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

ABSTRACT

A field investigation was conducted during *Rabi* season of 2020-21 at Professor JayashankarTelangana State Agricultural University, Rajendranagar, Hyderabad to assess the herbicide efficacy as influenced by spray fluid quality and adjuvants on yield and economics of maize (*Zea mays* L.). 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 fluidascompared to application of herbicides with saline waters alone. Tank mix application of halosulfuron methyl at 67.5 g $ha^{-1}$ + atrazine at 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 tons $ha^{-1}$) and economics of maize with reference to other saline water treatment combinations and proved as effective treatment following to halosulfuron methyl at 67.5 g $ha^{-1}$ + atrazine at 0.5 kg $ha^{-1}$ with 2%ammonium sulphate with distilled water as spray fluid.

**KEYWORDS:**Adjuvant, Economics, Maize, Spray fluid quality, Yield.

## 1. INTRODUCTION

Maize (*Zea mays*L.) is one of the major cereal crops and is also known as “Miracle crop”.In India,maize is grown asgrain and fodder crop and ranks 5$^{th}$ in area (9.18 million ha) and 3$^{rd}$in production (27.23 million tons) with an average productivity of 2965 kg $ha^{-1}$ during the year 2018-19 **(Agricultural Statistics at Glance, 2019)**. InIndia, maize ranks third after rice and wheat. Weeds constitute one of the major economic problems 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.

The 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 and 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 underhigh 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 (AMS) is most popularly used which reduces the antagonist effect of hard water cations and improve efficacy of herbicides.

## 2. 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 *viz.*, $H_1$: 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 (AMS) at 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, $H_4$: post-emergence application of 2,4-D-Dimethyl amine 58% SL 0.5 kg $ha^{-1}$ + ammonium sulphate at 2% as adjuvant, $H_5$: 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 and $H_6$: post-emergence application of halosulfuron methyl 75% WDG 67.5 g $ha^{-1}$ + atrazine 50% WP 0.5 kg $ha^{-1}$ + ammonium sulphate at 2% as adjuvant as tank mix and 3 levels of quality of spray fluids 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 days after sowing (DAS) were evaluated in factorial randomized block design with three replications. Different spray fluids were prepared in the laboratory by dissolving different proportions of 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 $P_2O_5$ + 60 kg $K_2O$ $ha^{-1}$ in the form of urea, di- ammonium phosphate and muriate of potash respectively. Post-emergence herbicides were applied at 21 days after sowing (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.

## 3. 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 at 67.5 g $ha^{-1}$ + atrazine at 0.5 kg $ha^{-1}$ + 2% AMS at 21 DAS resulted in statistically maximum grain yield (5.14 tons $ha^{-1}$) 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 tons $ha^{-1}$). With regard to interaction, significantly higher grain yield (5.48 tons $ha^{-1}$) was recorded with tank mix application halosulfuron methyl at 67.5 g $ha^{-1}$ + atrazine at 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 at 67.5 g $ha^{-1}$ + atrazine at 0.5 kg $ha^{-1}$ + 2% AMS at 21 DAS recorded significantly maximum stover yield (8.28 tons $ha^{-1}$). Among the quality of spray fluids, maximum stover yield (7.54 tons $ha^{-1}$) 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 at 67.5 g $ha^{-1}$ + atrazine at 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 **VasudevMeena*et al.* (2019).**

Compared to other herbicides and saline water combinations, halosulfuron methyl at 67.5 g $ha^{-1}$ + atrazine at 0.5 kg $ha^{-1}$ + 2% AMS at 21 DAS with $C_3S_1$water as spray fluid resulted in higher grain and stover yield (5.00 and 8.15 tons $ha^{-1}$ respectively).

**Economics:**

The results showed that different herbicides + adjuvant treatments and quality of spray fluids and their interactions showed significant influence on economics (Table 2). Tank mix application of halosulfuron methyl at 67.5 g $ha^{-1}$ + atrazine at 0.5 kg $ha^{-1}$ + 2% AMS at 21 DAS with distilled water as spray fluid received maximum gross returns (124.87× $10^3$₹ $ha^{-1}$), net returns (85.03 × $10^3$₹ $ha^{-1}$) 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 at 67.5 g $ha^{-1}$ + atrazine at 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.

## 4. Conclusion

The field experiment conducted during *rabi*season of 2020-21 concluded that tank mix application of halosulfuron methyl at 67.5 g $ha^{-1}$ + atrazine at 0.5 kg $ha^{-1}$ + 2% AMS at 21 DAS (days after sowing) with $C_3S_1$ water as spray fluid following to halosulfuron methyl at 67.5 g $ha^{-1}$ + atrazine at 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 treatmentsindicating that control of weeds through hand weeding was more expensive than the use of herbicides in maize.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that no competing interests exist.

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**Table 1.Effect of herbicides + adjuvant and quality of spray fluids on grain and stover yield of maize**

| Herbicides + adjuvant | Grain yield (tons $ha^{-1}$) | | | | Stover yield (tons $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 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

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

$H_5$: 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 (×$10^3$ ₹ $ha^{-1}$) of different herbicides + adjuvant and quality of spray fluid treatments in maize**

| Herbicides + adjuvant | Gross returns (×$10^3$₹ $ha^{-1}$) | | | | Net returns (×$10^3$₹ $ha^{-1}$) | | | | 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 |
| $H_1$ | 83.57 | 77.10 | 100.12 | 86.93 | 44.89 | 38.41 | 61.43 | 48.24 | 2.16 | 1.99 | 2.59 | 2.25 |
| $H_2$ | 93.13 | 91.53 | 111.56 | 98.74 | 54.29 | 52.69 | 72.72 | 59.90 | 2.40 | 2.36 | 2.87 | 2.54 |
| $H_3$ | 54.98 | 48.80 | 69.73 | 57.84 | 19.29 | 13.11 | 34.05 | 22.15 | 1.54 | 1.37 | 1.95 | 1.62 |
| $H_4$ | 63.31 | 62.47 | 70.01 | 65.27 | 27.47 | 26.64 | 34.18 | 29.43 | 1.77 | 1.74 | 1.95 | 1.82 |
| $H_5$ | 103.58 | 102.51 | 123.03 | 109.71 | 63.89 | 62.82 | 83.34 | 70.02 | 2.61 | 2.58 | 3.10 | 2.76 |
| $H_6$ | 114.32 | 113.09 | 124.87 | 117.43 | 74.48 | 73.25 | 85.03 | 77.59 | 2.87 | 2.84 | 3.13 | 2.95 |
| Mean | 85.48 | 82.58 | 99.89 | | 47.39 | 44.49 | 61.79 | | 2.22 | 2.15 | 2.60 | |
| Control 1 | | | | 41.91 | | | | 7.31 | | | | 1.21 |
| Control 2 | | | | 126.78 | | | | 79.68 | | | | 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 |