Role of Phosphorous fertilizers and P Solubilizers on growth, yield and economics of different cultivars of gain amaranth (*Amaranthus hypochodriacus)*

Abstract

A Field experiment was carried out for two years during *Kharif* season 2018 and 2019 at Main Research Station (MRS), Hebbal, University of Agricultural Sciences, Bangalore. The pooled data of two years indicated that among the varieties, grain yield was significantly higher with Suvarna (1839 kg ha^{-1}) as compared to KBGA-4 (1671 kg ha^{-1}). Among P levels, significantly higher grain yield was recorded with application 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg^{-1}ha soil application + RD of NK&S (848 kg ha^{-1}) which was on par with RDF (2091 Kg ha^{-1}) and 20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} soil application +RD of NK&S (1894 kg ha^{-1}). However, significantly higher yield advantage and agronomic efficiency of P were recorded with application 20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} soil application + RD of NK&S (848 kg and 28.26, respectively) which was on par with 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg/ha + VAM @ 2.5 kg ha^{-1} soil application (522 kg and 26.12, respectively) and Recommended dose of fertilizer (NPKS). Similarly, plant height and panicle length was followed the same trend. Significantly higher gross returns, net returns and B:C ratio were recorded with application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} soil application + RD of NK&S (Rs. 110970 ha^{-1}, Rs.85381 ha^{-1} and 4.34, respectively) which was on par with RDF (NPKS) and 20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} soil application as compared to other treatments. Hence, application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} soil application + RD of NK&S is optimum for higher grain yield in grain amaranth.

Key words: Grain amaranth, Growth, yield, Phosphorous use efficiency, YieldEconomics

1. Introduction

Grain amaranth (*Amranthushypochodriacus*) is one of the pseudocereal which is highly nutritious especially in terms of protein and minerals when compared to other cereals and millets. ItThis is considered as drought tolerant and, climate resilient crop because of its variable climatic adaptabilityadoptability. Amaranth isa tropical annual herbaceous crop belongs to the family

Amaranthaceae. It plays a predominant role in nutrition as a cheapest source of minerals and vitamins. The leaves and stem of amaranth are rich in protein, fat, calcium, phosphorous, β-carotene, riboflavin, niacin, sodium, iron and ascorbic acid; where, calcium. Calcium, iron and phosphorus are the most important elements among the minerals present in amaranth (FAO, 2000). AmaranthThough the exact area and production is lacking in grain amaranth, it is cultivated as a minor crop in several countries like Mexico, Guatemala, Peru, Bolivia, Ecuador, Argentina, Sierra Leone, Nigeria, Zambia, Kenya, Egypt, Afghanistan, Persia, China, Manchuria, Nepal and Bhutan. In India, it is widely distributed and cultivated in seventeen states viz., Jammu and Kashmir, Himachal Pradesh, Uttaranchal, North Bihar, Sikkim, Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura, Gujarat, Madhya Pradesh, Maharastra, Karnataka, Kerala, Tamil Nadu and Orissa.Phosphorus is one of the major essential macronutrients for the biological growth and development of plants. Soils generally contain substantial reserves of total P, though less than onlya major part of it remains relatively inert. Less than 10% of the total soil P is actually utilized and enters the plant-animal cycle. Actually Indian soils are rich in P but more than two thirds of the native phosphates are in a chemical form which cannot be absorbed by plants (Thiyageshwari and Selvi 2006). Furthermore, applied P fertilizers are rendered unavailable due to its chemical fixation in the soil (Vassilev and Vassileva 2003). Amaranth crop is good in phosphorous uptake and voracious feeder of nutrients which are essential for crop plants. However, it has high P requirement and therefore responds to P application (Gupta and Thimba, 1992.). Its productivity can be improved at reduced cost through combined use of P solubilizers viz., Phosphorous Solubilizing Bacteria (PSB) and Vesicular-Arbuscular Mycorrhiza (VAM) which plays an important role in making P available to crop plants and thereby increase the yield of crop plants.

