Research reports

Response of glyphosate-resistant and susceptible biotypes of goosegrass (*Eleusine indica* (L.) Gaertn.) to fertilizer use

T.S. Chuah[A], S. Salmijah[B], Y.T. Teng[C] and B.S. Ismail[B]
[A] Faculty of Agrotechnology and Food Science, Kolej Universiti Sains dan Teknologi Malaysia, Mengabang, Telipot, 21030 Kuala Terengganu, Malaysia.
[B] School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia.
[C] Monsanto (M) Sdn Bhd., PO Box 144, 81707 Pasir Gudang, Johor, Malaysia.

Summary

Greenhouse studies were conducted to investigate responses of glyphosate-resistant (R) and susceptible (S) *Eleusine indica* biotypes to different combinations of inorganic fertilizers (NPK) and chicken manure on seedling emergence. Generally, the emergence of both R and S seedlings decreased as nitrogen (N) levels increased, regardless of the phosphorus (P) and/or potassium (K) levels. At high N rates (120 kg ha^{-1}), little or no emergence was observed for both biotypes. Chicken manure applied at 6000 kg ha^{-1} stimulated emergence of the R and S biotypes by approximately 60 and 270% of the control, respectively. The results of this study suggest that application of 6000 kg ha^{-1} chicken manure may increase seedling emergence of the R and S biotypes but urea at 120 kg ha^{-1} appears to limit the abundance of both biotypes. However, further field studies need to be undertaken at a range of sites to verify these findings.

Key words: Chicken manure, emergence, NPK, resistance, weed biotypes

Introduction

Eleusine indica (L.) Gaertn., a tufted annual grass, also known as goosegrass, is a common weed in vegetable farms, orchards, oil palm and rubber plantations as well as in wasteland and along the roadsides of Peninsular Malaysia (Holm *et al.* 1977). It was reported that *E. indica* could reduce yield in orchards and vegetables farms (Chee *et al.* 1990) due to its high tolerance to drought and high fecundity. A single plant can produce as many as 140,000 seeds (Chin and Raja 1979).

Soil fertility has been associated with variations in the abundance and growth of weeds. High application of urea has been shown to reduce *Striga asiatica* (witchgrass) infestations by inhibiting germination and radicle elongation (Mumera and Below 1993). However, Agenbag and de Villiers (1989) and Freyman *et al.* (1989) described positive effects of ammonium nitrate fertilizers on seedling emergence of *Avena fatua* L.

Phosphorus (P) was found to stimulate ground-cover development of weeds such as *Borreria latifolia* (Aubl.) Schum., *Digitaria horizonatalis* Willd. *Paspalum melanospermum* Desv. ex Poir. *Croton hirtus* L'Herit and *Mollugo verticillata* L. on sandy loam soil (Everaarts 1992). However, Raju *et al.* (1990) showed that P did not affect *Striga* seed germinability due to the inability of this element to interfere with the production and activity of the stimulating substance from the host plant.

Humphreys *et al.* (1999) reported that there was significant positive correlation between soil potassium (K) concentrations and abundance of *Rumex* spp. in pasture. Their study suggests that it is possible that maintenance of K at levels only up to 100 mg ha^{-1} may limit abundance of *Rumex* spp. in grasslands.

Chicken manure has been used as an important fertilizer in the cultivation of guava (*Annona muriacata* L.) and ciku (*Achras zapota* L.) in Bidor, Perak. It was found that seedlings of *E. indica* emerged following the application of chicken manure.

To date, there is no published information on the effects of nitrogen (N), phosphorous (P), potassium (K) and chicken manure on the glyphosate-resistant (R) and susceptible (S) biotypes of *E. indica*. This study was conducted to examine seedling emergence of the R and S biotypes under different NPK and chicken manure regimes. A better understanding of the differences in seedling emergence response of the R and S biotypes under various nutrient levels is very valuable for improving weed management of the R biotype. This paper is part of a series of studies on various aspects of biology of the R and S-biotypes of goosegrass (Ismail *et al.* 2002, 2003).

