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

ABSTRACT

An experiment was carried out at InstructionalFarm,DepartmentofAgronomy,CollegeofAgriculture,JunagadhAgricultural University, Junagadh (Gujarat). The aim of the research is to evaluate herbicides bio-efficacy on yield, quality parameters of sweet sorghum and their residual effects on soil microbial diversity. The higher grain yield and fodder yield(kg ha^{-1}), reducing, non-reducing sugars and total sugar in juice were recorded under weed-free plot (T_9), which was statistically at par with the treatmentsIC & 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 weedy check plot (T_{10}) had the highest microbial population, similar to weed-free and manual weeding treatments. Herbicide-treated plots had lower microbial populations. At harvest, the highest microbial population was foundin 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.

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

1. INTRODUCTION

In India, sweetsorghum shares about 0.002 per cent area out of total sorghum area. Its ratooning ability enables multiple harvests perseason, a feature that could expand the geographical range of sorghum cultivation. The grain,stalk juice and bagasse can be used toproduce food, fodder, ethanol and power. Owing to these favorable attributes, Dar (2012)refers to it as a SMART crop. It is known as the sugarcane of the desert and also ‘‘the camel among crops’’ for itsdroughthardycharacteristics(Sanderson*etal*.,1992). 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.

Amongthevariousbioticfactorslimitingsweetsorghumproductionandproductivity, weeds are of prime importance. Bitzer (1997)reported that plant density and weed management are among the main factors affecting growth, sugar and forage yields of sweet sorghum. In India, presence of weeds in general reduces cropyields by37 - 45% and in some cases can cause complete crop failure, when compared to 25% due todiseases, 20% due to insects, 15% due to storage and miscellaneous pests (Bahadur *et al.*,2015). To prevent yield losses, weeds have to be controlled at critical periods during the cropgrowthcycle(Knezevic*etal*.,2002).Silva*etal*.(2014)reportedthatonanaverage,weedcan reducetheyieldby50%insweetsorghum.Chemicalweedcontrolisabettersupplementto conventional method and forms an integral part of the modern crop production. It is quick,more effective, time and labour saving method than others (Abbas *et al.*, 2018). Among various sorghum yield limiting factors, weed infestation remains a big challenge (Tuinstra*etal*.,2009). 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.Certainrotational crops are extremely sensitive to herbicide carry over, particularly the residues ofpersistent herbicides. Accurate quantification of herbicide residues is essential as itmay alsodo harm to humans and animals through both water and food. Hence, studies on the residualeffects of herbicide on the succeeding crops are important, before it is finally recommendedfor field applications to the farmers. Chemical methods and field bioassays are most frequently usedfortheassessmentofherbicidesresiduesinsoil.

2. MATERIAL AND METHODS

A field experiment was conducted during *rabi*and summerseasons of 2022-23 and 2023-24 atInstructionalFarm,DepartmentofAgronomy,CollegeofAgriculture,JunagadhAgricultural University, Junagadh. The dominant soil type of the area is clayey in texture.

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) @ 95SP (T_2), halosulfuron-methyl75WG@ 60g/ha (T_3), topramezone33.6SC@ 25g/ha (T_4), clodinafop-propargyl15WP@ 60g/ha (T_5), tembotrione42SC@ 100g/ha (T_6),mesotrione+atrazine44. 97SC(Premix)@ 875g/ha (T_7), at 30 days after seeding (DAS), IC&HWat15 and30 DAS (T_8), weedfreeplot (T_9) and weedy check plot (T_{10}).

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^{-1}. 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 (Miller 1959).Non Reducing sugars was calculated by subtracting the value of reducing sugar from the total sugar. Total microbial count by serial dilution technique (Dhingra*et al*., 1993)and spread on a nutrient agar (NA) plate and incubated at 30-35 ^{o}C for 2-3 days in an incubator.The data on weed density and biomass were transformed to square root transformation $\sqrt{(x + 0.5)}$to normalize their distribution.

