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Influence of Fertilizer and Spacing on Seed Yield and Quality of Grain Amaranth (*Amaranthus hypochondriacus* L.) cv. Suvarna

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A field experiment was conducted to fix the optimum dose of N, P and K fertilizers and spacing levels for realizing higher seed yield associated with good quality characters in grain amaranth cv. Suvarna. The effect of fertilizer at three different schedules *viz.*, NPK @ 30:10:10; 40:20:20 and 50:30:30 kg ha^{-1} and three different spacing *viz.,* 45 X 10 cm^{2}; 45 X 15 cm^{2} and 45 X 20 cm^{2} on plant morphological characters *viz.,* plant height, number of leaves, stem diameter, number of spikelet spike^{-1}, spike length, spike breadth and seed physiological characters *viz.,* 100 seed weight, germination, vigour index and protein content were evaluated. The combined effect of fertilization of NPK and spacing of 45 x 15 cm^{2} significantly improved the plant height, spike length and breadth. Though the seed yield per plot was lower by 17.7 per cent than closer spacing, fore-going yield, grain amaranth could be spaced as 45 x 15 cm^{2} and fertilized as 50:30:30 kg ha^{-1} for higher quality seed yield.

Keywords: Grain amaranth, fertilizer, spacing, seed, yield, quality

Vegetables supply important vitamins, minerals and antioxidants required by human body for a healthy and active life.India is the world's second largest producer of vegetables next only to China. The production of vegetables is still inadequate and provides hardly 120 g as against 300 g per capita requirement per day.

Amaranthus aptly termed as "Poor man's spinach" has enough potential for combating under and malnutrition prevalent in many parts of the world. Grain amaranth (*Amaranthus* spp.) is an ancient crop originating from Central and South America (Stallknecht and Schulz-Schaeffer, 1993) and the high nutrition value of pale-seeded grain amaranth seed is the reason for the increasing research interest in this alternative cereal. Grain amaranth protein contains around 5 per cent lysine and 4.4 per cent sulfo-amino acids, which are limiting in other grains thus ensuring a balanced human diet (Sounders and Becker, 1983). The total lipid content of grain amaranth ranges from 5.4 to 17.0 per cent dry matter with almost 50 per cent as linoleic acid (Becker *et al.,* 1981). Seed production in grain amaranth crop is a specialized activity and the availability of information on seed technological aspects encompassing production, nutrient management, grading and storage of amaranth seeds is scanty in India thus requiring pertinent investigation.

Materials and Methods

A field experiment was laid out adopting split plot design with three replications during July 2007 at Department of Seed Science and Technology, TNAU, Coimbatore to fix the optimum dose of N,P and K at levels of 30:10:10; 40:20:20; 50:30:30 NPK kg ha^{-1} applied basally and at spacing levels of 45 X 10 cm^{2} for 45 X 20 cm^{2}, 45 X 30 cm^{2} for realizing higher seed yield associated with good quality characters in Amaranth cv. Suvarna.

The seeds were sown in raised bed and transplanted after two weeks to main field in a plot of size 4 x 4m^{2}. All other agronomic and plant protection measures were carried out as and when required as per the Crop Production Guide (Anon, 1999). Twenty five plants were randomly tagged in each of the plot (replication and treatment wise) and observed for the yield and yield attributes.

Results and Discussion

The productivity of grain amaranth in India is low compared to world's productivity (Ifthiqharulla, 2001) though there is ample scope for its increased production through proper crop management techniques. In the present study, it was observed that fertilizer schedule did not affect the spike initiation but non significantly reduced inter row spacing, days to 50% spike formation and duration of spike initiation. However other plant morphological characters *viz.,* plant height, number of leaves, stem diameter, number of spikelet spike^{-1}, spike length and spike breadth were increased by 7, 13, 18, 8, 2 and 4 per cent respectively with the application of NPK @ 50 : 30: 30 kg ha^{-1} compared to lower levels of NPK@ 30:10:10 kg ha^{-1} (Tables 1, 2).

