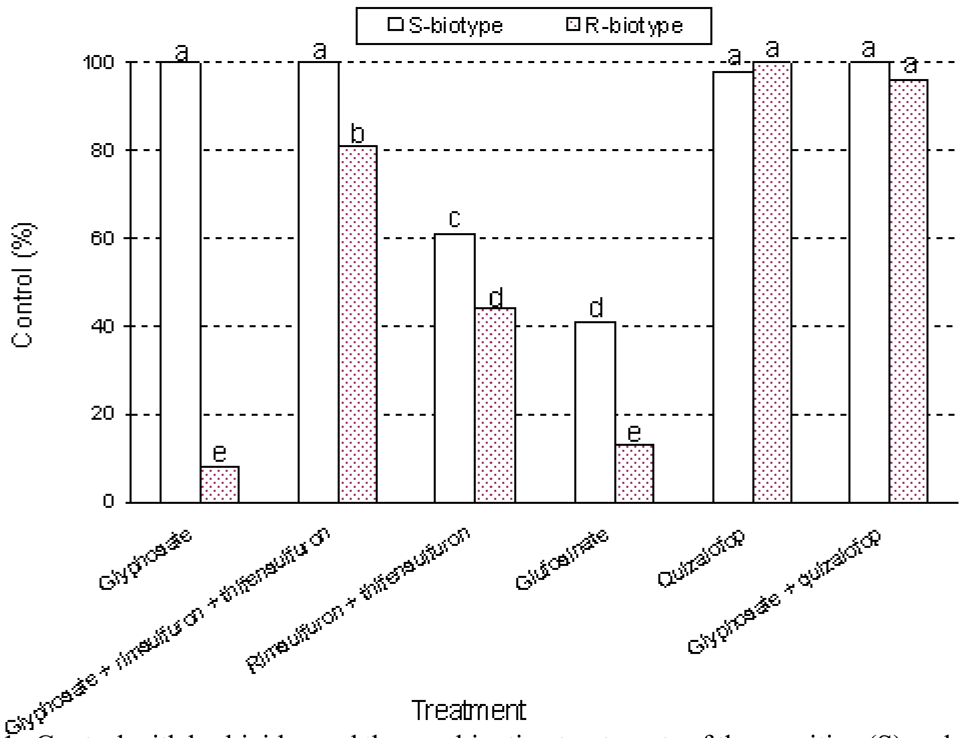

Figure 1. Control with herbicides and the combination treatments of the sensitive (S) and resistant (R) biotypes of rigid ryegrass assessed at 21 days after treatment (DAT). Vertical bars labeled with the same letters indicated no significant differences with LSD $_{0.05}$

The inheritance of glyphosate resistance in the R biotype was associated with more than one gene (Simarmata *et al*., 2005). Multi-gene inheritance of glyphosate resistance was first reported in field bindweed (Duncan and Weller, 1987). Simarmata (2003) previously concluded that the mechanism of glyphosate resistance in ryegrass was a target-site based.

In the last decade, herbicides continue to be a dominant method of weed control. Adoption of integrated weed management should be considered as a wise approach for weed control. Beckie (2006) suggested the herbicide tactics in weed management must be proactive to prevent or delay not only herbicide resistance weeds but also multiple resistances.

Some of the glyphosate resistant weeds have shown multiple resistance to other herbicides that have different mechanisms such as rigid ryegrass in Australia which has developed resistance to diclofop, chlorsulfuron, acetyl coenzyme A carboxylase (ACCase), acetolactate synthase (ALS), and paraquat (Anonymous, 2007; Neve *et al*., 2004; Yu *et al*., 2006). Thus far, in some places rigid ryegrass was known only to be resistant to glyphosate. The objective of this study was to determine whether the glyphosate resistant ryegrass biotype is also resistant to other herbicides which might be used for control of this species.

