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Effect of levels of nitrogen and iron on yield, harvest index and quality of grain amaranth (*Amaranthus hypochodriacus* L.) under different planting techniques

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ABSTRACT

A field experiment was conducted during rabi seasons of 2007-08 and 2008-09 at the Instructional Farm, Department of Agronomy, C. P. College of Agriculture, SDAU, Sardarkrushinagar in split plot design having three replications. The treatments comprising of three planting techniques (P_1: broadcasting, P_2: line sowing at 45 cm x 15 cm and P_3: paired row at 60 cm x 30 cm) in main plot, three levels of N (N_1: 40 kg ha^{-1}, N_2: 60 kg ha^{-1} (*i.e.*, RDN) and N_3: 80 hg ka^{-1}) as sub-plot and two levels of Fe (Fe_0: no $FeSO_4$ and Fe_1: 10 kg $FeSO_4$ ha^{-1}) as sub-sub plots. Among the planting techniques, line sowing recoded significantly higher plant height, length of main spikelets, number and length of lateral spikelets, grain and stover yields of amaranth. The harvest index and protein content was not altered significantly due to planting techniques. The highest harvest index was noted with line sowing during both the years and in pooled results. The yield and yield components of grain amaranth increased significantly under application of 60 kg N ha^{-1} and then decreased gradually as crop received higher proportion of N than RDN. Nitrogen treatment had significant influence on harvest index and protein content during both the years, but in pooled results it did not turn out significant. Iron application did not exert any significant response in harvest index and protein content, though the yield and yield attributes recoded higher under application of 10 kg $FeSO_4$ ha^{-1}. The highest net income (Rs. 34,130 ha^{-1}) and benefit cost ratio (3.83) was associated with application of 60 kg N ha^{-1} with 10 kg $FeSO_4$ under line sowing.

Key words: Amaranth, planting techniques, harvest index, protein content, iron, net income

Grain amaranth (*Amaranthus* spp.) is a C_4 dicotyledonous pseudo cereal crop having higher productivity potential added with substantial quantities of minerals, carbohydrates, fats and proteins are comparable with any other improved cereals. It is a lysine rich crop contains 17-18 per cent protein, which is nearly higher than conventional cereals. It could be used both for grains and green leaves which are rich in vitamin A, calcium and iron (Annapurna *et al.*, 2001).

In India, amaranth is commonly grown in Himachal Pradesh and in the hills of Uttar Pradesh for both grain and greens. However, it is mainly grown for grain, especially in Madhya Pradesh, Maharashtra and parts of Gujarat. In Gujarat, amaranth locally known as *'Rajagira'* is cultivated in Mehsana, Banaskantha, Sabarkantha, Gandhinagar and Kheda districts as a *rabi* crop. In Gujarat, amaranth is grown in an estimated area of about 3425 ha with productivity about 1700 kg ha^{-1} (Anonymous, 2010).

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MATERIALS AND METHODS

A field experiment was conducted at Instructional Farm, Department of Agronomy, C. P. College of Agriculture, SDAU, Sardarkrushinagar during rabi seasons of 2007-08 and 2008-09. Geographically, Sardarkrushinagar is situated at 24^0-19' North latitude and 72^0-19' East longitude with an elevation of 154.52 m above mean sea level. The soil of the experimental site was loamy sand in texture with pH 7.7 and organic carbon 0.15 %. Available N, P_2O_5, K_2O and Fe was 165, 43.13, 256.55 kg $ha^{-1}$and 4.63 ppm, respectively. The climate during the crop growing season was dry and cold. The mean annual maximum and minimum temperature varied between 20.7 to 38.0 and 5.3 to 20.0 °C. The experiment was laid out in split plot design with three replications. There were eighteen treatment combinations formed by three planting techniques (P_1: broadcasting, P_2: line sowing at 45 cm x 15 cm and P_3: paired row at 60 cm x 30 cm) in the main plot, three levels of nitrogen (N_1: 40 kg ha^{-1}, N_2: 60 kg ha^{-1} and N_3: 80 kg ha^{-1}) as sub-plot and two levels of iron (Fe_0: no $FeSO_4$ and Fe_1: 10 kg $FeSO_4$ ha^{-1}) assigned to sub-sub plot. FYM@ 5 t ha^{-1} was applied uniformly in whole experimental area and mixed in soil. Phosphorus from Diammonium Phosphate (DAP) @ 40 kg P_2O_5 ha^{-1} was applied as a basal dose in ploughed furrows before sowing. Nitrogen from urea was applied at three levels viz., 40, 60 and 80 kg ha^{-1}, each in three splits as per treatments. The half of nitrogen was applied as basal at the time of sowing in furrows and the remaining half as top dressed in two equal splits at 35 and 60 DAS in respective plots. The required amount of $FeSO_4$ was applied according to treatments as basal dose. The crop variety GA 2 was sown in the first week of November during both the years. Other management practices were adopted as per recommendations of the crop. Observations on growth attributes at different stages, yield components and yield were recorded at harvest. Protein content and nutrient uptake as per standard procedure and economics of produce considering the local prevailing market price of input and output were also estimated. The data were statistically analyzed for individual years as well as pooled over years and results were presented.

