

Nutrient Dynamics in Grain Amaranth and Competing Weeds under Different Weed Management Practices

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Abstract— A field experiment entitled "Effect of different post emergent herbicides on growth and yield of grain amaranth (*Amaranthus caudatus* L.)" was conducted at M block, field unit of AICRN on Potential Crops, University of Agricultural Sciences, Bengaluru during Kharif 2020. The experiment consisted of eight treatments which includes the application of five early post emergent herbicides (Fenoxaprop-p-ethyl, Quizalofop ethyl, Clomazone, Propaquizafop and Cyhalofop butyl), one manual weeding at 4 WAS, weed free check and weedy check which were replicated thrice in RCB design. Major weeds observed in the experimental plot were *Cyperus rotundus*, *Cynodon dactylon*, *Echinochloa colona*, *Eleusine indica*, *Ageratum conyzoides*, *Alternanthera spinosa* and *Borreria articularis*. Application of Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ recorded significantly higher grain amaranth yield (1896 kg ha⁻¹), net returns (Rs. 68,178 ha⁻¹) and B:C ratio (2.56) which was on par with Propaquizafop 10% EC at 12 g a.i. ha⁻¹ (1805 kg ha⁻¹, Rs.63,524 ha⁻¹ and 2.38, respectively) without any phytotoxic effect on grain amaranth crop. However, weedy check recorded significantly lower grain yield (1005 kg ha⁻¹), lower net returns (Rs.25,731 ha⁻¹), lower B:C ratio (1.05) and higher weed index (51.29%) compared to other treatments. Similarly, nitrogen, phosphorus and potassium uptake by grain amaranth crop at harvest was significantly higher with early post emergent application of Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ (74.1, 42.77 and 49.30 kg ha⁻¹, respectively) and lower in weedy check (30.44, 37.13 and 23.97 kg ha⁻¹, respectively).

Keywords— Quizalofop ethyl, Propaquizafop, Cyhalofop butyl, Nutrient uptake.

I. INTRODUCTION

Grain amaranth (*Amaranthus caudatus* L.) is a nutri-rich potential crop with C4 pathway, quick growing, broad leaved and multipurpose crop which can be grown for grain, leafy vegetable, ornamental and forage purpose. It is a warm season crop belongs to Amaranthaceae family and characterized as a plastic plant due to its high adaptability to drought, heat stress, high soil acidity and salinity. It is often called as Chaulai, Batu, Bhabhri, Harave, Keere, Marsha, Rajakeera, Sawal and Ram Dana in India.

Presently, it is mainly cultivated and consumed in India, Nepal, China, Indonesia, Malaysia; whole of Central America, Mexico, Southern and Eastern Africa. In India, grain amaranth is mostly cultivated in Himalayan region at higher and lower hilly regions as a pure crop with some mixed cropping pattern too. This crop especially grown in few parts of Gujarat, Maharashtra and in various parts of Uttarakhand. In Gujarat, the Banaskantha district have approximately an area of 10,000 ha where this future potential crop replaced wheat and potato due to increasing problem of water scarcity. In Karnataka, grain amaranth is being grown by tribal communities in BR hills (Biligiri Rangana) of Chamarajnagara district. The statistical data on area and production in India is lacking. However, it is estimated to be grown in about 40-50 thousand ha (Raiger et al., 2009).

Grain amaranth is very susceptible to weeds during its early growth period and it grows slowly after germination for the first few weeks and hence it is very susceptible to weed competition (Kudsk et al., 2012). Weeds are very high competitors to crop plants due to their analogous nature to growth resources of crop viz., light, moisture, nutrients, space and carbon dioxide which

not only diminish the yield, grain quality and impede harvest operations and surges the cost of production. The degree of damage by weeds relies upon the weed type, species density, period and extent of crop weed competition, soil type, soil moisture and soil fertility conditions. So, timely weed management is essential for achieving higher yield. No herbicides are yet standardized to control weeds in grain amaranth. Weed control is presently done by inter row cultivation but the shortage of labour is a setback. Suitable and economically feasible weed management practices for productive and effective suppression of weeds in grain amaranth is need of the hour. Therefore, this study was conducted to evaluate the efficacy of different post-emergent herbicides for weed control in grain amaranth and to assess their effects on crop growth, yield, nutrient uptake, and economics.