While varietal differences in efficiency of P uptake from soil has been studied for all crops but these studies are lacking in grain amaranth. Such information would be useful for identification, selection and subsequent development of breeding programsprogrammes genotypes with high capabilities for using P in low-P soils. Combined use of P fertilizers and P solubilizers may helphelps in efficient use of phosphorous in soil as well as reduction in application P fertilizer which can reduce cost of cultivation. In this context, an experiment has been conducted with different P levels along with P solubilizers in grain amaranth genotypes. as these fertilizers are very costly.Improved and selected grain amaranth varieties (NIHORT,1995) are known to exhibit variation with respect to grain quality, yield and disease tolerance. However, very little is known about their P requirements, uptake, and utilization. It is probable

that the differential performance exhibited by the selected grain amaranth varieties might partly be a function of their P uptake, utilization and physiological functions in the crop tissues (NIHORT, 1995).In this context, an experiment has been planned in Grain amaranth with different P levels along with different genotypes.

2. 2.Material and methods

The experiment was carried out for two years during Kharif2018 and 2019 at Main Research Station (MRS), Hebbal, University of Agricultural Sciences, Bangalore. to study the effect of P fertilizer levels along with P solubilizers in grain amaranth genotypes.

The soil of the experimental field was sandy loam in texture and low in organic carbon (0.36%), available nitrogen (254.41 kg/ha), medium in available P_2O_5 (28.32 kg/ha) and available K_2O (186.04 kg/ha). Soil is red sandy loam in texture with slightly acidic pH of 6.28 along with normal electrical conductivity (0.25 dS/m).

The experiment was laid in split plot design with two genotypes in main plots, viz., V_1- Suvarna, V_2- KBGA-4 and seven fertilizer levels in subplots, viz., T_1- Control, T_2- 20 kg P_2O_5/ha T_3- 30 kg P_2O_5/ha T_4- 20 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S, T_5- 30 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application, T_6- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone and T_7- recommendedRecommended dose of fertilizer (NPKS),). Recommended dose of fertilizer (RDF) applied @ 60:40:40 NPK kg/ha.

Recommended NK and &S is common for all treatments except T_7. Totally there were 14 treatment combinations which were replicated thrice. The source of NPK used were urea, DAP and MOP. About 50% of nitrogen and 100% of phosphorus and potassium were applied at the time of sowing. Remaining 50% of nitrogen was top dressed after hand weeding and at the time of intercultivation at 30 DAS. PSB and VAM werewas procured from Department of Microbiology,

College of Agriculture GKVK, Bangalore and applied as per the treatments. Necessary plant protection measures were taken during the infestation of sucking pests and defoliates, while no disease was found during the study period. Protective irrigation was given when there was moisture stress due to deficit of rainfall. The growth and yield parameters were recorded at the time of harvesting. Statistical analysis was done as per the formula given by Gomez and Gomez (1966).write the name of the software used for analysis.

3. 3. Results and discussion

3.1. Growth parameters of grain amaranth as influenced by P fertilizer levels along with P solubilizes

The growth and development of the grain amaranth varieties were influenced by P levels and use of P solubilizers (Table 1).. The mean data of two years indicated that, the plant height, panicle length and number of leaves per plant (150.56 cm) was significantly higher in Suvarna variety as compared to KBGA-4 (137.29 cm). Whereas, panicle length and number of leaves per plant were significantly higher in KBGA-4 variety (59.76 cm and 116.85, respectively) as compared to Suvarna (43.15 cm and 103.92, respectively). This could be due to varietal character in which a KBGA-4 bears more small leaves than Suvarna which bears larger broad leaves and shape of the panicle and width of the leaves in each variety may differs. Decreased growth and increased growth among varieties observed in this study corroborate with the findings ofdescribed by Sanginga *et al.* (2000) and Joshi *et al*. (2021) describingas earlier highlighted that hormonal, physiological and other genetic factors are responsible for growth differences. Among subplots, application of phosphorous @ 30 kg/ha along with PSB and VAM was resulted inrecorded higher plant height (152.17 cm) which was on par with RDF (150.50 cm) and application of phosphorous @ 20 kg/ha along with PSB and VAM (147.20 cm) as compared to other P levels.

