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Nutrient Uptake, Yield Attributes and Yield of Maize (*Zea mays* L.) as Influenced by Efficacy of Different Post emergence Herbicides Applied under varied Qualities of Spray Fluids

K. Bhavitha[1*], K. Suresh[2], T. Ram Prakash[3] and M. Madhavi[4]
[1]M.Sc. Scholar, Department of Agronomy,
PJTSAU, Hyderabad (Telangana), India.
[2]Professor, Department of Agronomy, O/o COE, Examination center,
PJTSAU, Rajendranagar, Hyderabad (Telangana), India.
[3]Principal Scientist, Department of Soil Science,
AICRP on Weed Management, Hyderabad (Telangana), India.
[4]Senior Professor (Agronomy), Department of Agronomy,
PJTSAU, Agricultural College, Aswaraopeta (Telangana), India.

(Corresponding author: K. Bhavitha)*
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ABSTRACT: Herbicide application is the most economical method of weed control due to shortage of labour and costly intercultivation. For optimum performance of the herbicides applied, quality of water plays a major role as it is a primary herbicide carrier solvent. In Telangana state, 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 C_3S_1 type (high salinity low sodium hazard) and 7.1% of samples fall under C_3S_2 type (high salinity and medium sodium). Based on the above problem, twenty treatments namely tank mix application of atrazine with 4 hydroxy-phenyl pyruvate dioxygenase (4-HPPD) and acetolactase acid synthase inhibiting herbicides (tembotrione and halosulfuron methyl respectively), 2,4-D-Dimethyl amine with and without adjuvant were sprayed as post-emergence (PoE) at 21 DAS with C_3S_1 (EC–0.75 to 2.25 dS m^{-1}; SAR–0 to 10) class, C_3S_2(EC–0.75 to 2.25 dS m^{-1}; SAR–10 to 18) class waters and distilled water as spray fluids, hand weeding at 20 and 40 DAS and unweeded check were evaluated in afield investigation conducted during 2020-21 of *rabi* season under factorial randomized block design to determine the nutrient uptake, yield attributes of maize and soil chemical properties. Tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} with 2% ammonium sulphate as PoE with C_3S_1 class water as spray fluid recorded higher yield attributes, yield and nutrient uptake in maize in comparison to other saline water treatment combinations next to tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} with 2% ammonium sulphate as PoE with distilled water as spray fluid.

Keywords: Nutrient uptake, Post-emergence herbicides, Saline waters, Soil chemical properties, Yield attributes.

INTRODUCTION

Maize stands first in production among cereals in the world and is named as “Miracle crop” and “queen of cereals” due to its versatile nature and highest genetic potential (Arockia Infant *et al*., 2020) and has wider adaptability to diverse agro-climatic conditions. In India, maize ranks 5th in area and 3rd in production. In Telangana state, the total cultivated area under maize is 5.6 lakh ha with total production and productivity of 20.3 lakh tons and 36.58 q ha^{-1} respectively during the year 2018-19 (Agricultural Statistics at a Glance, 2019). About 15 million farmers in India are engaged in cultivation of maize. Weeds pose severe problem in maize in contrast to several agronomic constraints and results in low productivity. Weeding after critical period of crop weed competition can reduce yield upto 65-83% (Anwesh Rai *et al*., 2018). Herbicide application is most economical weed control method in comparison to manual weeding due to labour shortage; hence, herbicide efficacy plays an important role in yield expression. There are very few herbicide options available for weed control in maize in India. At present, herbicides used for weed control in maize involves pre-emergence application of atrazine, alachlor, simazine, pendimethalin and post-emergence (PoE) application of 2, 4-D, atrazine. Post-emergence herbicides offer a long season control till critical period of crop-weed competition. To achieve efficient weed control, spray carrier quality plays a major role. Water is the primary herbicide carrier solvent and is a critical component for herbicide applications. Quality of groundwater is determined in terms of pH, electrical conductivity (EC), SAR respectively. Presence of dissolved cations in water like Ca^{+2}, Mg^{+2}, Fe^{+2}, Al^{+3}, Mn^{+2}, Na^{+}, K^{+} and Cesium can influence herbicide efficacy by the process of inactivation, breakdown or precipitation. Very hard water (greater than 1000ppm) can also affect surfactants and oils, and will change

their properties of wetting, emulsification and dispersion. An adjuvant is any compound that is added to a herbicide formulation or tank mix to facilitate the mixing, application, or effectiveness of that herbicide. Ammonium sulphate (AMS) as adjuvant reduces the antagonist effect of hard water cations and enhance herbicides efficacy by reacting with the dissolved cations to form insoluble sulfates that will not react with the herbicide.

