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Effect of Phosphorous Fertilizer Levels and P Solubilizers on Growth, Yield, Economics, Nutrient Uptake and Quality of Grain Amaranth (*Amaranthus hypochodriacus* L.)

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Abstract

A field experiment was conducted during *kharif* 2020 at M-Block, GKVK, Bengaluru to find out the effect of phosphorous levels and P solubilizers on growth and yield of grain amaranth. Data revealed that significantly higher plant height, leaf area per plant and total dry matter per plant (208.30 cm, 1970.54 cm^2 and 26.58 g, respectively) were recorded in suvarna variety as compared to KBGA-4 (182.92 cm, 1652.26 cm^2 $plant^{-1}$ and 19.83g, respectively). However, among phosphorous levels, application of 30 kg P_2O_5 ha^{-1} + PSB@ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + recommended dose of NK & S recorded significantly higher plant height (212.10 cm), number of leaves (23.58), leaf area (1955.74 cm^2 $plant^{-1}$) and dry matter per plant (30.42 g) as compared to other treatments. Among the varieties, significantly higher yield was recorded with suvarna variety as compared to KBGA-4. Among subplots, significantly higher yield (2180 kg ha^{-1}), higher net return and B:C ratio (Rs.78,600 ha^{-1} and 3.58) were obtained with the application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S. Application of 30 kg P_2O_5 ha^{-1} + PSB@ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S recorded significantly higher nutrient uptake at harvest (83.2 N kg ha^{-1}, 26.37 P_2O_5 kg ha^{-1} and 44.71 K_2O kg ha^{-1}) and lower nutrient uptake was recorded with application of RD of NK & S at harvest. The nutritional values of the crop in subplots did not differ significantly but numerically higher crude protein (15.78 g), calcium (403.36 mg), phosphorus (543.51 mg) and iron (13.97 mg) were found with application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S and it was on par with application of RDF as compared to other treatments. Among the varieties, the higher nutrient use efficiency was recorded with suvarna variety (31.5, 47.2 and 47.2 kg ha^{-1} N, P_2O_5, K_2O, respectively) as compared to KBGA- 4 (25.8, 38.3 and 38.3 kg ha^{-1} N, P_2O_5, K_2O, respectively). However, significantly higher NPK use efficiency was obtained with the application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application+RD of NK&S (36.3, 72.60 and 54.50 kg ha^{-1}) and lower NPK use efficiency (34.50, 51.60 & 51.60 kg ha^{-1}) was observed with RDF.

Keywords : Grain Amaranth, P levels, P solubilizers and Nutrient Uptake, Quality, yield, Economics of grain amaranthus

Grain amaranth (*Amaranthus hypochondriacus* L.) is one of the nutri-rich potential crop grouped under pseudocereals which is highly nutritious especially in terms of protein and minerals when compared to other cereals and millets. This is considered as drought tolerant, climate resilient crop because of its variable climatic adaptability. Amaranth is 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. Calcium, iron and phosphorus are the most important elements among the minerals present in amaranth (FAO, 2000). Though the exact area and production are 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, also it is widely distributed and cultivated in several states *viz*., Jammu and Kashmir, Himachal Pradesh, Uttarakhand, North Bihar, Sikkim, Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Kerala, Tamil Nadu and Orissa. In Karnataka, grain amaranth is being grown and utilized by the tribal people of Biligiri Rangana hills of Chamarajanagara district (Anand *et al.*, 2020). Nowadays, it is gaining popularity among rural farmers of Karnataka because of its nutritional quality and fit well into the cropping system.

Amaranth grain is considered to have a unique composition of protein, carbohydrate and lipid. It has high protein (12-18%) than other cereal grain. While the grain amaranth was the principle species used on the South American continent, Amaranth have been cultivated as vegetable crop by early civilization over 2000 years ago and continue to be used essentially world-wide even at present day.

