Original Research Article

Effect of integrated weed management practices on growth and yield of *rabi*sorghum (*Sorghum bicolor. L*)

ABSTRACT

A field study to"Evaluate the effect of new herbicide molecules in sorghum (*Sorghum Bicolor* L.)" was conducted during *rabi* season of 2023-24 at college farm, College of Agriculture, Professor Jayashankar Telangana Agriculture University,Rajendranagar, Hyderabad, Telangana. The experiment was laid out in randomized block design with twelve treatments each replicated thrice. The results revealed that weed free condition led to the highest growthparameters (plant height, dry matter production), yield attributing characters(number of ear heads per square meter, grains per ear head, ear head length, and 1000-grain weight), andmaximum grain and stover yield (2830 & 6795 kg ha^{-1})due to higher weed control efficiency of 93.21%, reduced weed density (2.67 No. m^{-2}) and weed dry matter (3.00 g. m^{-2}). Among the various weed management treatments, atrazine 0.5 kg a.i. ha^{-1} as pre-emergence (PE) *fb*mechanical weeding (MW) at 30 DAS, ready mix (RM) application of halosulfuron methyl 5% + atrazine 48% WG @ 56.25+540 g a.i. ha^{-1} as post-emergence (PoE) *fb* MW at 45 DAS and halosulfuron methyl 5% + atrazine 48% WG@ 56.25+540 g a.i. ha^{-1} as PoE recorded higher grain yield and on par with weed free treatment. This implies that these treatments serve as effective alternatives for attaining comparable weed control and yield advantages as the weed-free treatment.

Key words: - Atrazine;halosulfuron methyl + atrazine; ready mix; mechanical weeding.

1. INTRODUCTION

Sorghum (*Sorghum bicolor*), also called as king of millets, is a C_4 plant that originated in Africa's semi-arid regions and is now grown in tropical and subtropical areas. It ranks as the fifth most important cereal crop globally, following rice, wheat, maize, and barley, due to its high nutritional value. In India, it is known as "jowar" and is the fourth most important crop, especially in dryland farming. Sorghum is grown for food, animal feed, and biofuel production, making it a vital crop for both food and industry.It is better than maize and millets in tolerating salt, drought, and heat stress, making it crucial for food security in many developing countries, especially in Africa. It is also a key crop in arid regions, requiring less irrigation and thriving in hot summer conditions (Peerzada *et al.*,2016)

Sorghum grains are highly nutritious, containing 10.4% protein, 3.1% fat, 70.7%

Comment [A1]: values can be added regarding both weed free and herbicides

Comment [A2]: Table of weed dynamics is not given in text, either omit the weed dynamics data or add table which should be explained properly in the text.

Comment [A3]: mention about herbicides, since weed free is also weed mangement method

Comment [A4]: Can be rewritten in a more synchronous manner

Comment [A5]: not required , add more relevant keywords like sorghum, weed management etc.

Comment [A6]: Introduction lacks proper discussion of the topic, which include information about newer herbicide molecules.

Comment [A7]: ,not required

Comment [A8]: , not required

Comment [A9]: other millets

Comment [A10]: , not required

Comment [A11]: add about statistics of area production carbohydrates, and 2.0% crude fiber.The area under sorghum in India accounts 3.81 m ha, with a total production of 4.23 MMT and an average yield of 1110 kg ha^{-1}(Directorate of Economics and Statistics, GOI 2022).

Comment [A12]: , not required

Comment [A13]: rewrite in above paragraph

Weed pressure is high in sorghum due to its slow growth and low vigor during the first 20–25 days. However, as it matures, it forms a dense canopy, which helps it compete better with weeds in the later stages (Rizzardi *et al.,* 2004).According to Magani (2008), uncontrolled weed growth in sorghum can cause yield losses ranging from 40 to 60%.

Manual weeding and mechanical cultivation are the most common methods used for weed control in sorghum in tropical regions (Mishra *et al.,* 2015).But these methods are expensive and labor-intensive. Integrating herbicides with cultural practices or using a combination of pre-emergence and post-emergence herbicides along with mechanical methods can be more effective (Ishaya *et al.,* 2007). However, chemical weed control is a better alternative to manual weeding as it is more cost-effective and saves labor.

Among herbicides, atrazine (Sharma *et al.,* 2000) and2,4-D (Stahlman and Wicks 2000) are the most commonly used herbicides for grain sorghum cultivation.However, 2,4-D is selective for broad-leaved weeds, while atrazine is less effective against grasses and sedges, particularly under moisture stress conditions (Dan *et al.,* 2011).