MATERIAL AND METHODS

Afield trial was laid out at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *rabi* season of 2020-21 in randomized block design with two factors (herbicides + adjuvant and quality of spray fluids) and two external controls replicated thrice. Six levels of herbicides + adjuvant combinations (factor 1) included were H_1: tank mix application of tembotrione 34.4% SC 120 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} without adjuvant as PoE, H_2: tank mix application of tembotrione 34.4% SC 120 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1}+ ammonium sulphate @ 2% as adjuvant as PoE, H_3: 2,4-D-Dimethyl amine 58% SL 0.5 kg ha^{-1} without adjuvant as PoE, H_4: 2,4-D-Dimethyl amine 58% SL 0.5 kg ha^{-1} + ammonium sulphate @ 2% as adjuvant as PoE, H_5: tank mix application of halosulfuron methyl 75% WDG 67.5 g ha^{-1} + atrazine 50% WP 0.5 kg ha^{-1} without adjuvant as PoE and H_6: tank mix 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 PoE and three levels of quality of spray fluids (factor 2) namely *i.e.*, 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 two external controls, C_1: unweeded control and C_2: weed free plot (hand weeding at 20 and 40 DAS). The values of NPK contents for grain and stover were recorded treatment wise and then N, P and K uptakes were determined. It was evaluated by multiplying the nutrient content (%) with corresponding dry matter produced and expressed in kg ha^{-1}. The data recorded during the experiment was analysed statistically.

Nutrient uptake =

$$= \frac{\text{Dry matter produced (kg ha}^{-1} \times \text{nutrient content (\%)}}{100}$$

RESULTS AND DISCUSSION

Yield and yield attributes. Significantly higher number of cobs $plant^{-1}$ (1.68) and cob length (18.94 cm) were recorded with tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% as PoE among herbicides + adjuvant combinations. The above results were in agreement with findings of Tesfay *et al*. (2014); Quddus *et al*. (2012). Likewise, Shinde *et al*. (2001) also recorded significantly improved yield and related yield attributes in plots where weeds were below economic threshold level. Among different quality of spray carriers, significantly maximum no. of cobs $plant^{-1}$ (1.43) was recorded with use of distilled water as spray carrier. Data recorded on no. of rows cob^{-1} indicated that herbicides + adjuvant treatments and quality of spray carriers used did not significantly influence the parameters. Data on test weight (g) indicated that HW at 20 and 40 DAS (control 2) resulted in maximum test weight (26.10 g) and similar results were reported by Sapna Bhagat *et al*. (2019); Puscal *et al*. (2018); Skrzypczak *et al*. (2011); Abbas *et al*. (2018). Effect of herbicides + adjuvant treatments and quality of spray carriers did not influence test weight (g) significantly (Table 1).

Table 1: Effect of herbicides + adjuvant and quality of sprayfluids on yield attributes of maize.

Treatments	No. of cobs $plant^{-1}$	Cob length (cm)	No. of rows cob^{-1}	Test weight (g)
Herbicides + Adjuvant				
H_1	1.21	17.30	14.98	24.0
H_2	1.29	17.66	14.98	24.4
H_3	1.06	15.98	14.18	22.5
H_4	1.10	16.79	14.69	22.9
H_5	1.47	18.40	15.04	25.0
H_6	1.68	18.94	15.24	25.5
SEm±	0.04	0.48	0.43	0.80
CD (P=0.05)	0.12	1.37	NS	NS
Quality of spray fluid				
W_1	1.25	17.38	14.80	23.9
W_2	1.23	17.09	14.66	23.7
W_3	1.43	18.05	15.10	24.6
SEm±	0.03	0.34	0.30	0.57
CD (P=0.05)	0.09	NS	NS	NS
H × W				
SEm±	0.07	0.83	0.75	1.39
CD (P=0.05)	NS	NS	NS	NS
Control vs Rest				
C_1	1.00	14.77	14.27	21.0
C_2	2.00	19.52	16.20	26.1
SEm±	0.05	0.62	0.56	1.04
CD (P=0.05)	0.11	1.25	NS	2.10

