# Evaluating herbicides bio-efficacy on ~~sweet sorghum~~ yield, quality parameters of sweet sorghum and their residual effects on soil microbial diversity


## ABSTRACT

An experiment was carried out at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat). The aim of the research is to evaluate herbicides bio-efficacy on sweet sorghum yield, quality parameters and their residual effects on soil microbial diversity. ~~The sweet sorghum (SSV 84) was sown with standard package of practices.~~ The ~~H~~higher grain yield and fodder yield (kg $ha^{-1}$), reducing, non-reducing sugars and total sugar in juice were recorded under weed-free conditions ($T_9$), which was statistically at par with the treatments ~~comparable to~~ IC & HW at 15 and 30 DAS ($T_8$), PE application of atrazine 50 WP 500 g/ha *fb* mesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, ($T_7$) and PE application of atrazine 50 WP 500 g/ha + IC & HW ($T_1$). Before sowing, no significant differences in microbial population were observed. At 20 days after herbicide application, the un weeded control ($T_{10}$) had the highest microbial population, similar to weed-free and manual weeding treatments. Herbicide-treated plots had lower microbial populations. ~~By~~ at harvest, the highest microbial population was found in atrazine 50 WP 500 g/ha (PE) followed by tembotrione 42 SC 100 g/ha (PoE) which remained statistically at par with the rest of herbicidal treatments. ~~While the lowest was in atrazine 50 WP 500 g/ha (PE) followed by inter cultivation and hand weeding.~~



*Keywords: [Sweet sorghum, Herbicide, Weed management, Microbial population, Bioassay, Herbicide Residue]*


## 1. INTRODUCTION

In India, sweet sorghum shares about 0.002 per cent area out of total sorghum area. ~~The high WUE and low N requirements of sorghum also provide significant advantages to the growers, because sorghum fits into a normal rotation scheme with corn and soybeans, yet has lower production costs and employs similar production equipment.~~ Its ratooning ability enables multiple harvests per season, a feature that could expand the geographical range of sorghum cultivation. The grain, stalk juice and bagasse can be used to produce food, fodder, ethanol and power. Owing to these favorable attributes, [1] refers to it as a SMART crop. It is known as the sugarcane of the desert and also ''the camel among crops'' for its drought hardy characteristics [2]. These important characteristics, along with its suitability for seed propagation, mechanized crop production and comparable ethanol production capacity vis-a-vis sugarcane and sugar beet makes sweet sorghum a viable alternative source for ethanol production.

Among the various biotic factors limiting sweet sorghum production and productivity, weeds are of prime importance. [3] reported that plant density and weed management are among the main factors affecting growth, sugar and forage yields of sweet sorghum. In

**Comment [DSKC1]:** Write grain yield ( .... kg $ha^{-1}$)

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India, presence of weeds in general reduces crop yields by 37 - 45% and in some cases can cause complete crop failure, when compared to 25% due to diseases, 20% due to insects, 15% due to storage and miscellaneous pests [4]. To prevent yield losses, weeds have to be controlled at critical periods during the crop growth cycle [5]. [6] reported that on an average, weed can reduce the yield by 50% in sweet sorghum. Chemical weed control is a better supplement to conventional method and forms an integral part of the modern crop production. It is quick, more effective, time and labour saving method than others [7]. Among various sorghum yield limiting factors, weed infestation remains a big challenge [8]. Hence, the present study was undertaken to evaluate herbicide bio-efficacy on sweet sorghum yield, quality parameters and their residual effects on soil microbial diversity.

## 2. MATERIAL AND METHODS

### ~~2.1 Location of the experiment~~

A field experiment was conducted during *rabi* and summer seasons of 2022-23 and 2023-24 at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh ~~and is situated at 21.5°N latitude and 70.5° E longitude with an altitude of 60 m above the mean sea level in South Saurashtra Agro-climatic Zone of Gujarat state, India.~~ The dominant soil type of the area is clayey in texture.

### ~~2.3 Experimental design~~

The experiment was laid out in a randomized block design with ten treatments and replicated thrice. Sweet sorghum (SSV 84) was sown at a spacing of 60 x 10 cm. The weed management treatments consisted of pre-emergence application (PE) of atrazine 50 WP 500 g/ha. The pre-emergence herbicide was supplemented with inter-cultivation ($T_1$) or post-emergence application (PoE) of 2,4-D (SS) 95 SP ($T_2$), halosulfuron- methyl 75 WG 60 g/ha ($T_3$), topramezone 33.6 SC 25 g/ha ($T_4$), clodinafop-propargyl 15 WP 60 g/ha ($T_5$), tembotrione 42 SC 100 g/ha ($T_6$), mesotrione + atrazine 44. 97 SC (Premix) 875 g/ha ($T_7$), at 30 days after seeding (DAS), IC & HW at 15 and 30 DAS ($T_8$), ~~Weed free check~~ weed free plot ($T_9$) and ~~Unweeded control~~ weed check plot ($T_{10}$).

