

Evaluating herbicides bio-efficacy on sweet sorghum yield, quality parameters 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. Higher grain and fodder yield, reducing, non-reducing sugars and total sugar in juice were recorded under weed-free conditions (T₉), comparable to IC & HW at 15 and 30 DAS (T₈), PE application of atrazine 50 WP 500 g/ha + fbmesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, (T₇) and PE application of atrazine 50 WP 500 g/ha + IC & HW (T₁). Before sowing, no significant differences in microbial population were observed. At 20 days after herbicide application, the unweeded control (T₁₀) had the highest microbial population, similar to weed-free and manual weeding treatments. Herbicide-treated plots had lower microbial populations. By harvest, the highest microbial population was 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 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 (T₁) or post-emergence application (PoE) of 2,4-D (SS) 95SP (T₂), halosulfuron-methyl 75WG 60g/ha (T₃), topramezone 33.6SC 25g/ha (T₄), clodinafop-propargyl 15WP 60g/ha (T₅), tembotrione 42SC 100g/ha (T₆), mesotrione + atrazine 44.97SC (Premix) 875g/ha (T₇), at 30 days after seeding (DAS), IC & HW at 15 and 30 DAS (T₈), Weed free check (T₉) and Unweeded control (T₁₀).

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-P₂O₅-K₂O kg/ha and which were supplied to crop through urea (46% N), single super phosphate (16% P₂O₅, 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 biomass were recorded randomly with the help of 0.25 m² quadrat. The estimation of reducing sugar in sweet sorghum juice and grain was carried by 3, 5 Dinitrosalicylic 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 °C 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].

Atrazine <i>fb</i> 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 <i>fb</i> 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 <i>fb</i> Halosulfuron-methyl	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
Atrazine PE <i>fb</i> 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 <i>fb</i> Clofopropargyl	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 <i>fb</i> 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 <i>fb</i> 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: Intercultivation; *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 discoloration in sweet sorghum. This may be due to inhibition of D₁ protein in photosystem-II in crop plants, which in turn stop the photosynthesis leading to slight stunted growth and discoloration 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 daysto50percentflowering

At 60 DAS and at harvest the weed free check (T₉) 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 (T₈). 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, (T₇) 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 (T₁).

Among the different treatments, the weed-free check (T₉) 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 unweeded control (T₁₀), 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
Atrazinefb2,4-D(SS)	500	1+30	0	0	127.00	131.30	129.15	137.60	142.50	140.05
AtrazinePEfbHalosulfuron-methyl	500+60	1+30	0	0	125.20	129.50	127.35	132.20	136.10	134.15
AtrazinePEfbTopramezone	500+25	1+30	0	1	102.10	106.40	104.25	141.30	145.20	143.25
AtrazinefbClodinafop-propargyl	500+60	1+30	0	0	124.40	128.70	126.55	135.40	139.30	137.35
AtrazinefbTembotrione	500+100	1+30	0	1	101.30	105.60	103.45	140.20	144.10	142.15
AtrazinefbMesotrione+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
Weedfreecheck			0	0	174.80	179.10	176.95	198.00	201.90	199.95
Unweededcontrol			-	-	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 daysto50percentflowering leaf area index at 60 DAS and at 90 DAS

Treatments	Dose (g/ha)	Daysto50percentflowering			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
Atrazinefb2,4-D(SS)	500	79	80	79	1.50	1.58	1.54	3.00	3.24	3.12
AtrazinePEfbHalosulfuron-methyl	500+60	79	80	80	1.39	1.47	1.43	2.61	2.85	2.73
AtrazinePEfbTopramezone	500+25	79	80	80	1.12	1.20	1.16	2.89	3.13	3.01

AtrazinefbClodinafop-propargyl	500+60	79	80	80	1.38	1.46	1.42	2.62	2.86	2.74
AtrazinefbTembotrione	500+100	78	79	79	1.11	1.19	1.15	2.88	3.12	3.00
AtrazinefbMesotrione+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
Weedfreecheck		76	77	77	2.88	2.96	2.92	4.38	4.62	4.50
Unweededcontrol		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 (T₉), which remained statistically at par with the IC&HW at 15 and 30 DAS (T₈), PE application of atrazine 50 WP 500g/ha fb mesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, (T₇) and PE application of atrazine 50 WP 500 g/ha fb intercultivation and hand weeding (IC & HW) at 30 DAS (T₁) 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 (T₁₀). 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	Pooled
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

