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Influence of Ammonium Sulfate, Diesel Oil, and Surfactant on Glyphosate Activity in Purple Nutsedge

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ABTRACT

Effects of additives on ^{14}C-glyphosate penetration into purple nutsedge leaves and efficacy of glyphosate for purple nutsedge control were examined in 2 weeks old plants. It was found that the addition of $(NH_4)_2SO_4$ at 1.0 % (v/v) + diesel oil at 1.0 % (v/v) + Tendal at 1.0 % (v/v) increased ^{14}C-glyphosate penetration into nutsedge leaves more than the addition of either one. $(NH_4)_2SO_4$ at 1.0 % + diesel oil at 1.0 % + Tendal at 0.12 or 0.25 % increased phytotoxicity of glyphosate at 0.5 and 0.75 kg ae/ha on the weed, in the greenhouse. Additives did not enhance glyphosate activity by reducing number of nutsedge tubers.
Key words : ammonium sulfate, diesel oil, surfactant, glyphosate, absorption

INTRODUCTION

Purple nutsedge (*Cyperus rotundus* L.) was ranked as one of the most serious weeds in the world (Holm *et al*., 1977). It is an important weed in corn, sorghum, soybean, mungbean, peanut, cotton, upland rice, and vegetables (Holm *et al*., 1977). Mechanical control of this weed is not successful because they can sprout new shoots from tubers. Various selective preemergence herbicides can not control this weed.

Glyphosate is a nonselective, translocated, foliar absorbed herbicide (Weed Science Society of America, 1994). Glyphosate has been reported to control purple nutsedge (Suwunnamek and Parker, 1975). However, application of glyphosate for weed control is restricted by cost. Appropriate adjuvants or additives might be used in combination with glyphosate to maintain its optimum activity but the reduced rate. Because a given adjuvant or additive might increased foliar absorption of herbicides (Hatzios and Penner, 1985).

$(NH_4)_2SO_4$ has been reported to increase activity of glyphosate for purple nutsedge control (Suwunnamek and Parker, 1975). Furthermore, calcium antagonism of glyphosate has been overcome with $(NH_4)_2SO_4$ (Nalewaja and Matysiak, 1991; Thelen *et al*., 1995a) citric acid, and organosilicone adjuvants (Thelen *et al*., 1995b).

Various additives including nonionic surfactants (Coret and Chamel, 1993), the organosilicone Silgard 309 (Reddy and Singh, 1992), and both petroleum and seed oils (Gauvrit and Cabanne, 1993) were reported to increase glyphosate activity. Organosilicone Silwet 77 enhanced ^{14}C-glyphosate uptake into bean (*Vicia faba* L.) leaf (Zabkiewicz *et al*., 1993). Furthermore, oils also increased glyphosate penetration (Gauvrit and Cabanne, 1993).

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The objectives of these experiments were to determine the effects of the various additives, $(NH_4)_2SO_4$, Tendal (surfactant), and diesel oil at appropriate concentrations on ^{14}C-glyphosate penetration into purple nutsedge leaves, and to determine the effects of additives on glyphosate efficacy for purple nutsedge control.

MATERIALS AND METHODS

Laboratory experiment

^{14}C-glyphosate and glyphosate at 1.5 kg ae/ha with several additives in the spray volume of 200 liters/ha were applied when the purple nutsedge plants were 5-6 leaves (approximately 2 weeks after planting). Eight drops of 0.5 μCi ^{14}C-glyphosate were applied on the same leaf of each plant. Plants were harvested at 2 or 24 hours after application. Cellulose acetate (6.0 %) in 9:1 acetone/water was painted on the ^{14}C-glyphosate treated leaves. After 2 minutes the dried cellulose acetate was removed and mixed with 2 ml glacial acetic acid. Two hundred micro liters solution of cellulose acetate in glacial acetic acid was mixed with scintillation cocktail to determine the amount of ^{14}C-glyphosate by liquid scintillation spectometry.