Number of grains cob^{-1} and grain weight cob^{-1} (Table 2) were significantly influenced by different herbicides + adjuvant treatments and quality of spray fluids and their interactions. Significantly highest no. of grains cob^{-1} (481.00) and grain weight cob^{-1} (125.05 g) were recorded with tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% at 21 DAS with distilled water as spray fluid and the above results might be attributed to higher weed control efficiency because of application of adjuvant with herbicide combination and use of distilled water as spray fluid increased the transfer of herbicide to the target site within the plant system and increased toxicity to the weeds which resulted in lower weed dry weight and better translocation of assimilates to the cobs and ultimately showed increase in no. of grains cob^{-1} and grain weight cob^{-1}. Improved penetration and enhanced phytotoxicity of herbicides improved weed control when herbicides used in combination with urea (as adjuvant) solution (Singh and Singh 2003; Bunting *et al*., 2004).

Among herbicides + adjuvant and saline waters combinations, tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% at 21 DAS with C_3S_1 saline water as spray fluid recorded significantly higher no. of grains cob^{-1} and grain weight cob^{-1} (458.33 and 116.32 g respectively) compared to other saline water combinations.

Significant influence on maize yield was observed with different herbicides + adjuvant and quality of spray fluid treatments and are presented in (Table 3). Harvest index (HI), is the proportion of percentage of grain yield to total biomass, and this can be used as a measure of reproductive efficiency. Therefore, HI is considered as novel trait to target for increasing yield potentials. Among herbicides + adjuvant combinations (Table 4), tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% at 21 DAS and tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} alone at 21 DAS resulted in highest HI (38.32% and 37.37% respectively). Among the quality of spray carriers, use of distilled water as spray carrier resulted in significantly maximum HI (35.80%). The interactions between different herbicides + adjuvants and quality of spray carriers were non-significant with reference to harvest index.

Table 2: Effect of herbicides + adjuvant and quality of spray fluids on yield attributes (no. of grain cob^{-1} and grain weight cob^{-1}) of maize.

Herbicides + adjuvant	No. of grains cob^{-1}				Grain weight cob^{-1}(g)			
	Quality of spray fluid				Quality of spray fluid			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
H_1	382.67	369.33	419.67	390.56	91.51	87.39	103.56	94.15
H_2	404.13	398.00	448.33	416.82	98.40	95.41	112.11	101.97
H_3	312.00	297.00	349.33	319.44	69.86	65.75	80.66	72.09
H_4	335.00	327.33	352.33	338.22	76.46	74.14	82.12	77.57
H_5	431.00	423.67	474.80	443.16	107.17	104.48	122.03	111.23
H_6	458.33	451.67	481.00	463.67	116.32	113.98	125.05	118.45
Mean	387.19	377.83	420.91		93.29	90.19	104.25	
Control 1				204.43				42.93
Control 2				490.00				127.75
	H	W	H x W	Control vs Rest	H	W	H x W	Control vs Rest
SEm±	2.78	1.97	4.82	3.59	0.83	0.58	1.43	1.07
CD (P=0.05)	7.96	5.63	13.79	7.27	2.30	1.67	4.09	2.16

Table 3: Yield (q ha^{-1}) in maize as influenced by herbicides + adjuvant and quality of spray fluids.

Herbicides + adjuvant	Grain yield (q ha^{-1})				Stover yield (q 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	35.42	32.23	43.50	37.05	69.25	65.76	76.98	70.67
H_2	40.19	39.43	48.75	42.79	73.50	72.72	81.19	75.80
H_3	21.82	18.73	28.67	23.07	54.63	54.54	61.99	57.06
H_4	25.34	24.99	29.01	26.45	58.50	58.07	62.33	59.64
H_5	45.08	44.49	53.91	47.83	77.64	77.24	85.01	79.96
H_6	50.06	49.47	54.82	51.45	81.54	81.40	85.47	82.80
Mean	36.32	34.89	43.11		69.18	68.29	75.49	
Control 1				15.68				53.02
Control 2				55.80				85.77
	H	W	H × W	Control vs Rest	H	W	H × 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

Table 4: Effect of herbicides + adjuvant and quality of spray fluids on harvest index (%) in maize.