II. MATERIALS AND METHODS

2.1 Study Site and Experimental Design:

A field experiment entitled "Effect of different post emergent herbicides on growth and yield of grain amaranth" was conducted during *Kharif* 2020 at M block, field unit of AICRN (All India Coordinated Research Network) on Potential Crops, University of Agricultural Sciences, Bengaluru. The experiment was laid out in randomized complete block design (RCBD) with eight treatments and three replications.

2.2 Treatments Details:

The treatments consisted of:

- T1: Fenoxaprop-p-ethyl 10% EC at 25 g a.i. ha⁻¹
- T2: Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹
- T3: Clomazone 20% EC at 750 g a.i. ha⁻¹
- T4: Propaquizafop 10% EC at 12 g a.i. ha⁻¹
- T5: Cyhalofop butyl 10% EC at 150 g a.i. ha⁻¹
- T6: One manual weeding at 4 weeks after sowing (WAS)
- T7: Weed free check
- T8: Weedy check

The herbicides were applied using spray volume of 500 L ha⁻¹ for post emergence with knapsack sprayer having flood jet nozzle. All herbicides were applied as post emergent.

2.3 Soil and Crop Management:

The soil of the experimental site was red sandy loam in texture. The soil was slightly acidic in reaction (pH 6.25) with electrical conductivity of 0.24 dS m⁻¹. The soil was low in organic carbon (0.35%) and medium in available N, P₂O₅ and K₂O with 252.7, 23.5 and 268.4 kg ha⁻¹, respectively.

Grain amaranth variety 'Suvarna' was sown with a spacing of 45 × 15 cm and the recommended dose of fertilizer i.e., 60:40:40 kg of N, P₂O₅ and K₂O was applied with two splits of nitrogen.

2.4 Observations Recorded:

Observations on weed density and weed dry matter were recorded in an area of 0.25 m² and converted to 1 m². For soil analysis, a composite soil sample was collected from the entire plot before sowing and it was dried under shade, powdered using wooden pestle and mortar and passed through 2 mm sieve and preserved for analysis. Similarly, after harvest individual soil samples were collected from each plot for analysis. The plant and weed samples at 30 days after sowing and at harvest were collected and dried at 60°C in a hot air oven, powdered using a grinder fitted with stainless steel blades and preserved in polythene bags for further analysis (Jackson, 1973). The samples collected were used for chemical analysis of N, P₂O₅ and K₂O content as

suggested by Subbiah and Asija (1956) for N, Olsen's method for P_2O_5 and neutral normal ammonium acetate method for K_2O (Jackson, 1973).

Total N, P_2O_5 and K_2O uptake by the plant and weed samples was calculated by using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)} \times \text{Biomass (kg ha}^{-1}\text{)}}{100} \quad (1)$$

2.5 Statistical Analysis

Since the data on weed density (No. m^{-2}) and weed dry weight (g m^{-2}) were not normally distributed, the data were transformed by using square root ($x+1$) or log ($x+2$) transformation as suggested by Gomez and Gomez (1984). The transformed data were subjected to Fisher's method of "Analysis of Variance" (ANOVA) as outlined by Panse and Sukhatme (1954). Wherever F-test was significant, for comparison between the treatment means, an appropriate value of critical difference (CD) was worked out at 5% probability level.

III. RESULTS AND DISCUSSION

3.1 Weed Flora:

Major weed flora observed in the experimental plots were *Cyperus rotundus* among sedges and *Cynodon dactylon*, *Echinochloa colona*, *Eleusine indica* and *Panicum maximum* among grasses. Whereas, the major broadleaved weeds were *Ageratum conyzoides*, *Alternanthera spinosa*, *Amaranthus viridis*, and *Borreria articularis*. While, the minor weeds observed were *Digitaria marginata*, *Commelina benghalensis*, *Legascea mollis* and *Chenopodium album*. In the experimental field grasses were dominant followed by broad leaved weeds and the lower were sedges based on the weed number in weedy check plots.