Phosphorus is one of the major essential macronutrient for the biological growth and development of plants and plays a key role in the balanced nutrition of any crop plant. 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 & 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 as Phosphorous Solubilizing Bacteria (PSB) and *Vesicular Arbuscular Mycorrhiza* (VAM) which play an important role in making P available to crop plants and thereby increases the yield of crop plants.

While varietal differences in the 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 programme where genotypes with high capabilities for using P in low-P soils. Combined use of P fertilizers and P solubilizers may help in efficient use of phosphorous in soil as well as reduction in application of P fertilizer which can reduce cost of cultivation as these fertilizers are very costly. In this context, an experiment was conducted on Grain amaranth with different P levels and P solubilizers along with different genotypes during *kharif* 2020 at M-Block, UAS, GKVK, Bengaluru.

Material and Methods

A field experiment was conducted during *kharif* 2020 at M-Block, GKVK, Bengaluru in red sandy loam soil (pH 5.8; OC 0.46%) with medium available nitrogen (262.08 kg ha^{-1}), phosphorus (20.05 kg ha^{-1}) and potassium (269.70 kg ha^{-1}). The experiment was laid out in Split plot, consisting of main plot varieties (Suvarna and KBGA-4) and sub plot with application of different P levels and P solubilizes. The varieties *viz*., Suvarna and KBGA-4 used for the experiment which were developed and released by AICRN on potential crops University of Agricultural Sciences, Bangalore. The land preparation was done by ploughing with tractor drawn disc plough followed by cultivator twice. The sowing was taken up on 5th August, 2020 and the treatments were imposed with the combination of different P fertilizer levels and P solubilizers were applied at the time of sowing as per the treatments. Fertilizers were applied as per the recommendation. Out of 60:40:40 NPK kg ha^{-1}, 50 per cent N and the entire dose of P and K were applied as basal and remaining 50 per cent N was applied at 30 DAS as top dressing. Two hand weedings were done manually at 20 and 40 DAS in order to keep the plots weed free. The crop was harvested on 24th November, 2020 at 109 days after sowing. The

cost of cultivation was computed by considering the present prices of inputs prevailed during their use for different treatments. Similarly, the prevailing market price for Grain amaranth was considered for calculating gross returns and net returns and computed by deduction of cost of cultivation. The levels of significance was tested with 'F' and 't' tests were at p = 0.05, critical difference values were calculated wherever the 'F' test was found to be significant.

Results and Discussion

Effect of P Levels and P Solubilizers on Growth Parameters of Grain Amaranth

Significantly higher plant height, leaf area per plant and total dry matter per plant (208.30 cm, 1970.54 cm^2 and 26.58 g $plant^{-1}$, respectively) were recorded in suvarna variety as compared to KBGA-4 (182.92 cm, 1652.26 cm^2 and 19.83 g $plant^{-1}$, respectively). Whereas, number of leaves per plant was significantly higher with KBGA-4 (19.61) variety as compared to suvarna (15.82) variety. This was mainly due to varietal characteristics. Among the sub plots, application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1}as soil application + RD of NK & S has recorded significantly higher plant height (212.10 cm), number of leaves $plant^{-1}$ (23.58), leaf area $plant^{-1}$ (1955.74 cm^2) and dry matter production $plant^{-1}$ (30.42 g $plant^{-1}$) as compared to other treatments. However, significantly lower plant height, number leaves $plant^{-1}$, leaf area $plant^{-1}$ and total dry matter $plant^{-1}$was recorded with control (Table 1).