Herbicides + Adjuvant	
H_1	34.25
H_2	36.00
H_3	28.57
H_4	30.64
H_5	37.37
H_6	38.32
SEm±	0.48
CD (P=0.05)	1.37
Quality of spray fluid	
W_1	33.78
W_2	33.00
W_3	35.80
SEm±	0.34
CD (P=0.05)	0.97
H × W	
SEm±	0.83
CD (P=0.05)	NS
Control vs Rest	
C_1	22.83
C_2	39.42
SEm±	0.62
CD (P=0.05)	1.25

Nutrient uptake. The data on nutrient uptake by grain and stover (N, P and K) were recorded after harvest of maize by multiplying the nutrient content with grain and stover yield respectively (Table 3).

(a) Nutrient uptake by grain. Among different herbicides + adjuvant and quality of spray carriers combinations (Table 5), significantly higher N, P and K uptake by grain (75.11 kg ha^{-1}, 12.34 kg ha^{-1} and 54.06 kg ha^{-1} respectively) was recorded with halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% at 21 DAS with distilled water as spray fluid and on par with halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} at 21 DAS with distilled water as spray fluid and was statistically significant over other treatment combinations which could be due to the effective weed control provided a competition free environment and improved physical, biological condition of the soil, which led to increased growth of crop and thereby increase in nutrient uptake by increasing the grain yield of maize. The results are inconformity with those reported by Birendra Kumar *et al*. (2017).

(b) Nutrient uptake by stover. The results showed (Table 6) that nutrient uptake by stover was significantly influenced by different herbicides + adjuvants and quality of spray carriers. Among different herbicides+ adjuvant and quality of spray carriers combinations, halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% at 21 DAS with distilled water as spray fluid recorded significantly higher N, P and K uptake (74.97 kg ha^{-1}, 9.42 kg $ha^{-1}$and 84.04 kg ha^{-1}) and on par with halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} at 21 DAS with distilled water as spray fluid and was statistically significant over other treatment combinations.

In addition, halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% at 21 DAS with C_3S_1water as spray fluid resulted in higher nutrient uptake in grain and stover compared to other herbicides combinations with saline waters. When unweeded check (control 1) versus other treatments was considered, nutrient uptake (N, P and K) in maize was significantly lowest. The lowest nutrient uptake in unweeded control was due to poor dry matter yield and grain yield of crop and reduced nutrient uptake because of heavy weed competition (Shravan Kumar *et al*., 2019).

Soil chemical properties. Soil analysis was done after the harvest of the crop and the data are presented in Table 7. The data indicated that the soil chemical parameters after harvest of crop did not differ much and thus failed to show significant difference among different herbicides + adjuvant treatments and quality of spray fluids used and between their treatment combinations. However, the values of pH, EC, OC, available N, P and K ranged from 7.75 to 8.13, 0.47 to 0.57 dS m^{-1}, 0.46 to 0.56%, 184.68 to 217.80 kg ha^{-1}, 7.28 to 9.10 kg ha^{-1} and 202.08 to 236.65 kg ha^{-1} respectively.

Table 5: N, P and K uptake (kg ha^{-1}) by grain at harvest of maize as influenced by herbicides + adjuvant and quality of spray fluids.

Herbicides + adjuvant	Grain uptake (kg ha^{-1})											
	Quality of spray fluid											
	Nitrogen				Phosphorus				Potassium			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
H_1	54.42	49.80	64.76	56.33	8.14	7.23	10.06	8.48	41.18	38.55	47.12	42.28
H_2	60.01	59.12	69.39	62.84	9.16	9.04	11.13	9.78	44.46	43.48	50.33	46.09
H_3	36.44	32.30	45.07	37.93	4.36	4.35	6.22	4.98	29.95	27.32	35.35	30.87
H_4	40.80	40.75	45.40	42.32	5.32	5.26	6.33	5.64	32.72	32.58	35.92	33.74
H_5	65.24	64.80	74.78	68.27	10.23	10.17	12.19	10.86	47.61	47.42	53.72	49.58
H_6	70.22	69.77	75.11	71.70	11.27	11.21	12.34	11.61	51.09	50.80	54.06	51.98
Mean	54.52	52.76	62.42		8.08	7.88	9.71		41.17	40.02	46.08	
Control 1				30.05				3.80				23.79
Control 2				77.44				12.95				55.97
	H	W	HxW	Control vs Rest	H	W	HxW	Control vs Rest	H	W	HxW	Control vs Rest
SEm±	0.83	0.59	1.43	1.07	0.14	0.10	0.25	0.18	0.48	0.34	0.83	0.62
CD (P=0.05)	2.37	1.68	4.11	2.16	0.41	0.29	0.71	0.37	1.38	0.97	2.39	1.26