3.2 Weed Dynamics:

The herbicides differed in the spectrum of the weeds that were controlled (Table 1). At 30 DAS, early post emergent application of Quizalofop ethyl 5% EC at 50 g a.i. ha^{-1} and Propaquizafop 10% EC at 12 g a.i. ha^{-1} had significantly reduced weed density of sedges and grasses (8.33, 7.00 and 9.33, 8.33 m^{-2} , respectively) and were on par with each other. Whereas, lower weed density of broad leaved weeds (15.00 m^{-2}) was recorded with application of Clomazone 20% EC at 750 g a.i. ha^{-1} . However, maximum weed density of sedges, grasses and broad leaf weeds (23.67, 67.33 and 28.33 m^{-2} , respectively) was recorded in weedy check. The total density of weeds was found significantly lower with early post emergent application of Quizalofop ethyl 5% EC at 50 g a.i. ha^{-1} (31.33 m^{-2}) which was on par with Propaquizafop 10% EC at 12 g a.i. ha^{-1} (37.33 m^{-2}), and higher total weed density (119.33 m^{-2}) was recorded in weedy check.

At 30 DAS, the early post emergent application of Quizalofop ethyl 5% EC at 50 g a.i. ha^{-1} and Propaquizafop 10% EC at 12 g a.i. ha^{-1} were superior in controlling weeds which recorded lower weed dry weight of sedges and grasses (1.00, 2.67 and 1.47, 8.53 g m^{-2} , respectively) among herbicide treatments and were on par with each other. Further, significantly minimum weed dry weight of broad leaved weeds (2.00 g m^{-2}) was recorded with application of Clomazone 20% EC at 750 g a.i. ha^{-1} . While, weed dry weight of sedges, grasses and broad leaf weeds (2.00, 35.53 and 6.67 g m^{-2} , respectively) were maximum in weedy check. However, significantly lower total dry weight of weeds was recorded with Quizalofop ethyl 5% EC at 50 g a.i. ha^{-1} (11.60 g m^{-2}) which was on par with Propaquizafop 10% EC at 12 g a.i. ha^{-1} (14.80 g m^{-2}), and weedy check had maximum weed dry weight of 44.20 g m^{-2} .

The lower total weed density and weed dry weight was noticed with post emergence application of Quizalofop ethyl 5% EC at 50 g a.i. ha^{-1} and Propaquizafop 10% EC at 12 g a.i. ha^{-1} which might be due to effectiveness of the herbicide in controlling grassy weeds which were actually reported to be higher in number than sedges and broad leaf weeds in experimental field during crop critical period of 15 to 30 DAS. Weed leaves turned purplish/red within 5-8 days after application and within 10-15 days they were completely killed by inhibition of fatty acids synthesis through acetyl-CoA carboxylase (ACCase) inhibition. Even though its effectiveness on broad leaved weeds was very less, they proved to be the best treatments which might be due to crop stature after critical period i.e., after 30 DAS. The grain amaranth has shown enormous plant growth with big broad

leaves that gave shading effect analogous to self-mulching type character by filtering most of the light and very less light might fall on the soil.

3.3 Weed Control Efficiency (%):

The data on weed control efficiency as influenced by weed management practices are presented in Table 1. At 30, 45, 60 DAS and at harvest, higher weed control efficiency (72.85, 76.55, 73.59 and 71.30%, respectively) was recorded with Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ and found on par with Propaquizafop 10% EC at 12 g a.i. ha⁻¹ with weed control efficiency of 66.70, 74.07, 72.23 and 69.76%, respectively. Whereas, weed control efficiency was lowest with Cyhalofop butyl 10% EC at 150 g a.i. ha⁻¹ (51.09, 55.61, 54.09 and 52.72%, respectively) among herbicide treatments due to lower efficiency.

Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ recorded higher weed control efficiency might be a reflection of lower weed density and dry weight of total weeds as a result of effective control of grassy weeds which were the dominant weed group among all weeds. This was also reported by Samant and Mishra (2014). Whereas lower weed control efficiency was reported with early post emergent application of Cyhalofop butyl 10% EC at 150 g a.i. ha⁻¹. The results obtained with Cyhalofop butyl 10% EC at 150 g a.i. ha⁻¹ were not similar to results obtained in black gram by Sasikala et al. (2015) and Deng et al. (2020) in rice. This might be due to control of a very narrow spectrum of weed flora which resulted in higher weed density and weed dry matter among all herbicide treatments.

