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Weed dynamics, crop growth and yield attributes of grain sorghum response to pre and post emergence herbicides

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Abstract
A field experiment was conducted at Reginal Agricultural Research station, Nandyal, Acharaya N.G. Ranga Agricultural University during *rabi* 2021-22 on Weed management in *rabi* grain sorghum. The present study revealed that the growth parameters *viz*., plant height, panicle weight, panicle length, 1000 seed test weight, grain yield and stover yield at harvest were significantly higher with weed free plot followed by pre and post emergence application of atrazine 50 WP @ 0.5 kg a.i/ha. Whereas, lower growth parameters and yield were noticed with weedy check *i.e.*, control. Among post emergence application of herbicides carentrazone ethyl 40% DF @20 g a.i/ha at 3-4 leaves stage followed by 2,4-D Na salt 80WP @ 0.5 kg a.i/ha at 20 DAS.

Keywords: Weed control, rabi-sorghum, herbicide, atrazine

Introduction
Sorghum (*Sorghum bicolor* L. Moench) is a staple food crop in semi-arid areas considered as the king of millets and fourth important crop in the country after rice, wheat and maize. It is the most effective C4 plant as far as photosynthesis pathway and widely cultivated for grain, feed/fodder, and bio-fuel uses in tropical and semi-arid areas of the world. A high efficiency water utilization mechanism and tolerance to drought and high temperatures favours it as an alternative crop to maize in areas with marginal water availability. When compared to other cereals, sorghum grows rapidly, and produces both high quality grains and large quantities of nutritious fodder. Sorghum grains contain 10–13% protein, 2–3% fat and 70–80% carbohydrates. Despite of its potential, Sorghum is a poor competitor against weeds due to slow growth and poor early vigour for the first 20–25 days, although it eventually establishes a dense canopy (Rizzardi *et al*., 2004) [8]. Due to these growth habits, it suffers severely from weed competition and causing 15–97% losses for sorghum growth and yield under different climatic conditions (Peerzada *et al*. 2017) [1] in many tropical and subtropical areas (Everaarts, 1993) [4].

This crop is underutilized given few weed management options. Even a low level of weed infestation in the early stages could be detrimental to sorghum yield. Stahlman and Wicks (2000) [10] reported that weeds usually compete for light, nutrients, and soil moisture, reduced the growth rate, lowers the crop yield and ultimately results in increased production costs, deteriorated grain quality, and cause a 30–50% yield loss. Further, each additional week of interference by grassy weeds resulted in a 3.6% yield loss (Smith *et al*., 1990) [9]. Depending on the weed species and environmental conditions, the weed growth duration beyond 2 weeks after grain sorghum emergence considerably reduced the yield due to a decrease in grains per panicle and panicles per plant (Smith *et al*., 1990) [9]. In most C_4 crops, continuous increases in atmospheric CO_2 results in reduced vegetative growth, increased susceptibility to competition, and decreased yield potential against C_3 weeds (Ziska, 2001) [11]. Ziska (2003) [12] indicated potentially increased yield losses in sorghum from weed competition when the atmospheric CO_2 increases. In short, yield losses in sorghum may range from 15 to 97%, depending upon the crop cultivars, row spacing, weed species, infestation duration, and ecological conditions.
Selection of an appropriate weed management strategy based on agronomical, economical, and environmental considerations is a difficult task (Gholami *et al*., 2013) [5].

In the semi-arid tropical regions, hand weeding and mechanical cultivation are most commonly practiced for weed control in grain sorghum (Mishra *et al*., 2015) [7]. Unfortunately, labour scarcity and the high cost of mechanical equipment limited the application of these strategies on a large scale. The main problems are: 1) scarce availability of herbicides registered both for pre- and post-emergence applications; 2) low efficacy of preemergence herbicides with inadequate rainfall conditions; 3) unavailability of selective post-emergence grass herbicides.