AtrazinePE fbHalo sulfuron-methyl	500+60	1+30	15.47	16.47	15.97	18.04	18.24	18.14
AtrazinePE fbTopramezone	500+25	1+30	20.70	21.70	21.20	18.78	18.98	18.88
AtrazinefbClodinafop-propargyl	500+60	1+30	15.17	16.17	15.67	17.99	18.19	18.09
AtrazinefbTembotrione	500+100	1+30	20.20	21.20	20.70	19.02	19.22	19.12
AtrazinefbMesotrione+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
Weedfreecheck			32.90	33.90	33.40	19.29	19.49	19.39
Unweededcontrol			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, higher B:C ratio (Table 5) was obtained with the PE application of atrazine 50 WP 500 g/ha fbmesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, (T₇), followed by atrazine 50 WP500 g/ha asPEfb IC&HWat30DAS (T₁) 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)			Dryfodder 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
Atrazinefb2,4-D(SS)	500	1790	1969	1879	7247	7329	7288	2.69	2.54	2.61
AtrazinePEfbHalo sulfuron-methyl	500+60	1568	1602	1585	6190	6272	6231	2.34	2.08	2.21
AtrazinePE fbTopramezone	500+25	1792	1974	1883	7174	7256	7215	2.69	2.54	2.62
AtrazinefbClodinafop-	500+60	1561	1597	1579	6098	6180	6139	2.28	2.03	2.16

propargyl										
AtrazinefbTembotrione	500+100	1785	1967	1876	7145	7227	7186	2.66	2.51	2.58
AtrazinefbMesotrione+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
Weedfreecheck		2452	2469	2460	8443	8505	8474	2.18	1.94	2.06
Unweededcontrol		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 (T₉), comparable to IC & HW at 15 and 30 DAS (T₈), PE application of atrazine 50 WP 500 g/ha fbmesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, (T₇) and PE application of atrazine 50 WP 500 g/ha + IC & HW (T₁). 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 (T₁₀), 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	2022-23	Pooled
Atrazine fb IC&HW	500	1.65	1.81	1.73	10.84	10.86	10.85	12.50	12.67	12.58
Atrazinefb2,4-D(SS)	500	1.30	1.41	1.36	8.81	9.12	8.97	10.11	10.53	10.32
AtrazinePEfbHalosulfuron-methyl	500+60	1.11	1.22	1.17	7.65	7.96	7.81	8.76	9.18	8.97
AtrazinePEfbTopramezone	500+25	1.30	1.41	1.36	8.75	9.06	8.90	10.05	10.47	10.26