### ~~2.4 Procedure~~

Pre-emergence herbicides were applied at 1 DAS and inter-cultivation/post-emergence herbicide, was applied at 30 DAS. All the pre-and post-emergence herbicides were applied with the help of knapsack sprayer fitted with flat fan nozzle and spray volume of 500 L/ha. The sweet sorghum was fertilized with 90-40-40 N-$P_2O_5$-$K_2O$ kg/ha ~~and which were supplied to crop through urea (46% N), single super phosphate (16% $P_2O_5$, 12% S 21%, Ca) and muriate of potash (K 60%) respectively. Half of total N, entire P and K should be applied as basal dressing and the remaining N should be applied at 30 DAS. The rest of the packages of practices were adopted as per recommendations of the JAU. Category wise weed density and~~ The weed biomass and density were recorded randomly with the help of 0.25 $m^2$ quadrat. The estimation of reducing sugar in sweet sorghum juice and grain was carried by 3, 5 Dinitrosalycyclic acid method [9]. Non Reducing sugars was calculated by subtracting the value of reducing sugar from the total sugar. Total microbial count by serial dilution technique [10] and spread on a nutrient agar (NA) plate and incubated at 30-35 $^oC$ for 2-3 days in an incubator.

### ~~2.5 Statistical analysis~~

The data on weed density and biomass were transformed to square root transformation $\sqrt{(x + 0.5)}$ to normalize their distribution. ~~Weed control efficiency was computed as per the method suggested by [11]. All the yield components, *viz.* grain weight per earhead (g) and 1000-grain weight were recorded at harvest. Benefit-cost ratio was calculated after dividing gross returns with cost of cultivation. The weed and crop data were analysed statistically by following the analysis of variance for randomized block design as suggested by [12].~~

## 3. RESULTS AND DISCUSSION

### 3.1 Weed density and dry weight

At harvest, higher weed density and dry weight were registered under the ~~unweeded control~~ weedy check plot ($T_{10}$). Among the different treatments, the ~~weed free check~~ weed free plot ($T_9$) recorded significantly the lowest weed density and dry weight, which is statistically at par to IC & HW at 15 and 30 DAS ($T_8$). This is followed by the PE application of atrazine 50 WP ~~500 g/ha~~ + IC & HW ($T_1$) which is statistically at par with PE application of atrazine 50 WP ~~500 g/ha~~ *fb* mesotrione + atrazine 44.97 SC (Premix) ~~875 g/ha~~ at 30 DAS, ($T_7$) in 2022-23, 2023-24. This might be due to inhibition of carotenoid biosynthesis by inhibiting the hydroxyphenylpyruvate dioxygenase (HPPD) enzyme, which results in plastoquinone (PQ) synthesis inhibition in weeds [13], [14] and [15].

### 3.2 Weed control efficiency and weed index

~~At~~ After harvest, highest weed control efficiency was observed in the weed free check ($T_9$) followed by IC & HW at 15 and 30 DAS ($T_8$) due to excellent performance in controlling all the categories of weeds. This was followed by the PE application of atrazine 50 WP 500 g/ha + IC & HW ($T_1$) with higher WCE followed by PE application of atrazine 50 WP 500 g/ha *fb* mesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, ($T_7$) in 2022-23, 2023-24, respectively (Table 1) due to broad-spectrum weed control and reduced total weed dry weight by inhibiting the plastoquinone biosynthesis and gives rise to bleaching symptoms on new growth in target plants and thereby reduce the dry weight of all categories of weeds.

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Among the different weed management treatments, higher WI was recorded under ~~was recorded under~~ the unweeded control ($T_{10}$), which indicates that the unrestricted weed growth reduced the sweet sorghum grain yield and fodder yield. Besides the weed free check ($T_9$), the lower WI was noted under the IC & HW at 15 and 30 DAS ($T_8$) followed by PE application of atrazine 50 WP 500 g/ha + IC & HW ($T_1$) followed by PE application of atrazine 50 WP 500 g/ha *fb* mesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, ($T_7$), PE application of atrazine 50 WP 500 g/ha + IC & HW ($T_1$) ~~during 2022-23 and 2023-24,~~ respectively (Table 1). Lower weed index might be due to lower weed population and dry weight of weeds and high weed control efficiency which led to higher yield. This might be due to elimination of weeds by integration of herbicides, interculturing and manual weeding. The combined effect on dry weight of weeds and grain yield under these treatments might have been responsible for excellent weed indices.

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**Table-1: Effect of different treatments on total weed density, dry weight, weed control efficiency and weed index at harvest**