In this context, a good approach to increase scientific information for farmers, is to improve chemical weed control strategies by investigating the efficacy of herbicides used at different times, at different doses and in different mixture with objective to investigate weed control efficacy of some herbicides applied alone and in mixtures

Materials and Methods

Field experiment on rabi grain sorghum were carried out in 2021-22 in Regional Agricultural Research Station, Nandyal, Acharya N.G. Ranga Agricultural University on a deep black soils. The experiment was designed as a randomized block with three replicates and plot size of 22.5 m^2 (4.5m x 5.1 m). The trials were carried out in accordance with recommended management practices, as concerns soil tillage and seedbed preparation. In each trial, some herbicides were used in pre or post-emergence applications at different mixtures in order to assess weed control ability and selectivity to the crop. Atrazine 50 WP @ 0.5 kg a.i/ha, Metalachlor 50% EC @ 1.0 kg a.i/ha, Pyroxasulfone 80% w/w WG @ 0.1275 kg a.i/ha are pre emergence herbicides applied next day after sowing, Post emergence application of Bentazone 480 g/l SL @ 960 g a.i/ha at 3-4 leaves, Carentrazone ethyl 40% DF @ 20 g a.i/ha at 3-4 leaves, Mesotrione 2.27% w/w @ 875 g a.i/ha at 15-18 DAS, Metsulfuron methyl 10% @ 25 g a.i/ha at 32 DAS, 2,4-D Na salt 80 WP @ 0.5 kg a.i/ha at 20 DAS, Atrazine 50 WP @ 0.5 kg a.i/ha at 20DAS. Weed free and weedy check plots were maintained.

Crop was sown soon after receipt of rainfall, sowing was taken up and pre-emergence herbicide is applied next day after sowing completed. Post emergence herbicides are applied as per the treatments with battery sprayer fan type nossil.

Weeds number in one square meter at three places per plot were collected, counted, weighed, oven dried at 105°C to determine dry weight. Data on weed density and weed dry weight were collected at 20 DAS (before post emergence application) and 40DAS (after post emergence application) used to calculate weed control efficacy (WCE) of different treatments relative to the untreated control, according to Chinnusamy *et al*. (2013) [2]:

$$WCE(\%) = \frac{W_u - W_t}{W_u}\ x\ 100$$

Where: W_u – weed density/dry weight in untreated plots, W_t – weed density/dry weight in treated plots. The sorghum yield (seed and dry weights) was determined by hand-harvesting the central part of each plot.

Results and Discussion

Effect of weed control treatments on growth

The results in Table 1, show that, the weedy check treatment had the recorded lowest plant height (125.6 cm) compared with all other weed control treatments. Among other herbicides pre and post emergence application of atrazine 50WP @ 0.5 kg a.i/ha highest plant height (139.2 cm) and weed free check recorded highest plant height (142.3 cm) among others but no significant difference was observed among all treatments (Table 1).

Table 1: Growth parameters of rabi grain sorghum as influenced by weed management practices

