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Effect of Adjuvants on Trifloxysulfuron Efficacy and Chlorophyll Fluorescence of Sicklepod, Guineagrass, Yellow Nutsedge and Cotton

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ABSTRACT

Trifloxysulfuron (CGA-362622) at 2.5, 5 and 10 g a. i./ha mixed with non-ionic (0.25% Induce and X-77), organosilicone (0.1% Kinetic and Silwet L-77) and crop oil concentrate (1.0 % Agridex and Meth-N-Oil) adjuvants was evaluated for bioefficacy, surface tension, contact angle and chlorophyll fluorescence responses in guineagrass (*Panicum maximum* L.), sicklepod (*Senna obtusifolia* L.), yellow nutsedge (*Cyperus esculentus* L.) and cotton (*Gossypium hirsutum* L.). The lowest surface tension and contact angle were recorded with L-77 mixed with trifloxysulfuron. Among the six adjuvants, surface tension and contact angle were highest with Meth-N-Oil; however, these differences did not greatly influence herbicide efficacy. Decreasing or increasing the adjuvant concentrations from 1X to 0.5 or 4X with 10 g/ha trifloxysulfuron had only 2 to 4% variations in surface tension and contact angle compared to recommended rates (X) when data were averaged over adjuvants and concentrations. Adjuvants had no antagonistic effects for trifloxysulfuron activity on any weed species. Phytotoxicity symptoms of trifloxysulfuron on cotton disappeared after two weeks, but plant height and fresh weight were reduced 3 WAT compared to control plants. Reduction in plant height or fresh weight of cotton was similar for different adjuvants mixed with trifloxysulfuron. Guineagrass was less affected by trifloxysulfuron plus adjuvants than yellow nutsedge or sicklepod. Kinetic mixed with trifloxysulfuron was more effective in reducing plant height and fresh weight of guineagrass compared to other adjuvants; however, activities were comparable when data averaged over species and rates for different adjuvants. Chlorophyll fluorescence was reduced in all the species after herbicide application, but the reduction was not consistent with application rates, species and duration of 1, 4, 7 and 14 days after treatment (DAT). Reduction in chlorophyll fluorescence in treated plants of cotton was less than weeds, but followed no particular trend with herbicide rates or adjuvant interaction. Visual mortality of 17, 53 and 36% at 2 WAT in guineagrass, sicklepod and yellow nutsedge, respectively, was not visible in similar reduction in chlorophyll fluorescence, when data were averaged over treatments. Chlorophyll fluorescence may not be an ideal tool to predict herbicidal efficacy of trifloxysulfuron in the test species.

INTRODUCTION

Trifloxysulfuron with the common name of Envoke (CGA-362622) N-[(4,6-dimethoxy-2-pyrimidinyl) carbomyl]-3-(2,2,2-trifluoroethoxy)-pyridin-2-sulfonamide sodium salt is an acetolactate synthase (ALS) inhibitor and a member of the sulfonylurea herbicide family that has been successfully evaluated for weed control in cotton (*Gossypium hirsutum* L.), sugarcane (*Saccharum officinarium* L.) and citrus [*Citrus sinensis* (L.) Osbeck.] (Rawls *et al*. 2000; Porterfield *et al*., 2002a, b; Porterfield and Wilcut 2003; Singh and Singh, 2004a). Trifloxysulfuron has also been evaluated for weed control in other crops, and warm season turf grasses (Lovelace *et al*., 2001; Wells *et al*., 2001; Barber *et al*., 2002; Fisher *et al*., 2002). Trifloxysulfuron is a low use rate herbicide with low mammalian toxicity and favourable environmental properties. Herbicide efficacy is greater on younger plants; growth stage of weed species significantly affects trifloxysulfuron uptake, translocation and weed mortality (Askew and Wilcut, 2002; Singh and Singh 2004b).

Tank mixing of a non-ionic surfactant greatly influenced the weed control efficacy of trifloxysulfuron (Singh and Singh 2004b). Adjuvants are already included in the formulations of some herbicides, whereas others need to be added to the tank prior to use for increased efficacy. Adjuvants are used to enhance herbicide efficacy to increase rainfastness, lower surface tension, increase herbicide penetration by adequate spray cover of plant surfaces, and improve delivery to target site (Roggenbuck *et al*., 1990; Reddy and Singh 1992; Bariuan *et al*., 1999; Kirkwood, 1999; Penner, 2000). Adjuvants help to reduce the application rates of herbicides by a quarter without compromising weed control efficacy (Malik and Singh, 1993). This not only

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lowers the environmental loading of herbicides, but also makes herbicides more economical to farmers. A non-ionic surfactant (NIS) or crop oil concentrate (COC) is generally recommended for use with ALS inhibiting herbicides (Richardson *et al*., 2004), but adjuvants differ greatly in efficacy enhancement of ALS herbicides (Woznica *et al*., 1997). An antagonistic effect of Silwet L-77 was observed on glyphosate uptake and resultant herbicidal efficacy (Gaskin and Stevens, 1993; Sharma and Singh, 2000). Specificity of adjuvants for distinct target weed species and herbicides has also been observed (Roggenbuck *et al*., 1990; Sun *et al*., 1996; Jordan, 1996; Jordan and Burns, 1997; Sharma and Singh, 2000; Strahan *et al*., 2000). Richardson *et al*. (2004) reported the effect of some adjuvants on cotton with post application of trifloxysulfuron, but no work has been reported on the efficacy of trifloxysulfuron on weed species with adjuvants that differ in their modes of action.

Surfactants can influence several biological activities in weed species when mixed with herbicides alongwith reduced surface tension (Ernst and Arditti, 1980; Imai *et al*., 1994; Hess and Foy, 2000) and contact angle (Penner, 2000) resulting in increased penetration, target site delivery and herbicide efficacy. There are limited data available explaining surface tension and contact angle.

ALS inhibiting herbicides are slow in developing toxicity symptoms as it takes generally 1 to 2 weeks for visible mortality to appear on treated weed species. The lower use rates and slow weed mortality may increase the risk of inadequate control of some weed species depending on the growth stage, application method and environmental conditions. A quick and reliable test to predict herbicide efficacy at an early stage after application would help in making a decision about a second application if the herbicide fails to control weed species after one application.