3. RESULTS AND DISCUSSION

3.1 Weed density and dry weight

At harvest, higher weed density and dry weight were registered under the weedy check plot(T_{10}). Among the different treatments, the 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 + IC & HW (T_1) which is statistically at par with PE application of atrazine 50 WP *fb*mesotrione + atrazine 44.97 SC (Premix) at 30 DAS, (T_7) in 2022-23, 2023-24. This might be due to inhibition ofcarotenoid biosynthesis by inhibiting the hydroxyphenylpyruvate dioxygenase (HPPD) enzyme, which results in plastoquinone (PQ) synthesis inhibition in weeds (Duke *et al*. (2000), Wichert*et al*. (1999), Takano *et al*. (2016), Simarmata*etal*.(2017)).

3.2 Weed control efficiency and weed index

After harvest highest weed control efficiency was observed in the weed free plot (T_9) followed by IC&HWat15 and30 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.

Among the different weed management treatments, higher WI was recorded under the weedy check plot (T_{10}), which indicates that the unrestricted weed growth reduced the sweet sorghum grain yield and fodder yield. Besides the weed free plot (T_9), the lower WI was noted under the IC&HWat15 and30 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) 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.

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

Treatments	At harvest

	Weed density (No./m^2)		Weed dry weight (g/m^2)		Weed Control Efficiency (%)		Weed Index (WI)	
	2022-23	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**
Atrazine 50 WP500 g/ha asPE*fb* IC&HWat30DAS	6.00 (39.17)	5.87 (34.78)	6.82 (46.22)	6.16 (40.69)	80.31	82.13	8.12	7.57
Atrazine50WP500g/haasPE *fb*2,4-D(SS) 95SP500g/haas PoE 30DAS	8.63 (74.50)	8.32 (69.50)	9.17 (83.75)	8.83 (77.65)	64.33	65.89	27.00	20.25
Atrazine50WP500g/haasPE*fb*Halosulfuron-methyl75WG60g/haasPoEat30 DAS	10.15 (102.90)	9.81 (96.20)	11.01 (121.54)	10.66 (113.58)	48.24	50.11	36.05	35.12
Atrazine50WP500g/haasPE *fb*Topramezone33.6SC25g/haas PoEat30DAS	8.76 (76.40)	8.43 (70.70)	9.28 (85.90)	8.91 (79.02)	63.41	65.28	26.92	20.05
Atrazine50WP500g/haasPE*fb*Clodinafop-propargyl15WP60g/haasPoEat30 DAS	11.17 (124.30)	10.83 (116.80)	11.88 (140.76)	11.48 (132.08)	40.05	41.98	36.34	35.32
Atrazine50WP500g/haasPE *fb*Tembotrione42SC100g/haPoE at30DAS	8.61 (73.90)	8.33 (69.10)	9.10 (83.15)	8.81 (77.25)	64.58	66.06	27.20	20.33
Atrazine50WP 500g/haasPE*fb*Mesotrione+Atrazine44. 97SC(Premix)875g/haat30DAS	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&HWat15 and30 DAS	1.79 (2.70)	1.61 (2.10)	2.01 (3.53)	2.41 (5.31)	98.50	97.67	5.34	5.31
Weedfreeplot	1.52 (1.80)	1.45 (1.60)	1.54 (1.88)	1.49 (1.72)	99.20	99.25	0.00	0.00
Weedy check plot	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	-	-	-	-

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

3.3 Crop growth parameters

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 Galon*et al.* (2016) in sweet sorghum.

Effect on growth parameters and daysto50percentflowering

At 60 DAS and at harvest the weed free plot (T_9) produced significantly higher plant height, LAI in pooled results(Table 2 and Table 3), which remained statistically at par with IC&HWat15 and30 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 pooled results. This remained statistically at par with the rest of the treatments (Table 3) except for the Weedy check plot (T_{10}), which recorded higher days to 50% flowering during the the pooled results.

