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K Bhavitha
M.Sc. Student, Department of Agronomy, Agricultural University, College of Agriculture, Rajendranagar, Hyderabad, Telangana, India

Dr. K Suresh
Professor, Department of Agronomy, O/o COE, Examination Center, Rajendranagar, Hyderabad, Telangana, India

Dr. M Madhavi
Senior Professor, Department of Agronomy, Associate Dean, Agricultural College, Aswaraopeta, PJTSAU, Kothagudem, Telangana, India

Dr. T Ram Prakash
Principal Scientist and Head, AICRP on Weed Management, College of Agriculture, Rajendranagar, Hyderabad, Telangana, India

Corresponding Author:
K Bhavitha
M.Sc. Student, Department of Agronomy, Agricultural University, College of Agriculture, Rajendranagar, Hyderabad, Telangana, India

Growth parameters of Maize (*Zea mays* L.) and weed control efficiency of post-emergence herbicides as influenced by quality of spray fluid

K Bhavitha, Dr. K Suresh, Dr. M Madhavi and Dr. T Ram Prakash

Abstract
The effect of post-emergence herbicides + adjuvants and quality of spray fluid combinations on growth parameters of maize (*Zea mays* L.) and weed control efficiency (WCE) was studied in an field experiment conducted during *rabi* 2020-21 at College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad. The results revealed that there is a negative influence on weed control efficiency and growth parameters of maize when saline waters (C_3S_1 and C_3S_2) were used as spray fluid in combination with herbicides + adjuvant (ammonium sulphate). Among chemical treatments, halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} with AMS @ 2% with distilled water as spray fluid followed by halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} alone with distilled water recorded higher growth parameters and WCE. Whereas, the lowest WCE and growth parameters were recorded with 2,4-D-Dimethyl amine @ 0.5 kg ha^{-1} alone with C_3S_2 water as spray fluid. Significantly higher WCE (%) and growth parameters were recorded in HW at 20 and 40 DAS. Distilled water as spray fluid with all the herbicide combinations recorded higher WCE and growth parameters in maize as compared to class C_3S_1 and C_3S_2 water as spray fluids.

Keywords: Maize, growth parameters, halosulfuron + atrazine, ammonium sulphate, distilled water, C_3S_1, C_3S_2 class spray fluid

Introduction
Maize (*Zea mays*) is one of the major cereal crops and stands first in production among cereals in the world. It is also known as "queen of cereals". The global consumption pattern of maize is feed-61%, industry-22% andfood-17%. In India, maize ranks third after rice and wheat and is grown for grain as well as fodder purpose. In India about 15 million farmers are engaged in maize cultivation. To meet the demand according to growing national consumption pattern, India would require about 45 M Mt of maize by 2022 (Source: Maize Vision, 2022) [4]. For the purpose of achieving the above scenario by 2022, there is need for increase in productivity of maize in India. There are several agronomic constraints for low productivity of maize. Among all other constraints, weeds constitute one of the major economic important problem for maize growers and it can reduce yield upto 65-83% if weeding is done after critical period of crop weed competition (Anwesh Rai *et al*., 2018) [1]. Although farmers use herbicides for efficient control of weeds, its efficiency is achieved only if quality of spray carrier is superior. Water is the primary herbicide carrier solvent and is a critical component for herbicide applications. Quality of water plays an important role for optimum performance of the herbicides. Herbicide performance has been inconsistent with variation of carrier water quality (Nalewaja and Matsyiak, 1991) [6].

Hard water is caused by the presence of calcium and magnesium bicarbonates, sulphates, chlorides and nitrates. These ions can interfere with chemicals by the process of inactivation, breakdown or precipitation. The neutralization or inactivation of hard water cations is possible by addition of a suitable adjuvant to the spray tank. 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) is most popularly used which reduces the antagonist effect of hard water cations and improve efficacy of herbicides. It conditions water by reacting with the dissolved cations to form insoluble sulfates that will not react with the herbicide and is recommended in most areas with hard water (Hartzler, 2001) [3].

Material and Methods

A field experiment was conducted during *rabi* 2020-21 at College farm, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad with twenty treatments, laid out in factorial randomized block design with three replications. The soil of the research field was sandy loam in texture with 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}). Total rainfall received during crop growth period was 18.8 mm with weekly maximum temperature ranging from 26.4^{0}C to 35.1^{0}C and minimum temperature ranging from 10.9^{0}C to 17.6^{0}C.