Table 1

Growth parameters of Grain Amaranth as influenced by levels of phosphorus fertilizer and P solubilizers

Treatments	Plant height (cm)	No. of leaves $plant^{-1}$	Leaf area $plant^{-1}$ (cm^2)	Dry matter production (g $plant^{-1}$)
Varieties				
V_1-Suvarna	208.30	15.82	1970.54	26.58
V_2- KBGA-4	182.92	19.61	1652.26	19.83
F-test	*	*	*	*
S. Em±	2.21	0.60	51.35	0.53
CD @5%	13.43	3.65	312.45	3.20
P levels				
P_1-Control (RD of NK & S)	175.02	13.54	1639.81	15.27
P_2 -20 kg P_2O_5 ha^{-1} + RD of NK & S	181.61	14.10	1700.63	17.04
P_3-30 kg P_2O_5 ha^{-1} + RD of NK & S	190.82	14.45	1775.43	19.72
P_4 -20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application+ RD of NK & S	208.57	21.98	1888.07	29.15
P_5 -30 kg $P_2O_5$$ha^{-1}$ + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S	212.10	23.58	1955.74	30.42
P_6 -PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application alone + RD of NK & S	191.10	15.62	1830.91	21.63
P_7 - RDF (60:40:40:20 NPKS kg ha^{-1})	210.35	22.72	1889.52	29.54
F-test	*	*	*	*
S. Em±	1.68	0.61	50.00	0.50
CD @5%	4.89	1.77	145.94	1.46

Continued....

TABLE 1 Continued....

Treatments	Plant height (cm)	No. of leaves plant^{-1}	Leaf area plant^{-1}(cm^2)	Dry matter production (g plant^{-1})
Interactions (VxP)				
F-test	NS	NS	NS	NS
S. Em±	5.84	1.55	83.20	1.38
CD @5%	-	-	-	-

Note : NS : Non-significant. DAS : Days after sowing

This could be due to the fact that phosphorus which encourages the formation of new cells, promotes root growth (particularly the development of fibrous roots) and thereby more nutrient absorption by the plant and in turn increases the plant growth. Similar increase in growth parameters under higher levels of phosphorus application were observed by 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 which resulted in higher growth and development. The above results were in line with the findings of Naveen and Mevada (2012) and Dongre (2011).

Effect of P Levels and P Solubilizers on Yield Parameters of Grain Amaranth

Significantly higher number of fingers per panicle, finger length, 10 ml seed weight and grain yield (35.60, 9.47 cm, 8.40 g and 18.30 g plant^{-1}, respectively) was recorded in suvarna variety. However, significantly lower leaf area recorded in KBGA-4 (32.15, 8.33 cm, 8.32 g and 14.62 g plant^{-1}). Application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kgha^{-1} as soil application + RD of NK&S has recorded significantly higher number of fingers per panicle, finger length, 10 ml seed weight and grain yield (41.26, 10.28 cm, 8.95 g and 17.23 g plant^{-1}, respectively) followed by application of recommended dose of fertilizer (NPKS). However, significantly lower yield parameters were recorded with control (24.17, 6.92 cm, 8.51 g and 14.72 g plant^{-1} (Table 2). This might be due to better growth and yield parameters and better availability of nutrients at crop growth period due to better root growth which helped in more absorption of moisture and nutrients was observed by Anil Kumar *et al*. (2010).

Effect of P Levels and P Solubilizers on Yield and Economics of Grain Amaranth

Suvarna variety recorded significantly higher grain yield, stover yield (1890 kg ha^{-1} and 2989 kg ha^{-1},

TABLE 2

Yield parameters of Grain Amaranth as influenced by levels of phosphorus fertilizer and P solubilizers

Treatment details	No. of fingers per panicle	Finger length (cm)	10 ml seed weight (g)	Grain yield (g plant^{-1})
Varieties(V)				
V_1-Suvarna	35.60	9.47	8.40	18.30
V_2- KBGA-4	32.15	8.33	8.32	14.62
F-test	*	*	NS	*
S. Em±	0.52	0.18	0.12	0.54
CD @5%	3.15	1.11	-	3.30

Continued....

TABLE 2 Continued....