Materials and methods

Seed source

Seed collection procedures of the R and S-biotypes of *E. indica* seeds were carried out as reported previously (Ismail *et al.* 2002).

Screening for the R and S biotypes

Screening procedures for the R and S-biotypes of *E. indica* seeds were carried out as described previously (Ismail *et al.* 2002). The R and S-biotype seeds collected from the first generation were used in the subsequent studies.

Seedling emergence study

Seeds of the R and S biotypes of *E. indica* were scarified using sandpaper and twenty seeds were sown in each of the 12 cm diameter pots containing sterilized and washed sand on the soil surface The pots were placed in a greenhouse maintained at 29 ± 4°C and a 12 h photoperiod with light intensity of 800 µE m^{-2} sec^{-1}. Holes at the bottom of the pots were sealed with wax to prevent leaching of nutrients. Nitrogen was applied as solution (urea – 46% N) at rates equivalent to 0, 60 and 120 kg ha^{-1}, phosphorus (superphosphate – 46% P) as solution at 0, 75 and 150 kg ha^{-1} and potassium (muriate of potash – 60% K) as solution at 0 and 70 kg ha^{-1}. Chicken manure was applied as powder by mixing with soil at rates equivalent to 3000 and 6000 kg ha^{-1}. These fertilizers rates are the rates recommended for orchards and oil palm plantations. From the start of the experiment, the soil was kept at 90% field capacity and this watering regime was maintained for 11 weeks. Seedling emergence was noted weekly for 11 weeks. Seedlings were considered emerged if the shoots appeared on the soil surface. Seedlings that had emerged were counted and gently removed after each count. At the end of the experiment, the emerged seedlings were expressed as a percentage of the total number of viable seeds used in each replication. A preliminary study using the tetrazolium test had shown that both biotype seeds were 100% viable.

Statistical analysis

The greenhouse experiment was arranged as a 2 × 3 × 3 × 2 factorial in randomized complete block design with four replications. The experiment on chicken manure utilized a randomized block design with four replications. Data were transformed to the arcsine value before conducting analysis of variance and means were compared by the Tukey test at the 5% level.

Results and discussion

Table 1 shows the interaction effects of chicken manure on the R and S biotypes of *E. indica*. The percentage emergence of both biotypes treated with 3000 kg ha^{-1} chicken manure did not differ significantly from the control. However, when the application rate of chicken manure was increased to 6000 kg ha^{-1}, the percentage emergence of the R and S biotypes increased by approximately 60 and 270% respectively. This may be due to the presence of potassium nitrate in the manure. Chemical analysis in our laboratory revealed that nitrate and potassium concentration in samples of chicken manure reached as high as 75,000 and 430 ppm, respectively (Chuah 2004). Previous studies have shown positive effects of potassium nitrate on germination (Hawton and Drennan 1980) as well as on emergence (Egley 1986) of *E. indica*.

Table 2 shows interaction effects of nitrogen (N) and potassium (K) fertilizers on seedling emergence of the R and S biotypes of *E. indica*. Significant N × K interactions were evident for the percentage emergence of the R and S biotypes. In the presence of N only at 60 kg ha^{-1}, the emergence of the S biotype did not differ from the control while the R biotype exhibited decrease in percentage emergence, suggesting that the S biotype was more tolerant to N increment as compared to the R biotype. No change in percentage emergence was evident in either biotypes when 70 kg ha^{-1} K was applied alone (N_0K_1) as compared to the control. However, a study by Farina *et al.* (1985) showed that K at 150 kg ha^{-1} stimulated the emergence of *Striga asiatica* (L.) Kuntze.