The experimental treatments comprised of twenty with two factors, factor 1 (herbicides + adjuvant) with 6 levels included were 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 factor 2 (quality of spray fluid) with 3 levels included were 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).

The maize cultivar sown was 'DHM-117' 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: 60: 60 kg ha^{-1} N, P_2O_5 and K_2O in the form of urea, di- ammonium phosphate (DAP) and muriate of potash (MOP) respectively. Post-emergence herbicides was applied at 21 DAS *i. e*., at 2-3 leaf stage of weeds using knapsack sprayer with flat fan nozzle predominantly on weeds with different qualitites of spray fluids prepared in laboratory. The data of weed parameters was recorded using 1.0 m × 1.0 m quadrat at 30 and 60 DAS. Statistical significance was tested by F–value at 0.05 level of probability and critical difference was worked out where ever the effects were significant.

Weed control efficiency (%) was calculated using formula suggested by Mani *et al*. (1973) [5].

$$WCE\ (\%) = \frac{DMc - DMt}{DMc} \times 100$$

DMc- Dry matter of weeds in the weedy check (g m^{-2})
DMt- Dry matter of weeds in the treated plots (g m^{-2})

Results and Discussion

Weed flora

The major weed flora noticed in the experimental field were *Cyperus rotundus* L., *Cynodon dactylon* L., *Digitaria sanguinalis* L., *Dactyloctenium aegyptium* L., *Echinocloa spp* L., *Eleusine indica* L., *Euphorbia hirta* L., *Parthenium hysterophorus* L., *Commelina benghalensis* L., *Celosia argentia* L., *Trianthema portulacastrum* L., *Cleome viscosa* L. and *Digera arvensis* L. The weed flora recorded in this investigation were also reported by Swetha *et al*. (2018) [9] in their study in sandy loam soils of Rajendranagar.

Weed control efficiency (%)

The weed control efficiency indicates the efficiency of the applied herbicide or weed control practices. It expresses the percentage reduction in weed dry matter of weed control treatments in comparison to weedy check. Persual of data on WCE (%) at 30, 60 and 90 DAS (Table 1) indicated that higher WCE was recorded with hand weeding at 20 and 40 DAS followed by tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% at 21 DAS as PoE with distilled water as spray fluid and tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1}alone at 21 DAS as PoE with distilled water as spray fluid. The lower WCE was recorded with 2, 4- D-Dimethyl amine @ 0.5 kg ha^{-1} with C_3S_2 water as spray fluid which might be due to the application of herbicide with C_3S_2 spray fluid in the absence of adjuvant reduced the toxicity of herbicide to weeds because of hard water cations and increased the weed dry matter compared to herbicide application with adjuvant. These results are in accordance with findings of Geoffrey and Aaron (2019) and Roskamp *et al.* (2013) [2, 7].

Growth parameters

The data on growth parameters were recorded at 30 days interval till harvest of the crop. The difference in growth parameters were statistically non-significant at 30 DAS and significant at 60, 90 DAS and at harvest among the treatments and between treatment combinations.

At 30 DAS, there was no significant difference in growth parameters between the treatments among both the factors (herbicides + adjuvant and quality of spray fluids) and two controls and this might be due to application of PoE herbicides at 21 DAS *i.e*., 2-3 leaf stage of the weeds which did not show much influence on growth parameters of maize immediately after application (Table 2).

Highest plant height (Table 3), leaf area (Table 4) and dry matter production (Table 5) at 60 and 90 DAS was recorded with tank mix application of halosulfuron methyl @ 67.5 g ha $^{-1}$ + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% with distilled water as spray fluid (H_6W_3) and superior to other treatment combinations and this could be attributed to broad spectrum control of weeds and reduced crop weed competition in the early stages of the crop due to application of adjuvant (AMS) and use of distilled water (hard water cations free) as spray carrier increased the herbicide efficacy by increasing the penetration of herbicide into the weed leaves and ultimately reflected in higher growth parameters. Ammonium ion of AMS increases the foliar absorption and trans-cuticular movement of the herbicides and increases herbicide efficacy and reflects in growth parameters as reported by Roskamp *et al*. (2013) [7] and lowest growth parameters were recorded with 2,4-D-Dimethyl amine @ 0.5 kg ha^{-1}alone with C_3S_2 class spray fluid. The similar findings of higher dry matter production in maize crop were also reported by Rasool and Khan (2016) [8].