Treatment details	No. of fingers per panicle	Finger length (cm)	10 ml seed weight (g)	Grain yield (g plant^{-1})
P levels (P)				
P_1-Control (RD of NK & S)	24.17	6.92	8.51	14.72
P_2 -20 kg P_2O_5 ha^{-1} + RD of NK & S	27.35	7.86	8.65	15.25
P_3-30 kg P_2O_5 ha^{-1} + RD of NK & S	29.82	8.83	8.71	15.81
P_4 -20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application+ RD of NK & S	40.28	9.75	8.89	17.23
P_5 -30 kg P_2O_5ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S	41.26	10.28	8.95	18.56
P_6 -PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application alone + RD of NK & S	34.21	9.04	8.76	16.62
P_7 - RDF (60:40:40:20 NPKS kg ha^{-1})	40.35	9.94	8.90	17.35
F-test	*	*	NS	*
S. Em±	0.39	0.19	0.07	0.46
CD @ 5%	1.13	0.57	-	1.35
Interactions (VXP)				
F-test	NS	NS	NS	NS
S. Em±	1.34	0.48	0.30	1.43
CD @5%	-	-	-	-

Note : NS : Non-significant. DAS : Days after sowing

respectively) as compared to the KBGA-4 variety (1535 kg ha^{-1} and 2554 kg ha^{-1}) (Table 3). However, application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK&S recorded significantly higher grain yield, stover yield (2180 kg ha^{-1}and 3330 kg ha^{-1}) followed by recommended dose of fertilizer (NPKS). The higher grain yield was obtained may be due to the cumulative effect of growth and yield attributes on the grain yield, which ultimately led to higher yield. Similar findings were also reported by Ramachandra and Thimmaraju (1983), Singh *et al.* (1985), Panchal *et al.* (1991), Chakhatrakan *et al.*(1994); Barik and Khanda (1999).

The increase in stover yield at higher level of phosphorus might be due to 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 or availability of primary nutrients to the host plants. Vesicular *Arbuscular mycorrhiza* is known to enhance the uptake and transport of mineral nutrients from the soil directly into host plant roots. Similar results were reported by Sandeep *et al.* (2014).

Similarly, the higher net return and B:C ratio (Rs.78,600 ha^{-1} and was obtained with application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S and lower net return of Rs.36,307 ha^{-1} was obtained with control (recommended dose of NK & S). Similarly, B: C ratio of 3.58 was recorded with application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S and was equivalent to application of recommended dose of fertilizer (NPKS), 20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK and S.

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TABLE 3

Grain yield, stover yield and economics of Grain Amaranth as influenced by levels of phosphorus fertilizer and P solubilizers

Treatment	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Net returns (Rs ha^{-1})	B:C Ratio
Varieties (V)				
V_1-Suvarna	1890	2989	65830	3.26
V_2- KBGA-4	1535	2554	47405	2.62
F-test	*	*	-	-
S. Em±	47.21	47.43	-	-
CD @5%	287.24	288.61	-	-
P levels (P)				
P_1-Control (RD of NK & S)	1290	2204	36307	2.31
P_2 -20 kg P_2O_5 ha^{-1} + RD of NK & S	1390	2354	40935	2.48
P_3-30 kg P_2O_5 ha^{-1} + RD of NK & S	1470	2416	46465	2.60
P_4-20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application+ RD of NK & S	2060	3242	73310	3.47
P_5-30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S	2180	3330	78600	3.58
P_6 - PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application alone + RD of NK & S	1520	2670	49625	2.93
P_7 - RDF (60:40:40:20 NPKS kg ha^{-1})	2066	3285	74995	3.48
F-test	*	*	-	-
S. Em±	43.10	44.33	-	-
CD @5%	125.79	129.40	-	-
Interactions (VXP)			-	-
F-test	NS	NS	-	-
S. Em±	101.98	125.49	-	-
CD @5%	-	-	-	-

Note : NS : Non-significant.

While, lower B:C ratio (2.31) was observed with control (RD of NK and S). The higher net return might be due to higher grain yield and lesser cost of cultivation. This was attributed to higher net return realized because of higher yield of grain amaranth, which also fetched higher price in the market. Similar results were earlier reported by Pratap *et al.* (2010). These results are in conformity with the findings of Patel *et al.* (2005) who had reported similar trend of results in grain amaranth.