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Table 1. Influence of spacing and fertilizer on days for spike initiation, days for 50% spike formation, plant height (cm), stem diameter (cm), number of leaves and number of spikelets spike^{-1}

Fertilizer levels NPK @ kg ha^{-1}	Spacing (cm^2)							
	Days for spike initiation				Days for 50% spike formation			
	45 X 10	45 X 15	45 X 20	Mean	45 X 10	45 X 15	45 X 20	Mean
30:10:10	43	43	43	43	45	45	45	45
40:20:20	41	41	41	41	43	43	43	43
50:30:30	40	40	40	40	42	42	42	42
Mean	41	41	41	41	43	43	43	43
	F	S	F at S		F	S	F at S	
SEd	0.415	0.509	0.838		0.415	0.521	0.846	
CD(P=0.05)	1.154	NS	NS		1.154	NS	NS	
	Plant Height (cm)				Stem diameter (cm)			
30:10:10	133	140	141	138	1.7	1.9	2.1	1.9
40:20:20	142	145	147	144	2.2	2.4	2.4	2.3
50:30:30	151	155	157	154	2.7	2.9	3.0	2.8
Mean	142	146	148	145	2.2	2.4	2.5	2.3
	F	S	F at S		F	S	F at S	
SEd	0.248	0.444	0.675		0.156	0.169	0.286	
CD(P=0.05)	0.689	0.968	1.527		0.435	NS	NS	
	Number of leaves				Number of spikelets spike^{-1}			
30:10:10	32	34	35	33	50	53	58	53
40:20:20	33	35	39	35	56	59	61	58
50:30:30	38	40	44	40	60	64	65	63
Mean	34	36	39	36	55	58	61	58
	F	S	F at S		F	S	F at S	
SEd	0.157	0.222	0.351		0.430	0.430	0.745	
CD(P=0.05)	0.436	0.484	0.807		1.194	0.937	1.772	

The seed yield plant^{-1} and seed yield ha^{-1} was also higher by 5.8 and 17.7 per cent respectively compared to lower dose of NPK @ 30:10:10 kg ha^{-1}. Similar improvement with application of slightly higher doses of fertilizer had been reported by Sasthri *et al.* (2001) in cotton, Sundaralingam *et al.* (1998) in carrot and Natarajan (2000) in marigold. The results of the present study also revealed that yield increase was always in accordance with the increase in yield attributing characters as reported by Menaka (2000) in Leaf Amaranth and Anon (1996) in Amaranth var. CO 2 with application of 50:30:30

Table 2. Influence of spacing and fertilizer on spike length (cm), spike breadth (cm), fresh weight spike^{-1}(g), dry weight spike^{-1} (g), seed yield plant^{-1} (g) and seed recovery (%)

Fertilizer levels NPK @ kg ha^{-1}	Spacing (cm^2)							
	Spike length (cm)				Spike breadth (cm)			
	45 X 10	45 X 15	45 X 20	Mean	45 X 10	45 X 15	45 X 20	Mean
30:10:10	53	53	54	53	20	22	23	22
40:20:20	54	56	57	56	22	23	23	23
50:30:30	55	58	60	57	23	24	24	23
Mean	54	56	57	55	22	23	23	22
	F	S	F at S		F	S	F at S	
SEd	0.967	0.878	0.862		0.409	0.573	0.555	
CD(P=0.05)	2.685	1.913	NS		1.136	1.248	NS	
	Fresh weight spike^{-1} (g)				Dry weight spike^{-1} (g)			
30:10:10	184	194	202	193	66.4	68.5	70.5	68.5
40:20:20	206	210	215	210	71.5	72.7.	73.9	72.7
50:30:30	214	218	222	218	73.6	74..5	75.6	74.6
Mean	201	207	213	207	70.5	71.9	73.3	71.9
	F	S	F at S		F	S	F at S	
SEd	1.855	1.099	2.845		0.813	1.098	1.104	
CD(P=0.05)	4.043	3.053	6.454		2.259	2.392	2.318	
	Seed yield plant^{-1} (g)				Seed recovery (%)			
30:10:10	36.7	36.7	37.3	37.0	55.3	53.6	52.9	54.0
40:20:20	36.7	38.0	39.0	38.0	51.3	52.3	52.8	52.3
50:30:30	37.7	39.3	30.7	39.3	51.2	52.8	40.6	52.7
Mean	37.0	38.0	39.0	38.0	52.5	52.9	53.2	52.9
	F	S	F at S		F	S	F at S	
SEd	0.653	0.709	1.197		0.607	0.519	1.003	
CD(P=0.05)	1.599	1.490	2.639		1.275	NS	NS	

kg NPK ha^{-1} colluding with the views of Austin,1972; Anon., 1996 and Rajan and Deepa, 1998. The 100 seed weight, germination, vigour index and protein content were 6, 5, 8 and 2 per cent and 3,2, 4 and 1 per cent higher with this fertilization compared to lower dose of NPK applied @ 30:10: 10 and 40:20:20 Kg ha^{-1} respectively (Table 3,4).

However, Rajan and Deepa (1998) obtained the maximum seed yield in grain amaranth with the application of 150:100:100 kg NPK ha^{-1} and Ananda and Dhanapal (2006) @ 80:80:40 kg ha^{-1}. The variation could be attributed to soil physiotype and character.