The additive, Sunlite ® is a local detergent. The surfactant, Tendal ® is the blend of 60 % alkyl aryl polyethoxylate and sodium salt of dialkyl sulfosuccinate plus 40 % solubilizer and couplers. Triton X-100 ® is dioctyl sulfonosuccinate, sodium salt. Herbicide, glyphosate is 36% ae Roundup®.

Experiments were carried out in a Randomized Complete Block Design with 6 replications. The temperature and relative humidity during application of first, second, and third experiments were 32°C, 65 %; 30°C, 70 % and 28°C 80 %, respectively.

Greenhouse experiment

Three purple nutsedge tubers were planted in polyethylene pots containing clay soil. The pot size was 14 cm diameter and 15 cm height. Plants were watered from the surface every day. At 2 weeks after germination, glyphosate was applied alone and in combination with additives. Herbicide was applied by laboratory sprayer at the spray volume of 200 liters/ha and the pressure was 87 kg/cm^2. The nozzle was a Teejet, flat fan No 8001. During application the temperature was 28°C with 75 % relative humidity.

The number of nutsedge shoots and tubers in each pot were recorded at 21 and 60 days after application. The experiment was carried out in a Randomized Complete Block Design with 4 replications. Both laboratory and greenhouse experiments were conducted at Dept. of Agronomy, Kasetsart University, Bangkhen Campus.

RESULTS AND DISCUSSION

Laboratory experiment

At 2 hours after application there was increased penetration of ^{14}C-glyphosate with the treatments which included Tendal + diesel oil at rates of 0.5 % and above or Triton X-100 + diesel oil at 1 % (Table 1). The other treatments gave smaller increases in penetration.

The treatment which included glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 % + Tendal 1.0 % + diesel oil 1.0 % gave the greatest penetration of ^{14}C-glyphosate. A further experiment studied the effect of lower levels of diesel oil (Table 2) which showed that diesel oil at 0.25 % and 0.5 % reduced the penetration compared to diesel oil at 1 % and was no better than the treatment without oil.

At 24 hours after application, $(NH_4)_2SO_4$ 1 % + Triton X-100 2 % increased ^{14}C-glyphosate penetration into nutsedge leaves (Table 3). The addition of diesel oil at 1 % did not give any further improvement. The treatments with $(NH_4)_2SO_4$ alone, Triton X-100 with or without oil and Sunlite with $(NH_4)_2SO_4$ and/or diesel oil did not improve penetration into nutsedge leaves compared to the control.

The increased penetration of ^{14}C-glyphosate into nutsedge leaves when using $(NH_4)_2SO_4$ might be due to a change of the glyphosate molecule to a more readily absorbed form. Using NMR spectoscopy Thelen *et al*. (1995a) showed that NH_4^+ from $(NH_4)_2SO_4$ complexed directly with the glyphosate molecule through the phosphonate and carboxylate groups and resulted in a more readily absorbed form of glyphosate. They also found that a nonionic organosilicone adjuvant increased ^{14}C-glyphosate absorption into sunflower leaves (Thelen *et al*., 1995b). However, the organosilicone adjuvant did not directly interact

Table 1 Effects of various additives on ^{14}C-glyphosate penetration into purple nutsedge leaves at 2 hours after application.

Treatment	% absorption
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %	6.2 d[1/]
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 0.25 %	24.8 bcd
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 0.5 %	35.2 abc
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 1.0 %	26.5 bcd
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 2.0 %	26.7 bcd
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 4.0 %	29.9 bcd
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 0.25 %+diesel oil 0.25 %	15.5 cd
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 0.5 %+diesel oil 0.5 %	38.6 abc
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 1.0 %+diesel oil 1.0 %	58.0 a
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 2.0 %+diesel oil 2.0 %	39.6 abc
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Tendal 4.0 %+diesel oil 4.0 %	46.9 ab
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Triton X-100 1.0 %+diesel oil 1.0 %	47.4 ab

[1/] Means in the same column followed by the same letters are not significantly different at 5 % level by DMRT.