**Comment [DSKC9]:** Write Pooled data

| Treatments | Dose (g/ha) | Time of application (DAS) | At harvest | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Weed density (No./m$^2$) | | Weed dry weight (g/m$^2$) | | WCE (%) | | WI | |
| | | | 2022-23 | 2023-24 | 2022-23 | 2023-24 | 2022-23 | 2023-24 | 2022-23 | 2023-24 |
| Atrazine *fb* IC & HW | 500 | 1+30 | 6.00 (39.17) | 5.87 (34.78) | 6.82 (46.22) | 6.16 (40.69) | 80.31 | 82.13 | 8.12 | 7.57 |
| Atrazine *fb* 2,4-D (SS) | 500 | 1+30 | 8.63 (74.50) | 8.32 (69.50) | 9.17 (83.75) | 8.83 (77.65) | 64.33 | 65.89 | 27.00 | 20.25 |
| Atrazine PE *fb* Halosulfuron- | 500+60 | 1+30 | 10.15 (102.90) | 9.81 (96.20) | 11.01 (121.54) | 10.66 (113.58) | 48.24 | 50.11 | 36.05 | 35.12 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| methyl | | | | | | | | | | |
| Atrazine PE *fb* Topramezone | 500+25 | 1+30 | 8.76 (76.40) | 8.43 (70.70) | 9.28 (85.90) | 8.91 (79.02) | 63.41 | 65.28 | 26.92 | 20.05 |
| Atrazine *fb* Clodinafop-propargyl | 500+60 | 1+30 | 11.17 (124.30) | 10.83 (116.80) | 11.88 (140.76) | 11.48 (132.08) | 40.05 | 41.98 | 36.34 | 35.32 |
| Atrazine *fb* Tembotrione | 500+100 | 1+30 | 8.61 (73.90) | 8.33 (69.10) | 9.10 (83.15) | 8.81 (77.25) | 64.58 | 66.06 | 27.20 | 20.33 |
| Atrazine *fb* Mesotrione + Atrazine (Premix) | 500+ 875 | 15+30 | 6.54 (42.30) | 6.09 (36.70) | 7.05 (49.47) | 6.56 (42.68) | 78.93 | 81.25 | 7.34 | 7.29 |
| IC & HW | | | 1.79 (2.70) | 1.61 (2.10) | 2.01 (3.53) | 2.41 (5.31) | 98.50 | 97.67 | 5.34 | 5.31 |
| Weed free check | | | 1.52 (1.80) | 1.45 (1.60) | 1.54 (1.88) | 1.49 (1.72) | 99.20 | 99.25 | 0.00 | 0.00 |
| Unweeded control | | | 14.30 (204.50) | 14.05 (197.50) | 15.31 (234.79) | 15.09 (227.63) | 0.00 | 0.00 | 49.59 | 47.51 |
| SEm ± | | | 0.48 | 0.40 | 0.43 | 0.52 | - | - | - | - |
| C.D. at 5% | | | 1.44 | 1.19 | 1.29 | 1.54 | - | - | - | - |
| ~~C.V.%~~ | | | ~~10.83~~ | ~~9.27~~ | ~~9.06~~ | ~~11.16~~ | - | - | - | - |

Data given in parenthesis are original values. Original data subjected to square root transformation.
WCE: weed control efficiency; WI: weed index: IC: Inter cultivation; *fb*: followed by

### 3.3 Crop growth parameters

#### ~~3.3.1~~ Phytotoxicity

Topramezone and tembotrione applied at 30 DAS showed slight stunting or discoloration in sweet sorghum with phytotoxicity rating of '1' (Table 2), which indicates slight stunting injury due to reduction in internodal length or discolouration in sweet sorghum. This may be due to inhibition of $D_1$ protein in photosystem-II in crop plants, which in turn stop the photosynthesis leading to slight stunted growth and dicolouration but there was no stand loss and the crop fully recovered within 25-30 days. These results were in conformity with the finding of [16] in sweet sorghum.

#### ~~3.3.2~~ Effect on growth parameters and days to 50 per cent flowering

At 60 DAS and at harvest the weed free check ($T_9$) produced significantly higher plant height, LAI during 2022-23, 2023-24 and in pooled results, respectively (Table 2 and Table 3), which remained statistically at par with IC & HW at 15 and 30 DAS ($T_8$). The next best treatment is the PE application of atrazine 50 WP 500 g/ha *fb* mesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, ($T_7$) which is statistically at par with the atrazine 50 WP 500 g/ha as a pre-emergence *fb* intercultivation and hand weeding (IC & HW) at 30 DAS ($T_1$).

Among the different treatments, the weed-free check ($T_9$) took significantly fewer days to reach 50% flowering in 2022-23, 2023-24 and pooled results, respectively. This remained statistically at par with the rest of the treatments (Table 3) except for the

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unweeded control ($T_{10}$), which recorded higher days to 50% flowering during the years 2022-23, 2023-24 and in the pooled results.

**Table-2: Effect of different treatments on on phytotoxicity symptoms, plant height at 60 DAS and at harvest**

| Treatments | Dose (g/ha) | Time of application (DAS) | Phytotoxicity scoring | | Plant height (cm) at 60 DAS | | | Plant height (cm) at harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | PE | PoE | 2022-23 | 2023-24 | Pooled | 2022-23 | 2023-24 | Pooled |
| Atrazine *fb* IC & HW | 500 | 1 | 0 | 0 | 147.48 | 152.50 | 149.99 | 161.99 | 171.20 | 166.59 |
| Atrazine *fb* 2,4-D (SS) | 500 | 1+30 | 0 | 0 | 127.00 | 131.30 | 129.15 | 137.60 | 142.50 | 140.05 |
| Atrazine PE *fb* Halosulfuron- methyl | 500+60 | 1+30 | 0 | 0 | 125.20 | 129.50 | 127.35 | 132.20 | 136.10 | 134.15 |
| Atrazine PE *fb* Topramezone | 500+25 | 1+30 | 0 | 1 | 102.10 | 106.40 | 104.25 | 141.30 | 145.20 | 143.25 |
| Atrazine *fb* Clodinafop-propargyl | 500+60 | 1+30 | 0 | 0 | 124.40 | 128.70 | 126.55 | 135.40 | 139.30 | 137.35 |
| Atrazine *fb* Tembotrione | 500+100 | 1+30 | 0 | 1 | 101.30 | 105.60 | 103.45 | 140.20 | 144.10 | 142.15 |
| Atrazine *fb* Mesotrione + Atrazine (Premix) | 500+875 | 1+30 | 0 | 0 | 146.50 | 151.80 | 149.15 | 166.50 | 170.40 | 168.45 |
| IC & HW | | 15+30 | 0 | 0 | 171.90 | 176.20 | 174.05 | 190.00 | 193.90 | 191.95 |
| Weed free check | | | 0 | 0 | 174.80 | 179.10 | 176.95 | 198.00 | 201.90 | 199.95 |
| Unweeded control | | | - | - | 80.30 | 84.60 | 82.45 | 100.80 | 104.70 | 102.75 |
| SEm ± | | | - | - | 5.96 | 1.38 | 4.47 | 7.84 | 6.79 | 5.35 |
| C.D. at 5% | | | | | 17.71 | 3.94 | 12.82 | 23.29 | 20.17 | 15.34 |
| C.V.% | | | | | 7.93 | 8.31 | 8.27 | 8.76 | 8.76 | 8.58 |
| Y x T | | | | | | | | | | |
| SEm ± | | | | | | | 6.32 | | | 7.56 |
| C.D. at 5% | | | | | | | NS | | | NS |