At harvest, also highest plant height and dry matter production were recorded with tank mix application of halosulfuron methyl @ 67.5 g ha $^{-1}$ + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% with distilled water as spray fluid (H_6W_3) and

superior to other treatment combinations and data on leaf area at harvest (Table 2) revealed that different herbicides + adjuvant and quality of spray fluid have a significant influence but their interaction effects were non-significant. The leaf area at harvest was reduced compared to 90 DAS in all the treatments which might be due to devoid of physiological processes at the time of harvest makes the leaves tend to dryup resulting in lower leaf area. HW at 20 and 40 DAS recorded maximum leaf area and superior to other treatments. Whereas in different herbicides + adjuvant treatments, tank mix application of halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% at 2-4 leaf stage of weeds as PoE recorded maximum leaf area and statistically significant over other treatments. Under quality of spray fluids, maximum leaf area was observed with use of distilled water as spray fluid and found to be superior over spray fluids of class C_3S_1 and C_3S_2. Among all the herbicidal combinations, 2,4-D-Dimethyl amine @ 0.5 kg ha^{-1} alone with C_3S_2class water as spray fluid recorded lowest WCE and growth parameters.

Table 1: Effect of herbicides + adjuvant and quality of spray carriers on weed control efficiency (WCE %) at 30, 60 and 90 DAS in maize

Treatments	30 DAS	60 DAS	90 DAS
H_1W_1	65.05	47.84	39.74
H_1W_2	56.01	39.96	33.03
H_1W_3	83.31	64.73	57.30
H_2W_1	77.57	54.96	49.82
H_2W_2	74.64	52.12	47.54
H_2W_3	85.86	73.33	60.55
H_3W_1	47.66	29.69	31.05
H_3W_2	41.61	38.10	29.24
H_3W_3	65.90	50.77	46.96
H_4W_1	57.21	49.53	43.03
H_4W_2	51.30	45.90	41.67
H_4W_3	66.90	55.73	50.11
H_5W_1	75.71	62.67	54.29
H_5W_2	74.17	59.02	53.61
H_5W_3	89.49	79.56	74.08
H_6W_1	83.72	70.26	62.80
H_6W_2	81.97	69.58	61.94
H_6W_3	91.45	80.42	75.16
C_1	-	-	-
C_2	95.49	88.42	83.53

Table 2: Effect of herbicides + adjuvant and quality of spray carriers on growth parameters in maize at 30 DAS

Treatments	Plant height (cm)	Leaf area (cm^2) at 30 DAS	Leaf area (cm^2) at harvest	Dry matter production (kg ha^{-1})
Herbicides + Adjuvant				
H_1	31.11	206.33	1394.88	204
H_2	31.57	211.63	1484.07	207
H_3	30.99	199.60	1262.65	198
H_4	31.16	208.49	1297.66	200
H_5	31.00	201.16	1522.38	208
H_6	31.28	209.94	1619.08	210
S.Em±	0.91	6.25	30.24	6.49
CD (P=0.05)	NS	NS	86.57	NS
Water Quality				
W_1	31.27	207.51	1411.50	204
W_2	31.01	202.48	1391.12	203
W_3	31.28	208.58	1487.74	207
S.Em±	0.64	4.42	21.39	4.59
CD (P=0.05)	NS	NS	61.21	NS
H × W				
S.Em±	1.57	10.83	52.39	11.24
CD (P=0.05)	NS	NS	NS	NS
Control vs Rest				
C_1	31.30	198.00	1141.34	194
C_2	31.60	216.22	1702.61	212
S.Em±	1.17	8.07	39.05	8.38
CD (P=0.05)	NS	NS	79.03	NS

Table 3: Effect of herbicides + adjuvant and quality of spray carriers on plant height (cm) in maize at 60, 90 DAS and at harvest

Herbicide + adjuvant	60 DAS				90 DAS				At harvest			
	Water Quality				Water Quality				Water Quality			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
H_1	120.65	113.66	136.33	123.55	194.00	181.67	221.64	199.10	198.00	185.33	225.00	202.78
H_2	129.19	127.65	146.45	134.43	208.31	206.90	236.76	217.32	212.31	210.23	239.76	220.77

