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Comparison of Nitrogen Fertilizers, Induce and Zinc Addition on Glyphosate Efficacy on Three Different Weed Species.

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ABSTRACT

Herbicides are often tank-mixed with fertilizers to save time, labour, energy, and equipment costs. However addition of some additives with glyphosate may result in reducing glyphosate efficacy. Therefore we evaluated the potential of three nitrogen sources (ammonium sulphate (AMS) at 2 or 4% w/v, ammonium nitrate (AN) at 1 or 2% w/v, urea at 1 or 2 % w/v), nonionic adjuvant (Induce at 0.05% v/v) and Zn at 250 g Zn/ha (1321 ppm) to enhance glyphosate efficacy on pig weed (*Amaranthus retroflexus* L.), crowfoot grass (*Dactyloctenium egyptium* L.) and yellow nutsedge (*Cyperus esculentus* L.) under greenhouse conditions. The results indicated that there were variations in susceptibility of the three weeds to glyphosate+adjuvant treatments. Addition of AN at 2% reduced the efficacy of glyphosate on crowfoot grass. There was an antagonistic effect between glyphosate herbicide and Zn; the phytotoxic effect of glyphosate on the three weeds was less than 50 %. Zinc tank-mixed with glyphosate resulted in a greater number of tubers and shoots per plant than the untreatedol. Addition of AN or urea at 2% reduced glyphosate efficacy by about 2.3 and 9 %, respectively, relative to their addition at 1%. Tankmixes of urea (1%), AN (1%), AMS (2%) and Induce adjuvant (0.05%) generally enhanced the efficacy of glyphosate (0.85 kg/ha), whereas the addition of Zn, as zinc sulphate, to glyphosate sprays adversely affected herbicide efficacy.

INTRODUCTION

Glyphosate is a non-selective, systematic, a broad-spectrum, that is registered in over 50 crops and is used widely to control annual and perennial grasses, sedges, broad-leaved weeds and woody plants [1,2,3]. However glyphosate, the most widely used herbicide in agriculture, has a strong tendency to sorb on minerals by bonding with surface metals through its metal-coordinating functional groups. In addition, reducing costs and environmental concerns encourage researchers and growers to reduce herbicides use by using reduced herbicide rates. Several studies have been conducted to evaluate reduced herbicide rate applications using mixtures of some additives with glyphosate herbicide to increase its efficacy and acceptable weed control have been attempted [4]. Many adjuvants increase the efficacy of foliar-applied herbicides. Urea, ammonium nitrate and ammonium sulphate are primarily using as a foliar-applied nitrogen fertilizers. Several studies have indicated that nitrogen compounds can increase the efficacy of some POST herbicides [5, 6]. Adjuvants, particularly ammonium sulfate, have been shown to enhance glyphosate activity [2, 7, 8]. Enhancement in some cases may be substantial, as in the control of quackgrass, where ammonium sulfate at 7.5 g/L decreased the ED 50 for glyphosate fivefold [7]. Wills and McWhorter [9] further reported that the monovalent cations NH_4^+ and K^+ in combination with anions including NO_3^-, Cl^-, and CO_3^{2-} increased the phytotoxicity of glyphosate. Urea has been used as a source of foliar N due to its unique properties such as rapid absorption, low phytotoxicity and high solubility in both oil and water [10]. In addition, urea can enhance the absorption of foliar-applied chemicals such as herbicides, growth regulators and plant nutrients [10,11].The enhancement of herbicide efficacy by addition of AMS varies among weed species, with velvetleaf being one of the most responsive species [12]. Common lambsquarters typically has not shown a significant response to the addition of AMS with herbicides [12]. Zinc (Zn) is a divalent essential mineral nutrient and a cofactor of > 300 enzymes and proteins involved in cell division, nucleic acid metabolism, and protein synthesis in plant tissues [13]. Furthermore, Zn is required for the biosynthesis of tryptophan, a precursor of the auxin indole-3-acetic acid (IAA) [14]. Zinc deficiency symptoms develop in many agricultural and horticultural settings and generally occur when susceptible genotypes are grown in calcareous soils where Zn availability is limited and must be added as foliar spray [15]. Therefore most growers needed to added Zn nutrients to the economic plants and sometimes make a mixture between Zn nutrient and herbicides. However, some mixtures of additives with glyphosate may result in antagonism between the additives and glyphosate, reducing herbicide efficacy [8, 16]. Jordan *et al.* [17] stated that enhanced control or activity of glyphosate by addition of ammonium sulfate is not always realized. However, the efficacy of glyphosate has been observed to be affected when mixed with nutrient solutions containing ammonium, magnesium (Mg), manganese (Mn), iron (Fe), and Zn [16, 18]. Cationic micronutrients in spray solutions reduce the herbicidal effectiveness of glyphosate for weed control. Foliar fertilization uses low rates, and the micronutrient does not directly contact the soil, which avoids losses through fixation [19]. The appearance of micronutrients deficiency symptoms frequently coincides with time of POST herbicide applications. Producers have tank-mixed herbicides and fertilizers to save time, labor, energy, and equipment costs [16]. Foliar Zn nutrient has been applied at rates of 300 to 4,000 ppmw [19, 20]. Recent reports indicate that Mn, applied as a foliar fertilizer in tank-mixtures with glyphosate, has the potential to antagonize glyphosate efficacy and reduce weed control [16, 21]. It was hypothesized that Mn complexes with glyphosate in a manner similar to Ca forming salts that were not readily absorbed and thereby reducing glyphosate efficacy. Yellow nutsedge, crowfoot grass and pigweed are C_4 weeds and among the most troublesome weeds in many cropping systems [22]. Yellow nutsedge and crow foot grass are distribution in 92 and 45 countries, and associated with 52 and 19 crops [22, 23]. The objectives of this study were to study the efficacy control of glyphosate in tank mixtures with urea, ammonium nitrate and ammonium sulphate at two levels of each, Zn nutrient and induce on pigweed, crowfoot grass and yellow nutsedge weeds.