Comment [A14]: new references can be added

These days, new-generation and ready-mix herbicides are becoming popular. New-generation herbicides work well at low doses, target different types of weeds, have a shorter lifespan in the environment, and are less harmful to mammals. Ready-mix or pre-mix herbicides are pre-made products that combine two or more herbicides with different ways of working to control various weeds in a single application.Therefore, the present study was taken up to assess the effectiveness of these herbicides for better weed control and improved growth and yield of sorghum.

Comment [A15]: merge paragraphs in order to reduce number of paragraphs

Comment [A16]: introduction can be rewritten and in the last paragraph include research gaps and how this research addresses the gap

2. MATERIAL AND METHODS

This experiment was conducted at college farm, College of Agriculture, Professor Jayashankar Telangana Agriculture University,Rajendranagar, Hyderabad, Telangana during *rabi*, 2023-24. The experimental site was situated at an altitude of 542.3m above mean sea level, at 17° 19' 21" N latitude and 78° 24' 36" E longitude, within the Southern Telangana Agro-Climatic Zone, classified as part of the Semi-Arid Tropical (SAT) region.The soil texture was sandy loam with pH of 7.2, low in organic carbon of (0.54%), low available nitrogen of (191 kg ha^{-1}), high in available phosphorus of (48 kg ha^{-1}) and high available potash of (333 kg ha^{-1}).The experiment included 12 treatment combinations, laid out in a randomized block design with three replications each.Treatments include T_1-atrazine 50% WP 0.50 kg a.i.ha^{-1} as PE, T_2-pyroxasulfone 85% WG @95.625 g a.i.ha^{-1} as PE, T_3-pyroxasulfone 85% WG @95.625 g a.i.ha^{-1} as PE *fb* topramezone 336 gl^{-1}as PoE, T_4-pyroxasulfone 85% WG @ 95.625 g a.i.ha^{-1}as PE*fb*halosulfuron methyl @ 50.625 g a.iha^{-1}as PoE, T_5- atrazine 50% WP@ 0.50 kg a.i.ha^{-1}as PE *fb*MW at 30 DAS, T_6- pyroxasulfone 85% WG @ 95.625 g a.i.ha^{-1}as PE *fb* MW at 30 DAS, T_7- topramezone 10 gl^{-1} + atrazine 300 g l^{-1} SC (RM) @ 581 ga.i.ha^{-1}as PoE, T_8- topramezone 10 gl^{-1} + atrazine 300 g l^{-1} SC (RM) @ 581 ga.i.ha^{-1}as PoE *fb* MW at 45 DAS, T_9- halosulfuron methyl 5% + atrazine 48% WG (RM)@ 56.25+540 ga.i.ha^{-1}as PoE, T_{10}- halosulfuron methyl 5% + atrazine 48% WG (RM)@ 56.25+540 ga.i.ha^{-1}as PoE *fb* MW at 45 DAS, T_{11}- weed free (MW at 20 & 40 DAS + intra row HW), T_{12}- weedy check.The crop was sown on October 16, 2023, with a spacing of 45 cm×15 cm. A total of 100 kg ha^{-1} of nitrogen (N), 60 kg ha^{-1} of phosphorus pentoxide (P_2O_5), and 40 kg ha^{-1} of potassium oxide (K_2O) was applied as the recommended fertilizer dose (RDF) following PJTAU guidelines, using urea, single superphosphate, and muriate of potash as source.Nitrogen was supplied in three splits at the time of sowing (basal), knee high and during flowering stage using the pocketing method, while the entire quantities of phosphorus and potassium were applied at the time of sowing.The weekly mean maximum temperature rangedbetween 27.7 and 34.3 °C, with an average of 31°C, throughout the crop growth period, while the weekly mean minimum temperature ranged from 15.3 to 21.1°C, with an average of 18.2°C. In terms of relative humidity, the weekly mean RH-I (morning) ranged from 81 to 90 % with an average of 85.5%, while the RH-II (afternoon) ranged from 21 to 62 %, with an average of 41.5 %.The weekly mean bright sunshine hours per day ranged from 3.5 to 9.3 hours per day with an average of 6.4 hours. There was a total of 13.4 mm of rainfall over one rainy day received during the crop growth period.Weekly mean evaporation ranged from 2.9 to 5.6 mm per day, with an average of 4.25 mm per day.The effect of various weed management practices on growth parameters (plant height, dry matter production, days to ear head initiation and maturity) and yield attributes (number of earheads per square meter, grains per earhead, earhead length, and 1000-grain weight) were recorded following standard procedures.