The result of this study is contrary to previous results reported by Farina *et al.* (1985) because K at the rate of 70 kg ha^{-1} was probably not high enough to induce the percentage emergence of the R and S biotypes. It is also likely that responses of both the R and S biotypes towards K may differ from that of *S. asiatica*. However, when 60 kg ha^{-1} N (N_1K_1) was added, the percentage emergence of the S seedling increased. A previous study had shown that a moderate rate of N increased the uptake of K (Wilkinson *et al.* 2000). Hence, increase in the percentage emergence of the S biotype by four fold compared to the control may be due to the effect of K as a 'stimulant' as has been shown for *Rumex* spp. (Humphreys *et al.* 1999). This result is also in agreement with that of a previous report which demonstrated that K increased the abundance of *E. indica* in sandy loam soil (Everaarts 1992). However, there was no significant difference in the percentage emergence of the R biotype between the N_1K_1 level and the control. This suggests that the S biotype is more sensitive to K increment than the R biotype.

Table 1. Effects of chicken manure on seedling emergence of glyphosate-resistant (R) and susceptible (S) biotypes of goosegrass.

Chicken manure (kg ha^{-1})	Emergence (%)	
	R	S
0	39 b	15 a
3000	38 b	20 ab
6000	63 c	53 c

Means with the same letter are not significantly different at the 5% level by the Tukey test.

At a high rate of N (120 kg ha^{-1}) alone (N_2K_0), no emergence was observed for both biotypes. With a combination of 120 kg ha^{-1} N and 70 kg ha^{-1} K (N_2K_1), the S and R biotypes exhibited 5% and 0% emergence, respectively. An earlier study demonstrated that high availability of N inhibited the uptake of K (Wilkinson *et al.* 2000) and the emergence of *Striga* sp. (Pesch and Pieterse 1982). Therefore, low or no emergence observed at N_2K_1 for both biotypes may be due to inhibition of K uptake by N at very high concentration.

Table 3 shows the interaction effects of nitrogen (N) and phosphorus (P) fertilizers on seedling emergence of the R and S biotypes. The presence of 75 kg ha^{-1} P (N_0P_1) or 150 kg ha^{-1} P (N_0P_2) alone had no effect on the percentage emergence of the S biotype compared to the control. However, P at rates of 75 (N_0P_1) and 150 kg ha^{-1} (N_0P_2) inhibited the emergence of the R biotype when applied alone, suggesting that the S biotype was more tolerant to the inhibition effect of P compared to the R biotype.

In the presence of N at 70 kg ha^{-1} (N_1P_1 or N_1P_2), the percentage emergence of the S biotype was inhibited. It has been suggested that the uptake of P is often increased by the presence of N (Adam 1980, Sumner and Farina 1986). Hence, the decrease in the percentage emergence observed for the S biotype at N_1P_1 or N_1P_2 may be due to an increase in P uptake, thereby resulting in lower emergence compared to the control. The R biotype also exhibited lower emergence at N_1P_1 and N_1P_2 compared to the control. These results are expected because at 60 kg ha^{-1} N, 75 kg ha^{-1} P as well as 150 kg ha^{-1} P alone have been shown to inhibit the emergence of the R biotype.

The combination of 120 kg ha^{-1} N with 75 or 150 kg ha^{-1} P (N_2P_1 and N_2P_2), caused a decrease in percentage emergence of both biotypes as compared to the control. This is likely due to the inhibition effect of high N (120 kg ha^{-1}) as well as the increased uptake of P. However, the interaction between P and K on the emergence of both biotypes was not significant (P >0.05).

Table 2. Effects of interactions between nitrogen (N) and potassium (K) on seedling emergence of glyphosate-resistant (R) and susceptible (S) biotypes of goosegrass.