MATERIALS AND METHODS

Pig weed (*Amaranthus retroflexus* L.), crowfoot grass (*Dactyloctenium egyptium* L.) and yellow nutsedge (*Cyperus esculentus* L.) were treated with glyphosate alone or plus additives after 28 days from sowing weeds, in order to examine the effect of some additives on glyphosate efficacy control. The weeds planted in plastic trays in a greenhouse. Each tray had a total of 72 round planting pits. Each of the three weed species was planted in 12 pits of a tray using a commercial potting medium (Metro-Mix 500, contains Canadian sphagnum peat moss, horticultural vermiculite, processed bark ash, composed pine bark and washed sand) (Grace Sierra Company, USA). The plants were watered and fertilized with Tracite Foliar fertilizer containing $20N-20P_2O_5-20K_2O$ as required to promote optimum growth). The test weeds were grown to the four- to five-leaf stage, and the experiments were conducted when the weeds reached 15- 20, 8-10 and 13-18 cm height for crowfoot grass, pigweed and yellow nutsedge, respectively.

Glyphosate was applied at 0.850 and 1700 kg ai/ha with a bench-type sprayer equipped with an 80015LP tip calibrated to deliver 189 L/ha at 138 kPa. The source of three nitrogen fertilizer was Fisher Scientific, Philadelphia, USA. Ammonium sulphate (AMS), ammonium nitrate (AN) and urea were added to glyphosate at 1.0 or 2.0% (wt/solution spray volume). While nonionic surfactant (induce) was applied at 0.05% (v/v) and zinc at (1321*ppm*) 0.250kg/ha. Source of Zn nutrient was zinc sulphate ($ZnSO_4$) containing 21 % Zn. The treatments included glyphosate at 0.850 and 1.700 kg/ha alone, glyphosate at 0.850 kg/ha with ammonium sulphate (AMS) at 2 or 4% (w/v), glyphosate at 0.850 kg/ha with ammonium nitrate (AN) or urea at 1or 2% (w/v), glyphosate at 0.850 kg/ha with Zn at 0.250 kg/ha, glyphosate at 0.850 kg/ha with induce 0.05%, glyphosate at 1.70 kg/ha with urea at 1 or 2% and untreated check. Trays containing plants were watered before the application of spray, and no water was applied for the next 24 h. Thereafter, water was applied regularly to maintain adequate moisture for the plants.

