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Influence of Surfactants and Ammonium Sulfate on the Efficacy of Glyphosate

M. Singh, Shiv D. Sharma and Samar Singh[1]
Department of Horticultural Sciences
University of Florida/IFAS, Citrus Research and Education Center
700 Experiment Station Road, Lake Alfred, FL 33850

ABSTRACT

A study was conducted to examine the effect of ammonium sulfate (AMS) applied with and without surfactants (Induce, Silwet L-77 and Methylated seed oil) on the efficacy of glyphosate. Herbicide treatments were applied to broadleaf weeds–Brazil pusley (*Richardia brasiliensis*), Spanish needles (*Bidens pilosa*), Florida beggarweed (*Desmodium tortuosum*) and Pigweed (*Amaranthus retroflexus*) and grassy weeds–Guineagrass (*Panicum maximum*), Johnsongrass (*Sorghum halepense*) and Crowfoot grass (*Dactyloctenium aegyptium*). The per cent control of both weed types was significantly higher with the application of AMS or the surfactant individually, or the surfactant plus AMS to glyphosate at 370 g/ha over no surfactant or AMS. Per cent control of grass weeds was 100 with the addition of any one of the surfactant except with glyphosate+L-77, where per cent control of Guinea grass and Johnson grass was only 82 and 85, respectively, two weeks after treatment (WAT). Per cent control of Brazil pusley and Spanish needles with glyphosate at 370 g/ha was low (20-38) 1 WAT. Addition of AMS improved efficacy of glyphosate in Brazil pusley 1 and 2 WAT. This effect, however, could not be observed 3 WAT. Effect of addition of AMS was apparent in Spanish needles and Florida beggarweed 2 WAT. Glyphosate alone, however, provided 93-100% control of Spanish needles, Florida beggarweed and pigweed 3 WAT. Per cent control of grassy weeds was complete 2 WAT with glyphosate at 370 g/ha with or without surfactants except with L-77 where it showed antagonistic effect.

Key words : Glyphosate, surfactant, ammonium sulfate, efficacy, grassy and broadleaf weeds

INTRODUCTION

Glyphosate herbicide is the largest-selling single crop-protection chemical product in the market today. Initially, this non-selective systemic post-emergence herbicide was targeted at the non-cropped agricultural land and for industrial applications. Since the introduction of minimum- and no-tillage agricultural practices, glyphosate is now in use in a number of crops and can now be directly applied to genetically modified crops which are tolerant to this herbicide (Woodburn, 2000). In the United States alone, glyphosate was applied to 68% of soybean [*Glycine max* (L.) Merr.] area in 2001 (CAST, 2002). Chemical weed control remains the most economic method of weed management in citrus and reduction in the price of glyphosate has increased its usages. However, it provides a short duration control, and therefore, multiple applications are required to obtain effective year round control (Singh, 2000). Glyphosate is a weak acid herbicide and its maximum efficacy depends on the inclusion of effective adjuvants in spray solution (Penner and Michael, 2002; Penner *et al*., 2005). Dahl *et al*. (2006) reported that methylated seed oil plus ammonium sulfate (AMS) provided the greatest control for glyphosate tolerant corn. AMS enhanced burn down control of ryegrass when applied with glyphosate at 0.75 kg/ha, especially with Roundup Weather Max®. Increase in the rate of glyphosate from 0.75 to 1.125 kg/ha enhanced control better than addition of AMS to glyphosate (Martin, 2004).

Nitrogen fertilizers have also been frequently added to the spray solution as an surfactant to increase herbicide activity (Curran *et al*., 1999). Ammonium salts (NH_4^+) appear to be the active component of these fertilizer solutions and have improved the performance consistently on some weeds. Nitrogen fertilizers are usually added in addition to surfactant or crop oil concentrate with systemic products (Curran *et al*., 1999). The addition of 2% (w/w) AMS to glyphosate enhanced control of some species by as much as by 40% (Peterson and Thompson, 2007).

[1]CCSHAU RRS Uchani, Karnal (Haryana), India.

Addition of AMS is being promoted to reduce potential antagonism of glyphosate with hard water or antagonism with other pesticides. The objective of this study was to examine the effect of AMS on different surfactant types in improving glyphosate efficacy. The weed species examined under the study included broadleaf weeds–Brazil pusley (*Richardia brasiliensis*), Spanish needles (*Bidens pilosa*), Florida beggarweed (*Desmodium tortuosum*) and Pigweed (*Amaranthus retroflexus*), and grassy weeds–Guineagrass (*Panicum maximum*), Johnsongrass (*Sorghum halepense*) and Crowfoot grass (*Dactyloctenium aegyptium*).