AtrazinefbClodinafop-propargyl	500+60	1.10	1.27	1.19	7.24	7.55	7.40	8.34	8.82	8.58
AtrazinefbTembotrione	500+100	1.29	1.40	1.35	8.69	9.00	8.85	9.98	10.40	10.19
AtrazinefbMesotrione+Atrazine(Premix)	500+875	1.69	1.81	1.75	10.90	10.81	10.86	12.59	12.62	12.61
IC&HW		1.71	1.82	1.77	11.11	11.42	11.27	12.82	13.24	13.03
Weedfreecheck		1.72	1.83	1.78	11.17	11.48	11.33	12.89	13.31	13.10
Unweededcontrol		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 (T₁₀) which remained statistically at par with the treatments weed free check (T₉), IC & HW at 15 and 30 DAS (T₈). 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 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 atrazine50WP500g/haasPE fbtembotrione42SC100g/haPoE at30DAS (T₆) which remained statistically at par with the treatments atrazine50WP500g/haasPE fbtoprimezone33.6SC25g/haas PoEat30DAS (T₄), atrazine50WP500g/haasPE fb2,4-D(SS) 95SP500g/haas PoE 30DAS (T₂), atrazine50WP500g/haasPE fbhalosulfuron-methyl75WG60g/haasPoEat30DAS (T₃), atrazine50WP500g/haasPEfbclodinafop-propargyl15WP60g/haasPoEat30DAS (T₅), PE application of atrazine 50 WP 500 g/ha fbmesotrione + atrazine 44.97 SC (Premix) 875 g/ha at 30 DAS, (T₇) 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&HWat30DAS (T₁). 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 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 ($\times 10^7$ CFU/g)	Fungi ($\times 10^3$ CFU/g)	Actinomycetes ($\times 10^3$ CFU/g)	Bacteria ($\times 10^7$ CFU/g)	Fungi ($\times 10^3$ CFU/g)	Actinomycetes ($\times 10^3$ CFU/g)	Bacteria ($\times 10^7$ CFU/g)	Fungi ($\times 10^3$ CFU/g)	Actinomycetes ($\times 10^3$ 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
Atrazinefb2,4-D(SS)	500	23.75	23.10	28.45	18.15	17.00	21.85	32.80	30.20	35.85
AtrazinePEfbHalosulfuron-methyl	500+60	23.95	22.40	27.95	18.35	16.30	22.25	33.00	29.50	36.15
AtrazinePEfbTopramezone	500+25	23.65	22.70	27.75	18.05	16.60	21.75	32.70	29.80	35.75
AtrazinefbClodinafop-propargyl	500+60	24.95	23.20	28.35	18.68	17.10	21.55	33.33	30.30	35.55
AtrazinefbTembotrione	500+100	24.45	22.90	27.45	18.85	16.80	22.15	33.50	30.25	36.25
AtrazinefbMesotrione+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
Weedfreecheck		24.15	23.30	28.15	25.45	23.90	30.15	29.10	26.23	32.05
Unweededcontrol		24.95	22.30	27.85	26.15	24.40	30.45	28.93	25.73	32.35
SEm \pm		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
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	2022-23	2023-24	Pool ed	2022-23	2023-24	Pool ed	2022-23	2023-24	Pool ed	2022-23	2023-24	Pool ed
Atrazine <i>fb</i> 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 <i>fb</i> 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 <i>fb</i> 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 <i>fb</i> 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 <i>fb</i> 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 <i>fb</i> 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 <i>fb</i> 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
at 5% C.D.	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) 95SP 500g/ha, halosulfuron-methyl 75WG 60g/ha as PoE at 30 DAS, topamezone 33.6SC 25g/ha, Clodinafop-propargyl 15WP 60g/ha, tembotrione 42SC 100g/ha, *fb* mesotrione+atrazine 44.97SC (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, 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

The two-year study 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 had the highest microbial population. By 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 residual

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

REFERENCES

1. Dar WD. Towards a Prosperous, Food-secure and Resilient Dryland Tropics: A Compendium of Speeches by William D Dar January–December, 2012.
2. Sanderson MA, Jones RM, Ward J. and Wolfe R. Silage sorghum performance trial at Stephenville. Forage Research in Texas. Report PR-5018. 1992. Texas Agricultural Experimental Station, Stephenville, USA.
3. Bitzer MJ. Production of sweet sorghum for syrup in Kentucky. Extension 1997. Bult., Colleg, Agric., Univ. Kentucky, USA.
4. Bahadur S, Verma SK, Prasad SK, Madane AJ, Maurya SP, Gaurav VV. and Sihag SK. Eco-friendly weed management for sustainable crop production - A review. *Journal of Crop Weed*. 2015;11(1):181-189.
5. Knezevic SZ, Evans SP, Blankenship EE, Van Acker RC. and Lindquist JL. Critical period for weed control: the concept and data analysis. *Weed Science*. 2002;50(6):773-786.
6. Silva AF, Silva C, Vale WG, Petter FA, Karam D. Interferência de plantas daninhas na cultura do sorgo sacarino. *Bragantia*. 2014;73(4):438-445.
7. Abbas T, Zahir ZA, Naveed M. and Kremer RJ. Limitations of existing weed control practices necessitated development of alternative techniques based on biological approaches. *Advances in Agronomy*. 2018;147:239-280.
8. Tuinstra MR, Soumana S. and Khatib K. Efficacy of herbicide seed treatments for controlling infestation of sorghum. *Crop Science*. 2009;49:923-929.
9. Miller GL. Use of dinitrosalicylic acid reagent for determination of reducing sugar. 1959.
10. Dhingra OB. and Sinclair JB. "Basic Plant Pathology Methods". 1993. 2nd Edition, CRC Press, Boca Raton.
11. Mani S Malla ML, Gautam KC and Bhagwandas P. Weed killing chemicals in potato cultivation. *Indian Farming*. 1973;25(7):17-18.
12. Panse VG. and Sukhatme PV. Statistical Methods for Agricultural Workers. 1985. *Indian Council of Agricultural Research*, New Delhi.
13. Duke SO, Dayan FE, Romagni JG. and Rimando AM. Natural products as sources of herbicides: Current status and future trends. *Weed Research*. 2000;40:

99-111.