**Table-3: Effect of different treatments on days to 50 per cent flowering leaf area index at 60 DAS and at 90 DAS**

| Treatments | Dose (g/ha) | Days to 50 per cent flowering | | | Leaf area index at 60 DAS | | | Leaf area index at 90 DAS | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2022-23 | 2022-23 | Pooled | 2022-23 | 2022-23 | Pooled | 2022-23 | 2022-23 | Pooled |
| Atrazine *fb* IC & HW | 500 | 76 | 77 | 77 | 2.20 | 2.28 | 2.24 | 3.70 | 3.94 | 3.82 |
| Atrazine *fb* 2,4-D (SS) | 500 | 79 | 80 | 79 | 1.50 | 1.58 | 1.54 | 3.00 | 3.24 | 3.12 |
| Atrazine PE *fb* Halosulfuron- methyl | 500+60 | 79 | 80 | 80 | 1.39 | 1.47 | 1.43 | 2.61 | 2.85 | 2.73 |
| Atrazine PE *fb* Topramezone | 500+25 | 79 | 80 | 80 | 1.12 | 1.20 | 1.16 | 2.89 | 3.13 | 3.01 |
| Atrazine *fb* Clodinafop-propargyl | 500+60 | 79 | 80 | 80 | 1.38 | 1.46 | 1.42 | 2.62 | 2.86 | 2.74 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Atrazine *fb* Tembotrione | 500+100 | 78 | 79 | 79 | 1.11 | 1.19 | 1.15 | 2.88 | 3.12 | 3.00 |
| Atrazine *fb* Mesotrione + Atrazine (Premix) | 500+875 | 79 | 80 | 80 | 2.21 | 2.29 | 2.25 | 3.71 | 3.95 | 3.83 |
| IC & HW | | 77 | 78 | 78 | 2.82 | 2.90 | 2.86 | 4.32 | 4.56 | 4.44 |
| Weed free check | | 76 | 77 | 77 | 2.88 | 2.96 | 2.92 | 4.38 | 4.62 | 4.50 |
| Unweeded control | | 91 | 92 | 92 | 0.91 | 0.92 | 0.92 | 2.21 | 2.45 | 2.33 |
| SEm ± | | 3.72 | 3.87 | 2.68 | 0.04 | 0.03 | 0.03 | 0.09 | 0.07 | 0.05 |
| C.D. at 5% | | NS | NS | 7.7 | 0.13 | 0.09 | 0.09 | 0.25 | 0.22 | 0.15 |
| C.V.% | | 8.11 | 8.33 | 8.2 | 4.66 | 4.76 | 4.76 | 4.59 | 4.27 | 4.42 |
| Y x T | | | | | | | | | | |
| SEm ± | | | 0.05 | 0.05 | | | 0.09 | | 0.05 | 0.05 |
| C.D. at 5% | | | NS | NS | | | NS | | NS | NS |

### 3.4 Effect on yield attributes and yield

Significantly higher grain weight per earhead (g), grain and fodder yield (kg/ha) (Table 4 and Table 5) was recorded with the weed free check ($T_9$), which remained statistically at par with the IC & HW at 15 and 30 DAS ($T_8$), PE application of atrazine 50 WP 500 g/ha *fb* mesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, ($T_7$) and PE application of atrazine 50 WP 500 g/ha *fb* intercultivation and hand weeding (IC & HW) at 30 DAS ($T_1$) with higher yield attributes and yield in 2022-23, 2023-24 and pooled results (Table 5 and Table 6). The increased sweet sorghum yield is due to reduced weed competition, allowing more nutrients to be absorbed by the crop and mobilized to the grain. The combination of PE atrazine and PoE application of mesotrione + atrazine, along with manual weeding, provided broad-spectrum weed control, significantly boosting yield compared to unweeded control. Significantly lower grain and fodder yield were recorded under the unweeded control ($T_{10}$). Results reported in Table 5 revealed that different weed management treatments did not exert their significant effects on 1000 grain weight in 2022-23, 2023-24 and pooled data. The present findings are within the close vicinity of those reported with different weed management treatments by [17], [18], [19] and [20].