Upon the results of these experiments, the impact of Zn addition at different concentrations on glyphosate efficacy was examined in a separate experiment (Table 2 and Figs. 1, 3 and 4).

Visual injury ratings of redroot pigweed, crowfoot grass and yellow nutsedge control were recorded weekly up to 4 wk after treatment (WAT) on a scale of 0 (actively growing plants) to 100% (complete plant death) as approved by the Weed Science Society of America [24]. For nutsedge weed, at 4 and 6 WAT in the

1st and 2nd experment, respectively, plants were uprooted from each pot. Shoots were separated, and tubers were washed. Tuber number was recorded. At the same time, dry biomass of above-ground vegetation, dry weight of tubers and total dry weight per plant were determined after drying for 4 days at 60 C. A completely randomized design was employed with four replications.

The experiments were repeated and each weed species analyzed separately. Experiments were designed in a randomized complete block with four replications and repeated. The data were subjected to ANOVA after performing an arc-sine transformation using Pesticide Research Manager Software (Gylling Data ManagementInc, 405 Martin Blvd. Brookings, SD 57006), analysis of variance and mean separations were performed after the percent control data were normalized by arcsine square root conversion but original percent values are presented in the tables for easier interpretation. The data were combined for greater homogeneity. Means of the treatments were separated by Duncan's Multiple Range Test at $p \leq 0.05$ level.

RESULTS AND DISCUSSION

Effect of urea, ammonium sulphate (AMS) and ammonium nitrate (AN) on glyphosate efficiency

Data in Table (1) revealed that pigweed was sensitive to glyphosate followed by crowfoot grass while yellow nutsedge came in the last order. Glyphosate application alone provided less than 80% yellow nutsedge control. Similar finding was reported with Fischer and Harvey [25] in that single glyphosate applications at 0.84 kg ae/ha provided less than 75% yellow nutsedge control. Pig weed, crowfoot grass and yellow nutsedge control increase 5 to 20% with addition of one of the three nitrogen forms, but the increment level was varied according to the weed, N form and its concentration. Nearly the three N forms addition resulted in 90% or greater control of yellow nutsedge 4WAT. Franz *et al*.[2] demonstrated that ammonium sulphate, ammonium nitrate and urea has been claimed to increase the herbicidal activities of glyphosate.

Table 1: Visual control evaluations of pigweed, crowfoot grass and yellow nutsedge as affected by glyphosate with some additives at 1- 4 weeks after treatment (WAT)[a].

Treatments		Efficacy (%)[b]								
		Pigweed			Crowfoot grass			Yellow nutsedge		
		2 WAT	3 WAT	4 WAT	2 WAT	3 WAT	4 WAT	2 WAT	3 WAT	4 WAT
Glyphosate (kg/ha)	Adjuvant									
0.85		80b	87b	97a	80d	87b	94a	25bc	72c	79b
0.85	AMS (2%)	96a	100a	100a	90a-d	100a	100a	40ab	86b	95a
0.85	AMS (4%)	95a	100a	100a	90a-d	99a	100a	30ab	88ab	96a
0.85	Urea (1%)	84b	100a	100a	84cd	95a	100a	40b	85b	94a
0.85	Urea (2%)	84b	100a	100a	86bcd	93ab	98a	30bc	79b	85b
0.85	AN (1%)	98a	100a	100a	93abc	100a	100a	38b	84bc	95a
0.85	AN (2%)	93a	95a	98a	81d	91ab	97a	47a	83bc	93ab
0.85	Zn (0.25 kg-ha)	50c	50c	45b	30d	41c	40b	15d	17d	10c
0.85	Induce (0.05%v/v)	96a	100a	100a	90ab	100a	100a	48a	85bc	94ab
1.700		98a	100a	100a	95ab	100c	100a	46 a	98a	98a
1.700	Urea (1%)	100a	100a	100a	99a	100c	100a	50a	100a	100a
1.700	Urea (2%)	100a	100a	100a	94abc	100c	100a	55a	100a	100a

[a] Abbreviations: Gly. Glyphosate; AMS, ammonium sulfate; AN: ammonium nitrate; Zn, zinc.
[b] Means followed by the same letter within a column are not significantly different at P 5 0.05 according to Duncan's Multiple Range Test.