Table 2 Effects of $(NH_4)_2SO_4$, Tendal, and diesel oil on ^{14}C-glyphosate penetration into purple nutsedge leaves at 2 hours after application.

Treatment	% absorption
Glyphosate 1.5 kg ae/ha + $(NH_4)_2SO_4$ 1.0 %+Tendal 0.5 %	21.6 b
Glyphosate 1.5 kg ae/ha + $(NH_4)_2SO_4$ 1.0 %+Tendal 1.0 %	29.8 ab
Glyphosate 1.5 kg ae/ha + $(NH_4)_2SO_4$ 1.0 %+Tendal 1.0 %+diesel oil 0.25 %	19.5 b
Glyphosate 1.5 kg ae/ha + $(NH_4)_2SO_4$ 1.0 %+Tendal 1.0 %+diesel oil 0.5 %	25.7 b
Glyphosate 1.5 kg ae/ha + $(NH_4)_2SO_4$ 1.0 %+Tendal 1.0 %+diesel oil 1.0 %	42.4 a

[1/] Means in the same column followed by the same letters are not significantly different at 5 % level by DMRT.

Table 3 Effects of various additives on ^{14}C-glyphosate penetration into purple nutsedge leaves at 24 hours after application.

Treatment	% absorption
Glyphosate 1.5 kg ae/ha	63.8 bc[1/]
Glyphosate 1.5 kg ae/ha + $(NH_4)_2SO_4$ 1.0 %	68.2 ab
Glyphosate 1.5 kg ae/ha + Triton X-100 2.0 %	66.2 b
Glyphosate 1.5 kg ae/ha + $(NH_4)_2SO_4$ 1.0 %+Triton X-100 2.0 %	78.2 a
Glyphosate 1.5 kg ae/ha + Triton X-100 2.0 % + diesel oil 1.0 %	66.3 b
Glyphosate 1.5 kg ae/ha + $(NH_4)_2SO_4$ 1.0 %+Triton X-100 2.0 %+diesel oil 1.0 %	72.7 ab
Glyphosate 1.5 kg ae/ha + $(NH_4)_2SO_4$ 1.0 %+Sunlite 4.0 %	63.7 bc
Glyphosate 1.5 kg ae/ha + Sunlite 4.0 %+diesel oil 1.0 %	54.5 c
Glyphosate 1.5 kg ae/ha $(NH_4)_2SO_4$ 1.0 %+Sunlite 4.0 %+diesel oil 1.0 %	65.9 b

[1/] Means in the same column followed by the same letters are not significantly different at 5 % level by DMRT.

with glyphosate (Thelen *et al.*, 1995b). The organosilicone adjuvants might alter the physical properties of the spray solution or the leaf cuticle to the point where ^{14}C-glyphosate could directly penetrate the leaf.

Oils have seldom been tested with water soluble herbicides, although glyphosate efficacy against wheat was increased by both petroleum and seed oil (Gauvrit and Cabanne, 1993). The main action of adjuvant oils was increasing herbicide penetration but the mechanisms involved were poorly understood (Gauvrit and Cabanne, 1993).

Greenhouse experiment

At 7 days after application, $(NH_4)_2SO_4$ at 1.0 % + oil +Tendal at 0.12 % or 0.25 % increased nutsedge control of glyphosate at 0.75 kg ae/ha (Table 4). However, additives did not increase activity of glyphosate at higher rate (Table 4).

At 14 days after application, $(NH_4)_2SO_4$ at 1.0 % + oil at 1.0 % + Tendal at 0.12 % or 0.25 % increased activity of glyphosate at 0.5 and 0.75 kg ae/ha (Table 4). However, at 21 days after application, the additives increased activity of glyphosate only at 0.5 kg ae/ha (Table 4).