**Table-4: Effect of different treatments on grain weight per earhead and test weight**

| Treatments | Dose (g/ha) | Time of application (DAS) | Grain weight per earhead (g) | | | Test weight (g) | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2022-23 | 2023-24 | Pooled | 2022-23 | 2023-24 | |
| Atrazine *fb* IC & HW | 500 | 1 | 31.23 | 31.63 | 31.43 | 18.25 | 18.63 | 18.44 |
| Atrazine *fb* 2,4-D (SS) | 500 | 1+30 | 21.20 | 22.20 | 21.70 | 18.81 | 19.01 | 18.91 |
| Atrazine PE *fb* Halosulfuron- | 500+60 | 1+30 | 15.47 | 16.47 | 15.97 | 18.04 | 18.24 | 18.14 |

**Comment [DSKC15]:** Remove sepreate year data, keep only polled data

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| methyl | | | | | | | | |
| Atrazine PE *fb* Topramezone | 500+25 | 1+30 | 20.70 | 21.70 | 21.20 | 18.78 | 18.98 | 18.88 |
| Atrazine *fb* Clodinafop-propargyl | 500+60 | 1+30 | 15.17 | 16.17 | 15.67 | 17.99 | 18.19 | 18.09 |
| Atrazine *fb* Tembotrione | 500+100 | 1+30 | 20.20 | 21.20 | 20.70 | 19.02 | 19.22 | 19.12 |
| Atrazine *fb* Mesotrione + Atrazine (Premix) | 500+ 875 | 1+30 | 31.50 | 32.30 | 31.90 | 19.09 | 19.29 | 19.19 |
| IC & HW | | 15+30 | 31.43 | 32.43 | 31.93 | 19.28 | 19.48 | 19.38 |
| Weed free check | | | 32.90 | 33.90 | 33.40 | 19.29 | 19.49 | 19.39 |
| Unweeded control | | | 11.00 | 12.00 | 11.50 | 17.03 | 17.30 | 17.16 |
| SEm ± | | | 1.07 | 1.07 | 0.75 | 0.92 | 0.86 | 0.63 |
| C.D. at 5% | | | 3.17 | 3.17 | 2.16 | NS | NS | NS |
| C.V.% | | | 8.01 | 7.70 | 7.85 | 8.58 | 7.90 | 8.24 |
| **Y x T** | | | | | | | | |
| SEm ± | | | | | 1.07 | | | 0.89 |
| C.D. at 5% | | | | | NS | | | NS |

## 3.5 Economics

Among different weed management treatments, statistically higher B:C ratio (Table 5) was obtained with the PE application of atrazine 50 WP 500 g/ha *fb* mesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, ($T_7$), followed by atrazine 50 WP 500 g/ha as PE *fb* IC & HW at 30 DAS ($T_1$) with B:C ratio in 2022-23, 2023-24 and average of both years, respectively.

**Table 5: Effect of different treatments on grain, dry fodder and harvest index at harvest**

| Treatments | Dose (g/ha) | Grain yield (kg/ha) | | | Dry fodder yield (kg/ha) | | | B:C ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2022-23 | 2022-23 | Pooled | 2022-23 | 2022-23 | Pooled | 2022-23 | 2023-24 | Average |
| Atrazine *fb* IC & HW | 500 | 2253 | 2282 | 2267 | 8239 | 8322 | 8280 | 2.83 | 2.51 | 2.67 |
| Atrazine *fb* 2,4-D (SS) | 500 | 1790 | 1969 | 1879 | 7247 | 7329 | 7288 | 2.69 | 2.54 | 2.61 |
| Atrazine PE *fb* Halosulfuron- methyl | 500+60 | 1568 | 1602 | 1585 | 6190 | 6272 | 6231 | 2.34 | 2.08 | 2.21 |
| Atrazine PE *fb* Topramezone | 500+25 | 1792 | 1974 | 1883 | 7174 | 7256 | 7215 | 2.69 | 2.54 | 2.62 |
| Atrazine *fb* Clodinafop- | 500+60 | 1561 | 1597 | 1579 | 6098 | 6180 | 6139 | 2.28 | 2.03 | 2.16 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| propargyl | | | | | | | | | | |
| Atrazine *fb* Tembotrione | 500+100 | 1785 | 1967 | 1876 | 7145 | 7227 | 7186 | 2.66 | 2.51 | 2.58 |
| Atrazine *fb* Mesotrione + Atrazine (Premix) | 500+875 | 2272 | 2289 | 2281 | 8146 | 8261 | 8203 | 3.06 | 2.71 | 2.89 |
| IC & HW | | 2321 | 2338 | 2330 | 8367 | 8129 | 8248 | 2.21 | 1.96 | 2.08 |
| Weed free check | | 2452 | 2469 | 2460 | 8443 | 8505 | 8474 | 2.18 | 1.94 | 2.06 |
| Unweeded control | | 1236 | 1296 | 1266 | 4707 | 4969 | 4838 | 1.93 | 1.76 | 1.84 |
| SEm ± | | 96 | 101 | 69 | 290 | 305 | 211 | - | - | - |
| C.D. at 5% | | 285 | 299 | 199 | 862 | 907 | 604 | - | - | - |
| C.V.% | | 8.73 | 8.81 | 8.77 | 7.01 | 7.30 | 7.16 | - | - | - |
| Y x T | | | | | | | | | | |
| SEm ± | | | | 98 | | | 298 | | | |
| C.D. at 5% | | | | NS | | | NS | | | |