MATERIALS AND METHODS

The experiment was conducted at the University of Florida, Citrus Research and Education Center, Lake Alfred, USA. The experiment was conducted under controlled greenhouse conditions with day/night temperatures of 25/16°C (±0.5°C) and 70% (±5%) relative humidity. The greenhouse was unshaded and maximum photo synthetically active radiation was 1200 µmol/m^2/s at mid-day. Spanish needles, Florida beggarweed and pigweed seeds were directly sown in 10 x 15 cm plastic pots. Brazil pusley seedlings were uprooted from the field and transplanted into 10 x 15 cm plastic pots. Guinea grass, Johnson grass and Crowfoot grass seeds were sown in 72 hole plastic trays in potting medium on March 2, 2007 and for repeat study, on March 16, 2007. All plastic pots/trays were fertilized with a 20-20-20 N-P-K fertilizer two weeks after sowing and before treatment to have optimum growth of the plants. Three to four seedlings were left in each plastic pot. Herbicide treatments were applied at four fully expanded leaf stages.

Glyphosate as Credit® (isopropylamine salt) (4.0 lb/gal) at 0.370 and 0.680 kg/ha was applied and tank mixed with surfactants Induce at 0.5% v/v, Silwet L-77 at 0.1% v/v and MSO at 1.0% v/v separately (Table 1). These treatments were also tank mixed with AMS at 2% w/v separately. The treatment solutions were prepared immediately before use and were applied using a Chamber Track Sprayer. The sprayer was fitted with a Teejet 8003 flat fan spray nozzles delivering 190 l/ha at 22 psi pressure. After spraying, the plastic pots/trays containing plants were returned to the green house and were watered daily to avoid water stress. Visual observations on phytotoxic effect of glyphosate on the treated plants were observed as per cent control weekly until three weeks of treatment (WAT). A scale of 0 to 100% was used; 0 indicating no damage and 100 indicating complete damage as approved by the Weed Science Society of America (Frans *et al*., 1986).

The study was conducted in complete randomized block design and individual weed species were analyzed. A low rate of glyphosate was used to accentuate any difference of surfactants or AMS or surfactant+AMS. The per cent data were arcsine-transformed before analysis to stabilize the variance. The study was repeated and the data of the two repeated studies were combined after performing a test of homogeneity of variance. As transformation of data did not alter the data interpretation, the untransformed original per cent data were used in the analysis. The means were separated at 5% level of significance by Duncan's multiple range test.

Table 1. List and sources of surfactants used in the study

Adjuvant	Category and source
Induce	Non-ionic surfactant (Helena Chemicals, Memphis)
Silwet L-77	Organosilicone surfactant (Loveland Industries, Colorado)
Methylated seed oil (MSO)	Methylated vegetable seed oil+emulsifiers (Loveland Industries, Colorado)
Ammonium sulfate (AMS)	Fisher Scientific, Philadelphia

RESULTS AND DISCUSSION

Visual per cent control 1 WAT showed inconsistent effects of the treatments on the tested weeds species (Tables 2 and 3). AMS improved the efficacy of glyphosate in Brazil pusley at 1 WAT. The per cent control data recorded at 2 WAT indicated that the phytotoxic symptoms were more consistent. In general, overall per cent control of broadleaf (Table 2) was lesser than the per cent control of grasses (Table 3). Application of glyphosate at 370 g/ha achieved 27% control of Brazil pusley, 66% of Spanish needles, 78% of Florida

Table 2. Effect of different surfactant systems with ammonium sulfate on the efficacy of glyphosate applied to broadleaf weeds

Treatments	Rate (g/ha)	Visual control of weeds (%)											
		Brazil pusley (*Richardia brasiliensis*)			Spanish needles (*Bidens pilosa*)			Florida beggar weed (*Desmodium tortuosum*)			Pigweed (*Amaranthus retroflexus*)		
		1 WAT	2 WAT	3 WAT	1 WAT	2 WAT	3 WAT	1 WAT	2 WAT	3 WAT	1 WAT	2 WAT	3 WAT
Control		00j*	00h*	00f*	00d	00e	00e	00c	00d	00b	00d	00b	00b
Glyphosate	370	20i	27g	00f	38.3abc	66d	93ab	77b	78c	100a	78a	100a	100a
Glyphosate	680	65cd	83bc	88a	48a	88a	95ab	90a	100a	100a	80a	100a	100a
Glyphosate+AMS**	370 + 2%	73b	88ab	78b	45ab	80abc	100a	78b	87c	100a	77a	100a	100a
Glyphosate+Induce	370 + 0.5%	32h	45ef	7f	43abc	77c	85c	77b	85c	100a	38c	100a	100a
Glyphosate+Induce+AMS	370 + 0.5% + 2%	68c	90a	55c	40abc	82abc	90bc	78b	88bc	100a	40c	100a	100a
Glyphosate+L-77	370 + 0.1%	37fg	48e	30e	32c	78c	85c	82b	86bc	100a	72a	100a	100a
Glyphosate+L-77+AMS	370 + 0.1% + 2%	40f	59d	75b	32c	80abc	93ab	82b	90b	100a	72a	100a	100a
Glyphosate+MSO	370 + 1%	48e	52e	00f	33c	78c	95ab	80b	85bc	100a	80a	100a	100a
Glyphosate+MSO+AMS	370 + 1% + 2%	83a	92a	47d	35bc	83abc	95ab	82b	88b	100a	60b	100a	100a

*Data points followed by the same letter within the columns were not significant.