Fluorescence imaging has been shown to rapidly predict herbicide efficacy (deRuiter and Jalink, 2004); however, it is costly and lacks versatility for field use. Chlorophyll fluorescence has been used primarily for photosynthesis inhibiting herbicides, which offers quick and reliable data on photosystem II activity and herbicide mortality under field and greenhouse conditions (Ducruet *et al*., 1993; Singh *et al*., 1997). Not all herbicides directly affect photosynthesis, but a decrease in photosystem II provides an efficient tool to measure biological response of herbicides under different conditions. ALS and other herbicides that affect enzymatic system as a primary target have been shown to affect photosynthesis indirectly (Böger *et al*., 2002). Effects on chlorophyll fluorescence with imazaquin (Judy *et al*., 1990), imazamethabenz (Percival and Baker, 1991) and metsulfuron-methyl (Reithmuller *et al*., 2003) have been reported. Madsen *et al*. (1995) reported significant effects of glyphosate on chlorophyll fluorescence and carbon dioxide exchange rate.

This study was conducted to evaluate the effect of different adjuvants on surface tension and contact angle of trifloxysulfuron leading to efficacy enhancement on different weed species. Chlorophyll fluorescence as influenced by herbicide treatment at different rates and durations after application was also evaluated as a rapid assessment tool under greenhouse and field conditions to predict herbicide efficacy.

MATERIALS AND METHODS

Bioefficacy Study

Greenhouse experiments were conducted using weed seedlings growing in Metro-mix 500 potting media (The Scotts Company, Marysville, OH 43041) at University of Florida, Citrus Research and Education Center, Lake Alfred, Florida, USA. Ten seeds of guineagrass, sicklepod, yellow nutsedge and three seeds of cotton (Delta Pine 50) were planted separately in 11-cm plastic pots. After emergence, weed seedlings were thinned to four per pot. Plants were grown in a greenhouse under natural light (12 h day/night) with a PPFD of 478 µMol/m^2/s, 25/16±2°C (day/night) temperature and 70±5% relative humidity.

All herbicide and adjuvant treatments were applied at the 4- or 6-leaf stage of weeds using a chamber track sprayer (*Allen Track Sprayer, Allen Machine Works, 607 E. Miller Road, Midland, MI 48640*) fitted with flat fan spray nozzle (*8002 Teejet, Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189*) delivering a rate of 190 l/ha at 140 kPa. Herbicide treatments consisted of trifloxysulfuron at 2.5, 5 and 10 g ai/ha mixed with 0.25% (v/v) Induce (*Induce®, mixture of alkyl aryl polyoxyalkane ethers, free fatty acids and dimethyl polysiloxane (90%), surfactant content 70%, Helena Chemical Company, 5100 Poplar Ave., Memphis, TN 38137*), X-77 (*X-77®, blend of Alkylarylpolyoxyethylene, alkylpolyoxyethelene, fatty acids, glycols and dimethylpolysiloxane (90%), Loveland Industries Inc.*

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PO Box 1289, Greeley, CO 80632) (non-ionic surfactants), 0.1% Kinetic (*Kinetic®, proprietary blend of polyalkyleneoxide modified polydimethylsiloxane and non-ionic surfactant (90%), Helena Chemical Company, 5100 Poplar Ave., Memphis, TN 38137*), L-77 (*L-77®, contains polyalkyleneoxide, modified heptamethyltrisiloxane (99.5%) , Loveland Industries Inc. PO Box 1289, Greeley, CO 80632*) (organo silicone surfactant), 1% Agri-Dex (*Agri-Dex®, proprietary blend of heavy range paraffinic oil, polyol fatty acid esters and polyethoxylated derivatives thereof (99%); Surfactant content 17% and unsulfonated oil residues (UR) 95% minimum, Helena Chemical Company, 5100 Poplar Ave., Memphis, TN 38137*) and Meth-N-Oil (*Meth-N-Oil®, contains methylated canola oil (83%), surfactants and emulsifiers (17%), Jay-Mar, Inc. PO Box 429, Plover, WI 54467*) (crop oil concentrates) for each rate. All the plants of uniform height were selected for spraying from each species. Plant height of guineagrass, sicklepod, yellow nutsedge, and cotton was 38, 12, 54 and 22 cm during the first run and 45, 18, 62 and 24 cm for repeat, respectively, at spraying. Control plants were maintained for each species and herbicide rates. There were four replicated pots per treatment, arranged in a completely randomized design. Plants were watered daily and fertilized with a 20-20-20, N-P_2O_5-K_2O fertilizer once during the growth period. Visual observations on mortality were recorded at weekly intervals until three weeks after treatment (WAT) on a 0-100 scale, where 0=no effect and 100=complete mortality. The experiment was terminated after recording fresh weight and plant height of treated plants. Both experiments had similar results, hence, values were pooled for ANOVA using ARM (*Agriculture Research Manager, Gylling Data Management, Inc., 405 Martin Boulevard, Brookings, SD 57006*) software. Analyses of species, herbicides, application rates and growth stage interactions were also performed on combined data using SPSS (*Statistical Package for Social Sciences (SPSS), Version 10, SPSS., Inc. 233 S. Wacker Drive, 11th Floor, Chicago, IL 60606-6307*).

Static Surface Tension and Contact Angle

Herbicide and adjuvant solutions were freshly prepared using double glass distilled water with 0.125, 0.25, 0.5 and 1% non-ionic surfactant (NIS), 0.05, 0.1, 0.2 and 0.4% organo silicone (OS) or 0.5, 1.0, 2.0 and 4% crop-oil concentrate (COC) adjuvants (v/v). These solutions were used to measure both static surface tension (ST) and contact angle (CA) measurements for trifloxysulfuron at 10 g/ha plus adjuvants at different concentrations. Comparisons were made with double glass distilled water and herbicide alone. Static surface tension was determined by DuNouy ring method (Singh and Mack, 1993) using a CSC-DuNuoy Tensiometer (*CSC Scientific Company, Inc., Fairfax, VA 23031, USA*). There were 10 replicate samples of 50-ml volume in plastic Petri dishes of 9 cm diameter for measuring ST. The platinum-iridium ring was flame heated each time before measuring ST. The contact angle was measured with a NRL Contact Angle Goniometer (*Ramé – hart, Inc., Mountain Lakes, NJ 07046, USA*) using 2.5-µl droplets of test solution on Teflon slides. Both advancing and receding contact angles were measured and values averaged over 10 replicates. Two experiments were conducted for ST and three experiments for CA and values were combined for ANOVA using SPSS.