MATERIALS AND METHODS

Experiments were conducted in the greenhouse of Departmen of Crop and Soil Sciences, Michigan State University, East Lansing Michigan USA, from January to June 2008. Plants of R and S rigid ryegrass biotypes were grown individually in 950-ml pots containing commercial soil mix. They were maintained in the greenhouse at 25/20 ± 3 C day/night with supplemental sodium vapor light to provide 1,000 µmol $m^{-2}s^{-1}$ at midday to give 16-h day and 8-h night. The plants were sprayed in the vegetative stage, with glyphosate, rimsulfuron + thifensulfuron, glufosinate, quizalofop, and the combinations of glyphosate with rimsulfuron + thifensulfuron and with quizalofop . Each herbicide was applied POST at the label recommended rates (Table 1). Treatment solutions contained 2 to 3% w/v AMS and 1% v/v MSO as recommended on the label and sprayed at a volume of 187 L ha^{-1} and 172.5 kPa pressure using a flat-fan nozzle tip 8001E.

Figure 2A

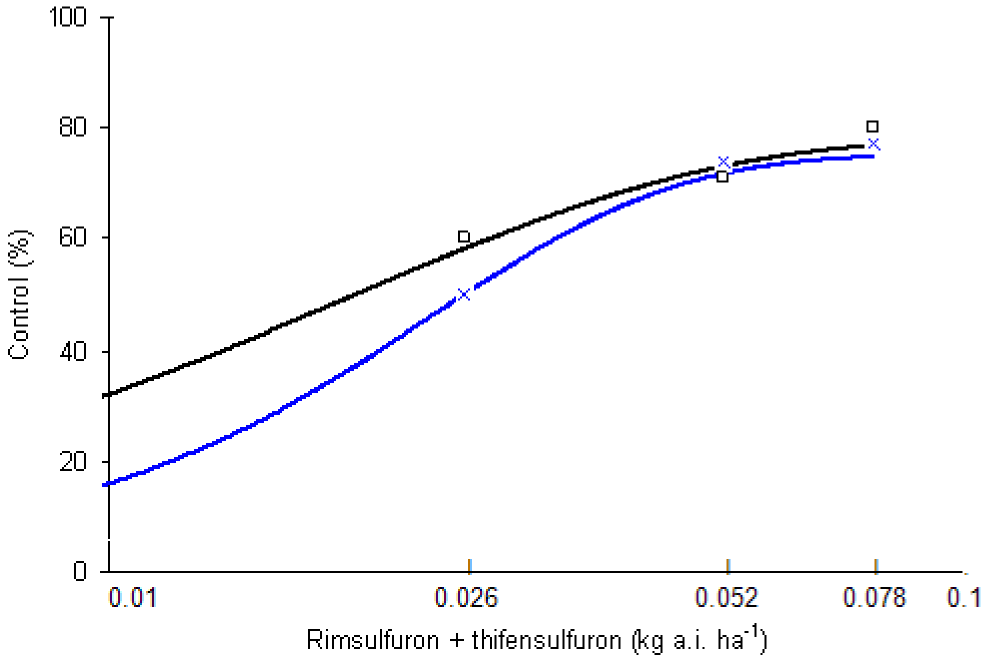

Figure 2B

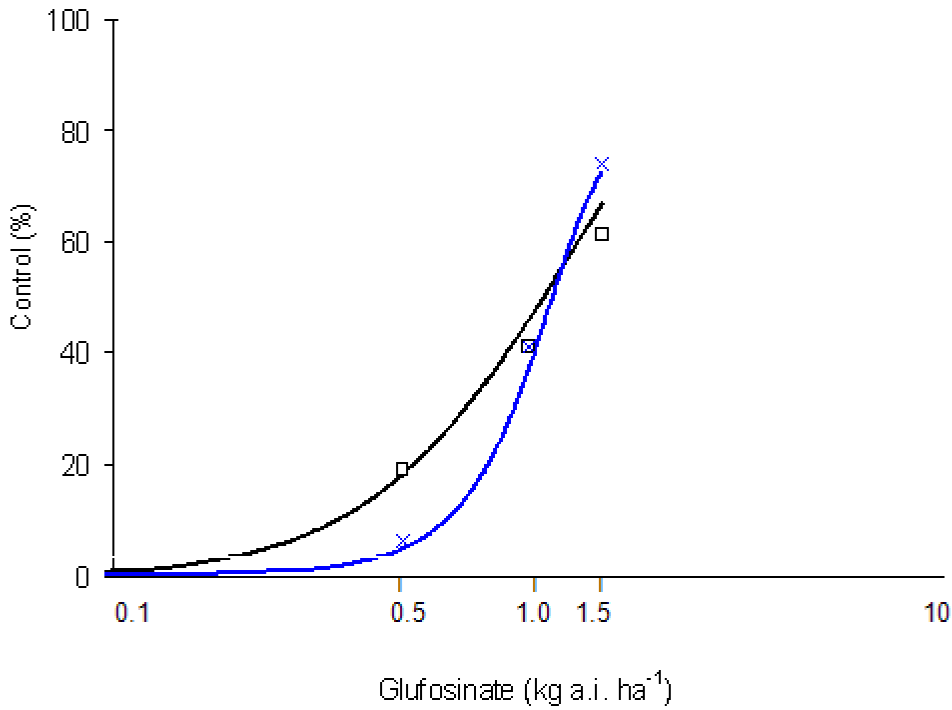

Figure 2A and B. Dose response curves for the control of sensitive (S = —j —) and resistant (R = —x —) biotypes of rigid ryegrass with rimsulfuron + thifensulfuron (2A) and with glufosinate (2B), symbols represent the means of duplicate experiments with four replications each and fitted lines are predicted log-logistic curves. Confidence intervals for the R and S biotypes respectively are 0,97 and 0,92 in curve (2A); and 0,83 and 0,87 in curve (2B).

Control of treated plants was assessed visually at 14 and 21 DAT with the rating scale 0 to 100 with no injury to death; respectively. The data from 21 DAT were subjected to ANOVA in SAS and separated with Fisher's Protected $LSD_{0.05}$. Data presented are the means of two experiments with four replications in each.

