Herbicide efficacy as influenced by spray fluid quality and adjuvants on yield and economics of Maize (*Zea mays* L.)

ABSTRACT

A field investigation was conducted during *rabi* season of 2020-21 at Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad to assess the herbicide efficacy as influenced by spray fluid quality and adjuvants on yield and economics of Maize. The results revealed that there was a positive influence on addition of ammonium sulphate as adjuvant when saline waters (C_3S_1 and C_3S_2 classes) were used as spray fluid as compared to application of herbicides with saline waters alone. Tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} with 2% ammonium sulphate with C_3S_1 class water as spray fluid recorded higher yield (5.00 and 8.15 t ha^{-1}) and economics of maize with reference to other saline water treatment combinations and proved as effective treatment following to halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} with 2% ammonium sulphate with distilled water as spray fluid.

KEYWORDS: Adjuvant, Economics, Maize, Quality of spray fluid, Yield.

INTRODUCTION

Maize (*Zea mays* L.) is one of the major cereal crops and is also known as "Miracle crop". In India, maize ranks 5th in area and 3rd in production and is being cultivated in an area of 9.18 Mha with a production of 27.23 Mt and average productivity of 2965 kg ha^{-1} during the year 2018-19 (Agricultural Statistics at Glance, 2019). In India, maize ranks third after rice and wheat and is grown for grain as well as fodder purpose. Weeds constitute one of the major economic problem for maize growers. For broad spectrum control of weeds tank mix application of herbicides like tembotrione, atrazine, 2,4-D-Dimethyl amine, halosulfuron methyl with superior quality of spray fluid is important for achieving herbicide efficiency.

Quality of groundwater is determined by several factors such as hardness, alkalinity and turbidity which are expressed in terms of water pH, electrical conductivity (EC), SAR

respectively. Therefore carrier water pH is an important factor that can affect herbicide performance (Green and Cahill 2003, Sarmah and Sabadie 2002). In Telangana state, groundwater is mildly alkaline to alkaline in nature with pH in the range of 6.6 to 8.6. As far as irrigation suitability of groundwater is concerned, it is found that most of the areas and 63.3% of water samples fall under high salinity low sodium hazard, 26.3% in medium salinity and low sodium and 7.1% of samples fall under high salinity and medium sodium(Ground water year book: 2016-2017, Telangana state).

Presence of dissolved cations like Ca^{+2}, Mg^{+2}, Fe^{+2}, Al^{+3}, Mn^{+2}, Na^{+}, K^{+} and Cesium can influence herbicide efficacy. Addition of a suitable adjuvant to the spray tank neutralizes the impact of hard water cations. Among ammonium fertilizer adjuvants, ammonium sulphate is most popularly used which reduces the antagonist effect of hard water cations and improve efficacy of herbicides.

MATERIAL AND METHODS

The field investigation conducted at Rajendranagar, Hyderabad during *rabi* season of 2020-21 is situated at an altitude of 822 m above mean sea level (MSL) with coordinates of $17^0$19'21" N latitude and $78^0$24'36" E longitude. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction (7.84), medium in organic carbon (6.9 g kg^{-1}), low in available nitrogen (220.77 kg ha^{-1}) and phosphorus (9.38 kg ha^{-1}) and high in available potassium (351.18 kg ha^{-1}). Six levels of herbicide and adjuvant combinations namely H_1: tembotrione 34.4% SC 120 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} without adjuvant, H_2: tembotrione 34.4% SC 120 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} + ammonium sulphate @ 2% as adjuvant, H_3: 2,4-D-Dimethyl amine 58% SL 0.5 kg ha^{-1} without adjuvant, H_4: 2,4-D-Dimethyl amine 58% SL 0.5 kg ha^{-1} + ammonium sulphate @ 2% as adjuvant, H_5: halosulfuron methyl 75% WDG 67.5 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} without adjuvant and H_6: halosulfuron methyl 75% WDG 67.5 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} +

ammonium sulphate @ 2% as adjuvant and 3 levels of quality of spray fluid namely W_1: C_3S_1 class (EC–0.75 to 2.25 dS m^{-1}; SAR–0 to 10), W_2: C_3S_2 class (EC–0.75 to 2.25 dS m^{-1} ; SAR–10 to 18) and W_3: distilled water and with two external controls, C_1: unweeded control and C_2: weed free plot (hand weeding at 20 and 40 DAS) were evaluated in factorial randomized block design with three replications. Different spray fluids were prepared in the laboratory by dissolving different proportions sulphates and chlorides of Ca, Mg, K and Na in the distilled water. Then the Ca^{+2} and Mg^{+2} ions were estimated by versenate titrate method using Ethylene Diamine Tetra Acetic acid (EDTA) as chelating agent. pH and EC were measured using pH and EC meter. Na^{+} ions were estimated by using flame photometer and expressed in terms of ppm.