Chlorophyll Fluorescence

The third leaf from the top of each plant was used for measuring chlorophyll fluorescence at 1, 4, 7 and 14 days after herbicide treatment (DAT) of the three weed species and cotton. The leaves were dark adapted with the clips for 30 min duration before measuring chlorophyll fluorescence using a Modulated Fluorometer (*OS1-FL, Modulated Fluorometer , Opti-Sciences, 164 Westford Rd # 4, Tyngsboro, MA 01879, USA*). The fluorescence meter measured Fv/Fm values, where Fv = variable fluorescence (Fm-F0), Fm = fluorescence level when Qa is transiently fully reduced, and F0=fluorescence level when plastoquinone electron acceptor pool (Qa) is fully oxidized (Singh *et al*., 1997). Fv/Fm is an arbitrary unit and is proportional to the quantum yield of photochemistry and highly correlated with the quantum yield of net photosynthesis. A value close to 0.800 or higher normally indicates healthy plants and reductions in Fv/FM values explain damage or reduction in the total number of photosystem II apparatus by herbicides or other factors. Chlorophyll fluorescence was recorded for both sets of bioefficacy study and data were pooled for ANOVA.

RESULTS AND DISCUSSION

Bioefficacy Studies

Guineagrass : Mortality of guineagrass was

lower compared to other weed species when trifloxysulfuron was used with different adjuvants (Fig. 1). The highest reduction of 52% in fresh weight of guineagrass was recorded with 10 g/ha trifloxysulfuron mixed with 0.1% Kinetic. Fresh weight reduction was greater when Kinetic or Agri-Dex was mixed with trifloxysulfuron compared to other adjuvants. Agri-Dex mixed with trifloxysulfuron was better in reducing the fresh weight of guineagrass compared to Meth-N-Oil, but none of them had any significant reduction in fresh weight with increasing herbicide rates from 2.5 to 10 g/ha. Trifloxysulfuron 10 g/ha mixed with Induce, X-77, or L-77 provided only 33 to 37% reduction in fresh weight of guineagrass (Fig. 1).

All treatments reduced the plant height of guineagrass compared to control plants, the reduction was significantly more at 10 g/ha rate of trifloxysulfuron, regardless of adjuvants (Fig. 2). Kinetic or Agri-Dex was more effective in reducing guineagrass height when mixed with trifloxysulfuron as compared to other adjuvants, but the differences were non-significant among the six adjuvants, when data were averaged over rates.

Sicklepod : The fresh weight of sicklepod was reduced by 61 to 88% by trifloxysulfuron tank mixed with adjuvants (Fig. 1). Agri-Dex, L-77, or X-77 when mixed with trifloxysulfuron reduced fresh weight of sicklepod less compared to other adjuvants. Trifloxysulfuron at 2.5 g/ha tank mixed with 1.0% Meth-N-Oil reduced fresh weight by 80%, the effect was similar to 10 g/ha of trifloxysulfuron mixed with other adjuvants. Reduction in fresh weight was less with increasing trifloxysulfuron rates from 2.5 to 5 g/ha, but significantly higher at 10 g/ha of trifloxysulfuron mixed with adjuvants, except with Meth-N-Oil which had similar effects at 2.5 g/ha.

Plant height of sicklepod was reduced by 60 to 68% by trifloxysulfuron tank mixed with different adjuvants (Fig. 2). There were no differences in the herbicide effect on plant height of sicklepod when used at different rates with any of the adjuvants.

Yellow nutsedge : Fresh weight of yellow nutsedge was reduced significantly by trifloxysulfuron 2.5 g/ha mixed with adjuvants compared to control (Fig. 1). All the adjuvants when mixed with trifloxysulfuron reduced fresh weight of yellow nutsedge; similarly, reduction was slightly lower with Kinetic or Agri-Dex when mixed with 2.5 g/ha of trifloxysulfuron, but was similar at higher rates of herbicide. When averaged over trifloxysulfuron rates, fresh weight of yellow nutsedge was reduced by 68, 65, 63, 66, 66 and 65% with the addition of Induce, X-77, Kinetic, L-77, Agri-Dex or Meth-N-Oil, respectively.

Trifloxysulfuron was effective in reducing the plant height of yellow nutsedge by 32 to 38%; all the adjuvants had similar effect on trifloxysulfuron efficacy as reflected in plant height of yellow nutsedge (Fig. 2). Reduction in plant height was not affected by trifloxysulfuron rates or adjuvants.

Cotton : Cotton fresh weight was reduced 3 WAT when trifloxysulfuron was applied tank mixed with adjuvants compared to control plants (Fig. 1); however, there were no significant differences among the six adjuvants in their phytotoxicity to cotton when mixed with trifloxysulfuron from 2.5 to 10 g/ha. Lowest reduction of 19% in the fresh weight of cotton was recorded when trifloxysulfuron was mixed with Kinetic and highest reduction of 25% with X-77, when data were averaged over rates.

Plant height of cotton was reduced from 7 to 18% when adjuvants were mixed with different rates of trifloxysulfuron at 3 WAT (Fig. 2). Reduction in plant height of cotton was less at 2.5 g/ha of trifloxysulfuron plus adjuvants compared to higher rates except X-77. Kinetic mixed with trifloxysulfuron reduced plant height less than other adjuvants; there were no significant differences among adjuvants when the data were averaged over herbicide rates.

Trifloxysulfuron provided good control of several broadleaf weed species and yellow nutsedge (Barber *et al*., 2002; Porterfield *et al*., 2002 a, b), but no control was recorded for grass weed species under greenhouse or field conditions (Burke *et al*., 2002). Rawls *et al*. (2000) and Brecke *et al*. (2001); however, reported fair to excellent control of Alexandergrass, signalgrass species, panicum species, browntop millet and large crabgrass depending upon application rates and timing. Under field conditions, trifloxysulfuron upto 63 g/ha could not provide effective control of Texas panicum and growth was only suppressed (Singh and Singh, 2004a). In the present study, no control of guineagrass was observed upto 10 g/ha of trifloxysulfuron when mixed with different adjuvants. Improved control of grassy weeds by Rawls *et al*. (2000) and Brecke *et al*. (2001) could be due to herbicide application at an early growth stage of weed species. Lower activity of trifloxysulfuron has been documented on tall than smaller weed plants (Culpepper and York,