H_3	90.85	83.94	105.79	93.53	144.94	132.61	169.48	149.01	148.27	137.27	173.15	152.90
H_4	98.79	97.74	106.66	101.06	157.41	156.94	169.57	161.31	162.00	160.93	173.90	165.61
H_5	139.45	138.02	155.85	144.44	224.51	222.23	250.46	232.40	228.18	226.00	254.12	236.10
H_6	148.85	147.00	157.07	150.97	237.96	237.83	252.87	242.89	241.29	240.17	255.54	245.66
Mean	121.30	118.00	134.69		194.52	189.70	216.80		198.34	193.32	220.25	
Control 1				79.93				126.27				130.61
Control 2				161.35				259.60				262.26
	H	W	H x W	Control vs Rest	H	W	H x W	Control vs Rest	H	W	H x W	Control vs Rest
S.Em±	1.27	0.89	2.19	1.63	2.34	1.65	4.05	3.02	2.25	1.59	3.90	2.91
CD (P=0.05)	3.62	2.56	6.27	3.31	6.69	4.73	11.59	6.11	6.45	4.56	11.17	5.88

Table 4: Effect of herbicides + adjuvant and quality of spray carriers on leaf area (cm^2) in maize at 60 and 90 DAS

Herbicides + adjuvant	**60 DAS**				**90 DAS**			
	Water Quality				**Water Quality**			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
H_1	2099.52	1949.53	2405.55	2151.53	3618.14	3436.81	4068.42	3707.79
H_2	2264.23	2240.52	2600.09	2368.28	3866.42	3823.14	4300.25	3996.60
H_3	1506.94	1364.12	1800.96	1557.34	2813.20	2641.20	3200.23	2884.88
H_4	1657.63	1646.61	1810.52	1704.92	3028.57	2986.53	3265.14	3093.41
H_5	2443.43	2413.27	2783.85	2546.85	4102.24	4082.77	4555.24	4246.75
H_6	2640.51	2619.84	2855.27	2705.21	4385.24	4313.55	4560.56	4419.79
Mean	2102.04	2038.98	2376.04		3635.63	3547.33	3991.64	
Control 1				1251.95				2542.20
Control 2				2951.42				4671.31
	H	W	H x W	Control vs Rest	H	W	H x W	Control vs Rest
S.Em±	24.60	17.39	42.60	31.75	33.58	23.74	58.15	43.35
CD (P=0.05)	70.40	49.78	121.94	64.27	96.11	67.96	166.46	87.73

Table 5: Effect of herbicides + adjuvant and quality of spray carriers on dry matter production (kg ha^{-1}) in maize at 60, 90 DAS and at harvest

Herbicides + Adjuvant	**60 DAS**				**90 DAS**				**At harvest**			
	Water Quality				**Water Quality**				**Water Quality**			
	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean	W_1	W_2	W_3	Mean
H_1	2364	2210	2712	2429	7558	7178	8177	7638	11405	10698	12655	11586
H_2	2567	2517	2930	2671	7891	7842	8499	8077	12013	11949	13399	12454
H_3	1666	1508	2017	1730	6330	6046	6939	6438	8729	8457	10015	9067
H_4	1855	1826	2066	1916	6654	6610	6992	6752	9374	9365	10057	9599
H_5	2775	2734	3174	2894	8216	8198	8847	8420	12691	12657	14033	13127
H_6	3029	2975	3253	3086	8567	8501	8866	8644	13501	13447	14084	13677
Mean	2376	2295	2692		7536	7396	8053		11286	11095	12374	
Control 1				1383				5899				7996
Control 2				3353				9013				14175
	H	W	H x W	Control vs Rest	H	W	H x W	Control vs Rest	H	W	H x W	Control vs Rest
S.Em±	24.45	17.29	42.35	31.57	54.91	38.82	95.10	70.88	111.37	78.75	192.91	143.78
CD (P=0.05)	69.99	49.49	121.22	63.89	157.16	111.13	272.21	143.47	318.79	225.42	552.17	291.02

Conclusions

Among all the treatments, tank mix application of PoE herbicides halosulfuron methyl @ 67.5 g ha^{-1} + atrazine @ 0.5 kg ha^{-1} + AMS @ 2% with distilled water as spray fluid proved to be effective in weed control. Distilled water as spray fluid proved to be effective in increasing the herbicide efficacy compared to class C_3S_1 and C_3S_2 water as spray fluids and showed increased growth parameters. Though hand weeding at 20 and 40 DAS recorded maximum growth parameters and WCE but realized maximum cost of cultivation compared to herbicidal treatments.

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