## 3.6 Effect on quality parameters

Higher reducing, non-reducing sugars and total sugar in juice (Table 6) were recorded under weed-free conditions ($T_9$), comparable to statistically at par with IC & HW at 15 and 30 DAS ($T_8$), PE application of atrazine 50 WP 500 g/ha *fb* mesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, ($T_7$) and PE application of atrazine 50 WP 500 g/ha + IC & HW ($T_1$). This improvement is due to better weed control, leading to enhanced nutrient absorption by the crop and increased sucrose accumulation in sweet sorghum stems. Effective weed management allows more efficient use of resources, boosting sucrose transport from source to sink. The lowest values of quality parameters were observed under the unweeded control ($T_{10}$), which can be ascribed to severe competition by weeds with the crop and resulted in low absorption of nutrients and ultimately resulted in the inferior quality. Similar results have been found by [21].

**Table 6: Effect of different treatments on reducing sugar in juice, non-reducing sugar in juice and total sugars in juice**

| Treatments | Dose (g/ha) | Reducing sugar in juice (%) | | | Non-reducing sugar in juice (%) | | | Total sugar (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2022-23 | 2022-23 | Pooled | 2022-23 | 2022-23 | Pooled | 2022-23 | 2022-2 | Pooled |
| Atrazine *fb* IC & HW | 500 | 1.65 | 1.81 | 1.73 | 10.84 | 10.86 | 10.85 | 12.50 | 12.67 | 12.58 |
| Atrazine *fb* 2,4-D (SS) | 500 | 1.30 | 1.41 | 1.36 | 8.81 | 9.12 | 8.97 | 10.11 | 10.53 | 10.32 |
| Atrazine PE *fb* Halosulfuron- methyl | 500+60 | 1.11 | 1.22 | 1.17 | 7.65 | 7.96 | 7.81 | 8.76 | 9.18 | 8.97 |
| Atrazine PE *fb* Topramezone | 500+25 | 1.30 | 1.41 | 1.36 | 8.75 | 9.06 | 8.90 | 10.05 | 10.47 | 10.26 |
| Atrazine *fb* Clodinafop-propargyl | 500+60 | 1.10 | 1.27 | 1.19 | 7.24 | 7.55 | 7.40 | 8.34 | 8.82 | 8.58 |
| Atrazine *fb* Tembotrione | 500+100 | 1.29 | 1.40 | 1.35 | 8.69 | 9.00 | 8.85 | 9.98 | 10.40 | 10.19 |
| Atrazine *fb* Mesotrione + Atrazine (Premix) | 500+875 | 1.69 | 1.81 | 1.75 | 10.90 | 10.81 | 10.86 | 12.59 | 12.62 | 12.61 |

Comment [DSKC16]: Same year

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| IC & HW | | 1.71 | 1.82 | 1.77 | 11.11 | 11.42 | 11.27 | 12.82 | 13.24 | 13.03 |
| Weed free check | | 1.72 | 1.83 | 1.78 | 11.17 | 11.48 | 11.33 | 12.89 | 13.31 | 13.10 |
| Unweeded control | | 0.92 | 1.03 | 0.97 | 5.89 | 6.20 | 6.05 | 6.81 | 7.23 | 7.02 |
| SEm ± | | 0.04 | 0.04 | 0.03 | 0.25 | 0.25 | 0.18 | 0.28 | 0.26 | 0.19 |
| C.D. at 5% | | 0.11 | 0.11 | 0.07 | 0.75 | 0.74 | 0.51 | 0.82 | 0.76 | 0.54 |
| C.V.% | | 4.64 | 4.13 | 4.38 | 4.83 | 4.63 | 4.73 | 4.58 | 4.10 | 4.34 |
| Y x T | | | | | | | | | | |
| SEm ± | | | | 0.04 | | | 0.25 | | | 0.27 |
| C.D. at 5% | | | | NS | | | NS | | | NS |

## 3.7 Effect on microbial population

There is non-significant effect on the total microbial population (bacterial, fungi and actinomycetes) before sowing in 2022-23, 2023-24, and in the pooled results (Table 7).

### 3.7.1 Total microbial population at 20 days after application of PoE herbicides

As far as total bacterial, fungal and actinomycetes population in soil is concern, significantly highest total population in soil was observed in unweeded control ($T_{10}$) which remained statistically at par with the treatments weed free check ($T_9$), IC & HW at 15 and 30 DAS ($T_8$). Minimum bacterial population was observed in all the herbicidal treated plots, which performed similarly to each other (Table 7). Shortly after application of herbicides significant differences in population of soil microorganisms was noticed as compared to their population before herbicide application. Such inhibitory effect of herbicides used in the study persisted upto 30 days after spraying of herbicides in the crop with respect to either pre-emergence single herbicide or post-emergence herbicides. However, under sequential application of pre-emergence herbicide on 1 one day after sowing followed by post-emergence spray on 30 days after sowing the effect of herbicides on soil micro-organisms population extended beyond 30 days after spraying of herbicides in the crop.