The maize cultivar 'DHM-117'was sown with a seed rate of 20 kg ha^{-1} at a spacing of 60 cm × 20 cm at a depth of 5-7 cm. The crop was fertilized with 180 kg N + 60 kg P + 60 kg K ha^{-1} in the form of urea, di- ammonium phosphate and muriate of potash respectively. Post-emergence herbicides were applied at 21 DAS using knapsack sprayer with flat fan nozzle predominantly on weeds with different qualities of spray fluids. Economic analysis was carried out by calculating cost of cultivation for different field operations done during crop growth. Gross returns were calculated from grain and straw yield of maize obtained from different treatments and multiplied with respective value of grain and straw yield. Then by deducting the cost of cultivation from gross returns net returns were worked out. The statistical significance was tested with 'F' test at 5% level of significance and for the significant values, critical difference (CD) was worked out to test the significance.

RESULTS AND DISCUSSION

YIELD

Significant influence on maize yield was observed with different herbicides + adjuvant and quality of spray carrier treatments (table 1). With regard to herbicides + adjuvant combinations, tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + 2% AMS at 21 DAS resulted in statistically maximum grain yield (5.14 t ha^{-1}) which was mainly due to low crop weed competition because of poor density of weeds and better weed control efficiency because of increased penetration of herbicide by the addition of adjuvant to the spray tank and increased competitive ability of the crop due to taller plants and large canopy closure smothering the weeds led to increased availability of resources and their translocation from source to sink which directly affected the yield components in maize by proper reproductive structures development and influenced the grain yield in maize which was also reported by Hassan *et al.* (2010) and similar results were reported by Kapusta *et al.* (1994) and Mritunjay Kumar (2018). Among quality of spray fluids, distilled water as spray fluid resulted in significantly maximum grain yield (4.31 t ha^{-1}). With regard to interaction, significantly higher grain yield (5.48t ha^{-1}) was recorded with tank mix application halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + 2% AMS at 21 DAS with distilled water as spray fluid with 71.39% increase over unweeded control. Gregory *et al.* (1994) also observed that increase in yield was mainly due to increased kernel size due to effective weed management through herbicides.

Among the herbicides + adjuvant treatments, tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + 2% AMS at 21 DAS recorded significantly maximum stover yield (8.28 t ha^{-1}). Among the quality of spray fluids, maximum stover yield (7.54 t ha^{-1}) was recorded with use of distilled water and was significantly superior over other spray fluids. With regard to stover yield, interactions among different herbicides + adjuvants and quality of spray fluids were significant. Among the interactions, tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + 2% AMS at 21 DAS with

distilled water as spray fluid recorded significantly higher stover yield (8.54 t ha^{-1}). This could be attributed to inhibition of enzyme acetolactate synthase by halosulfuron methyl herbicide which acts as catalyst in the first step of the biosynthesis of essential amino acids and moreover addition of adjuvant helps in easy absorption and translocation of herbicide into the weed which led to lower weed dry weight and increased the uptake and translocation of assimilates in the maize plant system and influenced the stover yield as reported by Vasudev Meena *et al.* (2019).

Halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + 2% AMS at 21 DAS with C_3S_1water as spray fluid resulted in higher grain and stover yield (5.00 and 8.15t ha^{-1} respectively) compared to other herbicides and saline water combinations.

Economics

Weed free treatment received two hand weeding at 20 and 40 DAS realized maximum cost of cultivation (₹ 47099 ha^{-1}) to control weeds while expenditure incurred under all other herbicidal treatments was minimum compared to hand weeding treatment, indicating that control of weed through hand weeding was more expensive than the use of herbicides in maize.

The results (table 2) showed that different herbicides + adjuvant treatments and quality of spray fluids and their interactions showed significant influence on economics. Tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + 2% AMS at 21 DAS with distilled water as spray fluid received maximum gross returns (₹ 124873 ha^{-1}), net returns (₹ 85034 ha^{-1}) and B:C ratio (3.13) and superior to other treatment combinations. Among combination of herbicides + adjuvant and saline waters as spray fluid, halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + 2% AMS at 21 DAS with C_3S_1 water as spray fluid resulted in higher economics compared to other treatment combinations with saline waters.