RESULTS AND DISCUSSION

Phytotoxicity

Among various herbicidal treatments, pyroxasulfoneas pre-emergence (PE) and combination oftopramezone+atrazine aspost-emergence (PoE) treatments have shown

Comment [A17]: , not required

Comment [A18]: graph can be added of meteorological data

Comment [A19]: can be ellaborated a little more, including phtotoxicity

Comment [A20]: Smaller paragraphs can be avoided, discussion should be ellaborated and results should be discussed in detail phytotoxic effects on sorghum. Pyroxasulfone85% WG @95.625 g a.i.ha^{-1} as PEsignificantly impacted germination, resulting in subsequent stand loss with phytotoxicity rating of 7 (Bhutada *et al.* 2022). Affected plants exhibited chlorosis (yellowing), necrosis (tissue death), and stunting. Symptoms of chlorosis and necrosis resolved by 21 days after application (DAA), while stunting persisted until harvest.Similarly, topramezone 10 gl^{-1} + atrazine 300 g l^{-1} SC (RM) @ 581 ga.i.ha^{-1}as PoE treatment also led to chlorosis and stunting with phytotoxicity rating of 2-3 (Krishnamurthy *et al.* 2021). Although plants recovered fully from chlorosis 14 DAA, stunting remained until harvest.

Comment [A21]: phytotoxicity reading table based on scale can be added

Growth parameters

Plant height (cm)

Data onplant height (cm)as influenced by various weed management practicesis presented in Table 1.

Comment [A22]: can be merged in next paragraph

Comment [A23]: not mentioned in table 1

Among various treatments, significantly taller plants (216 cm), were observed under weed free (T_{11}) and it was on par with T_5- atrazine 50% WP 0.50 kg a.i.ha^{-1}as PE *fb*MW at 30 DAS, T_{10}- halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 ga.i.ha^{-1}as PoE *fb* MW at 45 DAS, T_1-atrazine 50% WP 0.50 kg a.i.ha^{-1} as PE, T_9-halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 ga.i.ha^{-1}as PoEand T_8-topramezone 10 gl^{-1} + atrazine 300 g l^{-1} SC (RM) 581 ga.i.ha^{-1}as PoE *fb* MW at 45 DAS.Except for the phytotoxicity-affected treatments, such as pyroxasulfone PE (T_2, T_3, T_4 and T_6) and topramezone + atrazine(RM) PoE (T_8), the lowest plant height (178 cm) was observed in the unweeded control (T_{12}). This was due to intense competition for resources between the crop and weeds, resulting in reduced internodal length and less translocation of photosynthates compared to other treatments. Similar results were reported by Patel *et al.* (2014) andPrasanna *et al.* (2020)

Comment [A24]: reason can be ellaborated

Dry matter production (kg ha^{-1})

Data on dry matter production(kg ha^{-1})as influenced by various weed management practices is presented in Table 1.

Comment [A25]: can be merged in next paragraph

Weed free treatment recorded higher dry matter accumulation compared to all other treatments and it was on par with T_5- atrazine 50% WP 0.50 kg a.i.ha^{-1}as PE *fb*MW at 30 DAS, T_{10}- halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 ga.i.ha^{-1}as PoE *fb* MW at 45 DAS and T_9-halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 ga.i.ha^{-}

^{1}as PoE. This was due to effective weed control during the critical period of crop-weed competition through herbicides or mechanical weeding. These methods improve soil aeration, enhance nutrient uptake, and reduce weed competition, allowing sorghum to grow more vigorously and utilize resources efficiently.In contrast, the application of atrazine + topramezone atPoE (ready mix), resulted in lower crop growth despite achieving higher weed control efficiency. This reduction in growth can be attributed to the occurrence of phyto-toxicity, which negatively impacted the growth and yield of sorghum. These results are consistent with the findings of Krishnamurthy*et al.* (2021) in sorghum.Unweeded control (T_{12}) recorded lowest dry matter production due to higher crop- weed competition.

Yield attributes

Data on yield attributes as influenced by various weed management practices are presented in Table 2.

Yield attributes, such as the number of earheads per square meter, grains per earhead, earhead length, and 1000-grain weight, were registered higher with weed free which was found on par with atrazine 0.5 kg a.i. ha^{-1} as PE *fb* MW at 30 DAS, halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 g a.i. ha^{-1} as PoE *fb* MW at 45 DAS and halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 g a.i. ha^{-1} as PoE. This may be due to increased dry matter accumulation and improved translocation of photosynthates from the source to the sink.

Grainand stover yield(kg ha^{-1})

Data on grain and stover yield (kg ha^{-1}) as influenced by different weed management practices are presented in Table 2.