Effect of P Levels and P Solubilizers on Nutrient Uptake of Grain Amaranth

The nutrient uptake was significantly influenced by varieties (Table 4). Significantly higher NPK nutrient uptake was noticed in suvarna (57.81 kg ha^{-1}, 25.99 kg ha^{-1}, 42.68 kg ha^{-1}, respectively) as compared to KBGA-4. Among subplots, the application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S recorded

TABLE 4

Nutrient uptake of Grain Amaranth at harvest as influenced by levels of phosphorus fertilizer and P solubilizers

Treatments	Nutrient uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
Varieties			
V_1-Suvarna	57.81	25.99	42.68
V_2- KBGA-4	54.95	22.39	36.68
F-test	*	*	*
S. Em±	0.46	0.47	0.81
CD @5%	2.80	2.88	4.93
P levels			
P_1-Control (RD of NK & S)	33.83	22.06	35.68
P_2 -20 kg P_2O_5 ha^{-1} + RD of NK & S	35.95	22.82	36.45
P_3-30 kg P_2O_5 ha^{-1} + RD of NK & S	36.42	23.13	37.74
P_4 -20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application+ RD of NK & S	81.75	25.62	42.63
P_5 -30 kg P_2O_5ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S	83.02	26.37	44.71
P_6 -PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application alone + RD of NK & S	41.07	23.75	37.93
P_7-RDF (60:40:40:20 NPKS kg ha^{-1})	82.85	25.81	42.81
F-test	*	*	*
S. Em±	0.45	0.41	0.75
CD @5%	1.32	1.19	2.19
Interactions (VXP)			
F-test	NS	NS	NS
S. Em±	1.22	1.23	2.11
CD @5%	-	-	-

Note : NS : Non-significant.

significantly higher NPK nutrient uptake (83.02 kg ha^{-1}, 26.37 kg ha^{-1}, 44.71 kg ha^{-1}, respectively) which was on par with RDF (NPKS). This might be due to increased dry matter accumulation in leaf, stem and grain and enhanced absorption of nitrogen during peak growth period which was due to better root spread and higher root weight. This is in conformity with findings of Ananda and Dhanapal (2006), Modhvadia *et al*. (2007) and Chaudhari *et al*. (2009) who also reported higher nitrogen uptake with fertilizers and organic sources applied at higher quantity. The solubility action of organic acids produced during the decomposition of organic matter might have favoured in more release of native and applied phosphorus (Duryodhana *et al.,* 2004). Higher phosphorus uptake was also attributed to better root growth and development Chaudhari *et al,* 2009. The higher uptake of potassium by both stover and grain could be due to higher total dry matter production and grain yield. Similar results were opined by Khanda and Mohapatra (2003).

TABLE 5

Nutritional value of Grain Amaranth seed (per 100 g) as influenced by levels of phosphorus fertilizer and P solubilizers

Treatment	Crude protein (g)	Calcium (mg)	Phosphorus (mg)	Fe (mg)
Varieties(V)				
V_1-Suvarna	14.98	393.84	539.93	13.04
V_2- KBGA-4	13.92	385.83	532.76	12.92
F-test	NS	NS	NS	NS
S. Em±	0.39	7.20	7.15	0.40
CD @5%	-	-	-	-
P levels(P)				
P_{1-}-Control (RD of NK & S)	13.23	372.16	526.52	12.34
P_2 -20 kg P_2O_5 ha^{-1} + RD of NK & S	14.12	384.82	533.29	12.65
P_3-30 kg P_2O_5 ha^{-1} + RD of NK & S	14.05	390.14	536.71	12.72
P_4 -20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application+ RD of NK & S	14.89	392.16	538.34	13.05
P_5 -30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S	15.78	403.36	543.51	13.97
P_6 -PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application alone + RD of NK & S	14.30	393.82	532.83	12.83
P_7 –RDF (60:40:40:20 NPKS kg ha^{-1})	14.91	397.53	543.32	13.21
F-test	NS	NS	NS	NS
S. Em±	0.29	6.98	6.38	0.38
CD @5%	-	-	-	-
Interactions (VXP)				
F-test	NS	NS	NS	NS
S. Em±	1.04	19.05	18.93	1.06
CD @5%	-	-	-	-

Note : NS : Non-significant.