Tank-mix of AMS provided the greatest increase in weed control when added to the lower (0.850 kg/ha) glyphosate rate (Table 1), followed by urea and AN. Glyphosate at 0.850 kg/ha plus urea provided greater control of nutsedge than glyphosate at 0.850 kg/ha without urea; however, glyphosate at 1.7 kg/ha plus urea at 1 or 2% did not provide greater control of yellow nutsedge than glyphosate at 0.84 kg/ha without urea. At the same rating times, pigweed and crowfoot grass control was 95% or greater for high rate of glyphosate (1.7 kg/ha) alone or with urea and tank-mix containing glyphosate with urea, AMS and at 1, 2 and 2% (w/v), respectively. Increasing glyphosate rate from 0.850 to 1.7 kg/ha or addition of nitrogen to glyphosate at low rate tank-mix resulted in shorten the time requirement for complete control or speed the efficacy beside increased the control level. No significant difference in glyphosate control efficacy on weeds was noticed with increasing the urea levels in tank- mixture; however addition of urea increased the glyphosate efficacy. Similar finding was reported [26].

Tankmixed AMS improved glyphosate efficacy control of the three weeds when pooled over the other N sources, induce or Zn, however, in most cases there is no significant differences between N forms as well as between induce and N forms. When glyphosate at 0.85 kg/ha was mixed with AN it is control efficacy on pigweed, crowfoot grass and yellow nutsedge was increased by 3, 6 and 16 % than glyphosate alone, respectively. While increasing urea level to 2%w/v in glyphosate (0.850 kg/ha) tankmix resulted in decreasing the control efficacy on yellow nutsedge by 9 (from 94 to 85%), however with glyphosate at 1.70 kg/ha, insignificant difference was recorded. Tarlok *et al.* [27] found that the mixing of 3%urea with glyphosate at 1kg/ha did not increase its efficacy on cotton weeds over its alone application.

Using glyphosate at 1.7 kg/ha tankmixed with or without urea gave more than 98% control of the three tested weeds within 2 weeks (Table 1). Similar finding was noticed [28].

The enhancement of glyphosate efficacy with addition of AN, AMS and urea in tankmix was recorded [6, 29]. These enhancements may due to that urea, AMS and AN can decrease the surface tension and increase leaf adhesion of spray droplet [7] and increasing absorption and translocation of glyphosate in the plant [29].

Effect of Induce on glyphosate efficiency

More or less, tank mixed induce with glyphosate gave similar effect of the three nitrogen forms (Table 1). When induce was tank-mixed with glyphosate at 0850 kg/ha, yellow nutsedge control averaged for 4 WAT was increased from 79% (glyphosate alone) to 94%, respectively. Complete control of pigweed and crowfoot grass was achieved with induce tankmixed with glyphosate at 4WAT. Similar finding was reported [30].

Effect of Zn on Glyphosate Efficiency

Glyphosate alone at 0.850 kg/ha provided 78 and 90% control of yellow nutsedge at 3 and 5 WAT, respectively (Table 2 and Fig.1). Mixing glyphosate at 0.850 kg/ha with Zn at 500 ppmw antagonized glyphosate efficacy. An abrupt decrease in glyphosate efficacy was observed between 500 and 1,000 ppmw Zn (Table 2 and Fig.1). In addition, Zn concentration in the spray solution completely eliminated glyphosate phytotoxicity on yellow nutsedge 6 WAT at 1,000 ppmw, 3 WAT at 2,000 ppmw, and 4 WAT at 4,000 ppmw (Table 2).

Table 2: Effect of glyphosate–Zn tank-mixes yellow nutsedge control at 2, 4 and 6 WAT, number and dry weight of tubers and whole yellow nutsedge plant at 6 wk after treatments.[a,b]

Treatments			Efficacy (%)[c]					
Glyphosate rate (kg/ha)	Adjuvant	Adjuvant concentration (ppmw)	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT
0.850	-	-	0d	22 ec	78b	87 b	90b	95 b
0.850	AMS	2%	45b	98 a	98a	100 a	100a	100 a
0.850	Zn	500	0d	37 c	48d	77 c	80c	80 c
0.850	Zn	1000	0d	37 c	24c	16 e	8e	0 d
0.850	Zn	2000	0d	20 e	0g	0 f	0f	0 d
0.850	Zn	4000	0d	27 d	15f	0 f	0f	0 d
1.700	Zn	8000	30c	53 c	72c	63 d	47d	35d
2.550	Zn	8000	70a	85 b	100a	100 a	100a	100 a

[a] Abouziena *et al.* (2009).
[b] Abbreviations: AMS, ammonium sulfate; WAT, weeks after treatment; Zn, zinc.
[c]Means followed by the same letter within a column are not significantly different at P 5 0.05 according to Duncan's Multiple Range Test.