Table 6: N, P and K uptake (kg ha^{-1}) by stover at harvest of maize as influenced by herbicides + adjuvant and quality of spray fluids.

Herbicides + adjuvant	Stover uptake (kg ha^{-1})											
	Quality of spray fluid											
	Nitrogen				Phosphorus				Potassium			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
H_1	51.78	46.64	62.90	53.77	6.53	6.01	7.67	6.74	59.81	57.81	71.33	62.99
H_2	57.77	56.98	68.99	61.24	7.19	7.03	8.46	7.56	65.59	65.22	77.94	69.58
H_3	28.96	28.16	41.04	32.72	4.33	4.18	5.45	4.65	39.91	38.40	52.11	43.47
H_4	35.80	34.16	41.54	37.17	4.93	4.85	5.53	5.10	46.64	45.28	52.37	48.10
H_5	63.81	63.01	74.67	67.17	7.86	7.81	9.37	8.35	72.45	71.71	83.85	76.00
H_6	69.47	69.16	74.97	71.20	8.80	8.59	9.42	8.94	78.27	78.17	84.04	80.16
Mean	51.26	49.69	60.68		6.61	6.41	7.65		60.44	59.43	70.27	
Control 1				25.56				3.88				35.51
Control 2				76.28				9.81				85.94
	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±	0.83	0.58	1.43	1.07	0.09	0.07	0.16	0.12	0.77	0.55	1.34	1.00
CD (P=0.05)	2.37	1.67	4.10	2.16	0.26	0.19	0.46	0.24	2.21	1.56	3.83	2.02

Table 7: Effect of herbicides + adjuvant and quality of spray fluids on soil chemical properties after harvest of maize.

Treatments	pH	EC (dS m^{-1})	OC (%)	Available N(kg ha^{-1})	Available P(kg ha^{-1})	Available K(kg ha^{-1})
Herbicides + Adjuvant						
H_1	7.89	0.52	0.51	195.56	7.98	223.38
H_2	7.86	0.55	0.49	197.80	8.17	226.40
H_3	8.05	0.54	0.48	188.03	7.51	212.22
H_4	8.05	0.57	0.51	189.79	7.63	215.16
H_5	8.05	0.53	0.49	203.45	8.41	230.29
H_6	7.93	0.55	0.52	204.42	8.69	232.73
SEm±	0.21	0.024	0.026	7.58	0.37	7.63
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Quality of spray fluid						
W_1	7.99	0.54	0.53	195.07	8.00	222.63
W_2	7.99	0.53	0.46	193.74	7.91	220.66
W_3	7.95	0.56	0.51	200.72	8.28	226.80
SEm±	0.15	0.017	0.018	5.36	0.26	5.40
CD (P=0.05)	NS	NS	NS	NS	NS	NS
H × W						
SEm±	0.37	0.042	0.045	13.12	0.65	13.22
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Control vs Rest						
C_1	8.13	0.49	0.56	184.68	7.28	202.08
C_2	7.75	0.47	0.49	217.80	9.10	236.65
SEm±	0.28	0.031	0.033	9.78	0.48	9.85
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Initial	7.84	0.62	0.69	220.77	9.38	351.18

CONCLUSION

It was concluded from the field investigation conducted during *rabi* 2020-21 that the herbicide efficacy can be improved when saline waters (C_3S_1 class water) were used as spray fluids with tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5kg ha^{-1}along with 2% ammonium sulphate as PoE and efficient weed control in maize can be obtained without any phytotoxic effect in areas where there is shortage of labour and high cost of labour for manual weeding.

FUTURE SCOPE

There is a need to take up the bioassay studies to find out the residual effect of herbicides and quality of spray fluids on soil and soil microbial activity can also be studied further.

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