NK combination^A (kg ha^{-1})		Emergence (%)	
		R	S
Control		39 e	15 bed
N_0	K_1	23 cde	15 bed
N_1	K_0	10 bc	7 b
N_1	K_1	30 de	60 e
N_2	K_0	0 a	0 a
N_2	K_1	0 a	5 ab

^{A} N_0, N_1, N_2 is 0, 60 and 120 kg ha^{-1} respectively; K_0 and K_1 is 0 and 70 kg ha^{-1} respectively. For control, only deionized water is applied.
Means with the same letter are not significantly different at the 5% level by the Tukey test.

Table 3. Effects of interactions between nitrogen (N) and phosphorous (P) on seedling emergence of glyphosate-resistant (R) and susceptible (S) biotypes of goosegrass.

NP combination^A (kg ha^{-1})		Emergence (%)	
		R	S
Control		39 f	15 de
N_0	P_1	2 ab	7 cde
N_0	P_2	8 cde	10 de
N_1	P_0	10 cde	7 cde
N_1	P_1	3 abc	5 bc
N_1	P_2	5 bc	3 abc
N_2	P_0	0 a	0 a
N_2	P_1	0 a	0 a
N_2	P_2	0 a	2 ab

^{A} N_0, N_1, N_2 is 0, 60 and 120 kg ha^{-1} respectively; P_0, P_1, P_2 is 0, 75 and 150 kg ha^{-1} respectively. For control, only deionized water is applied.
Means with the same letter are not significantly different at the 5% level by the Tukey test

It can be stated that application of 6000 kg ha^{-1} chicken manure which contains high nitrate and potassium levels, may increase seedling emergence of the R and S biotypes. Chemical fertilizers such as urea at 120 kg ha^{-1} may play a role in limiting the abundance of both biotypes. Under laboratory and greenhouse conditions, it has been shown that the emergence of some weed species are promoted by nitrate (Bouwmeester *et al.* 1994, Hilhorst 1990) and potassium (Raju *et al.* 1990) but inhibited by urea (Mumera and Below 1993). However, greenhouse or laboratory results cannot be directly extrapolated to field conditions since the field responses to N and K fertilizers are likely to be influenced by other environmental factors, such as soil temperature (Robin 2000), soil moisture (Vincent and Caver 1978), types of NK fertilizers, timing of applications (Freyman *et al.* 1989) and rate of application (Hurtt and Taylorson 1986). Hence, further studies have to be undertaken in the field at a range of sites to verify the findings of this greenhouse experiment.

Acknowledgements
This project was funded by the research grant D/8/2000 from Monsanto (M) Sdn. Bhd. Thanks are also extended to Mr Teo Kee Chiong and Mr Fong Tick Seong for technical assistance.

References

Adam, F. (1980). Interactions of phosphorus with other elements in soils and in plants. *In* 'The role of phosphorus in agriculture', ed R.C. Dinauer, p. 655-80. (American Society of Agronomy, Madison).

Agenbag, G.A. and de Villiers, O.T. (1989). The effect of nitrogen fertilizers on the germination and seedling emergence of wild oat (*Avena fatua* L.) seed in different soil types. *Weed Research* 29, 239-45.

Chee, Y.K., Lee, S.A., Ahmad, A.I., Teo, L.C., Chung, G.F. and Khairuddin, H. (1990). Crop loss by weed in Malaysia. Proceedings of the 3rd Tropical Weed Science Conference, Kuala Lumpur, pp. 1-21.

Chin, H.F. and Raja, H. (1979). Ecology and physiology of *Eleusine indica* seed. Proceedings of the 7th Asia-Pacific Weed Science Conference, pp. 115-19.

Chuah, T.S. (2004). Biology and control of glyphosate-resistant and susceptible biotypes of *Eleusine indica* (L.) Gaertn. Ph.D. Thesis, Universiti Kebangsaan Malaysia, Bangi, Malaysia.

Bouwmeester, H.J., Derks, L., Keizer, J.J. and Karsen, C.M. (1994). Effects of endogenous nitrate content of *Sisymbrium officinale* seeds on germination and dormancy. *Acta Botanica Neerlandica* 43, 39-50.