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

Treatments	Phytotoxicity scoring		Plant height (cm) at 60 DAS	Plant height (cm) at harvest
	PE	PoE	Pooled	Pooled
Atrazine 50 WP500 g/ha asPE*fb* IC&HWat30DAS	0	0	149.99	166.59

Atrazine50WP500g/haasPE *fb*2,4-D(SS) 95SP500g/haas PoE 30DAS	0	0	129.15	140.05
Atrazine50WP500g/haasPE*fb*Halosulfuron-methyl75WG60g/haasPoEat30 DAS	0	0	127.35	134.15
Atrazine50WP500g/haasPE *fb*Topramezone33.6SC25g/haas PoEat30DAS	0	1	104.25	143.25
Atrazine50WP500g/haasPE*fb*Clodinafop-propargyl15WP60g/haasPoEat30 DAS	0	0	126.55	137.35
Atrazine50WP500g/haasPE *fb*Tembotrione42SC100g/haPoE at30DAS	0	1	103.45	142.15
Atrazine50WP 500g/haasPE*fb*Mesotrione+Atrazine44. 97SC(Premix)875g/haat30DAS	0	0	149.15	168.45
IC&HWat15 and30 DAS	0	0	174.05	191.95
Weedfreeplot	0	0	176.95	199.95
Weedy check plot	-	-	82.45	102.75
SEm ±	-	-	4.47	5.35
C.D. at 5%			12.82	15.34

Table-3: Effect of different treatments on daysto50percentflowering leaf area index at 60 DAS and at 90 DAS

Treatments	Daysto50percentflowering	Leaf area index at 60 DAS	Leaf area index at 90 DAS
	Pooled	**Pooled**	**Pooled**
Atrazine 50 WP500 g/ha asPE*fb* IC&HWat30DAS	77	2.24	3.82
Atrazine50WP500g/haasPE *fb*2,4-D(SS) 95SP500g/haas PoE 30DAS	79	1.54	3.12
Atrazine50WP500g/haasPE*fb*Halosulfuron-methyl75WG60g/haasPoEat30 DAS	80	1.43	2.73
Atrazine50WP500g/haasPE *fb*Topramezone33.6SC25g/haas PoEat30DAS	80	1.16	3.01
Atrazine50WP500g/haasPE*fb*Clodinafop-	80	1.42	2.74

propargyl15WP60g/haasPoEat30 DAS			
Atrazine50WP500g/haasPE *fb*Tembotrione42SC100g/haPoE at30DAS	79	1.15	3.00
Atrazine50WP 500g/haasPE*fb*Mesotrione+Atrazine44.97SC(Premix)875g/haat30DAS	80	2.25	3.83
IC&HWat15 and30 DAS	78	2.86	4.44
Weedfreeplot	77	2.92	4.50
Weedy check plot	92	0.92	2.33
SEm ±	2.68	0.03	0.05
C.D. at 5%	7.7	0.09	0.15

Effect on yield attributes and yield

Significantly higher grainweightperearhead (g), grain and fodder yield (kg ha^{-1}) (Table 4 and Table 5) was recorded with the weed free plot (T_9), which remained statistically at par with the IC&HWat15 and30 DAS (T_8), PE application of atrazine50WP 500g/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 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 Weedy check plot. Significantly lower grain and fodder yield were recorded under the Weedy check plot (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 Mishra*etal*.(2012), Mukherjee *et al*. (2019), Krishnamurthy*etal*.(2021), Kumar *et al*. (2022).