The experimental findings revealed that,maximum grain and stover yield was registered with weed free (2830&6795 kg ha^{-1}). Among the herbicides, atrazine 0.5 kg a.i. ha^{-1} as PE *fb* MW at 30 DAS, halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 g a.i. ha^{-1} as PoE *fb* MW at 45 DAS and halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 g a.i. ha^{-1} as PoEhad recorded higher grain and stover yield and on par with weed free treatment.The higher yields achieved with the combination of halosulfuron methyl 5% + atrazine 48% WG (RM) as post-emergence (PoE) treatments result from their effective weed control during the critical period of crop-weed competition, which enhances growth and yield attributes.

when atrazine PE is combined with mechanical weeding (MW), there is a significant improvement in plant height, dry matter accumulation, and grain yield compared to using atrazine PE alone.These findings align with those of Kaushik *et al.* (2005).Mechanical weeding at 30 days after sowing (DAS) and 45 DAS helps keep the crop free from weeds for a longer time, which improves soil aeration and ultimately boosts growth and yield. This practice also enhances the effectiveness of both atrazine and the halosulfuron methyl 5% + atrazine 48% WG (RM) combination.

Lower grain and stover yield wererecorded in pyroxsulfone treatments (T_2, T_3, T_4 & T_6) due to their phytotoxicity effect on sorghum germination and same was reported by Bhutada *et al.*(2022) in sorghum.This led to a decreased plant stand, subsequently impairing growth and development, which ultimately resulted in overall lower yields.

Comment [A26]: data of different parameters can be mentioned in the text . Further increase or decrease per cent can be included where necessary

Fig 1. Bar graph showing plant height measurement

Comment [A27]: not mentioned in text

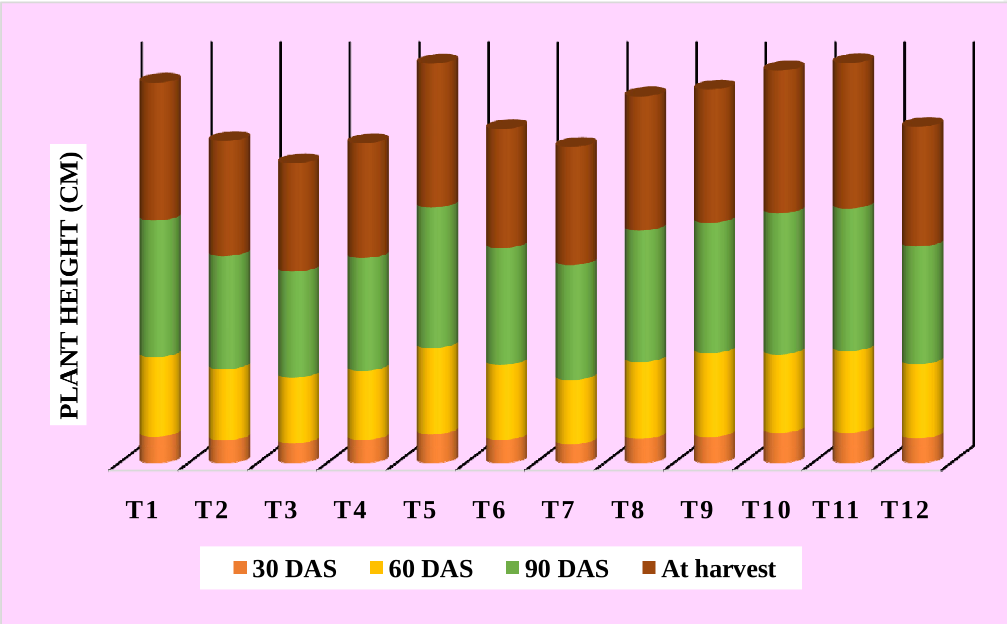
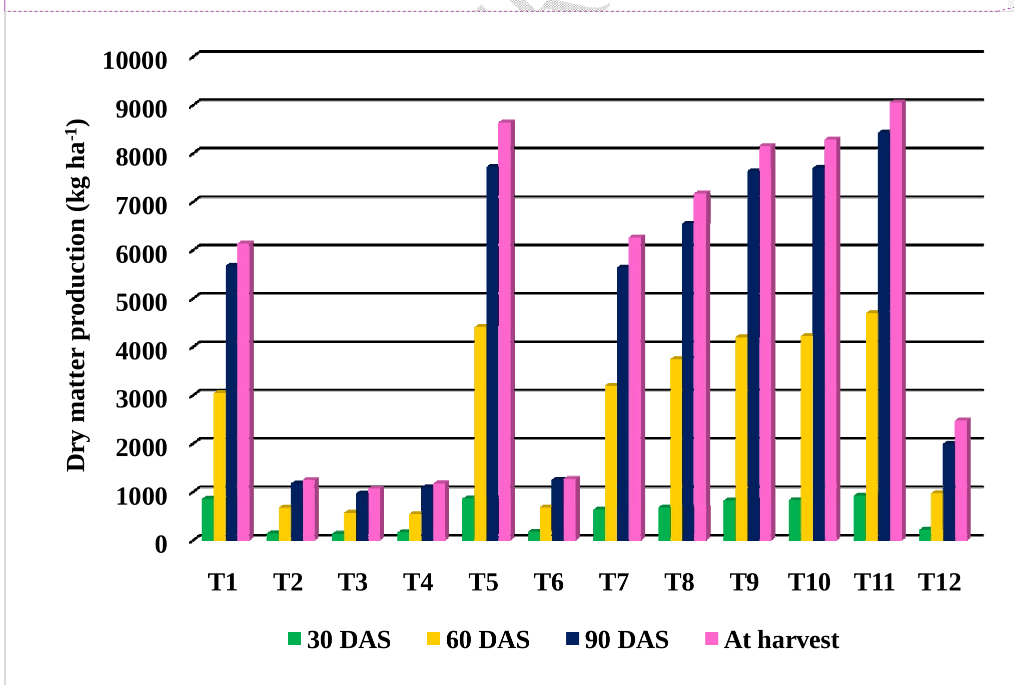