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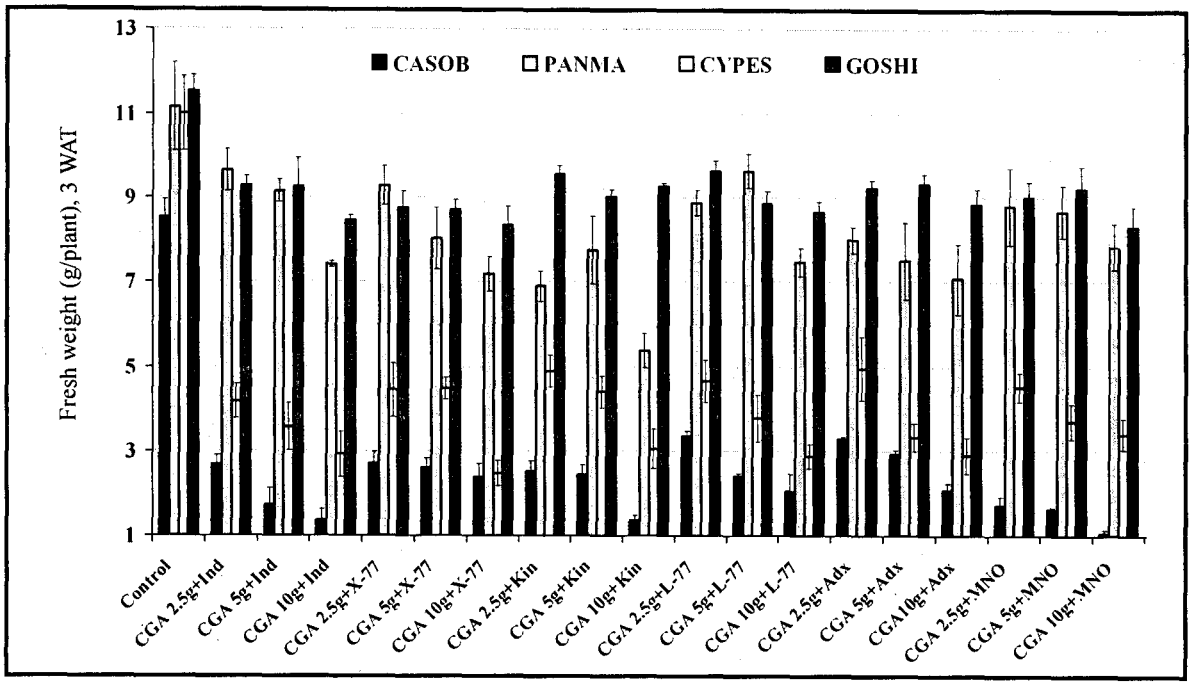

Fig. 1. Effect of adjuvants plus trifloxysulfuron on fresh weight of sicklepod, guineagrass, yellow nutsedge and cotton, three weeks after treatment (Ind=Induce, Kin=Kinetic, Adx=Agridex and MNO=Meth-N-Oil, CGA=Trifloxysulfuron, CASOB=Sicklepod, PANMA=Guineagrass, CYPES=Yellow nutsedge and GOSHI=Cotton)

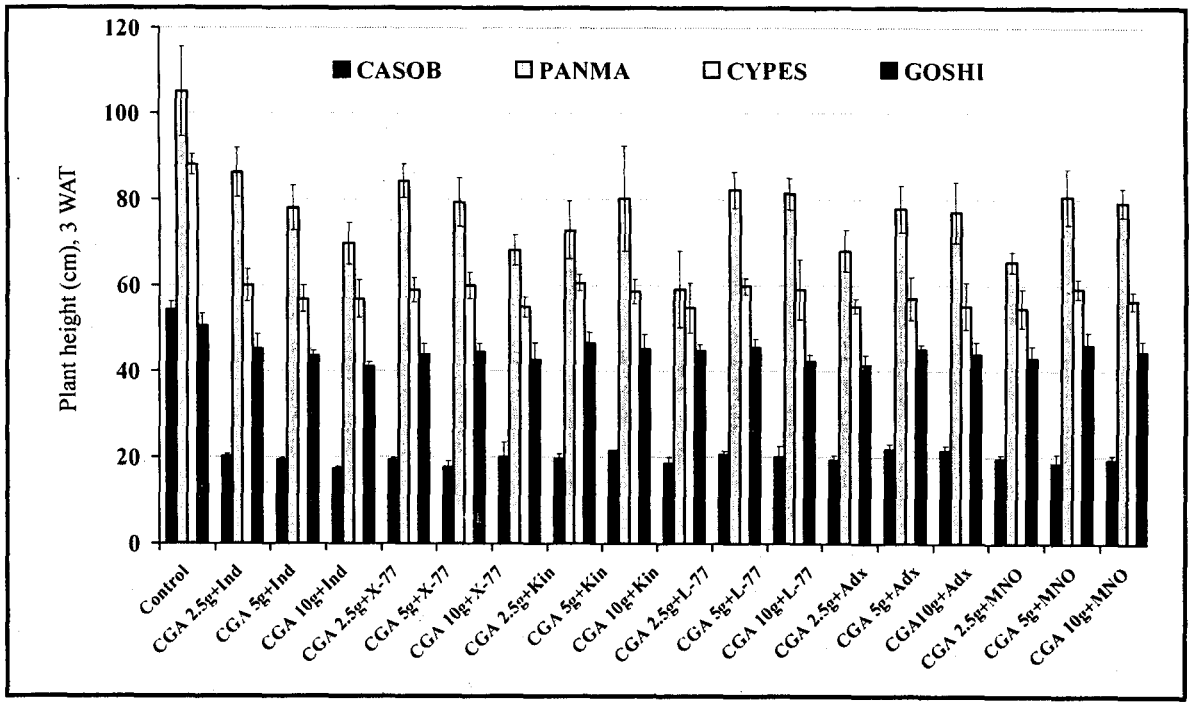

Fig. 2. Effect of adjuvants plus trifloxysulfuron on fresh weight of sicklepod, guineagrass, yellow nutsedge and cotton, three weeks after treatment (Ind=Induce, Kin=Kinetic, Adx=Agridex and MNO=Meth-N-Oil, CGA=Trifloxysulfuron, CASOB=Sicklepod, PANMA=Guineagrass, CYPES=Yellow nutsedge and GOSHI=Cotton).

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2001; Singh and Singh, 2004b).

Cotton injury was observed within a few days of trifloxysulfuron application at 2.5 to 10 g/ha with six adjuvants, but differences were not significant at 3 WAT, although plant height reduction was significant with herbicide application. Cotton injury and reduction in plant height were similar with any adjuvants mixed with trifloxysulfuron. Richardson *et al*. (2004) found that COC was more injurious to cotton in the field than other adjuvants; however, reduction in plant height or injury was non-significant at 8 WAT and caused no reduction in cotton yield or fiber quality.