Table-4: Effect of different treatments on grainweightper earhead and testweight

Treatments	Grain weight per	Test weight (g)

	earhead (g)	
	Pooled	Pooled
Atrazine 50 WP500 g/ha asPE*fb* IC&HWat30DAS	31.43	18.44
Atrazine50WP500g/haasPE *fb*2,4-D(SS) 95SP500g/haas PoE 30DAS	21.70	18.91
Atrazine50WP500g/haasPE*fb*Halosulfuron-methyl75WG60g/haasPoEat30 DAS	15.97	18.14
Atrazine50WP500g/haasPE *fb*Topramezone33.6SC25g/haas PoEat30DAS	21.20	18.88
Atrazine50WP500g/haasPE*fb*Clodinafop-propargyl15WP60g/haasPoEat30 DAS	15.67	18.09
Atrazine50WP500g/haasPE *fb*Tembotrione42SC100g/haPoE at30DAS	20.70	19.12
Atrazine50WP 500g/haasPE*fb*Mesotrione+Atrazine44. 97SC(Premix)875g/haat30DAS	31.90	19.19
IC&HWat15 and30 DAS	31.93	19.38
Weedfreeplot	33.40	19.39
Weedy check plot	11.50	17.16
SEm ±	0.75	0.63
C.D. at 5%	2.16	NS

3.5 Economics

Among different weed management treatments, 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 asPE*fb* IC&HWat30DAS (T_1) with B:C ratio in average of both years.

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

Treatments	Grainyield (kg ha^{-1})	Dryfodder yield (kg ha^{-1})	B:C ratio
	Pooled	Pooled	Average

Atrazine 50 WP500 g/ha asPE*fb* IC&HWat30DAS	2267	8280	2.67
Atrazine50WP500g/haasPE *fb*2,4-D(SS) 95SP500g/haas PoE 30DAS	1879	7288	2.61
Atrazine50WP500g/haasPE*fb*Halosulfuron-methyl75WG60g/haasPoEat30 DAS	1585	6231	2.21
Atrazine50WP500g/haasPE *fb*Topramezone33.6SC25g/haas PoEat30DAS	1883	7215	2.62
Atrazine50WP500g/haasPE*fb*Clodinafop-propargyl15WP60g/haasPoEat30 DAS	1579	6139	2.16
Atrazine50WP500g/haasPE *fb*Tembotrione42SC100g/haPoE at30DAS	1876	7186	2.58
Atrazine50WP 500g/haasPE*fb*Mesotrione+Atrazine44. 97SC(Premix)875g/haat30DAS	2281	8203	2.89
IC&HWat15 and30 DAS	2330	8248	2.08
Weedfreeplot	2460	8474	2.06
Weedy check plot	1266	4838	1.84
SEm ±	69	211	-
C.D. at 5%	199	604	-

Effect on quality parameters

Higher reducing, non-reducing sugars and total sugar in juice (Table 6) were recorded under weed-free conditions (T_9), statistically at par withIC & 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 Weedy check plot (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 byReis*etal*.(2019).

Table 6: Effect of different treatments on reducingsugarinjuice, non-reducingsugar injuiceand total sugars in juice

Treatments	Reducingsugar injuice (%)	Non-reducingsugarinjuice (%)	Totalsugar (%)
	Pooled	Pooled	Pooled
Atrazine 50 WP500 g/ha asPE*fb* IC&HWat30DAS	1.73	10.85	12.58
Atrazine50WP500g/haasPE *fb*2,4-D(SS) 95SP500g/haas PoE 30DAS	1.36	8.97	10.32
Atrazine50WP500g/haasPE*fb*Halosulfuron-methyl75WG60g/haasPoEat30 DAS	1.17	7.81	8.97
Atrazine50WP500g/haasPE *fb*Topramezone33.6SC25g/haas PoEat30DAS	1.36	8.90	10.26
Atrazine50WP500g/haasPE*fb*Clodinafop-propargyl15WP60g/haasPoEat30 DAS	1.19	7.40	8.58
Atrazine50WP500g/haasPE *fb*Tembotrione42SC100g/haPoE at30DAS	1.35	8.85	10.19
Atrazine50WP 500g/haasPE*fb*Mesotrione+Atrazine44. 97SC(Premix)875g/haat30DAS	1.75	10.86	12.61
IC&HWat15 and30 DAS	1.77	11.27	13.03
Weedfreeplot	1.78	11.33	13.10
Weedy check plot	0.97	6.05	7.02
SEm ±	0.03	0.18	0.19
C.D. at 5%	0.07	0.51	0.54

Effect on microbial population

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

Total microbial population at 20 days after application of PoEherbicides

As far as total bacterial, fungal and actinomycetes population in soil is concern, significantly highest total population in soil was observed in Weedy check plot (T_{10}) which remained statistically at par with the treatments weed free plot (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 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.