### 3.7.2 Total microbial population at harvest

As far as total bacterial, fungal and actinomycetes population in soil is concern, significantly highest total population in soil was observed in atrazine 50 WP 500 g/ha as PE *fb* tembotrione 42 SC 100 g/ha PoE at 30 DAS ($T_6$) which remained statistically at par with the treatments atrazine 50 WP @ 500 g/ha as PE *fb* topramezone 33.6 SC 25 g/ha as PoE at 30 DAS ($T_4$), atrazine 50 WP 500 g/ha as PE *fb* 2,4-D (SS) 95 SP 500 g/ha as PoE 30 DAS ($T_2$), atrazine 50 WP 500 g/ha as PE *fb* halosulfuron- methyl 75 WG 60 g/ha as PoE at 30DAS ($T_3$), atrazine 50 WP 500 g/ha as PE *fb* clodinafop-propargyl 15 WP 60 g/ha as PoE at 30DAS ($T_5$), PE application of atrazine 50 WP 500 g/ha *fb* mesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, ($T_7$) in 2022-23, 2023-24, and in the pooled results (Table 7).. Minimum microbial population was observed in PE application of atrazine 50 WP 500 g/ha *fb* IC & HW at 30 DAS ($T_1$). But at the time of harvest of the crop, the microbial population with all the treatments attained, the level equal to that of initial level or even more than original level of population in some treatments. The microbial population was higher with application of pre-emergence herbicides followed by recommended dose of post-emergence herbicides. This might be due to the fact that applied herbicides themselves might serve as source of carbon to microbes and might also increase microbial multiplication

**Comment [DSKC17]:** Symbol of at the rate @ must write before quantity of herbicide spray

on increased supply of nutrients available in the form of microorganisms killed by herbicides. When herbicide compound has been decomposed and have no toxic properties, hence it can be a source of organic matter for both sensitive and tolerant soil microorganisms and can increase the growth of bacterial, fungal and actinomycetes populations progressively. Similar results of increased total microbial population at harvest were observed by [22], [23] and [24].

**Table 7: Effect of different treatments on pooled total microbial population before sowing, at 20 DAA and at harvest**

| Treatments | Dose (g/ha) | Before sowing | | | 20 DAA | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Bacteria ($\times10^7$ CFU/g) | Fungi ($\times10^3$ CFU/g) | Actinomycetes ($\times10^3$ CFU/g) | Bacteria ($\times10^7$ CFU/g) | Fungi ($\times10^3$ CFU/g) | Actinomycetes ($\times10^3$ CFU/g) | Bacteria ($\times10^7$ CFU/g) | Fungi ($\times10^3$ CFU/g) | Actinomycetes ($\times10^3$ CFU/g) |
| Atrazine *fb* IC & HW | 500 | 24.11 | 21.81 | 28.05 | 21.45 | 19.95 | 25.15 | 25.02 | 22.49 | 27.82 |
| Atrazine *fb* 2,4-D (SS) | 500 | 23.75 | 23.10 | 28.45 | 18.15 | 17.00 | 21.85 | 32.80 | 30.20 | 35.85 |
| Atrazine PE *fb* Halosulfuron- methyl | 500+60 | 23.95 | 22.40 | 27.95 | 18.35 | 16.30 | 22.25 | 33.00 | 29.50 | 36.15 |
| Atrazine PE *fb* Topramezone | 500+25 | 23.65 | 22.70 | 27.75 | 18.05 | 16.60 | 21.75 | 32.70 | 29.80 | 35.75 |
| Atrazine *fb* Clodinafop-propargyl | 500+60 | 24.95 | 23.20 | 28.35 | 18.68 | 17.10 | 21.55 | 33.33 | 30.30 | 35.55 |
| Atrazine *fb* Tembotrione | 500+100 | 24.45 | 22.90 | 27.45 | 18.85 | 16.80 | 22.15 | 33.50 | 30.25 | 36.25 |
| Atrazine *fb* Mesotrione + Atrazine (Premix) | 500+ 875 | 23.65 | 22.30 | 28.65 | 18.05 | 16.20 | 21.25 | 32.70 | 29.40 | 35.25 |
| IC & HW | | 24.65 | 23.50 | 27.85 | 24.38 | 23.17 | 29.25 | 29.00 | 26.10 | 31.15 |
| Weed free check | | 24.15 | 23.30 | 28.15 | 25.45 | 23.90 | 30.15 | 29.10 | 26.23 | 32.05 |
| Unweeded control | | 24.95 | 22.30 | 27.85 | 26.15 | 24.40 | 30.45 | 28.93 | 25.73 | 32.35 |
| SEm ± | | 0.44 | 0.42 | 0.46 | 0.41 | 0.31 | 0.43 | 0.54 | 0.46 | 0.53 |
| C.D. at 5% | | 1.27 | 1.22 | 1.31 | 1.19 | 0.89 | 1.24 | 1.53 | 1.31 | 1.53 |
| ~~C.V.%~~ | | ~~5.17~~ | ~~5.27~~ | ~~4.59~~ | ~~5.63~~ | ~~4.57~~ | ~~4.98~~ | ~~4.88~~ | ~~4.63~~ | ~~4.46~~ |

## ~~3.8~~ BIOASSAY STUDIES

Bioassay is a major tool for quantitative and qualitative determination of herbicides persistence effect. In this method, the property of a chemical is measured in terms of some biological responses using indicator plants grown in a field and is compared with that of similar plant grown in untreated soil.