Egley, G.H. (1986). Stimulation of weed seeds germination in soil. *Review of Weed Science* 2, 69-84.

Everaarts, A.P. (1992). Response of weed to application of nitrogen, phosphorus and potassium on low-fertility acid soils in Suriname. *Weed Research* 32, 385-90.

Farina, M.P.W., Thomas, P.E.L. and Channon, P. (1985). Nitrogen, phosphorus and potassium effect on incidence of *Striga asiatica* (L.) Kuntze in maize. *Weed Research* 25, 443-47.

Freyman, S., Kowalenko, C.G. and Hall, J.W. (1989). Effect of nitrogen, phosphorus and potassium on weed emergence and subsequent weed communities in south coastal British Columbia. *Canadian Journal of Plant Science* 69, 1001-10.

Hawton, D. and Drennan, D.S.H. (1980). Studies on longevity and germination of seed of *Eleusine indica* and *Crotalaria goreensis*. *Weed Research* 20, 217-23.

Hilhorst, H.W.M. (1990). Dose-response analysis of factors involved in germination and secondary of seeds of *Sisymbrium officinale*. II. Nitrate. *Plant Physiology* 94, 1096-102.

Holm, L.G., Plucknett, D.L., Pancho, J.V. and Herberger, J.P. (1977). 'The World's worst weeds: distribution and biology.' (The University Press of Hawaii, Honolulu).

Humphreys, J., Jansen, T., Culleton, N., Macnaeidhe, F.S. and Storey, T. (1999). Soil potassium application and *Rumex obtusifolius* and *Rumex crispus* abundance in silage and grazed grassland sward. *Weed Research* 39, 1-13.

Hurtt, W. and Taylorson, R.B. (1986). Chemical manipulations of weed emergence. *Weed Research* 26, 259-67.

Ismail, B.S., Chuah, T.S., Salmijah, S., Teng, Y.T and Schumacher, R.W. (2002). Germination and seedling emergence of the glyphosate-resistant and -susceptible biotype of goosegrass (*Eleusine indica* (L.) Gaertn.). *Weed Biology and Management* 2, 177-85.

Ismail, B.S., Chuah, T.S., Salmijah, S. and Teng, Y.T. (2003). Effects of shade and watering frequency on growth and development of glyphosate-resistant and susceptible biotypes of goosegrass (*Eleusine indica* (L.) Gaertn.). *Plant Protection Quarterly* 18, 30-4.

Mumera, L.M. and Below, F.E. (1993). Role of nitrogen in resistance to *Striga* parasitism in maize. *Crop Science* 33, 758-63.

Pesch, C. and Pieterse, A.H. (1982). Inhibition of germination in *Striga* by means of urea. *Experientia* 38, 559-60.

Raju, P.S., Osman, M.A., Soman, P. and Peacock, J.M. (1990). Effects of N, P and K on *Striga asiatica* (L.) Kuntze seed germination and infestation of sorghum. *Weed Research* 30, 139-44.

Robin, J.P. (2000). The role of temperature, in regulation of seed dormancy and germination. *In* 'Seed. The ecology of regeneration in plant communities', 2nd Edition, ed. M. Fenner, pp. 261-85 (CABI Publishing, New York).

Sumner, M.E. and Farina, M.P.W. (1986). Phosphorus interactions with other nutrients and lime in field cropping systems. *Advance Soil Science* 5, 201-36.

Wilkinson, S.R., Grunes, D.L. and Sumner, M.E. (2000). Nutrient interactions in soil and plant nutrition. *In*. 'Handbook of soil science.' ed M.E. Sumner, pp. D89-D107. (CRC Press, Boca Raton).

Vincent, E.M. and Caver, P.B. (1978). The effects of wetting and drying on the subsequent germination of *Rumex crispus* L. *Canadian Journal of Botany* 56, 2207-17.