This could be dueto the fact that phosphorus which encourages formation of new cells, promotes. Root growth (particularly the development of fibrous root growth facilitating roots) and there by more nutrient absorption by the plant increasingin turn increases the plant growth. Similar resultsincrease in growth parameters under higher levels of phosphorus applicationwerereportedobservedby Chakravarty and Gogoi (1991) and Jayshree *et al*. (1996). This could also be due to higher availability of nutrients which has accelerated the synthesis of chlorophyll and amino acids which are associated with photosynthetic process of plants resultingwhich resulted in higher growth and development. The presentabove results were in line with the findings of Naveen and Mevada (2012) and Dongre (2011).

3.2. Yield and yield parameters of grain amaranth as influenced by P fertilizer levels along with P solubilizes

The pooled data of two years (Table 2)indicated that among the varieties, grain yield

and stover yield was significantly higher with Suvarna (1839 and 2064 kg/ha, respectively) as compared to KBGA-4 (1671 and 1819 kg/ha, respectively). Among the subplots, significantly higher grain yield was recorded from thewith application of 30 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S (848 kg kg/ha) which was on par with recommendedRecommended dose of fertilizer (NPKS) (2091 g/ha) and 20 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S (1894 kg/ha).

However, yield advantage over control and agronomic efficiency of P did not differ significantly due to the varieties but differed significantly with phosphorous levels (Table 3).. Significantly higher yield advantage and agronomic efficiency of P were recorded with the applicationof 30 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S (848 kg and 28.26, respectively) which was on par with 20 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S (522 kg and 26.12, respectively) and recommendedRecommended dose of fertilizer (NPKS) (522 kg and 26.12, respectively). Similarly, plant height and panicle length was followed the same trend. However, 10 ml seed weight did not differ significantly (Table 2). This might be dueto better growth and yield parameters and better availability of nutrients at thecrop growth period due to better root developmentgrowth which helped in more absorption of moisture and nutrients aswas observed by Anil Kumar *et al*. (2010) and Ojo *et al*. (2010).

The increase in stover yield at higher level of phosphorus might be due to the significant increase in growth attributes. Similar findings were revealed by Tiwari and Mishra (1997). The results obtained might also be due to beneficial response of the crop due to bio-fertilizers. Bio-fertilizers colonize the rhizosphere of the plant and promote growth by increasing the supply and/or availability of primary nutrients to the host plants. Vesicular *ArbuscularMycorrhiza* is known to enhance the uptake and transport of mineral nutrients from the soil directly into host plant roots. TheSimilar results from the present study were in agreement withreported by Sandeep *et al.* (2014).

3.3.Effect of P fertilizer levels along with P solubilizers on economics of grain amaranth

Economics was did not found significant with the varieties (Table 4).. Whereas, significantly higher gross returns, net returns and B:C ratio were recorded with application of 30 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S (Rs.

110970/ha, Rs.85381/ha and 4.34, respectively) which was on par with recommendedwhich was on par with Recommended dose of fertilizer (NPKS) and 20 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S as compared to other treatments (Table 4). The higher economic advantage could be due to the fact that higher market value for grain amaranth which ultimately led to higher economic returns. Similar findings were also reported by Ramachandra and Thimmaraju (1983) and Singh *et al.* (1985).

4. Conclusion

The findingsresults of the two years studyfindings indicated that application of 30 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S has evidenced in higher growth and yield which was on par with 20 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S. This shows that 50% per cent phosphorous can be reduced when we apply P solubilizing bacteria along with P fertilizers under *Alfisols* of Eastern Dry Zone of Karnataka.

5. References

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Table 1. Growth parameters of Grain amaranth as influenced by levels of phosphorous fertilizer and bio fertilizers.