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 atrazine50WP@ 500g/haasPE *fb*tembotrione42SC@ 100g/haPoE at30DAS (T_6) which remained statistically at par with the treatments atrazine50WP@ 500g/haasPE *fb*topramezone33.6SC25g/haas PoEat30DAS (T_4), atrazine50WP@ 500g/haasPE *fb*2,4-D(SS) 95SP@ 500g/haas PoE 30DAS (T_2), atrazine50WP@ 500g/haasPE*fb*halosulfuron-methyl75WG@ 60g/haasPoEat30DAS (T_3), atrazine50WP@ 500g/haasPE*fb*clodinafop-propargyl15WP@ 60g/haasPoEat30DAS (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 the pooled results (Table 7). 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 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 Hatti *et al*. (2014), Veeresh*et al*. (2014) Tyagi*et al*. (2018).

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

Treatments	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 50 WP500 g/ha asPE*fb* IC&HWat30DAS	24.11	21.81	28.05	21.45	19.95	25.15	25.02	22.49	27.82
Atrazine50WP500g/haasPE *fb*2,4-D(SS) 95SP500g/haas PoE 30DAS	23.75	23.10	28.45	18.15	17.00	21.85	32.80	30.20	35.85
Atrazine50WP500g/haasPE*fb* Halosulfuron-methyl75WG60g/haasPoEat30 DAS	23.95	22.40	27.95	18.35	16.30	22.25	33.00	29.50	36.15
Atrazine50WP500g/haasPE *fb*Topramezone33.6SC25g/haas PoEat30DAS	23.65	22.70	27.75	18.05	16.60	21.75	32.70	29.80	35.75
Atrazine50WP500g/haasPE*fb* Clodinafop-propargyl15WP60g/haasPoEat30 DAS	24.95	23.20	28.35	18.68	17.10	21.55	33.33	30.30	35.55
Atrazine50WP500g/haasPE *fb*Tembotrione42SC100g/haPoE at30DAS	24.45	22.90	27.45	18.85	16.80	22.15	33.50	30.25	36.25
Atrazine50WP 500g/haasPE*fb*Mesotrione+Atrazine44. 97SC(Premix)875g/haat30DAS	23.65	22.30	28.65	18.05	16.20	21.25	32.70	29.40	35.25
IC&HWat15 and30 DAS	24.65	23.50	27.85	24.38	23.17	29.25	29.00	26.10	31.15
Weedfreeplot	24.15	23.30	28.15	25.45	23.90	30.15	29.10	26.23	32.05
Weedy check plot	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

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
	Pooled	Pooled	Pooled	Pooled
Atrazine 50 WP500 g/ha asPE*fb* IC&HWat30DAS	7.05	17.44	19.97	8.46
Atrazine50WP500g/haasPE *fb*2,4-D(SS) 95SP500g/haas PoE 30DAS	7.29	21.45	23.45	8.99
Atrazine50WP500g/haasPE*fb*Halosulfuron-methyl75WG60g/haasPoEat30 DAS	7.01	19.55	21.55	8.70
Atrazine50WP500g/haasPE *fb*Topramezone33.6SC25g/haas PoEat30DAS	7.18	21.65	23.65	8.88
Atrazine50WP500g/haasPE*fb*Clodinafop-propargyl15WP60g/haasPoEat30 DAS	6.93	20.58	22.58	8.63
Atrazine50WP500g/haasPE *fb*Tembotrione42SC100g/haPoE at30DAS	7.29	21.95	23.95	8.99
Atrazine50WP 500g/haasPE*fb*Mesotrione+Atrazine44. 97SC(Premix)875g/haat30DAS	7.31	21.05	23.05	9.01
IC&HWat15 and30 DAS	7.53	18.92	20.92	9.23
Weedfreeplot	7.63	20.37	22.37	9.33
Weedy check plot	7.13	19.45	21.45	8.83
SEm ±	0.31	0.55	0.60	0.24