Figure 1: The visual injury of yellow nutsedge as affected by the interaction effect between glyphosate and zinc [Treatments: 1, Gly.850 g a.e/ha; 2,Gly.850/ha +AMS; 3, Gly.850/ha +500ppmZn; 4, Gly.850/ha +1000ppmZn ;, 5 Gly.850/ha +2000ppmZn, and 6, Gly.850g/ha+ 4000 ppm Zn resp.; 7,Gly.1700 g/ha+8000ppm Zn; 8,Gly.2550 +8000ppm Zn ; 9, control (unsprayed plant); Gly., glyphosate].

These results indicate that the using zinc sulphate as additive with herbicide glyphosate in mixture may alter glyphosate activity and reduce its control efficacy. Zn in form of zinc sulphate, when used as an additive, may adversely affect the effectiveness of glyphosate. Similar finding was reported [31].

Yellow nutsedge growth

Tubers are an effective means of reproduction and spread for both purple and yellow nutsedges [22]. Because tubers play an important role in the propagation of these weeds, best control could be achieved by reducing density of viable tubers, thus resulting in long-term control of these weeds [31].

The effect of glyphosate alone and tankmixed with additives on the yellow nutsedge growth was evaluated in terms of the number and dry weight of tubers/plants and total dry weight/plant (Figs 2, 3 and 4). The number and dry weight of tubers/plants were significantly reduced by 36 and 90%, respectively, when glyphosate tankmixed with urea at 2%. Similar finding was reported [26]. The least tuber number/plant was recorded with the application of glyphosate at 1.7 kg/ha with or without urea, while the highest number was noticed with glyphosate tankmixed with Zn and untreated plant (Fig. 2). The higher tuber number recorded with glyphosate tankmixed with Zn may be due to antagonistic of Zn on glyphosate efficacy as mentioned [32].

Glyphosate application at 0.850 kg/ha reduced dry weight of tubers per plant by 74% and of whole plants by 72%, compared with nontreated plants (Fig. 2). Similar finding was reported [31]. Mixing glyphosate at 0.850 kg/ha with Zn at 500 ppmw antagonized glyphosate toxicity and decreased phytotoxicity for most yellow nutsedge growth parameters, compared with glyphosate alone. Zn at 1,000, 2,000, and 4,000 ppmw in the glyphosate solution eliminated the effect of glyphosate on produced plants with more shoots and tubers per plant than those of control (nontreated) plants (Figs. 3 &4). Plants treated with 0.850 kg/ha glyphosate tank-mixed with 2,000 ppmw Zn had 25 shoots and 11 tubers/plant compared with 1 shoot and 1 tuber/plant for those treated with glyphosate alone and 5 shoots and 7 tubers/plant for nontreated plants. A gradual increase in dry weight of shoots, tubers, and whole plants was observed by increasing Zn from 500 to 2,000 ppmw (Figs. 3 and 4). Application of Zn at 2,000 ppmw was the most antagonistic, completely eliminating biomass reductions with glyphosate. Additionally, Zn at 2,000 ppmw resulted in increased dry weight of shoots and whole plants by 27 and 22%, respectively, compared with nontreated plants.

Tankmixed Zn at 4,000 ppmw with 0.850 kg/ha glyphosate in the spray solution produced plants with 21-fold more shoot dry weight, threefold more tuber dry weight, and 11-fold more whole plant dry weight compared with the glyphosate alone treatment.

Mixing 1.700 kg/ha glyphosate with 8,000 ppmw Zn resulted in increments of dry weight of shoots and whole plants, but had no effect on the number and dry weight of tubers, when compared with glyphosate alone (Figs. 3 & 4). Tank-mixed of zinc with glyphosate resulted in a greater number of tillers per plant than the control. Similar finding was reported with Eker *et al.* [33] who reported that cationic micronutrients in spray solutions reduce the herbicidal effectiveness of glyphosate for weed control due to

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the formation of metal-glyphosate complexes.