Treatment details	Plant height (cm)			Panicle length (cm)			No. of leaves per plant at harvest		
Mail Plot (Varieties)	**2018**	**2019**	**Mean**	**2018**	**2019**	**Mean**	**2018**	**2019**	**Mean**
V_1-Suvarna	174.30	106.81	**140.56**	45.53	40.76	**43.15**	15.16	12.68	**13.92**
V_2- KBGA-4	162.19	112.38	**137.29**	62.89	56.64	**59.76**	25.45	21.26	**23.36**
S.Em±	2.19	2.14	1.77	2.72	3.10	0.78	0.86	1.05	**0.96**
CD @5%	**9.44**	**9.21**	**7.61**	**11.71**	**13.33**	**3.35**	**2.25**	**3.20**	**2.73**
Subplots (P levels)									
S_1	148.33	95.00	**121.67**	43.67	38.67	**41.17**	10.14	8.25	**9.20**
S_2	160.00	100.00	**130.00**	49.83	44.83	**47.33**	13.25	10.45	**11.85**
S_3	170.00	109.67	**139.83**	54.37	50.67	**52.52**	15.45	12.48	**13.97**
S_4	178.57	115.83	**147.20**	58.67	53.33	**56.00**	17.35	15.26	**16.31**
S_5	185.17	119.17	**152.17**	62.90	56.07	**59.48**	18.16	16.24	**17.20**
S_6	154.67	107.50	**131.08**	50.00	45.00	**47.50**	12.14	9.25	**10.70**
S_7	181.00	120.00	**150.50**	60.03	52.33	**56.18**	17.85	14.65	**16.25**
S.Em±	**2.76**	**2.94**	**1.62**	**1.65**	**2.01**	**1.62**	**0.32**	**0.65**	**0.49**
CD @%	**8.06**	**8.59**	**4.72**	**4.82**	**5.87**	**4.72**	**1.05**	**1.85**	**1.45**
Interactions (MxS)									
S.Em±	**3.93**	**4.16**	**2.49**	**2.38**	**2.19**	**2.29**	**2.13**	**2.56**	**2.45**
CD @5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NOTE : S1- Control (Recommended dose of NK&S) S2- 20 kg P_2O_5/ha + Recommended dose of NK&S
S3- 30 kg P_2O_5/ha + Recommended dose of NK&S S4- 20 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S S5- 30 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S
S6- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone + RD of NK&S, S7. Recommended dose of fertilizer (NPKS)

Table 2. Yield and yield parameters of Grain amaranth as influenced by levels of phosphorous fertilizer and P solubilizers.

Treatment details	Grain yield (kg/ha)			Fresh stover yield (t/ha)			10 ml seed weight		
Mail Plot (Varieties)	**2018**	**2019**	**Mean**	**2018**	**2019**	**Mean**	**2018**	**2019**	**Mean**
V_1-Suvarna	1837	1513	**1675**	2336	2018	**2177**	9.02	8.48	**8.75**
V_2- KBGA-4	1671	1332	**1502**	2175	1836	**2005**	9.00	8.71	**8.86**
S.Em±	**27**	**25**	**19**	**38**	**42**	**40**	**0.23**	**0.29**	**0.24**
CD @5%	**114**	**107**	**82**	**125**	**132**	**128**	**0.98**	**1.25**	**1.05**
Subplots (P levels)									
S_1	1372	1001	**1186**	1870	1552	**1711**	8.92	8.33	**8.63**
S_2	1501	1196	**1349**	2061	1694	**1877**	9.00	8.33	**8.67**
S_3	1675	1396	**1535**	2176	1891	**2033**	9.00	8.67	**8.83**
S_4	1894	1635	**1764**	2398	2130	**2264**	9.00	8.67	**8.83**
S_5	2019	1759	**1889**	2520	2252	**2386**	9.50	9.17	**9.33**
S_6	1533	1267	**1400**	2032	1756	**1894**	9.00	8.67	**8.83**
S_7	2004	1709	**1856**	2540	2230	**2385**	8.67	8.33	**8.50**
S.Em±	**58**	**24**	**30**	**58**	**44**	**51**	**0.20**	**0.16**	**0.15**
CD @%	**171**	**70**	**86**	**171**	**135**	**153**	**0.59**	**0.46**	**0.43**
Interactions (MXS)									
S.Em±	**80.62**	**35.10**	**40.89**	**85.62**	**38.10**	**61.86**	**0.31**	**0.29**	**0.26**
CD @5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NOTE : S1- Control (Recommended dose of NK&S) S2- 20 kg P_2O_5/ha + Recommended dose of NK&S
S3- 30 kg P_2O_5/ha + Recommended dose of NK&S S4- 20 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S S5- 30 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S
S6- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone + RD of NK&S, S7. Recommended dose of fertilizer (NPKS)

Table 3. Yield advantage and agronomic efficiency of Grain amaranth as influenced by levels of phosphorous fertilizer and bio fertilizers.