The additives increased glyphosate phytotoxicity on nutsedge plants by burning down the leaves, but dry weight and number of tubers were not affected (Table 5). The synergism of herbicidal activity by selected additives appeared to be the result of either an enhanced penetration and translocation or a reduce biotransformation of a given herbicide (Hatzios and Penner, 1985). In this case, the laboratory results indicated that additives increased glyphosate penetration into nutsedge leaves (Table 1, 2 and 3) but they might not increased the herbicide translocation downward to the tubers. Unfortunately, the amout of ^{14}C-glyphosate in the tubers of the weed did not measure to determine its translocation or transformation.

CONCLUSION

The addition of $(NH_4)_2SO_4$ at 1.0 % + oil at 1.0 % + Tendal at 1.0 % increased ^{14}C-glyphosate penetration into nutsedge leaves more than the addition of either one.

The addition of $(NH_4)_2SO_4$ at 1.0 % + oil at 1.0 % + Tendal at 0.12 or 0.25 or 1.0 % increased phytotoxicity of glyphosate at 0.5 and 0.75 kg

Table 4 Purple nutsedge control with glyphosate in combination with various additives under greenhouse condition.

Glyphosate (kg ae/ha)	$(NH_4)_2SO_4$ (% v/v)	Diesel oil (% v/v)	Tendal (% v/v)	Days after application[1/]			
				4	7	14	21
0.5	-	-	-	18 d[2/]	45 e	59 c	81 b
0.75	-	-	-	23 bcd	43 e	69 bc	83 a
1.5	-	-	-	28 a-d	65 abc	98 a	100 a
0.5	1	1	0.12	20 cd	45 e	89 a	93 ab
0.75	1	1	0.12	28 a-d	63 a-d	90 a	95 ab
1.5	1	1	0.12	35 ab	75 a	100 a	100 a
0.5	1	1	0.25	25 a-d	53 cde	83 ab	90 ab
0.75	1	1	0.25	30 abc	68 abc	95 a	100 a
1.5	1	1	0.25	33 abc	73 ab	99 a	100 a
0.5	1	1	1	23 bcd	58 b-c	79 ab	93 ab
0.75	1	1	1	25 a-d	48 d-e	82 ab	90 ab
1.5	1	1	1	38 a	73 ab	91 a	91 ab
Nontreated	-	-	-	0 e	0 f	0 d	0 c

[1/] % Weed Control; 0 = no control, 100 = complete control.
[2/] Means in the same column followed by the same letters are not significantly different at 5 % level by DMRT.

Table 5 Effect of glyphosate in combination with various additives on dry weight and number of purple nutsedge tubers under greenhouse condition.

Glyphosate (kg ae/ha)	$(NH_4)_2SO_4$ (% v/v)	Diesel oil (% v/v)	Tendal (% v/v)	Dry weight[1/] (g/pot)	Number[2/] of tubers/pot
0.5	-	-	-	0.43 b[2/]	6 b
0.75	-	-	-	0.64 b	8 b
1.5	-	-	-	0.79 b	4 b
0.5	1	1	0.12	0.31 b	7 b
0.75	1	1	0.12	0.39 b	5 b
1.5	1	1	0.12	0.44 b	3 b
0.5	1	1	0.25	0.31 b	5 b
0.75	1	1	0.25	0.53 b	6 b
1.5	1	1	0.25	0.43 b	4 b
0.5	1	1	1	0.64 b	4 b
0.75	1	1	1	0.45 b	6 b
1.5	1	1	1	0.34 b	4 b
Nontreated	-	-	-	4.31 a	23 a

[1/] A 21 days after application.
[2/] At 60 days after application.
[3/] Means in the same column followed by the same letters are not significantly different at 5 % level by DMRT.

ae/ha 7 and 14 days after application in the greenhouse. Additives in combination with glyphosate did not reduce number of nutsedge tubers compared with glyphosate alone.

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