3.4 Nutrient Dynamics:

At both 30 DAS and at harvest (Table 2), early post emergent application of Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ recorded significantly higher uptake of nitrogen, phosphorus and potassium by grain amaranth (14.51, 0.46, 13.89 kg ha⁻¹ at 30 DAS and 74.17, 42.77, 49.30 kg ha⁻¹ at harvest, respectively) which was on par with Propaquizafop 10% EC at 12 g a.i. ha⁻¹. However, weedy check recorded significantly lower uptake of nitrogen, phosphorus and potassium (6.40, 0.20 and 6.34 kg ha⁻¹ at 30 DAS and 30.44, 37.13 and 23.97 kg ha⁻¹ at harvest, respectively) compared to all other treatments.

There was a positive correlation between nutrient uptake by crop at 30 DAS and at harvest with grain and stover yield. Hence, grain and stover yields were higher whenever the nutrient uptake was higher. Among different treatments, nitrogen, phosphorus and potassium uptake by grain amaranth crop at 30 DAS and at harvest was significantly higher in Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ as a result of higher dry matter production owing to better weed control and less weed competition. Whereas, the lower uptake of nitrogen, phosphorus and potassium by grain amaranth crop was recorded with weedy check which might be an outcome of weed competition resulting in lower dry matter production, as also reported by Ojo et al. (2011).

3.5 Grain Yield:

Significantly higher grain yield was recorded with weed free check (2162 kg ha⁻¹) which was on par with herbicide treatments of early post emergent application of Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ and Propaquizafop 10% EC at 12 g a.i. ha⁻¹ (1896 and 1805 kg ha⁻¹, respectively) and weedy check recorded significantly lower grain yield (1005 kg ha⁻¹) compared to all other treatments as presented in Table 2. The yield increase in herbicide treatments of Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ and Propaquizafop 10% EC at 12 g a.i. ha⁻¹ was of the order 88.65 and 79.60 per cent, respectively compared to weedy check.

The higher grain yield of grain amaranth among herbicide treatments recorded with Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ and Propaquizafop 10% EC at 12 g a.i. ha⁻¹ could be due to effective control of grassy weeds which dominated during the critical period of crop weed competition along with control of sedges and broad leaf weeds, which otherwise were quite notorious for imposing competition for light, space and nutrients with crop. It has provided congenial environment for better expression of growth stature and yield attributes viz., panicle length, number of fingers panicle⁻¹ and finger length. The cumulative effect of all these yield components resulted in increased grain yield. All the yield attributing characters were adversely affected in weedy check treatment due to severe weed competition exerted by weeds for space, light, moisture and nutrients throughout the crop growth period which finally resulted in lower grain yield of grain amaranth. These findings were also in accordance with Anonymous (2004), Anonymous (2013), Shukla et al. (2014) and Mool et al. (2017) in grain amaranth.

TABLE 1

CATEGORY WISE WEED DENSITY (No. m⁻²), WEED DRY WEIGHT (g m⁻²) AND WEED CONTROL EFFICIENCY (WCE) AT 30 DAS IN GRAIN AMARANTH AS INFLUENCED BY WEED MANAGEMENT PRACTICES

Treatments	Weed density				Weed dry weight				WCE (%)
	Sedge ⁺	Grasses [#]	Broad leaf weeds ⁺	Total [#]	Sedge ⁺	Grasses ⁺	Broad leaf weeds ⁺	Total [#]	
T1	2.64 (6.00)	1.01 (8.33)	5.06 (24.67)	1.61 (39.00)	1.68 (1.87)	0.62 (2.67)	3.83 (13.67)	1.24 (16.11)	65.95
T2	3.04 (8.33)	0.95 (7.00)	4.10 (16.00)	1.52 (31.33)	1.41 (1.00)	0.62 (2.67)	2.96 (7.93)	1.13 (11.60)	76.55
T3	3.41 (10.67)	1.28 (17.00)	4.11 (15.00)	1.55 (42.67)	1.99 (3.00)	1.01 (11.27)	1.40 (2.00)	1.26 (16.27)	64.41
T4	3.20 (9.33)	1.01 (8.33)	4.53 (19.67)	1.58 (37.33)	1.57 (1.47)	1.10 (8.53)	1.72 (4.80)	1.12 (14.80)	74.07
T5	3.82 (13.67)	1.09 (10.33)	5.69 (31.33)	1.76 (55.33)	1.98 (2.93)	0.77 (4.00)	3.78 (13.33)	1.35 (20.27)	55.61
T6	1.00 (0.00)	0.30 (0.00)	1.00 (0.00)	0.30 (0.00)	1.00 (0.00)	0.30 (0.00)	1.00 (0.00)	0.30 (0.00)	83.26
T7	1.00 (0.00)	0.30 (0.00)	1.00 (0.00)	0.30 (0.00)	1.00 (0.00)	0.30 (0.00)	1.00 (0.00)	0.30 (0.00)	100
T8	4.96 (23.67)	1.84 (67.33)	5.41 (28.33)	2.08 (119.33)	1.73 (2.00)	1.56 (35.53)	2.77 (6.67)	1.65 (44.20)	0
S.Em±	0.13	0.04	0.2	0.1	0.08	0.06	0.16	0.08	NA
CD at 5%	0.38	0.12	0.6	0.29	0.25	0.19	0.49	0.24	NA