Effect on Surface Tension and Contact Angle

Highest reduction in surface tension and contact angle of 69 and 78%, respectively, was recorded with L-77 compared to water or trifloxysulfuron alone, when data were averaged over concentrations (Figs. 3a & b). There were statistically significant differences in ST and CA reduction of trifloxysulfuron among the six adjuvants; reduction was higher with OS followed by NIS and COC adjuvants.

Statistically increasing the concentrations of adjuvants from 0.5 to 1X produced similar values of ST and CA, but the effect was slightly more at 2 or 4X concentrations when data were averaged over adjuvants. The ST of trifloxysulfuron plus Kinetic or L-77 was similar from 0.5 to 4X; reduction in ST by 3, 4, 4 and 8%, respectively, was observed at 4X concentrations of Meth-N-Oil, Agri-Dex, Induce, or X-77 compared to 0.5X. The reduction in ST was statistically similar at 0.5 or 1X concentrations with all the adjuvants except Agri-Dex, when trifloxysulfuron was applied at 10 g/ha.

The CA of Kinetic, L-77 or Meth-N-Oil was reduced from 0.5 to 1X concentrations with trifloxysulfuron, but no major reduction was measured with Induce, X-77 or Agri-Dex (Fig. 3a). Increasing the concentration of adjuvants from 1X to 2X produced similar values for all the adjuvants mixed with trifloxysulfuron, further increase to 4X lowered the CA of Kinetic, Agri-Dex and Meth-N-Oil only. Although, further increase in concentrations of adjuvants to 4X statistically lowered these values, the reduction was not sufficient to warrant use of higher concentrations. The reduction in ST and CA had almost similar trend to each other for different adjuvants mixed with trifloxysulfuron at different rates (Fig. 3a & b).

As a salt, trifloxysulfuron does not have any impact on ST and CA, and thus a surfactant is vital for lowering these parameters enabling increased penetration and enhanced herbicide efficacy. Lowering ST and CA improves herbicide efficacy and OS have been found to lower ST and CA greater than adjuvant of other chemical classes (Singh and Mack, 1993; Sharma and Singh, 2000). The ST and CA values of trifloxysulfuron were greatly reduced by all adjuvants at recommended rates. Conversely, reduction in ST and CA may not necessarily increase weed mortality (Roggenbuck *et al*., 1990) as there are several interrelated factors governing the herbicide efficacy. All the adjuvants in the present study reduced the ST and CA of trifloxysulfuron and the effect was evident on reduced fresh weight of weeds (Fig. 1), but large differences between OS and COC in ST and CA did not result in differential weed mortality. There were some variations in the activity of trifloxysulfuron on different weed species, when mixed with adjuvants of different chemistries, but in general there were no significant differences to show the affinity of any particular adjuvant to trifloxysulfuron or any large effect to lower ST or CA.

Chlorophyll Fluorescence Studies

Guineagrass **:** Reduction in chlorophyll fluorescence was observed after 24 h in all treatments except trifloxysulfuron plus L-77 or Induce at the higher rates (Fig. 4). Reduction in chlorophyll fluorescence 4 DAT was greater at 10 g/ha of trifloxysulfuron with all the adjuvants than with lower rates, but there was no further decrease at 7 or 14 DAT. Chlorophyll fluorescence was lower in plants treated with trifloxysulfuron plus L-77 or Meth-N-Oil compared with other adjuvants, but no particular trend was apparent with herbicide rates.

Sicklepod **:** Reduction in chlorophyll fluorescence in plants treated with trifloxysulfuron plus adjuvants was less in sicklepod compared to guineagrass, but followed no particular trend with respect to herbicide rates or adjuvants at any observation date (Fig. 5). Chlorophyll fluorescence of control plants was lower than herbicide treated plants at 7 and 14 DAT.

Yellow nutsedge **:** Trifloxysulfuron plus X-77 reduced the chlorophyll fluorescence of yellow nutsedge within 24 h in all the herbicidal treatments except where L-77 or Meth-N-Oil was mixed with lower rates of trifloxysulfuron (Fig. 6). Significant reduction in

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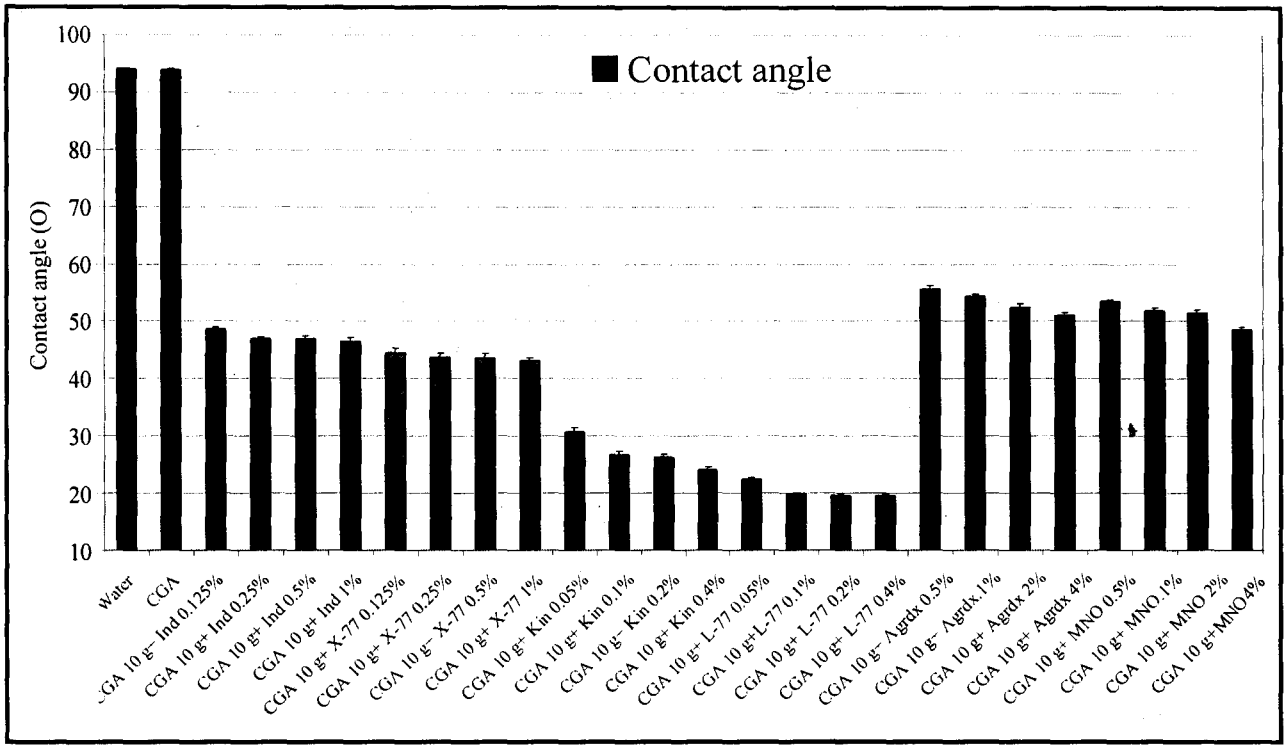

Fig. 3a. Effect of adujuvants mixed with trifloxysulfuron on contact angle (GCA=Trifloxysulfuron, Ind=Induce, Kin=Kinetic, Adx=Agridex and MNO=Meth-N-Oil).