**AMS–Ammonium sulfate, Induce–Non-ionic surfactant, L-77–Organosilicone surfactant, MSO–Emulsified methylated seed oil.

Table 3. Effect of different surfactant systems with ammonium sulfate on the efficacy of glyphosate applied to grassy weeds

Treatments	Rate (g/ha)	Visual control of weeds (%)								
		Guineagrass (*Panicum maximum*)			Johnsongrass (*Sorghum halepense*)			Crowfoot grass (*Dactyloctenium aegyptium*)		
		1 WAT	2 WAT	3 WAT	1 WAT	2 WAT	3 WAT	1 WAT	2 WAT	3 WAT
Control		00d*	00c*	00b*	00e	00c	00b	00g	00c	00b
Glyphosate	370	53ab	100a	100a	47bc	100a	100a	28d	100a	100a
Glyphosate	680	55a	100a	100a	43cd	100a	100a	38b	100a	100a
Glyphosate+AMS**	370 + 2%	43c	100a	100a	52b	100a	100a	30cd	100a	100a
Glyphosate+Induce	370 + 0.5%	42c	100a	100a	42cd	100a	100a	27de	100a	100a
Glyphosate+Induce+AMS	370 + 0.5% + 2%	57a	100a	100a	52b	100a	100a	22f	100a	100a
Glyphosate+L-77	370 + 0.1%	55a	82b	100a	62a	85b	100a	33c	100a	100a
Glyphosate+L-77+AMS	370 + 0.1% + 2%	40c	100a	100a	38d	100a	100a	23ef	100a	100a
Glyphosate+MSO	370 + 1%	47bc	100a	100a	62a	100a	100a	52a	100a	100a
Glyphosate+MSO+AMS	370 + 1% + 2%	52ab	100a		60a	100a	100a	48a	100a	100a

*Data points followed by the same letter within the columns were not significant.
**AMS–Ammonium sulfate, Induce–Non-ionic surfactant, L-77–Organosilicone surfactant, MSO–Emulsified methylated seed oil.

beggarweed, 100% of pigweed and grassy weeds 2 WAT. There was a significant increase in per cent control of both types of weeds with the incorporation of AMS or surfactant or surfactant plus AMS to 370 g/ha glyphosate. The per cent control of broadleaf weed achieved with glyphosate incorporated with AMS or surfactant or surfactant plus AMS was parallel to glyphosate applied alone at 680 g/ha. Addition of AMS to glyphosate+either surfactant further increased the per cent control of broadleaf weeds (Table 2). While in the case of grass weeds addition of either surfactant achieved 100% control except with glyphosate+L-77 where per cent control of Guinea grass and Johnson grass was only 82 and 85%, respectively (Table 3). Several workers also reported that the addition of AMS has been shown to improve the efficacy of glyphosate (Turner and Loader, 1975; O'Sullivan *et al*., 1981; Wills and McWhorter, 1985; Donald, 1988; Salisbury *et al*., 1991; de Ruiter and Meinen, 1996; Singh and Singh, 2005). Ammonium sulfate added to glyphosate+surfactant combinations reduced the ED_{50} for glyphosate 5-fold (de Ruiter *et al*., 1996).

When the data were recorded at 3 WAT (Table 2), interestingly, Brazil pusley started to recover from the phytotoxic effects in some of the treatments shown at 1 and 2 WAT. Observations in several field experiments indicated that Brazil pusley plants were hard-to-control with glyphosate. Similar effects of glyphosate treatments with and without surfactants were found in this study on the growth of Brazil pusley. When glyphosate was applied at 0.680 kg/ha, per cent control of Brazil pusley was 88% 3 WAT. Per cent control of Brazil pusley was significantly reduced at 3 WAT compared to 2 WAT with glyphosate+surfactant, and glyphosate+surfactant+AMS except glyphosate + L-77 + AMS (Table 2). Brazil pusley plants indicated significant recovery at this stage. In contrast, percent control of spanish needles increased with time and was highest at 3 WAT. Complete control of Florida beggarweed and pigweed was achieved under all the treatments in the study at 3 WAT.

All the grass weeds achieved complete control under all the treatments applied in the study (Table 3). Salisbury *et al*. (1991) found that AMS enhanced the initial control of Johnson grass by glyphosate. Singh and Sharma (2001) found that glyphosate with L-77 or Kinetic showed some antagonistic effect on barnyardgrass. In this study, addition of AMS showed its beneficial effect over the adjuvants. Maschhoff *et al*. (2000) reported that addition of AMS at 20 g/l increased the efficacy of glufosinate on *Echinochloa crus-galli, Setaria faberi* and *Abutilon theophrasti,* but not on *Amaranthus rudis* or *Chenopodium album.* Penner *et al*. (2005) reported that a water conditioning surfactant such as diammonium sulfate was commonly recommended for glyphosate application in hard water. This is especially necessary for applications to velvetleaf, which has calcium-rich leaves. It is possible that there was some antagonism of AMS with salts present on the leaf surface of Brazil pusley. Otherwise inclusion of AMS helped in improving the per cent control to glyphosate or glyphosate+surfactant.

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