RESULTS AND DISCUSSION

Growth attributes

The results showed that planting techniques had significant effect on plant height at 60 DAS and at harvest. Line sowing (P_2) recorded significantly taller plants than paired row (P_3) and broadcasting (P_1) during both the years and in pooled data. Similarly, line sowing attained more number of days to 50 % flowering and maturity (Table 1). The lower plant density and proper plant geometry under line sowing might have favoured in efficient utilization of space, light, available nutrients and soil moisture that virtually increased plant height. Similar findings have been reported by Henderson *et al.*, (2000).

Nitrogen levels showed significantly positive response to the plant height and number of days to flowering and maturity. Application of 80 kg N ha^{-1} (N_3) produced taller plants at 60 DAS and at harvest during both the years and on pooled basis, but was at par with 60 kg N ha^{-1} (N_2) (Table 1). The increase in plant height with higher dose of N is ascribed to more uptake of nutrients by the crop. Such increase in plant height with nitrogen application was observed in grain amaranth by Nehra (2000). Data presented in Table 1 indicated that days to 50 per cent flowering and maturity were significantly influenced by levels of nitrogen during both the years and in pooled data. It was observed that with increase in level of nitrogen, the physiological stage at which grain amaranth crop attained 50 % flowering and maturity got delayed. Significantly higher number of days to 50 % flowering was noted with N_3 (80 kg N ha^{-1}) during both the years and in pooled data. The reason is quite clear that higher amount of nitrogen prolonged vegetative growth and ultimately, delayed the reproductive stage. Similar response has been noticed by Myres (1998) in grain amaranth with higher dose of nitrogen. Results on plant height and number of days required for 50 % flowering and maturity in Table 1 showed non-significant effect during both the years and as well on pooled basis. However, more number of days to 50% flowering and maturity was observed under Fe_1 (10 kg $FeSO_4$ ha^{-1}).

Yield attributes yield and harvest index

The highest values of yield attributes, *viz.* length of

Table 1 Growth of grain amaranth as affected by levels of N and Fe under different planting techniques

Treatments	Plant height (cm)						Days to 50% flowering			Days to 50% maturity		
	At 60 DAS			At harvest								
	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled
Planting techniques												
P_1: Broadcasting	106.62	105.02	105.81	153.93	152.07	153.00	46.50	46.72	46.61	96.55	95.50	96.03
P_2: Line sowing	135.21	133.31	134.28	195.92	192.96	194.44	48.28	48.00	48.14	97.61	97.28	97.44
P_3: Paired row	122.80	121.04	121.91	176.44	175.01	175.73	47.56	47.55	47.56	97.05	96.22	96.64
S.Em. ±	2.80	2.98	2.04	4.57	4.42	3.18	0.61	0.56	0.42	0.66	0.50	0.41
C.D. at 5 %	10.99	11.70	6.66	17.93	17.36	10.36	NS	NS	NS	NS	NS	NS
C.V. %	9.77	10.56	10.16	11.04	10.82	10.94	5.49	5.03	5.26	2.87	2.21	2.56
N- levels												
N_1: 40 kg ha^{-1}	109.26	107.63	108.44	157.73	155.51	156.62	46.27	46.22	46.25	93.22	92.33	92.78
N_2: 60 kg ha^{-1}	125.68	123.90	124.78	180.58	179.11	179.85	47.33	47.39	47.36	97.44	96.28	96.86
N_3: 80 kg ha^{-1}	129.68	127.83	128376	187.97	185.43	186.70	48.72	48.67	48.69	100.56	100.39	100.47
S.Em. ±	2.54	2.64	1.83	3.79	3.85	2.70	0.40	0.38	0.28	0.49	0.38	0.31
C.D. at 5 %	7.34	7.62	5.18	10.95	11.12	7.64	1.16	1.11	0.79	1.42	1.10	0.88
Fe- levels												
Fe_0: 0 kg ha^{-1}	119.39	118.17	118.78	172.03	170.63	171.33	47.18	47.16	47.17	96.98	96.00	96.49
Fe_1: 10 kg ha^{-1}	123.69	121.40	122.54	178.83	176.07	177.45	47.70	47.71	47.70	97.17	96.67	96.92
S.Em. ±	2.07	2.15	1.50	3.10	3.14	2.21	0.33	0.31	0.28	0.40	0.31	0.25
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	-	-	-	-	-	-	-	-	-	-	-	-
C.V. %	8.87	9.35	9.11	9.17	9.42	9.30	3.58	3.43	3.51	2.14	1.67	1.92