C.D. at 5%	NS	NS	NS	NS
C.V.%	7.29	7.67	7.66	7.47

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,pearlmilletandsoyabean(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) @ 500g/ha, halosulfuron-methyl75WG@ 60g/haasPoEat30DAS, topramezone33.6SC@ 25g/ha, Clodinafop-propargyl15WP@ 60g/ha, tembotrione42SC@ 100g/ha, *fb*mesotrione+atrazine44. 97SC(Premix)@ 875g/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,pearlmilletandsoyabean. Hence, it is safe to sow groundnut,sesame,pearlmilletandsoyabean after harvesting of sweet sorghum crop in which pre-emergence application and post-emergence application have been made.Results corroborate with those of Chowdhuri*et al*. (2017), Siabusu*et al*. (2020), Rani *et al*. (2022), Saimaheswari*et al*. (2022).

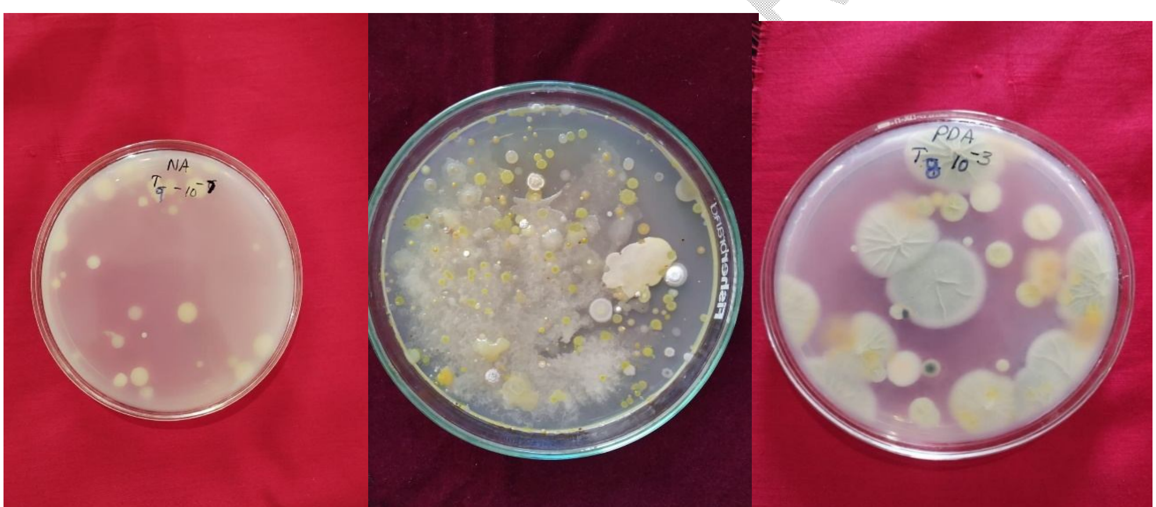
CONCLUSION

On the basis of polled data of the two-year experiment we concludes that effective weed control and profitable 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. after 20 days, weedy check plot had the highest microbial population. After harvest, atrazine *fb*PoEtreated 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 phytotoxicityeffect was observed, making it safe for subsequent crops like groundnut, sesame, pearl millet, and soybean.

Plate No. 1: Overall view of the experimental field of sweet sorghum at 40 DAS

Plate No. 2: Weed occurrence in sweet sorghum crop in unweeded control at 30, 60 DAS

Plate No. 3: Sweet sorghum crop at 100 DAS with PE application atrazine50WP



Bacteria **Actinomycetes** **Fungi**

Plate No. 4: Microbial population analysis

Disclaimer (Artificial intelligence)
Option 1:
Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.
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Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology
Details of the AI usage are given below:
1.ChatGP

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