Note: Data within parentheses are original values; # - data analyzed using log(x+2) transformation; + - square root (x+1) transformation

T1: Fenoxaprop-p-ethyl 10% EC at 25 g a.i. ha⁻¹, T2: Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹, T3: Clomazone 20% EC at 750 g a.i. ha⁻¹, T4: Propaquizafop 10% EC at 12 g a.i. ha⁻¹, T5: Cyhalofop butyl 10% EC at 150 g a.i. ha⁻¹, T6: One manual weeding at 4 WAS, T7: Weed free check, T8: Weedy check

TABLE 2

EFFECT OF WEED MANAGEMENT PRACTICES ON NUTRIENT UPTAKE BY WEEDS AND GRAIN AMARANTH AT 30 DAS AND GRAIN YIELD OF GRAIN AMARANTH

Treatments	Nutrient uptake (kg ha ⁻¹)						
	Weeds			Grain amaranth			Grain yield (kg ha ⁻¹)
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	
T1	15.79	1.1	12.7	9.93	0.32	10.11	1554
T2	6.31	0.5	7.84	14.51	0.46	13.89	1896
T3	22.94	1.42	15.99	9.59	0.31	9.54	1358
T4	9.95	0.66	9.06	13.25	0.44	12.56	1805
T5	27.1	1.97	17.44	7.64	0.3	8.46	1274
T6	10.37	1.04	11.92	11.78	0.36	11.21	1878
T7	0	0	0	16.54	0.58	14.71	2162
T8	28.97	2.71	20.57	6.4	0.2	6.34	1005
S.Em±	1.23	0.08	0.75	0.92	0.02	0.8	194
CD at 5%	3.72	0.26	2.28	2.8	0.08	2.43	581

Note: T1: Fenoxaprop-p-ethyl 10% EC at 25 g a.i. ha⁻¹, T2: Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹, T3: Clomazone 20% EC at 750 g a.i. ha⁻¹, T4: Propaquizafop 10% EC at 12 g a.i. ha⁻¹, T5: Cyhalofop butyl 10% EC at 150 g a.i. ha⁻¹, T6: One manual weeding at 4 WAS, T7: Weed free check, T8: Weedy check. DAS: Days after sowing. All herbicides were applied as post emergent.

IV. CONCLUSION

Based on the results of this study, it can be concluded that early post emergent application of Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ and Propaquizafop 10% EC at 12 g a.i. ha⁻¹ were the most effective herbicide treatments for weed management in grain amaranth. These herbicides significantly reduced weed density and weed dry weight, resulting in higher nutrient uptake by the crop and ultimately leading to grain yields (1896 and 1805 kg ha⁻¹, respectively) that were statistically comparable to the weed-free check (2162 kg ha⁻¹). The economic analysis revealed that Quizalofop ethyl treatment recorded the highest net returns (Rs. 68,178 ha⁻¹) and B:C ratio (2.56), followed by Propaquizafop (Rs. 63,524 ha⁻¹ and 2.38). Both herbicides showed no phytotoxic effects on the crop. In contrast, the weedy check recorded significantly lower grain yield (1005 kg ha⁻¹), lower net returns (Rs. 25,731 ha⁻¹), and higher weed index (51.29%). Therefore, Quizalofop ethyl 5% EC at 50 g a.i. ha⁻¹ and Propaquizafop 10% EC at 12 g a.i. ha⁻¹ can be recommended as effective post-emergent herbicides for weed management in grain amaranth, providing farmers with viable options to combat weed competition and improve productivity.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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