	Treatments	Plant height (cm)	Panicle length (cm)	Panicle weight (g)	1000 seed weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	WCE %	WI %
T_1	PE application of Atrazine 50 WP @ 0.5 kg a.i/ha	133.6	20.1	80.1	37.3	3246	5265	38.14	50.0	26.7
T_2	PE application of Metalachlor 50% EC @ 1.0 kg a.i/ha	132.4	20.3	80.5	37.6	3156	4968	38.85	48.0	28.7
T_3	PE application of Pyroxasulfone 80% w/w WG @ 0.1275 kg a.i/ha	136.2	20.4	81.2	36.3	3421	6075	36.03	50.0	22.8
T_4	T_1 + PoE application of Bentazone 480 g/l SL @ 960 g a.i/ha at 3-4 leaves	137.3	20.8	83.2	35.4	3981	6735	37.15	85.4	10.1
T_5	T_1 + PoE application of Carentrazone ethyl 40% DF @ 20 g a.i/ha at 3-4 leaves	138.8	21.5	84.2	37.1	4216	6956	37.74	89.5	4.8
T_6	T_1 + PoE application of Mesotrione 2.27% w/w @ 875 g a.i/ha at 15-18 DAS	136.4	20.4	76.2	36.5	3654	6483	36.05	83.2	17.5
T_7	T_1 + PoE application of Metsulfuron methyl 10% @ 25 g a.i/ha at 32 DAS	132.5	20.3	73.8	36.6	3632	5763	38.66	79.1	17.9
T_8	T_2 + PoE application of Bentazone 480 g/l SL @ 960 g a.i/ha at 3-4 leaves	136.5	20.6	82.6	37.2	3742	6526	36.44	83.6	15.4
T_9	T_2 + PoE application of Carentrazone ethyl 40% DF @ 20 g a.i/ha at 3-4 leaves	137.5	21.1	83.1	36.8	4068	6813	37.39	86.6	8.1
T_{10}	T_2 + PoE application of Mesotrione 2.27% w/w @ 875 g a.i/ha at 15-18 DAS	136.3	20.3	75.3	37.1	3645	5983	37.86	79.5	17.6
T_{11}	T_2 + PoE application of Metsulfuron methyl 10% @ 25 g a.i/ha at 32 DAS	134.6	20.1	75.4	37.2	3564	5368	39.9	51.2	19.4
T_{12}	T_1 + PoE application of 2,4-D Na salt 80 WP @ 0.5 kg a.i/ha at 20 DAS	137.9	21.3	79	37.5	4157	6873	37.69	87.2	6.2
T_{13}	PE & PoE application of Atrazine 50 WP @ 0.5 kg a.i/ha	139.2	21.8	82.9	37	4290	7023	37.92	89.6	3.1
T_{14}	T_3+ PoE application of 2,4-D Na salt 80 WP @ 0.5 kg a.i/ha at 20 DAS	136.7	20.6	81.7	37.1	3821	6634	36.55	84.4	13.7
T_{15}	Weed free (Two hand weedings at 15 & 35 DAS)	142.3	21	85.1	37.1	4428	7236	37.96	100.0	0.0
T_{16}	Weedy check	125.6	17.5	70.3	33.1	2568	4103	38.49	0.0	41.9
	CD (P=0.05)	NS	NS	27.8	NS	208.57	422.7	1.42		
	SEm±	3.6	1.2	10	0.56	68.97	80.58	0.47		
	C.V (%)	5.17	10.2	20.2	2.67	12	11	1.84		

Effect of weed control on yield components and yield of sorghum

The results show that, weed free plot produced longer panicles of sorghum comparable to other treatments, while the weedy check produced the shortest panicles. However, weed free plot recorded highest panicle weight followed by pre & post emergence application of atrazine and pre emergence application of atrazine along with post emergence application of carentrazone ethyl which are on par with other treatments except weedy check. The weedy check recorded lowest

panicle weight. There were no significant differences between treatments of the panicle length and 1000 seed weight of sorghum, even though the lowest was always observed in the Weed check (Table 1).

Among different weed management practices, weed free plot recorded highest grain yield, straw yield followed by pre and post emergence application of atrazine. The weedy check treatment produced the least grain yield of sorghum compared with all other treatments

Effect of weed control treatments on weed

The results in Table 1 show that, application of all herbicide treatments reduced weed density compared with the weedy check. While, the weedy check treatment had higher weed density than all other weed control treatments. Similarly, weed free plot reduced weed dry weight compared with the all herbicide treatments and the weedy check. The weedy check treatment had the highest weed dry matter production compared with all other weed control treatments.

Considering pre-emergence applications, all treatments gave quite similar weed control results. The weed control efficiency was highest with weed free plot followed by pre & post emergence application of atrazine and pre emergence application of atrazine along with post emergence application of carentrazone ethyl the result is also in line with Grichar *et al*, (2004) [6]. The weed index was low with weed free plot followed by pre and post emergence application of atrazine and pre emergence application of atrazine followed by postemergence application of carentrazone ethyl. However, among different herbicidal treatments pre emergence application of metalachlor recorded lowest weed control efficiency and highest weed index (Table:1).