Fig 2. Bar graph showing dry matter production



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Comment [A29]: graphs are not mentioned in text

Table1Yield attributes and yield ofsorghum as influenced by various weed management practices.

Treatments		No. of earheads m^{-2}	Earhead length (cm)	No. of grains earhead^{-1}	Test weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
T_1	Atrazine 50% WP 0.50 kg a.i.ha^{-1} as PE	12	14.4	755	24.5	2125	5177	29.10
T_2	Pyroxasulfone 85% WG 95.625 g a.i.ha^{-}as PE	6	14.0	289	23.94	430	1105	28.01
T_3	Pyroxasulfone 85% WG 95.625 g a.i.ha^{-}as PE *fb* topramezone 336 g/lit PoE	5	14.0	198	23.55	380	948	28.61
T_4	Pyroxasulfone 85% WG 95.625 g a.i.ha^{-}as PE*fb*halosulfuron methyl 50.625 g a.i/ha as PoE	6	14.7	222	24.00	453	990	31.39
T_5	Atrazine 50% WP 0.50 kg a.i.ha^{-1}as PE *fb*MW at 30 DAS	17	16.9	907	25.36	2792	6596	29.74
T_6	Pyroxasulfone 85% WG 95.625 g a.i.ha^{-}as PE *fb* MW at 30 DAS	6	13.3	316	24.05	485	1078	31.03
T_7	Topramezone 10 g l^{-1} + atrazine 300 g l^{-1} SC (RM) 581 g a.i. ha^{-1} as PoE	13	16.2	795	24.15	2216	5217	30.00
T_8	Topramezone 10 gl^{-1} + atrazine 300 g l^{-1} SC (RM) 581 ga.i.ha^{-1}as PoE *fb* MW at 45 DAS	14	16.3	817	24.87	2480	5759	30.10
T_9	Halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 ga.i.ha^{-1}as PoE	16	15.8	856	24.45	2593	6188	29.53
T_{10}	Halosulfuron methyl 5% + atrazine 48% WG (RM) 56.25+540 ga.i.ha^{-1}as PoE *fb* MW at 45 DAS	17	16.8	861	24.98	2656	6347	29.50
T_{11}	Weed free (MW at 20 & 40 DAS + intra row HW)	18	17.9	942	25.62	2830	6795	29.40
T_{12}	Weedy check	8	13.1	352	23.39	680	1600	29.82
	S.Em ±	0.6	0.7	32.3	0.92	93.3	242.5	1.47
	CD	2.0	2.1	94.8	NS	273.7	711.2	NS

CONCLUSION

Among all the weed management treatments, atrazine @ 0.5 kg a.i. ha^{-1} as PE followed by mechanical weeding (MW) at 30 DAS orhalosulfuron methyl 5% + atrazine 48% WG (RM) @ 56.25 + 540 g a.i. ha^{-1} as PoE with or without MW at 45 DAS controlled the weeds effectively in yellowsorghum and were on par with weed free treatment. These practices can be recommended to farmers for effective weed control and higher yields.

Comment [A30]: conclusion can be rewritten with future scope.

Comment [A31]: recheck it how a year study can be recommended to farmers

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Comment [A32]: make it appropriate to journal standards

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