Conclusion

The field experiment conducted during *rabi* season of 2020-21 concluded that tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + 2% AMS at 21 DAS with C_3S_1 water as spray fluid following to halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + 2% AMS with distilled water as spray fluid showed positive influence on yield and economics specifying the positive effect of ammonium sulphate on herbicide efficacy when used in combination with saline waters and proved that ammonium sulphate as adjuvant neutralizes the effect of saline water cations. Hand weeding at 20 and 40 DAS recorded maximum yield and gross returns but realized maximum cost of cultivation compared to herbicidal treatments.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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Table 1. Effect of herbicides + adjuvant and quality of spray fluids on yield (t ha^{-1}) of maize

Herbicides + adjuvant	Grain yield (t ha^{-1})				Stover yield (t ha^{-1})			
	Quality of spray fluid				Quality of spray fluid			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
H_1	3.54	3.22	4.35	3.70	6.92	6.57	7.69	7.06
H_2	4.01	3.94	4.87	4.27	7.35	7.27	8.11	7.58
H_3	2.18	1.87	2.86	2.30	5.46	5.45	6.19	5.70
H_4	2.53	2.49	2.90	2.64	5.85	5.80	6.23	5.96
H_5	4.50	4.44	5.39	4.78	7.76	7.72	8.50	7.99
H_6	5.00	4.94	5.48	5.14	8.15	8.14	8.54	8.28
Mean	3.63	3.48	4.31		6.91	6.82	7.54	
Control 1				1.56				5.30
Control 2				5.58				8.57
	H	W	H x W	Control vs Rest	H	W	H x W	Control vs Rest
SEm±	61.99	43.83	107.36	80.02	57.60	40.73	99.76	74.36
CD (P=0.05)	177.43	125.46	307.32	161.97	164.87	116.58	285.56	150.50

H_1: post emergence application of tembotrione 34.4% SC 120 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} without adjuvant as tank mix

H_2: post emergence application of tembotrione 34.4% SC 120 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} + ammonium sulphate @ 2% as adjuvant as tank mix

H_3: post emergence application of 2,4-D-Dimethyl amine 58% SL 0.5 kg ha^{-1} without adjuvant as tank mix

H_4: post emergence application of 2,4-D-Dimethyl amine 58% SL 0.5 kg ha^{-1} + ammonium sulphate @ 2% as adjuvant as tank mix

H_5: post emergence application of halosulfuron methyl 75% WDG 67.5 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} without adjuvant as tank mix

H_6: post emergence application of halosulfuron methyl 75% WDG 67.5 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} + ammonium sulphate @ 2% as adjuvant as tank mix

W_1: C_3S_1 class (EC–0.75 to 2.25 dS m^{-1}; SAR–0 to 10)

W_2: C_3S_2 class (EC–0.75 to 2.25 dS m^{-1}; SAR–10 to 18) and W_3: distilled water

C_1: unweeded control and C_2: weed free plot

Table 2. Economics (₹ ha^{-1}) of different herbicides + adjuvant and quality of spray fluid treatments in maize

Herbicides + adjuvant	Gross returns (₹ ha^{-1})				Net returns (₹ ha^{-1})				B:C ratio			
	Quality of spray fluid				Quality of spray fluid				Quality of spray fluid			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
H_1	83579	77105	100126	86937	44890	38416	61436	48247	2.16	1.99	2.59	2.25
H_2	93134	91535	111566	98745	54294	52696	72727	59906	2.40	2.36	2.87	2.54
H_3	54984	48801	69737	57840	19297	13115	34050	22154	1.54	1.37	1.95	1.62
H_4	63315	62476	70018	65270	27479	26640	34181	29433	1.77	1.74	1.95	1.82
H_5	103582	102516	123030	109710	63893	62827	83341	70020	2.61	2.58	3.10	2.76
H_6	114325	113091	124873	117430	74485	73251	85034	77590	2.87	2.84	3.13	2.95
Mean	85486	82587	99892		47390	44491	61795		2.22	2.15	2.60	
Control 1				41912				7313				1.21
Control 2				126784				79684				2.69
	H	W	H x W	Control vs Rest	H	W	H x W	Control vs Rest	H	W	H x W	Control vs Rest
SEm±	1229.24	869.20	2129.10	1586.94	1100.60	778.24	1906.29	1420.87	0.03	0.02	0.05	0.04
CD (P=0.05)	3518.53	2487.97	6094.27	3211.96	3150.32	2227.61	5456.51	2875.83	0.09	0.06	0.15	0.08