All herbicides showed a good selectivity to the crop, although, post-emergence treatments showed higher transitory phytotoxicity effects than pre-emergence treatments. However, sorghum recovered quickly with phytotoxic symptoms that disappeared 5 or 6 weeks after sorghum emergence.

Weed free plot significantly reduced the weed density and weed dry matter (Table: 2&3). Among herbicidal treatments Application of herbicides, all herbicides reduced the weed density and weed dry matter. Application of pre and post application of atrazine significantly reduced the weed density as compared to weedy check. Pre application of metalachlor was less effective in reducing the density and dry weight of weeds as compared to other pre-emergence application.

Table 2: Weed density (No./m^2) in rabi grain sorghum as influenced by weed management practices

Treatments		Before treatment imposition				After treatment imposition			
		Grasses	**Sedges**	**BLW**	**Total**	**Grasses**	**Sedges**	**BLW**	**Total**
T_1	PE application of Atrazine 50 WP @ 0.5 kg a.i/ha	7.00 (3.65)	0.50 (1.71)	6.50 (3.55)	14.00 (4.75)	7.50 (3.74)	0.50 (1.71)	15.00 (4.87)	23.00 (5.80)
T_2	PE application of Metalachlor 50% EC @ 1.0 kg a.i/ha	7.00 (3.65)	0.50 (1.71)	7.50 (3.74)	15.00 (4.87)	7.00 (3.65)	0.00 (1.00)	15.50 (4.94)	22.50 (5.74)
T_3	PE application of Pyroxasulfone 80% w/w WG @ 0.1275 kg a.i/ha	7.00 (3.65)	0.00 (1.00)	5.50 (3.35)	12.50 (4.54)	6.50 (3.55)	0.00 (1.00)	4.00 (3.00)	10.50 (4.24)
T_4	T_1 + PoE application of Bentazone 480 g/l SL @ 960 g a.i/ha at 3-4 leaves	5.00 (3.24)	0.00 (1.00)	5.00 (3.24)	10.00 (4.16)	3.00 (2.73)	0.00 (1.00)	2.00 (2.41)	5.00 (3.24)
T_5	T_1 + PoE application of Carentrazone ethyl 40% DF @ 20 g a.i/ha at 3-4 leaves	5.00 (3.24)	1.50 (2.22)	7.50 (3.74)	14.00 (4.74)	1.50 (2.22)	1.00 (2.00)	3.00 (2.73)	5.50 (3.35)