Table 2 Yield attributes and yield of grain amaranth as affected by levels of N and Fe under different planting techniques

Treatments	Length of main inflorescence(cm)			Number of lateral spikelets			Length of lateral spikelets (cm)			Harvest index(%)		
	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled
Planting techniques												
P_1: Broadcasting	62.33	61.72	62.03	60.17	59.16	59.67	37.42	37.26	37.34	22.33	22.34	22.29
P_2: Line sowing	73.24	72.57	72.91	66.50	66.11	66.31	39.60	39.59	39.59	23.43	23.40	23.42
P_3: Paired row	70.39	71.05	70.72	64.28	62.61	63.44	38.56	38.55	38.55	22.65	23.62	22.99
S.Em. ±	1.40	1.36	0.976	1.17	1.15	0.817	0.86	0.95	0.642	0.47	0.55	0.36
C.D. at 5 %	5.50	5.33	3.18	4.58	4.50	2.015	NS	NS	NS	NS	NS	NS
C.V. %	8.66	8.41	8.54	7.77	7.76	7.77	9.49	10.50	10.01	8.67	10.21	9.48
N-levels												
N_1: 40 kg ha^{-1}	59.61	59.35	59.48	59.94	59.06	59.50	35.43	35.77	35.60	21.72	21.48	21.60
N_2: 60 kg ha^{-1}	73.72	73.39	73.55	66.67	65.72	66.19	40.48	40.47	40.47	23.58	24.13	23.85
N_3: 80 kg ha^{-1}	72.63	72.61	72.62	64.33	63.11	63.72	39.67	39.16	39.41	23.02	23.45	23.23
S.Em. ±	1.22	1.21	0.861	1.02	0.98	0.707	0.79	0.84	0.57	0.44	0.40	0.30
C.D. at 5 %	3.53	3.50	2.43	2.93	2.84	2.00	2.29	2.43	81.63	1.26	1.16	NS
Fe-levels												
Fe_0: 0 kg ha^{-1}	67.70	67.42	67.57	63.22	62.11	62.66	37.80	37.69	38.24	22.58	22.82	22.70
Fe_1: 10 kg ha^{-1}	69.60	69.48	69.54	64.07	63.15	63.61	38.25	39.24	38.75	22.97	23.22	23.09
S.Em. ±	1.00	0.99	0.703	0.83	0.80	0.577	0.65	0.69	0.47	0.36	0.33	0.24
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	-	-	-	-	-	-	-	-	-	-	-	-
C.V. %	7.56	7.50	7.53	6.77	6.67	6.72	8.75	9.27	9.01	8.13	7.43	7.78

Table 3 Protein, N and P content of grain amaranth as affected by levels of N and Fe under different planting techniques

Treatments	Protein content (%)			Grain yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled	2007-08	2008-09	Pooled
Planting techniques									
P_1: Broadcasting	13.84	13.97	13.90	1054	1055	1055	3682	3664	3673
P_2: Line sowing	14.01	14.14	14.08	1233	1237	1235	4022	4035	4028
P_3: Paired row	13.92	14.05	13.99	1166	1168	1167	3975	3835	3905
S.Em. +	0.08	0.08	0.06	28	28	20	68	65	47
C.D. at 5 %	NS	NS	NS	108	110	64	267	254	153
C.V. %	2.44	2.40	2.42	10.15	10.28	10.21	7.41	7.15	7.28
N-levels									
N_1: 40 kg ha-1	13.72	13.84	13.78	998	1006	1002	3603	3679	3641
N_2: 60 kg ha-1	13.92	14.04	13.98	1255	1255	1255	4061	3943	4002
N_3: 80 kg ha-1	14.14	14.27	14.21	1200	1199	1199	4014	3911	3963
S.Em. +	0.07	0.07	0.05	23	22.13	16	64	58	43
C.D. at 5 %	0.20	0.20	0.14	67	63.92	45	185.55	167	122
Fe-levels									
Fe_0: 0 kg ha-1	13.88	14.01	13.94	1124	1129	1126	3842	3811	3827
Fe_1: 10 kg ha-1	13.97	14.10	14.03	1177	1178	1178	3943	3878	3911
S.Em. +	0.06	0.06	0.04	19	18	13	52	47	35
C.D. at 5%	NS	NS	NS	NS	NS	37	NS	NS	NS
Interaction	-	-	-	-	-	-	-	-	-
C.V. %	2.09	2.07	2.08	8.56	8.14	8.35	7.00	6.38	6.70