Treatment details	Yield advantage over control (kg)			Agronomic efficiency of P (Kg grains kg^{-1} P)		
Mail Plot (Varieties)	**2018**	**2019**	**Mean**	**2018**	**2019**	**Mean**
V_1-Suvarna	460	473	466	14.68	15.58	15.13
V_2- KBGA-4	307	372	339	10.74	12.30	11.52
S.Em ±	**286**	**17**	**112**	**5.94**	**0.58**	**3.25**
CD @5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Subplots (P levels)						
S_1	0	0	0	0	0	0
S_2	130	195	162	6.49	9.75	8.12
S_3	303	395	349	10.12	13.16	11.64
S_4	522	634	578	26.12	31.69	28.90
S_5	848	758	803	28.26	25.26	26.76
S_6	161	266	213	0.00	0.00	0.00
S_7	719	708	714	17.98	17.70	17.84
S.Em ±	**136**	**24**	**69**	**3.61**	**4.81**	**4.65**
CD @%	**397**	**70**	**202**	**10.53**	**15.58**	**15.13**
Interactions (MXS)						
S.Em ±	**32.15**	**33.84**	**120.0**	**6.32**	**3.41**	**2.34**
CD @5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Note: AE= (GYf-GYc)/Ps Where, GYf- grain yield of fertilized plot, GYc- grain yield of control plot, Ps- Quantity of P fertilizer applied

NOTE : S1- Control (Recommended dose of NK&S) S2- 20 kg P_2O_5/ha + Recommended dose of NK&S

S3- 30 kg P_2O_5/ha + Recommended dose of NK&S S4- 20 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S S5- 30 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S
S6- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone + RD of NK&S, S7. Recommended dose of fertilizer (NPKS)

Table 4. Economics of Grain amaranth as influenced by levels of phosphorous fertilizer and bio fertilizers.

Treatment details	Cost of cultivation (Rs./ha)			Net returns (Rs./ha)			B:C ratio		
Mail Plot (Varieties)	**2018**	**2019**	**Mean**	**2018**	**2019**	**Mean**	**2018**	**2019**	**Mean**
V_1-Suvarna	27834	28834	28334	61080	46835	53958	2.23	1.62	1.92
V_2- KBGA-4	27834	28834	28334	54159	37789	45974	1.98	1.31	1.64
SE.m	-	-	-	**1481**	**1244**	**838**	**0.05**	**0.04**	**0.03**
CD @5%	-	-	-	**6373**	**5354**	**3604**	**0.23**	**0.18**	**0.12**
Subplots (P levels)									
S_1	26589	27589	27089	40992	22444	31718	1.58	0.81	1.20
S_2	27864	28864	28364	46211	30919	38565	1.69	1.07	1.38
S_3	28589	29589	29089	54162	40186	47174	1.93	1.36	1.64
S_4	28364	29364	28864	65335	52361	58848	2.34	1.78	2.06
S_5	29589	30152	29870	72644	60336	66490	2.84	2.19	2.52
S_6	26986	27986	27486	48639	35352	41996	1.84	1.26	1.55
S_7	29856	30856	30356	73352	54586	63969	2.49	1.77	2.13
SE.m	-	-	-	**2598**	**1204**	**1357**	**0.09**	**0.04**	**0.05**
CD @%	-	-	-	**7583**	**3513**	**3960**	**0.27**	**0.12**	**0.14**
Interactions (MXS)									
SE.m	-	-	-	**9735**	**1804**	**5057**	**0.20**	**0.15**	**0.17**
CD @5%	-	-	-	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

NOTE : S1- Control (Recommended dose of NK&S) S2- 20 kg P_2O_5/ha + Recommended dose of NK&S S3- 30 kg P_2O_5/ha + Recommended dose of NK&S S4- 20 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application +RD of NK&S S5- 30 kg P_2O_5/ha + PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application + RD of NK&S S6- PSB @ 2.5 kg/ha + VAM @ 2.5 kg/ha soil application alone + RD of NK&S, S7. Recommended dose of fertilizer (NPKS)