Effect of P Levels and P Solubilizers on Quality Parameters of Grain Amaranth

The varieties did not differ significantly with respect to crude protein (g), calcium (mg), phosphorus (mg) and iron (mg) in 100 g of grain amaranth seed. However numerically higher values were recorded in Suvarna variety; crude protein (14.98 g), calcium (393.84 mg), phosphorus (539.93 mg) and Fe (13.04 mg) as compared to KBGA-4 variety which was recorded lower values of crude protein (13.92 g), calcium (385.83 mg), phosphorus (532.76 mg) and Fe (12.92 mg). Among the P levels and P solubilizers, the crude protein (g), calcium (mg), phosphorus (mg) and iron (mg) did not differ significantly. However, the application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S was noticed numerically higher values of crude protein (15.78g), calcium (403.36mg), phosphorus (543.51mg) and iron (13.97mg) content per 100g. Neeraja and Patel (2015) noticed the higher protein content in grains due to the higher vegetative growth and yield attributing characters,

TABLE 6
Nutrient use efficiency of Grain Amaranth at harvest as influenced by levels of phosphorus fertilizer and P solubilizers

Treatments	Nutrient Use Efficiency (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
Varieties			
V_1-Suvarna	31.5	47.2	47.2
V_2- KBGA-4	25.8	38.3	38.3
P levels			
P_{1-}- Control (RD of NK & S)	21.5	-	32.2
P_2 -20 kg P_2O_5 ha^{-1} + RD of NK & S	23.1	69.5	34.7
P_3-30 kg P_2O_5 ha^{-1} + RD of NK & S	24.5	49.2	36.7
P_4 -20 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application+ RD of NK & S	34.3	85.6	51.5
P_5 -30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S	36.3	72.6	54.5
P_6 -PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application alone + RD of NK & S	25.3	-	38
P_7 -RDF (60:40:40:20 NPKS kg ha^{-1})	34.4	51.6	51.6

which might have helped in the increased uptake of nitrogen. Higher protein content in seed might be due to root enlargement, better microbial activities resulting more availability and uptake of nitrogen (Naveen and Mevada, 2012).

Effect of P Levels and P Solubilizers on Nutrient use Efficiency of Grain Amaranth

The nutrient use efficiency of grain amaranth as influenced by different P levels and P solubilizers at harvest are presented in Table 6. Among the varieties, the higher nutrient use efficiency recorded by Suvarna variety (31.5, 47.2 and 47.2 kg ha^{-1} N, P_2O_5, K_2O, respectively) as compared to KBGA-4 (25.8, 38.3 and 38.3 kg ha^{-1} N, P_2O_5, K_2O, respectively). However, significantly higher NPK use efficiency was obtained with application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S (36.3, 72.60 and 54.50 kg ha^{-1}, respectively) and lower NPK use efficiency (34.50, 51.60 and 51.60 kg ha^{-1}, respectively) was observed with RDF. The application of 30 kg P_2O_5 ha^{-1} + PSB @ 2.5 kg ha^{-1} + VAM @ 2.5 kg ha^{-1} as soil application + RD of NK & S resulted in higher uptake and utilization with respect to all major nutrients which in turn resulted in higher nutrient use efficiency. Ramachandra & Thimmaraju (1983) reported increase in P percentage in plant due to increasing in levels of both N & P in grain amaranth. This may be attributed to increased availability of soil P owing to decomposition of organic matter added through FYM and vermicompost which might have contributed to the solubilisation of native and applied P_2O_5 (Geethakumari and Shivashankar, 1991).

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