Figure 2: Number of Tubers/plant (left), dry weight of tubers and whole plant (right) of yellow nutsedge as affected by glyphosate and additives (G. glyphosate at 0.85 kg/ha, G1: glyphosate at 1.700 kg/ha, AMS: Ammonium sulphate, AN: ammonium nitrate, Zn: zinc,). Columns with the same letters are not statistically different at *P* = 0.05.SD=2.7

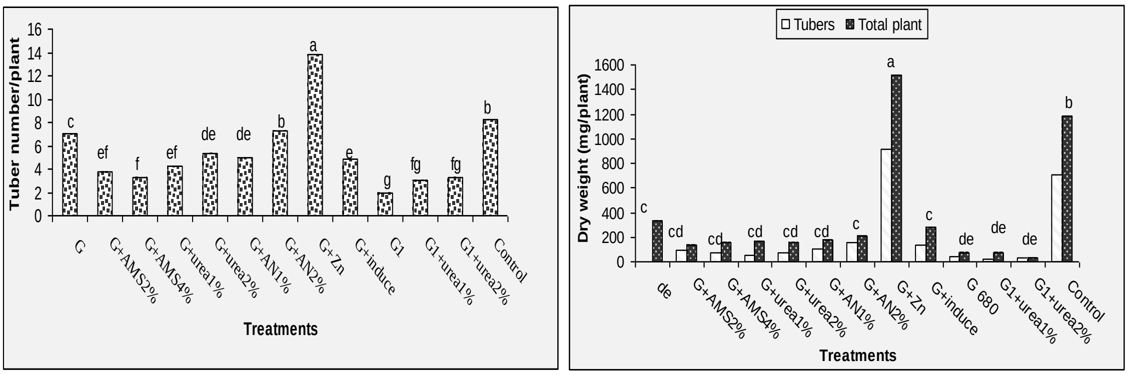


Figure 3. Tuber number of yellow nutsedge at six weeks after treatments as affected by additives (G. glyphosate at 0.85 kg/ha, G1: glyphosate at 1.700 kg/ha, Zn: zinc, AMS: Ammonium sulphate). Columns with the same letters are not statistically different at *P* = 0.05.

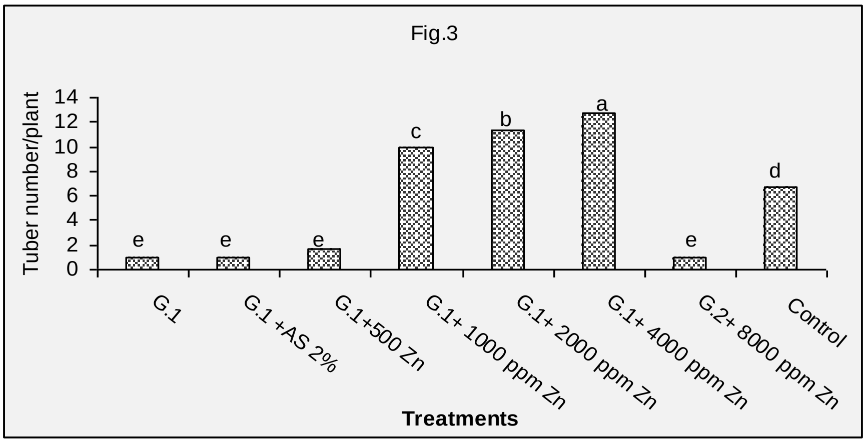
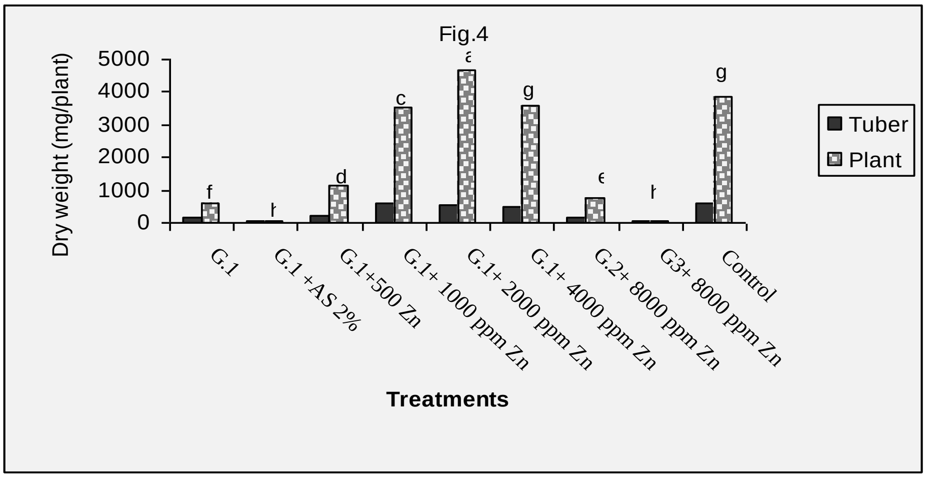