T_6	T_1 + PoE application of Mesotrione 2.27% w/w @ 875 g a.i/ha at 15-18 DAS	7.50 (3.74)	0.00 (1.00)	6.50 (3.55)	14.00 (4.76)	5.50 (3.35)	0.00 (1.00)	4.50 (3.12)	10.00 (4.16)
T_7	T_1 + PoE application of Metsulfuron methyl 10% @ 25 g a.i/ha at 32 DAS	7.00 (3.65)	0.00 (1.00)	6.00 (3.45)	13.00 (4.61)	9.50 (4.08)	0.00 (1.00)	3.50 (2.87)	13.00 (4.61)
T_8	T_2 + PoE application of Bentazone 480 g/l SL @ 960 g a.i/ha at 3-4 leaves	7.50 (3.74)	0.00 (1.00)	6.50 (3.55)	14.00 (4.76)	3.00 (2.73)	0.00 (1.00)	3.50 (2.87)	6.50 (3.55)
T_9	T_2 + PoE application of Carentrazone ethyl 40% DF @ 20 g a.i/ha at 3-4 leaves	6.00 (3.45)	1.00 (2.00)	6.00 (3.45)	13.00 (4.61)	5.00 (3.24)	0.50 (1.71)	2.50 (2.58)	8.00 (3.83)
T_{10}	T_2 + PoE application of Mesotrione 2.27% w/w @ 875 g a.i/ha at 15-18 DAS	8.50 (3.65)	0.00 (1.00)	8.50 (3.92)	17.00 (5.12)	7.00 (3.65)	1.00 (2.00)	3.50 (2.87)	11.50 (4.39)
T_{11}	T_2 + PoE application of Metsulfuron methyl 10% @ 25 g a.i/ha at 32 DAS	7.00 (3.65)	2.00 (2.41)	7.00 (3.65)	16.00 (5.00)	7.50 (3.74)	2.00 (2.41)	15.00 (4.87)	24.50 (5.95)
T_{12}	T_1 + PoE application of 2,4-D Na salt 80 WP @ 0.5 kg a.i/ha at 20 DAS	5.50 (3.35)	0.00 (1.00)	8.00 (3.83)	13.50 (4.61)	3.50 (2.87)	0.00 (1.00)	3.50 (2.87)	7.00 (3.65)
T_{13}	PE & PoE application of Atrazine 50 WP @ 0.5 kg a.i/ha	7.00 (3.65)	0.50 (1.71)	5.50 (3.35)	13.00 (4.61)	3.00 (2.73)	1.00 (2.00)	2.50 (2.58)	6.50 (3.55)
T_{14}	T_3+ PoE application of 2,4-D Na salt 80 WP @ 0.5 kg a.i/ha at 20 DAS	7.00 (3.65)	1.50 (2.22)	5.50 (3.35)	14.00 (4.74)	3.00 (2.73)	1.50 (2.22)	4.00 (3.00)	8.50 (3.92)
T_{15}	Weed free (Two hand weedings at 15 & 35 DAS)	1.50 (2.22)	1.50 (2.22)	1.50 (2.22)	4.50 (3.12)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_{16}	Weedy check	15.50 (4.94)	1.00 (2.00)	21.00 (5.58)	37.50 (7.12)	21.00 (5.58)	1.50 (2.22)	24.00 (5.90)	46.50 (7.82)
	CD (P=0.05)	1.02	0.32	1.08	1.13	0.66	0.29	0.75	0.76
	SEm±	0.33	0.45	0.36	0.37	0.21	0.09	0.25	0.25
	C.V (%)	23.74	42.37	19.57	15.95	15.11	13.19	18.43	12.98