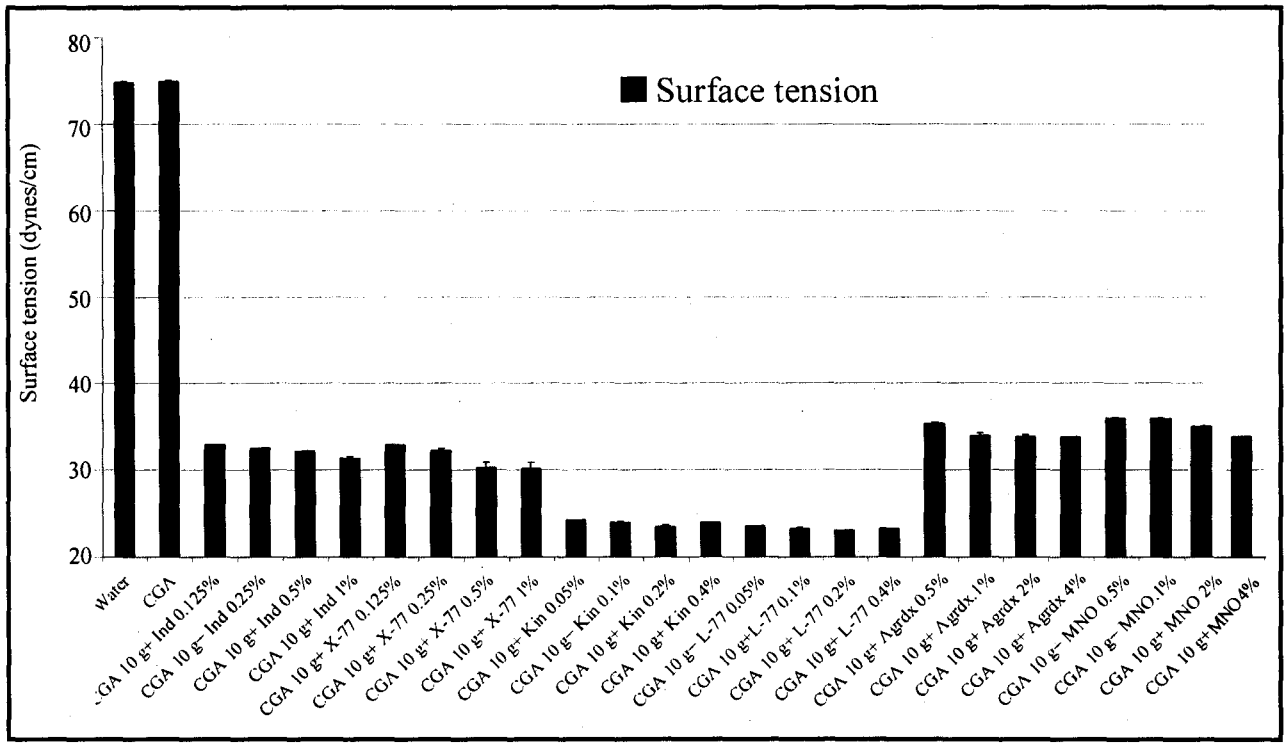

Fig. 3b. Effect of adujuvants mixed with trifloxysulfuron on surface tension (CGA=Trifloxysulfuron, Ind=Induce, Kin=Kinetic, Adx=Agridex and MNO=Meth-N-Oil).

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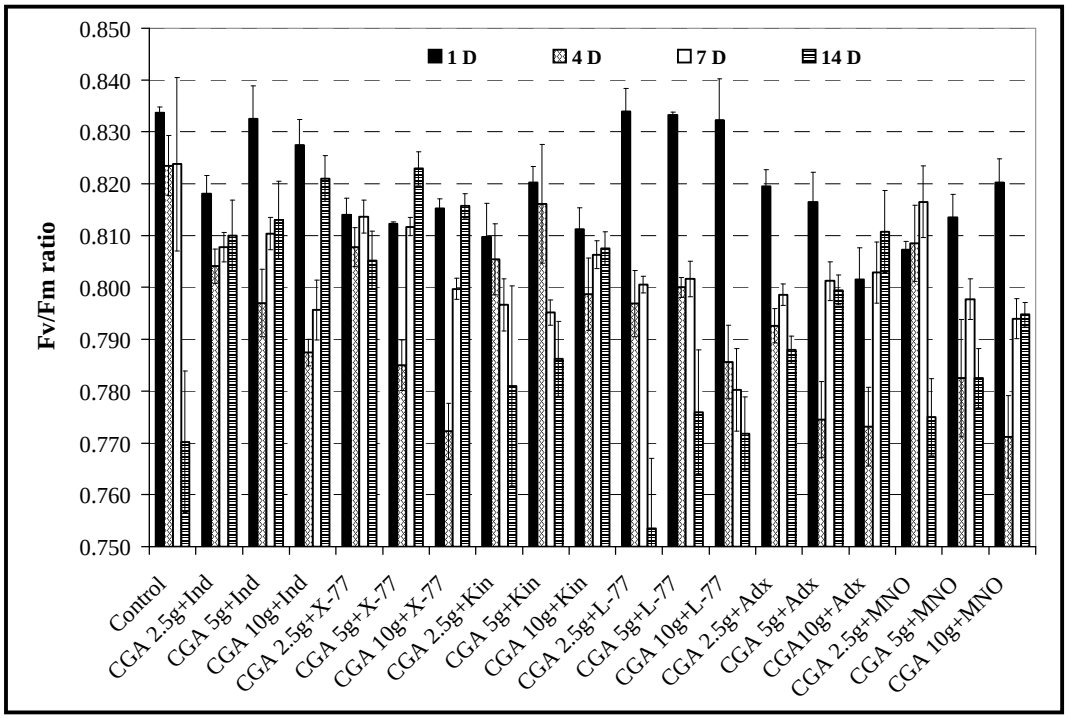