Figure 4. Tuber dry weight of yellow nutsedge at six weeks after treatments as affected by additives (G. glyphosate at 0.85 kg/ha, G1: glyphosate at 1.700 kg/ha, Zn: zinc, AMS: Ammonium sulphate). Columns with the same letters are not statistically different at *P* = 0.05.



CONCLUSION

Tankmixed glyphosate at 0.85 kg/ha with urea at 1% (w/v), ammonium nitrate at 1% (w/v), ammonium sulphate at 2% (w/v) and induce at 0.05% (v/v) generally increased glyphosate efficacy control, while Zn in form of zinc sulphate, when used as additive; adversely affect the effectiveness of glyphosate.

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REFERENCES

1. Duke SO. Glyphosate. In: Kearney PC, Kaufman DD (eds), Herbicides*:* Chemistry*,* Degradation, and Mode of Action. 1988; New York: Marcel Dekker. Pp. 1–70.
2. Franz JE, Mao MK, Sikorski JA. Glyphosate: A Unique Global Herbicide (Acs Monograph). An American Chemical Society Publication (October 7, 1998).
3. Abouziena HF, Hafez OM, El-Metwally IM, Sharma SD, Singh M. Comparison of weed suppression and mandarin fruit yield and quality obtained with organic mulches, synthetic mulches, cultivation, and glyphosate. HortScience 2008; 43(3):795–799.
4. Singh D, Singh M. Absorption and translocation of glyphosate with conventional and organosilicone adjuvants. J of Weed Biology & Manag. 2008; 8:104-111.
5. Sanders JC, Monks DC, Patterson MG, Delaney DP, Moore DP, Wells LW. Effectiveness of ammonium thiosulfate to enhance weed control and reduce cotton (*Gossypium hirsutum*) injury. Weed Techn. 2001; 15(2)236-241.
6. Tao B, Zhou J, Messersmith CG, Nalewaja JD. Efficacy of glyphosate plus bentazon or quizalofop on glyphosate-resistant canola or corn. Weed Techn. 2007; 21:97-101.
7. de Ruiter H, Uffing AJM, Meinen E, Prins A. (Influence of surfactants and plant species on leaf retention of spray solutions. Weed Sci. 1990; 38:567-572.
8. Abouziena HF, Elmergawi RA, Sharma S, Omar AA, Singh M. Zinc antagonizes glyphosate efficacy on yellow nutsedge (*Cyperus esculentus*). Weed Sci. 2009; 57:16–20.
9. Wills GD, McWhorter CG. Effect of inorganic salts on the toxicity and translocation of glyphosate and MSMA in purple nutsedge (*Cyperus rotundus*). Weed Sci.1985; 33:755–761.
10. Bondada BR, Petracek PD, Syversten JP, Albrigo LG. Cuticular penetration characteristics of urea in citrus leaves. J Hortic Sci & Techn. 2006; 81(2):219–224.
11. Bowman DC, Paul KL. Foliar absorption of urea, ammonium, and nitrate by perennial ryegrass turf. J of the Am Soc for Hortic Sci. 1992; 117: 75–79.
12. Maschhoff, JR, SE Hart, JL Balwin. Effect of ammonium sulfate on the efficacy, absorption and translocation of glufosinate. Weed Sci. 2000; 48: 2–6.
13. Marschner H. Functions of mineral nutrients: macronutrients. In: Mineral Nutrition of Higher Plants, Academic Press, Orlando, FL. 1986; pp: 195-267.
14. Oosterhuis, D, Hake K, Burmester C. Foliar feeding cotton. Cotton Physiol Today 1991; 2: 1- 7 (Cotton Council of America). Ames.
15. Jolley, VD, Hansen NC, Shiffler AK. XII Inter. Sym. on Iron Nutrition and Interactions in Plants, Tokyo, Japan, 11-15 April 2004 (ed. Mori, S.). Soil Sci and Plant Nutrition 2004; 50 (7) 973-981.
16. Bernards ML, Thelen KD, Penner D. Glyphosate efficacy is antagonized by manganese. Weed Techn. 2005; 19:27–34
17. Jordan DL, York AC, Griffin JL, Clay PC, Vidrine PR, Reynolds DB. Influence of application variables on efficacy of glyphosate. Weed Techn. 1997; 11:354–362.
18. Glass RL. Metal complex formation by glyphosate. J of Agric and Food Chem. 1984; 32: 1249–1253.
19. Teixeira, IR, Borem A, Araujo DGA, Fontes RLF. Manganese and zinc leaf application on common bean grown on a ''Cerrado''. Soil Sci Agric. 2004; 61:77–81.
20. El-Khawaga AS. Reduction in fruit cracking in manfaluty pomegranate following a foliar application with paclobutrazol and zinc sulphate. J Applied Sci Res. 2007; 3:837–840.
21. Thomas WE, Pline-Srnic WA, Viator RP, Wilcut JW. Effects of glyphosate application timing and rate on Sicklepod (*Senna obtusifolia*) fecundity. Weed Techn. 2005; 19:55–61.
22. Holm LG, Plucknett DL, Pancho JV, Herberger JP. The World's Worst Weeds, Distribution and Biology. Honolulu: Honolulu University Press 1977; 609 p.
23. Holm LG, Plucknett DL, Pancho JV, Herberger JP. The World's Worst Weeds. Distribution and Biology. Honolulu, HI: Univ of Hawaii Press. 1991; Pp.125–133.
24. Frans R, Talbert R, Marx D (1986) Experimental design and techniques for measuring and