Due to poor control with the lowest recommended rate, rimsulfuron + thifensulfuron and glufosinate treatments were repeated in an additional study to determine the appropriate dose from dose response curves. Rimsulfuron + thifensulfuron was sprayed at 0; 0,026; 0,052, and 0,078; and glufosinate was sprayed 0, 0.5, 1.0, and 1,5 kg ai ha^{-1} (Table 1). Plant preparation, spraying mixtures, methods, and data assessment were similar to the experiment described previously. Dose-response curves of the two herbicide treatments for R and S biotypes were obtained with nonlinear regression using the following log-logistic equation (Seefeldt *et al.,* 1995):

$$y = C + \frac{D - C}{1 + [x/I_{50}]^{b}} \qquad [1]$$

where y = prediction of control, C = lower limit, D = upper limit, x = dose of herbicide, and I_{50} = dose of herbicide required to obtain 50% injury, and b is the slope around I_{50}.

RESULTS AND DISCUSSION

Rimsulfuron + thifensulfuron (pre-mixed) are sulfonylurea herbicides for POST control of grass species such as barnyardgrass, bluegrass, and foxtail (Anonymous, 1997; Kalnay and Glenn, 1997). Glufosinate is labeled for POST control a broad spectrum of annual and perennial grass and quizalofop, a member of aryloxyphenoxy propionate family, is labeled for POST control of annual and perennial grass weeds (Ahrens *et al.,* 1994).

At 21 DAT, control of the S biotype was 100, 100, 100, 98, 61 and 41 percent by glyphosate, glyphosate and rimsulfuron + thifensulfuron, glyphosate and quizalofop, quizalofop, rimsulfuron + thifensulfuron, and glufosinate; whereas for the R biotype it was 8, 80, 96, 100, 44 and 13 percent, respectively (Figure 1). Rimsulfuron + thifensulfuron and glufosinate did not provide good control of either the S or R biotype. However, at higher rates control was obtained (Figure 2). No indication of multiple resistances in the R biotype of rigid ryegrass from California was evident as S and R biotypes showed similar responses to the herbicide tested. This is in contrast to reports from Australia where multiple resistances to several herbicides with different mechanism have evolved (Anonymous, 2007; Neve *et al.,* 2004; Yu *et al.,* 2007).