Adoption of plant geometry is another important factor that contributes to higher seed yield and quality involving no additional expenditure. Ponnuswamy and Rangaswamy (1996) also opined that for getting higher seed yield and quality, maintenance of adequate plant density is a vital seed agronomic factor. The present study made with three different spacings and evaluated for plant height, number of leaves and stem diameter were found to be highly influenced by the plant spacings. Wider spacing (45 x 20 cm^2) recorded 2 and 4 per cent taller plants compared to the closer spacing (45 x 15 cm^2 and 45 x 10 cm^2) (Table 1). The number of leaves increased with wider spacing (45 x 20 cm^2) by 8 and 13 per cent compared to closer spacing as per the phenomenon of adaptive mechanism. Similar results were also reported by Anon., (1996) who revealed that in grain amaranth (*Amaranth hypochondriacus*), adoption of 30 x 30 cm^2 wider spacing gave the maximum seed yield for var. CO 2. Henderson *et al.,* (1993) also revealed that at low population densities (74,000 plants ha^{-1}) fields consistently produced the highest seed yield and that row spacing had no effect. At the higher density, more grain was produced with the wider (76.2 cm) row spacing. While Ananda and Dhanapal (2006) obtained improved grain yield, number of panicles per plant, per plant seed yield and seed test weight at a closer spacing of 30 x 15 cm^2. Tiwari and Namdeo (1997) and Hussain *et al.,* (2000) also reported similar observation in sesame and cotton respectively.

Table 3. Influences of spacing and fertilizer on seed yield plot^{-1} (kg), seed yield kg ha^{-1}, 100 seed weight (mg) and germination (%)

Fertilizer levels NPK @ kg ha^{-1}	Spacing (cm^2)							
	Seed yield plot^{-1}(kg)				Seed yield ha^{-1}(kg)			
	45 X 10	45 X 15	45 X 20	Mean	45 X 10	45 X 15	45 X 20	Mean
30:10:10	4.4	3.9	2.8	3.7	2750	2438	1750	2313
40:20:20	4.9	4.4	3.0	4.1	3063	2750	1875	2563
50:30:30	5.3	4.8	3.3	4.5	3313	3000	2063	2813
Mean	4.9	4.4	3.0	4.1	3063	2750	1875	2563
	F	S	F at S		F	S	F at S	
SEd	0.049	0.031	0.067		30.410	19.726	41.268	
CD(P=0.05)	0.138	0.069	0.168		84.433	42.980	103.309	
		100 seed weight (mg)				Germination (%)		
30:10:10	82	84	87	84	87 (68.98)	90 (71.61)	93 (75.06)	90 (71.88)
40:20:20	84	87	88	86	90 (71.63)	93 (74.99)	95 (79.36)	93 (75.33)
50:30:30	87	90	90	89	91 (72.75)	95 (77.28)	97 (80.95)	95 (76.99)
Mean	84	87	88	87	89 (71.12)	93 (74.63)	96 (78.45)	93 (74.73
	F	S	F at S		F	S	F at S	
SEd	1.178	1.018	1.946		1.123	1.352	1.946	
CD(P=0.05)	2.476	2.491	NS		3.360	3.310	NS	

In the present study, the inter plant spacing also played its contribution in improving the spike production. Among the observed spike characters *viz.,* physical measurement of spikes, the number of spikelets spike^{-1} were 5 and 10 per cent higher in wider spacing (45 x 20 cm^2) than in the closer spacing *viz.*, 45 x 15 cm^2 and 45 x 10 cm^2 respectively. The seed recovery was also higher in wider spacing recording 0.5 and 1.3 per cent higher than closer spacing *viz*., 45 x 15 and 45 x 10 cm, respectively due to the higher rate of morphological and photosynthetic efficiency that have resulted in higher production with each of the spike.

Among the evaluated seed characters *viz.*, seed yield plant^{-1}, 100 seed weight were also more in wider spacing. The seed yield plant^{-1} was higher with the spacing observed as 45 x 20 cm^2 and was 3 and 7 per cent higher than closer spacing. 100 seed weight was maximum in wider spacing recording 1 and 5 per cent higher weight than closer spacings *viz.*, 45 x 15cm^2 and 45 x 10 cm^2 respectively. The improved yield also could be due to the higher opportunity for proper growth and development of individual plants as the availability of adequate moisture, plant nutrients, space and other growth promoting factors were more in wider spacing as stated by Jain *et al.* (1990) and in tune with the findings of Sharma, 1969; Gomez *et al.* 1988; Gnanamurthy *et al.,* 1992; Behera *et al.,* 1994; Patil *et al.,* 1996.