analyzing plant responses to weed control practices. In Camper ND (ed), Research Methods in Weed Science, Champaign, IL, USA. Pp. 9-46.
25. Fischer DW and Harvey RG. Yellow nutsedge (*Cyperus esculentus*) and annual weed control in glyphosate-resistant field corn (*Zea mays*). Weed Techn. 2002; 16:482–487.
26. Paslawar AN, Chauke RP, Zade VR. Studies on the use of weedicides in Nagpur mandarin. Indian J of Citriculture 2002; I (1):66-71.
27. Tarlok S, Bhatia RK, Singh S, Mehra SP. Bio-efficacy of glyfosinate ammonium for weed control in American cotton. Indian J of Weed Sci. 2004; 36:306-307.
28. Molin WT, Hirase K. Comparison of commercial glyphosate formulations for control of prickly sida, purple nutsedge, morningglory and sicklepod. Weed Biology and Manag. 2004; 4:136 –141.
29. Belles D, Shaner D, Westra P, Brunk G. Comparison of efficacy, absorption and translocation of three glyphosate formulations on velvetleaf (*Abutilon theophrasti*). Pest Manag Sci. 2006: 62:1177–1181.
30. Sharma SD, Singh M. Effect of two surfactant series on absorption and translocation of 14C-glyphosate in sicklepod and prickly sida. J of Weed Biology & Manag. 2007; 7:219-225.
31. Akin DS, Shaw DR. Purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) control in glyphosate tolerant soybean (*Glycine max*). Weed Techn. 2001; 15(3)564–570
32. Nalewaja JD, Matysiak R. Salt antagonism of glyphosate. Weed Sci. 1991; 39:622–628.
33. Eker S, Ozturk L, Yazici A, Erenoglu B, Romheld V, Cakmak I. Foliar-applied glyphosate substantially reduced uptake and transport of iron and manganese in sunflower (*Helianthus annuus* L.) plants. J of Agric and Food Chem. 2006; 54 (26):10019-10025.