Mixing glyphosate with quizalofop did not change the level of control of S and R biotypes. Even though rimsulfuron + thifensulfuron at the low rates provided poor control of both S and R biotypes, the combination with glyphosate was synergistic increasing the control of both biotypes (Figure 1). This synergistic mixture could prove beneficial in the control of the R biotypes of rigid ryegrass in California.

Dose response curves for control of the two biotypes with rimsulfuron + thifensulfuron and glufosinate are shown in Figure 2A and 2B. The rates evaluated stayed within the range of the recommendation label (Anonymous, 1997). Rimsulfuron + thifensulfuron and glufosinate appear effective for control of both biotypes at the maximum rates of recommendation. These experiments showed no indication of multiple herbicide resistance in rigid ryegrass from California with modes of action represented by the herbicide tested. Furthermore, synergism between rimsulfuron + thifensulfuron in combination with glyphosate was evident.

CONCLUSION

Multiple resistant to (rimsulfuron + thifensulfuron), glufosinate, and quizalofop was not indicated in the resistant biotypes of Rigid ryegrass

From the evaluated herbicides, quizalofop was provided an excellent control to both the resistant and sensitive biotypes

Combination of (Rimsulfuron + thifensulfuron) with glufosinate showed a very poor control (tolerance to the lowest rates from the ranges of recommended) both to the resistant and sensitive biotypes.

Combination of (Rimsulfuron + thifensulfuron) with glyphosate appeared to be synergist to increase the injury level on the resistant biotype up to 80 percent

REFERENCES

Ahrens, W. H. et al. eds. 1994. Herbicide Handbook 7th ed. Champaign, IL: Weed Science Society of America.

Anonymous. 1997. Basis® herbicide product label. Wilmington, DE: DuPont Co.

Anonymous. 2007. Herbicide resistant weeds: glycines (G/9) resistant weeds by species and country.*http://www.weed science.org.Accessed:* January 20, 2007

Baylis, A. D. 2000. Why glyphosate is a global herbicide: strength, weaknesses and prospects. Pest. Manag. Sci. 56:299-308.

Beckie, H. J. 2006. Herbicide resistant weeds: management tactics and practices. WeedTechnol. 20: 793-814.

Duncan, C. N. and S. C. Weller. 1987. Heritability of glyphosate susceptibility among biotypes of field bindweed. J. of Heredity 78:257-260.

Kalnay, P. A. and S. Glenn. 1997. Rimsulfuron/ thifensulfuron activity in no till corn. Page 32 *in* Proceeding of the 51st Meeting: Northeast Weed Science Society.

Neve, P., J. Sadler, and S. B. Powles. 2004. Multiple herbicide resistance in a glyphosate resistant rigid ryegrass (*Lolium rigidum*) population. Weed Sci. 52:920-928.

Powles, S. B., and C. Preston. 2006. Evolved glyphosate resistance in plants: biochemical and genetic basis of resistance. Weed Technol. 20:282-289.

Seefeldt, S. S., J. E. Jensen, and E. P. Fuerst. 1995. Log-logistic analysis of herbicide dose-response relationships. Weed Technol. 9:218–225.

Simarmata, M., J. E. Kaufmann, and D. Penner. 2001. Progress in determining the origin of the glyphosate-resistant ryegrass in California. Pages 95-96 in Abstract of the 51st Meeting. Greensboro, NC: Weed Science Society of America.

Simarmata, M., J. E. Kaufmann, and D. Penner. 2003. Potential basis of glyphosate resistance in California rigid ryegrass (*Lolium rigidum*). Weed Sci. 51:678-682.

Simarmata, M., S. Bughrara, and D. Penner. 2005. Inheritance of glyphosate resistance in rigid ryegrass (*Lolium rigidum*) from California. Weed sci. 53:615-619.

USDA. 2000. Federal Noxious Weed List. Animal and Plant Health Inspection Service (APHIS). *http:/www.usda.gov. Accessed*: November 19, 2006

Wakelin, A. M., and C. Preston. 2006. A target-site mutation is present in a glyphosate-resistant*Lolium rigidum* population. Weed Res. 46:432-440.

Yu, Q., A. Cairns, and S. Powles. 2006. Glyphosate, paraquat and ACCase multiple herbicide resistance evolved in a *Lolium rigidum* biotype. Planta 225:499-513.