Table 4. Influences of spacing and fertilizer on root length (cm), shoot length (cm), dry matter production 10 seedling $^{-1}$ (mg), vigour index, protein content (%) and oil content (%)

Fertilizer levels NPK @ kg ha^{-1}	Spacing (cm^2)							
	Spike length (cm)				Spike breadth (cm)			
	45 X 10	45 X 15	45 X 20	Mean	45 X 10	45 X 15	45 X 20	Mean
30:10:10	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
40:20:20	5.0	5.2	5.0	5.2	5.0	5.2	5.0	5.2
50:30:30	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Mean	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
	F	S	F	S	F	S	F	S
SEd	0.141	0.143	0.141	0.143	0.141	0.143	0.141	0.143
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
	Dry matter production 10 seedling -1 (mg)				Vigour index			
30:10:10	6.7	6.1	6.2	6.3	783	792	846	807
40:20:20	6.0	6.3	6.5	6.2	792	846	893	844
50:30:30	5.5	6.0	6.1	6.2	837	884	912	878
Mean	6.3	6.1	6.3	6.3	809	846	883	846
	F	S	F at S		F	S	F at S	
SEd	0.126	0.169	0.270		11.366	9.977	19.686	
CD(P=0.05)	NS	NS	NS		23.879	24.415	NS	
	Protein content (%)				Oil content (%)			
30:10:10	15.32	15.23	15.40	15.31	3.2	3.2	3.4	3.2
40:20:20	15.44	15.35	15.55	15.44	3.3	3.4	3.4	3.3
50:30:30	15.56	15.40	15.61	15.52	3.4	3.3	3.5	3.4
Mean	15.42	15.32	15.52	15.42	3.3	3.3	3.4	3.3
	F	S	F at S		F	S	F at S	
SEd	0.068	0.060	0.061		0.100	0.091	0.085	
CD(P=0.05)	0.189	NS	NS		NS	NS	NS	

The seed yield plot^{-1} (4.9 kg plot^{-1}) and computed seed yield ha^{-1} (3036 kg ha^{-1}) were also higher in closer spacing of 45 x 10 cm^2 and 45 x 15 cm^2 by 38.7 per cent and 38.0 per cent respectively, compared to the wider spacing of 45 x 20 cm^2. Malarkodi and Srimathi (2001) in sorghum reported that the plot yield (912 kg ha^{-1}) was higher under the closer spacing of 45 x 15 cm^2, owing to higher population compared to the ear heads produced under wider spacing of 75 x 60 cm^2 which was lower in yield by 44 per cent. Kirby (1969) elucidated that the grain yield in any given population was determined by the carbohydrate's supply during the grain filling period which might be more in closer spacing due to higher plant population that resulted in increased yield.

In the present study the results on seed quality characters including 100 seed weight were more with 45 x 20 cm^2 spacing though the yield is lower by 38.7 per cent compared to plot yield, Among the seed quality characters the germination was 3 and 7 per cent higher in reduced inter plant spacing ie. than 45 x 15cm^2 and 45 x 10 cm^2 respectively, which might be due to bolder seed size obtained from the wider spacing as revealed by higher 100 seed weight which was 1 and 5 per cent higher than at 45 x 15 cm^2 and 45 x 10 cm^2 respectively. However, the vital seedling quality characters *viz.,* root length, shoot length, dry matter production and seed nutrient status *viz.,* protein and oil content were non significant. A comparison of major seed quality characters and seed yield focused with the objective of the study revealed as follows.

Yield and quality Character	45 x 10 cm^2	45 x 15 cm^2	45 x 20 cm^2
Seed yield kg ha^{-1}	Highest	10.2 % lesser	38.7 % lesser
100 seed weight (mg)	4.5 % Lesser	1 % Lesser	Highest
Germination (%)	7 % Lesser (89 %)	3 % Lesser (93 %)	Highest (96 %)
Vigour index	8 % Lesser	4 % Lesser	Highest
Protein & Oil	Non significant		

Based on the results considering both the quality and yield of seed, 45 x 15 cm^2 could be recommended as the germination reduction was only 3.0 per cent but the seed weight which is positively correlated with seed vigour and storability (Srimathi *et al .,* 2001) was only 1 per cent lesser to 45 x 20 cm^2. Hence, for getting higher yield with quality without much economic loss, the fertilizer recommendation of NPK @ 50: 30: 30 kg ha^{-1} and spacing of 45 x 15 cm^2 will be optimum.

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