Fig. 4. Effect of adjuvants plus trifloxysulfuron on chlorophyll fluorescence of guineagrass (Ind= Induce, Kin = Kinetic Adx = Agridex, and MNO = Meth-N-Oil, CGA = Trifloxysulfuron)

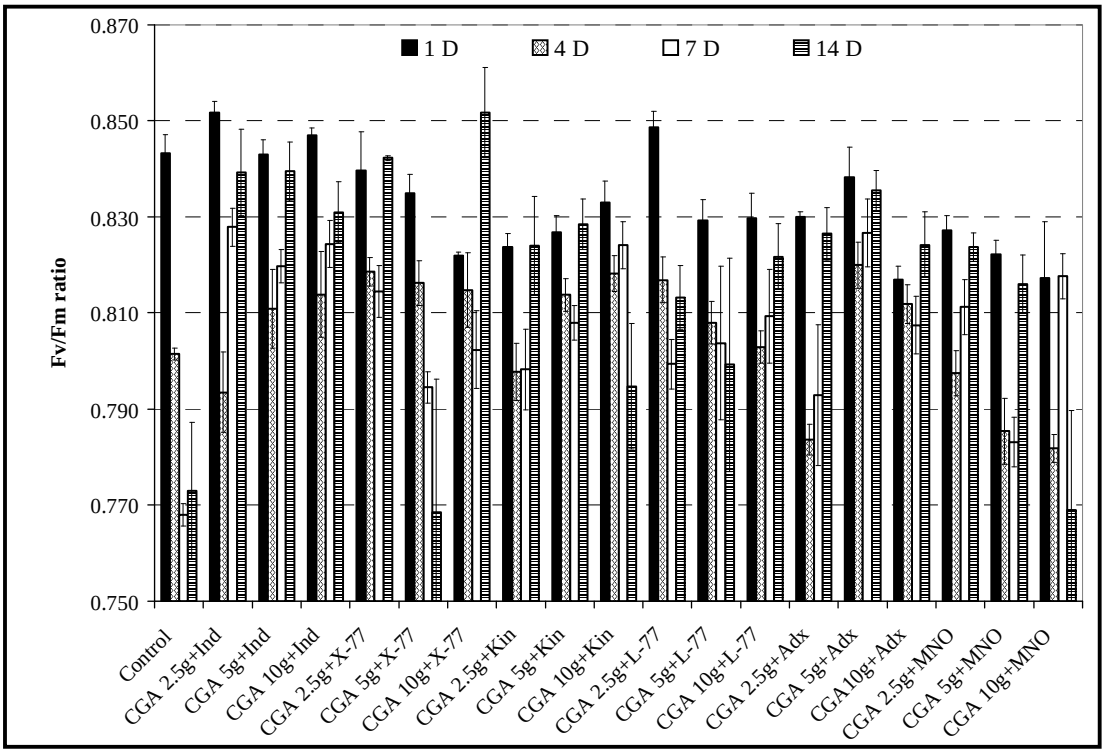

Fig. 5. Effect of adjuvants plus trifloxysulfuron on chlorophyll fluorescence of guineagrass (Ind = Induce, Kin = Kinetic, Adx = Agridex and MNO = Meth-N-Oil, CGA = Trifloxysulfuron).

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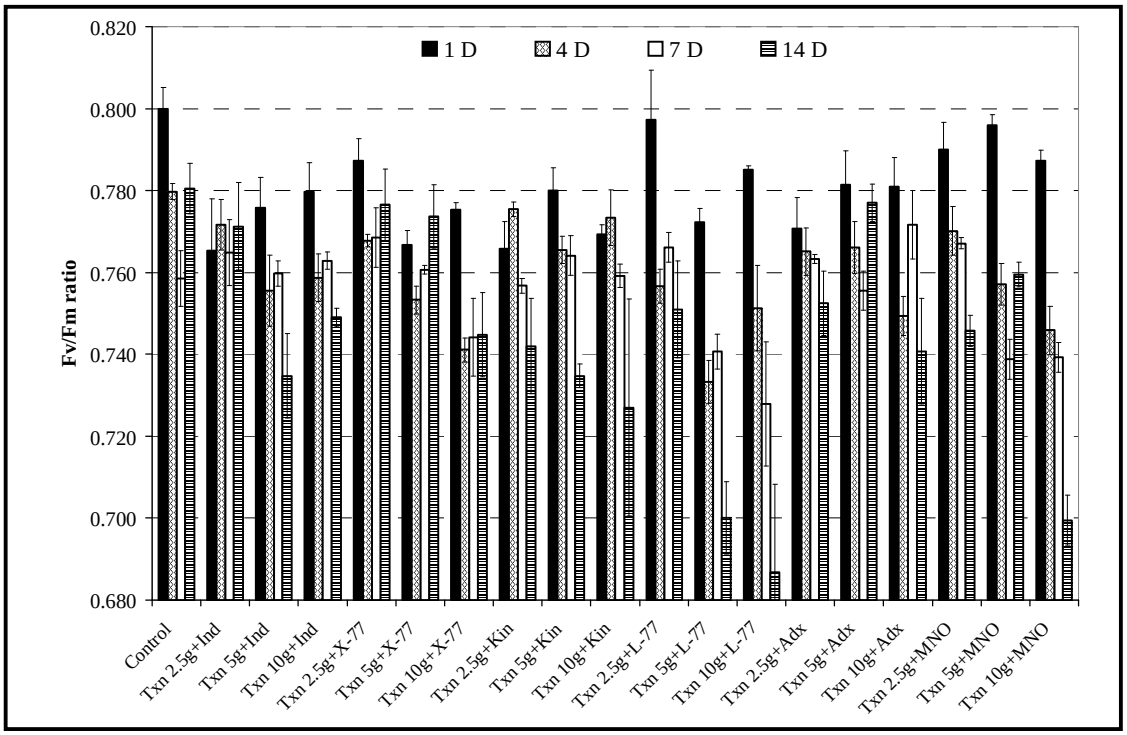

Fig. 6. Effect of adjuvants plus trifloxysulfuron on chlorophyll fluorescence of yellow nutsedge (Ind= Induce, Kin = Kinetic, Adx = Agridex and MNO = Meth-N-Oil, CGA = Trifloxysulfuron).