**Table 8: Phytotoxicity of different herbicides on bioassay parameters of succeeding crops at 30 DAS**

| Treatments | Groundnut | | | Sesame | | | Pearlmillet | | | Soyabean | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ~~2022-23~~ | ~~2023-24~~ | Pooled | ~~2022-23~~ | ~~2023-24~~ | Pooled | ~~2022-23~~ | ~~2023-24~~ | Pooled | 2022-23 | 2023-24 | Pooled |
| Atrazine *fb* IC & HW | ~~7.07~~ | ~~7.04~~ | 7.05 | ~~17.28~~ | ~~17.60~~ | 17.44 | ~~19.95~~ | ~~19.99~~ | 19.97 | ~~8.20~~ | ~~8.71~~ | 8.46 |
| Atrazine *fb* 2,4-D (SS) | ~~7.19~~ | ~~7.39~~ | 7.29 | ~~21.00~~ | ~~21.90~~ | 21.45 | ~~23.10~~ | ~~23.80~~ | 23.45 | ~~8.59~~ | ~~9.39~~ | 8.99 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atrazine PE *fb* Halosulfuron-methyl | 6.90 | 7.10 | 7.01 | 19.10 | 20.00 | 19.55 | 21.20 | 21.90 | 21.55 | 8.30 | 9.10 | 8.70 |
| Atrazine PE *fb* Topramezone | 7.08 | 7.28 | 7.18 | 21.20 | 22.10 | 21.65 | 23.30 | 24.00 | 23.65 | 8.48 | 9.28 | 8.88 |
| Atrazine *fb* Clodinafop-propargyl | 6.83 | 7.03 | 6.93 | 20.13 | 21.03 | 20.58 | 22.23 | 22.93 | 22.58 | 8.23 | 9.03 | 8.63 |
| Atrazine *fb* Tembotrione | 7.19 | 7.39 | 7.29 | 21.50 | 22.40 | 21.95 | 23.60 | 24.30 | 23.95 | 8.59 | 9.39 | 8.99 |
| Atrazine *fb* Mesotrione + Atrazine (Premix) | 7.21 | 7.41 | 7.31 | 20.60 | 21.50 | 21.05 | 22.70 | 23.40 | 23.05 | 8.61 | 9.41 | 9.01 |
| IC & HW | 7.43 | 7.63 | 7.53 | 18.47 | 19.37 | 18.92 | 20.57 | 21.27 | 20.92 | 8.83 | 9.63 | 9.23 |
| Weed free check | 7.53 | 7.73 | 7.63 | 19.92 | 20.82 | 20.37 | 22.02 | 22.72 | 22.37 | 8.93 | 9.73 | 9.33 |
| Unweeded control | 7.03 | 7.23 | 7.13 | 19.00 | 19.90 | 19.45 | 21.10 | 21.80 | 21.45 | 8.43 | 9.23 | 8.83 |
| SEm ± | 0.32 | 0.26 | 0.31 | 0.90 | 0.78 | 0.55 | 0.96 | 0.87 | 0.60 | 0.39 | 0.32 | 0.24 |
| C.D. at 5% | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| C.V.% | 7.84 | 7.19 | 7.29 | 7.82 | 7.52 | 7.67 | 7.58 | 7.73 | 7.66 | 8.01 | 6.97 | 7.47 |

### 3.8.1 Residual effect on succeeding crops

The residual effect of different herbicides applied in sweet sorghum crop was found non-significant on germination percentage (10 DAS) of succeeding crops *i.e.*, groundnut, sesame, pearl millet and soyabean (Table 8). The results clearly indicated that different herbicides *viz.*, atrazine 50 WP 500 g/ha pre-emergence as well as 2,4-D (SS) 95 SP 500 g/ha, halosulfuron- methyl 75 WG 60 g/ha as PoE at 30 DAS, topramezone 33.6 SC 25 g/ha, Clodinafop-propargyl 15 WP 60 g/ha, tembotrione 42 SC 100 g/ha, *fb* mesotrione + atrazine 44. 97 SC (Premix) 875 g/ha as post-emergence herbicides did not leave their residual phytotoxic effect in the soil after harvesting of sweet sorghum crop on succeeding crops *i.e.*, groundnut, sesame, pearl millet and soyabean. Hence, it is safe to sow groundnut, sesame, pearl millet and soyabean after harvesting of sweet sorghum crop in which pre-emergence application and post-emergence application have been made. Results corroborate with those of [25], [26], [27] and [28].

## 4. CONCLUSION

On the basis of polled data of the two-year study experiment we concludes that effective weed control and profitable *rabi* sweet sorghum production can be achieved with a PE application of atrazine 50 WP (500 g/ha) *fb* mesotrione + atrazine (875 g/ha) at 30 DAS. Before sowing, microbial populations were similar across treatments, but after 20 days, unweeded control weedy check plot had the highest microbial population. By after harvest, atrazine *fb* PoE treated plots had the highest microbial population, while the lowest was in plots with atrazine *fb* inter-cultivation and hand weeding. There is no any residual

phytotoxicity effect was observed, making it safe for subsequent crops like groundnut, sesame, pearl millet, and soybean.

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