Table 3: Weed dry matter production (g/m^2) in rabi grain sorghum as influenced by weed management practices

	Treatments	Before treatment imposition				After treatment imposition			
		Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total
T_1	PE application of Atrazine 50 WP @ 0.5 kg a.i/ha	3.01 (2.73)	0.10 (1.32)	8.13S (3.85)	11.24 (4.35)	3.23 (2.80)	0.00 (1.00)	18.75 (5.33)	22.08 (5.70)
T_2	PE application of Metalachlor 50% EC @ 1.0 kg a.i/ha	2.87 (2.69)	0.15 (1.39)	9.75 (4.12)	12.77 (4.57)	2.87 (2.69)	0.00 (1.00)	20.15 (5.49)	23.02 (5.80)
T_3	PE application of Pyroxasulfone 80% w/w WG @ 0.1275 kg a.i/ha	3.99 (3.00)	0.00 (1.00)	6.88 (3.62)	10.87 (4.30)	3.24 (2.80)	0.00 (1.00)	18.70 (5.33)	22.09 (5.70)
T_4	T_1 + PoE application of Bentazone 480 g/l SL @ 960 g a.i/ha at 3-4 leaves	2.60 (2.61)	0.00 (1.00)	7.50 (3.74)	10.10 (4.18)	1.56 (2.25)	0.00 (1.00)	4.89 (3.21)	6.45 (3.54)
T_5	T_1 + PoE application of Carentrazone ethyl 40% DF @ 20 g a.i/ha at 3-4 leaves	2.40 (2.55)	0.36 (1.60)	9.23 (4.04)	11.99 (4.46)	0.72 (1.85)	0.24 (1.49)	3.69 (2.92)	4.65 (3.16)
T_6	T_1 + PoE application of Mesotrione 2.27% w/w @ 875 g a.i/ha at 15-18 DAS	3.23 (2.80)	0.00 (1.00)	7.80 (3.79)	11.03 (4.32)	2.01 (2.42)	0.00 (1.00)	5.40 (3.32)	7.41 (3.72)
T_7	T_1 + PoE application of Metsulfuron methyl 10% @ 25 g a.i/ha at 32 DAS	3.36 (2.83)	0.00 (1.00)	8.04 (3.84)	11.40 (4.38)	4.56 (3.14)	0.00 (1.00)	4.69 (3.17)	9.25 (4.04)
T_8	T_2 + PoE application of Bentazone 480 g/l SL @ 960 g a.i/ha at 3-4 leaves	3.23 (2.80)	0.00 (1.00)	8.78 (3.96)	12.00 (4.46)	2.58 (2.61)	0.00 (1.00)	4.73 (3.17)	7.31 (3.70)
T_9	T_2 + PoE application of Carentrazone ethyl 40% DF @ 20 g a.i/ha at 3-4 leaves	2.94 (2.71)	0.20 (1.45)	8.10 (3.85)	11.24 (4.35)	2.45 (2.57)	0.00 (1.00)	3.38 (2.84)	5.93 (3.43)
T_{10}	T_2 + PoE application of Mesotrione 2.27% w/w @ 875 g a.i/ha at 15-18 DAS	5.10 (3.26)	0.00 (1.00)	11.22 (4.35)	16.32 (5.04)	4.20 (3.05)	0.23 (1.32)	4.62 (3.15)	9.05 (4.01)
T_{11}	T_2 + PoE application of Metsulfuron methyl 10% @ 25 g a.i/ha at 32 DAS	2.94 (2.71)	0.40 (1.63)	8.40 (3.90)	11.74 (4.43)	3.15 (2.77)	0.40 (1.48)	18.00 (5.24)	21.55 (5.64)
T_{12}	T_1 + PoE application of 2,4-D Na salt 80 WP @ 0.5 kg a.i/ha at 20 DAS	2.37 (2.54)	0.00 (1.00)	9.60 (4.10)	11.97 (4.46)	1.51 (2.23)	0.00 (1.00)	4.20 (3.05)	5.71 (3.39)
T_{13}	PE & PoE application of Atrazine 50 WP @ 0.5 kg a.i/ha	3.22 (2.79)	0.12 (1.34)	6.60 (3.57)	9.94 (4.15)	1.38 (2.17)	0.23 (1.48)	3.00 (2.73)	4.61 (3.15)
T_{14}	T_3+ PoE application of 2,4-D Na salt 80 WP @ 0.5 kg a.i/ha at 20 DAS	3.50 (2.87)	0.35 (1.59)	6.93 (3.63)	10.78 (4.28)	1.50 (2.22)	0.35 (1.59)	5.04 (3.24)	6.89 (3.62)
T_{15}	Weed free (Two hand weedings at 15 & 35 DAS)	0.63 (1.79)	0.29 (1.53)	1.85 (2.36)	2.76 (2.66)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_{16}	Weedy check	8.99 (4.00)	0.26 (1.51)	27.72 (6.26)	36.97 (7.08)	12.18 (4.49)	0.39 (1.62)	31.68 (6.63)	44.25 (7.65)
	CD (P=0.05)	0.4	NS	0.23	0.41	0.31	0.12	0.45	0.41
	S.Em±	0.13	0.13	0.07	0.13	0.1	0.04	0.15	0.13
	C.V (%)	13.49	20.42	6.98	9.78	9.87	6.58	16.35	10.69

Conclusion

The present study revealed that the growth parameters *viz*., plant height, panicle weight, panicle length, 1000 seed test weight, grain yield and stover yield at harvest were significantly higher with weed free plot followed by pre and post emergence application of atrazine 50 WP @ 0.5 kg a.i/ha. Whereas, lower growth parameters and yield were noticed with weedy check i.e., control. Among post emergence application of herbicides carentrazone ethyl 40% DF @20 g a.i/ha at 3-4 leaves stage followed by 2,4-D Na salt 80WP @ 0.5 kg a.i/ha at 20 DAS

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