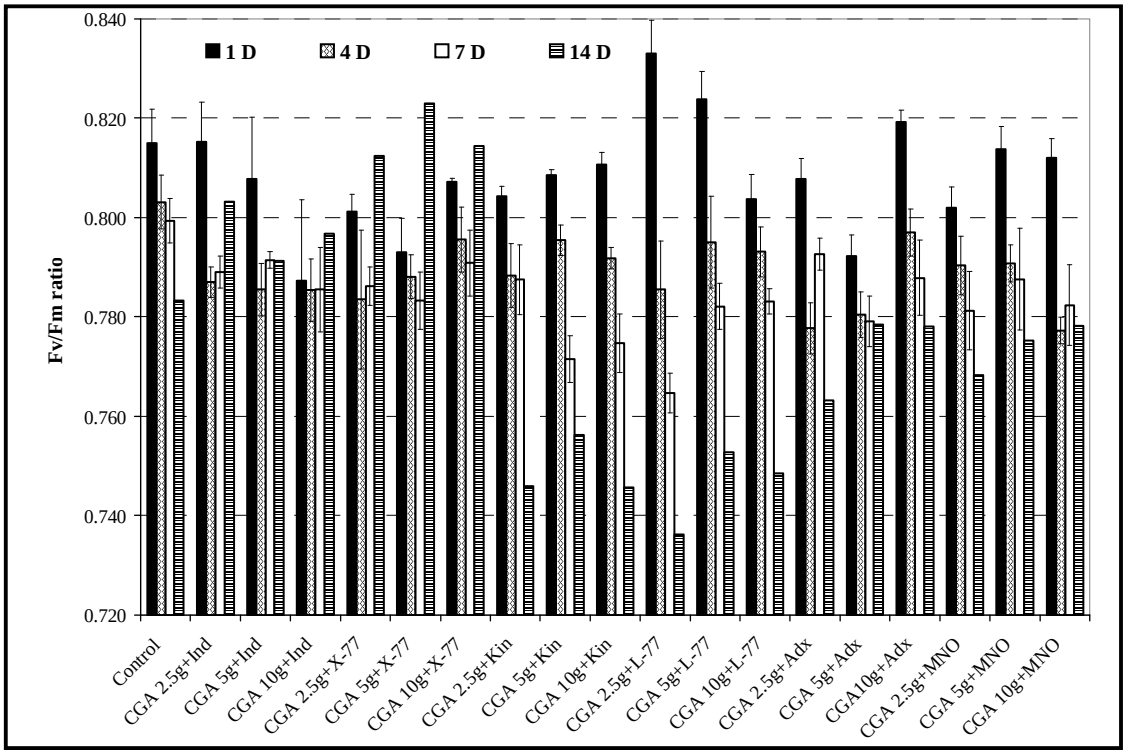

Fig. 7. Effect of adjuvants plus trifloxysulfuron on chlorophyll fluorescence of yellow nutsedge (Ind= Induce, Kin = Kinetic, Adx = Agridex and MNO = Meth-N-Oil, CGA = Trifloxysulfuron).

chlorophyll fluorescence at 4 DAT was recorded with 10 g/ha of trifloxysulfuron mixed with all adjuvants, except Kinetic. Reduction in chlorophyll fluorescence was recorded with all rates of trifloxysulfuron plus L-77 at 4 DAT and at 5 or 10 g/ha trifloxysulfuron at 7 DAT, but none was observed with Kinetic. However, at 14 DAT, lower chlorophyll fluorescence was recorded with both Kinetic or L-77 mixed with trifloxysulfuron.

***Cotton* :** Compared to control plants, there was no significant reduction in chlorophyll fluorescence of cotton plants treated with trifloxysulfuron plus adjuvants at 1 DAT, except at 5 g/ha with X-77 or Agri-Dex and 10 g/ha with Induce (Fig. 7). Reduction in chlorophyll fluorescence was not visible at 7 or 14 DAT when trifloxysulfuron was mixed with Induce, Agri-Dex or X-77, whereas significantly lower values were recorded when Kinetic or L-77 was mixed with the herbicide. Increased trifloxysulfuron rates did not affect chlorophyll fluorescence at 1 or 2 WAT.

Significant reduction in chlorophyll fluorescence of littleseed canarygrass (*Phalaris minor*) was recorded with PS II inhibitor herbicide, isoproturon (Singh *et al*., 1997). Reduction in chlorophyll fluorescence was recorded within 4 h of treatment of isoproturon, whereas in the present study similar reduction with trifloxysulfuron was not recorded with any test plants from 1 to 14 DAT. Chlorophyll fluorescence has been used to measure photosynthetic activity of PS II inhibiting herbicides, but also to detect resistance to these herbicides in weed species (van Oorschot and van Leeuwen, 1992; Moss, 1995; Singh *et al*., 1997). Reithmuller *et al*. (2003) reported that chlorophyll fluorescence (PS II efficiency) of black nightshade (*Solanum nigrum*) and redshank (*Polygonum persicaria*) was reduced significantly within a few days of application of metsulfuron-methyl. Both metsulfuron and trifloxysulfuron selectively inhibit acetolactate synthase, the common enzyme involved in the biosynthesis of essential amino acids in plants. Photosynthesis is not the primary target of ALS inhibiting herbicides, but it has been shown to affect the photosynthetic efficacy of treated plants at later stages of application. Reduction in chlorophyll fluorescence has been reported with other herbicides which do not have photosynthesis as the primary target of herbicide action (Judy *et al*., 1990; Percival and Baker, 1991; Madesn *et al*., 1995).

Assessment of PS II efficacy for metsulfuron treated plants by Reithmuller *et al*. (2003) was made by different method, where carbon dioxide fixation and PS I and PS II were significantly affected by the ALS inhibiting herbicide. Significant reduction in chlorophyll fluorescence was not detected at an early stage after treating the plants with trifloxysulfuron and adjuvants when using chlorophyll fluorescence meter in the present study. Visual mortality of 14, 20, 16, 7 and 17, 53, 36 and 5% at 7 and 14 DAT, respectively, for guineagrass, sicklepod, yellow nutsedge and cotton was observed with trifloxysulfuron plus adjuvants (data averaged over adjuvants and herbicide rates), but a similar reduction in chlorophyll fluorescence was not detected in these species. Weed mortality increased with increasing herbicide rates, but such a trend was not always observed with chlorophyll fluorescence measurements. Similar results were observed when ALS and ACCase inhibitor herbicides were used in measuring chlorophyll fluorescence with *Phalaris minor* (S. Singh, unpublished data). These results indicate that the chlorophyll fluorescence meter may not provide rapid and early measurement of PS II efficiency in plants treated with herbicides whose primary site of action is not photosynthesis inhibition.

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