14. Takano HK, Rubin RDS, Marques LH, Fadin DA, Kalsing A. and Neves R. Potential use of herbicides in different sorghum hybrids. *African Journal of Agricultural Research*. 2016;11(26):2277-2285.
15. Simarmata M, Turmudi E, Sitinjak J. and Setyowati N. Different application time of atrazine and mesotrione mixture to control weeds on grain sorghum (*Sorghum bicolor* L. Moench). *International Journal of Agricultural Technology*, 2017;13(7.2):1761-1772.
16. Galon L, Fernandes FF, Andres A, Silva AFD. and Forte CT. Selectivity and efficiency of herbicides in weed control on sweet sorghum. *Pesquisa Agropecuária Tropical*. 2016;46:123-131.
17. Mishra JS, Rao SS. and Dixit A. Evaluation of new herbicides for weed control and crop safety in rainy season sorghum. *Indian Journal of Weed Science*. 2012;44(1):71-72.
18. Mukherjee PK, Singh P, Sondhia S. and Sagar RL. Biology of weed flora, weed dynamics and weed management in different fodder crops. *Environment and Ecology*. 2019;18(2):320-322.
19. Krishnamurthy D, Gangaiah B. and Tonapi, VA. Nonsuitability of tembotrione and topramezone for weed management in sorghum (*Sorghum bicolor* (L.) Moench). *Indian Journal of Weed Science*. 2021;53(4):381-386.
20. Kumar KA, Bhagavathapriya T, Kumar YS, Babu KS, Prabhakar K, Parveen SI, Kiranmayi MJ. and Jaya M. Weed dynamics, crop growth and yield attributes of grain sorghum response to pre and post emergence herbicides. *The Pharma Innovation Journal*. 2022;11(12):2631-2634.
21. Reis RM, Freitas MS, Silva DV, Pereira GAM, De Jesus Passos ABR, Silva AF. and Dos Reis MR. Effects of weed management and plant arrangements on yield index of sweet sorghum. *Bioscience Journal*. 2019;35(4):983-991.
22. Hatti V, Sanjay MT, Prasad TR, Murthy KK, Kumbar B. and Shruthi MK. Effect of new herbicide molecules on yield, soil microbial biomass and their phytotoxicity on maize (*Zea mays* L.) under irrigated conditions. *The Bioscan*. 2014;9(3):1127-1130.
23. Veeresh H, Sanjay MT, Prasad TVR, Murthy KNK, Basavaraj K. and Shruthi MK. Effect of new herbicide molecules on yield, soil microbial biomass and their phytotoxicity on maize (*Zea Mays* L.) under irrigated conditions. *The Bio Scan*. 2014;9(3):1127-1130.
24. Tyagi S, Mandal SK, Rajesh K. and Sunil K. Effect of different herbicides on

soil microbial population dynamics in *rabi* maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Sciences*. 2018;7:3751-3758.

25. Chaudhari DD, Patel VJ, Patel HK, Mishra A, Patel BD. and Patel RB. Assessment of pre-mix broad spectrum herbicides for weed management in wheat. *Indian Journal of Weed Science*. 2017;49(1):33–35.

26. Siabusu L, Kambikambi T, Lungu D. and Chanda R. Efficacy and residual effects of Topramezone and Dicamba herbicide on weed control in selected crops (Doctoral dissertation, The University of Zambia). 2020.

27. Rani BS, Chandrika V, Reddy GP, Sudhakar P, Nagamadhuri KV. and Sagar GK. Residual effect of weed management practices executed in preceding maize on succeeding greengram. *Legume Research*. 2022;45(5):631-638.

28. Saimaheswari K, Sagar GK, Chandrika V, Sudhakar P. and Krishna TG. Effect of nitrogen and weed management practices in maize and their residual effect on succeeding groundnut. *Indian Journal of Weed Science*. 2022;54(1):36–41.

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