main inflorescence, number and length of lateral spikelets were recorded in line sowing (P_2) during both the years as well as in pooled data. Length of lateral spikelets and harvest index was found non-significant during experimental period (Table 2). The highest harvest index and protein content was observed under line sowing. Yield data revealed that among planting techniques, line sowing (P_2) produced significantly higher grain yield than other two planting techniques. Line sowing (P_2) produced 16.88, 17.25 and 17.06 per cent higher grain yield over P_1 (broadcasting) and 5.75, 5.91 and 5.83 per cent higher over P_3 (Paired row) during 2007-08, 2008-09 and in pooled, respectively. However, it was at par with treatment P_3 during both the years and in pooled analysis. Similar trend was observed in stover yields. The findings are in corroborating with the findings of Patel (2003).

Nitrogen levels showed marked improvement in yield attributing characters (Table 2) and yield (Table 3). Nitrogen treatments had significant influence on harvest index during both the years, but in pooled results it did not turn out significant. The highest harvest index was recorded with application of 60 kg N ha^{-1} (N_2) during the year 2007-08, 2008-09 and in pooled results, respectively. On pooled basis, significantly the highest grain yield (1255 kg ha^{-1}) was recorded under 60 kg N ha^{-1} (N_1) followed by 80 kg N ha^{-1} (1199 kg ha^{-1}) . Treatment N_2 (60 kg N ha^{-1}) achieved maximum grain yield which accounted 25.75, 24.75 and 25.25 per cent higher over N_1 (40 kg N ha^{-1}) during 2007-08, 2008-09 and in pooled, respectively. Same trend was observed in stover yield also. This is evidently due to the cumulative effect of improvement in growth and yield attributes and due to less inter and intra competition for space, light, water and nutrients under line sowing. The findings are in agreement with the findings of Gutte and Karanjikar (2007).

Iron application (Fe_1) expresses positive influence on yield attributes, grain and stover yields, but it did not cross the level of significance. Iron application exerted significant influence on grain and stover yields in pooled data (Table 3). The combined effect of growth and yield attributes improved grain yield. Similar results were also obtained by and Kushwaha *et al.*, (2003).

Protein content:

The results revealed that planting techniques did not show significant effect on protein content. However, line sowing (P_2) had positive response and recorded higher protein content (14.08) than those of paired row planting (P_3) and broadcasting (P_1) during individual years and in pooled data (Table 3). Protein content is a quality trait of crop/variety which is governed by genetic makeup of that particular crop/variety. Similar findings have been reported by Patel (2003).

Increasing levels of nitrogen significantly increase protein content. Among the nitrogen levels,

Table 4 Gross realization, net realization and benefit cost ratio for different treatments

Treatment	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Gross realization (₹ ha^{-1})	Cost of production (₹ ha^{-1})	Net realization (₹ ha^{-1})	BCR
Planting techniques						
P_1: Broadcasting	1055	3673	32186	8380	23806	2.84
P_2: Line Sowing	1235	4028	37644	8630	29015	3.36
P_3: Paired row	1167	3905	35596	8630	26966	3.13
N- levels						
N_1: 40 kg ha-1	1002	3641	31140	8327	22813	2.74
N_2: 60 kg ha-1	1255	4002	38250	8486	29765	3.51
N_3: 80 kg ha-1	1199	3963	36569	8724	27846	3.19
Fe- levels						
Fe_0: 0 kg $FeSO_4$ ha-1	1127	3827	34371	8211	26159	3.18
Fe_1: 10 kg $FeSO_4$ ha-1	1178	3911	35913	8881	27032	3.04

application of 80 kg N ha^{-1}(N_3) recorded significantly the highest protein content of during both the years and in pooled analysis followed by N_2. The lowest protein content was observed under N_1 (Table 3). Protein content increased at increasing level of nitrogen, mainly due to increase in nitrogen content in grain. These results are in accordance with the findings of Olaniyi *et al.*, (2008).

Application of $FeSO_4$ did not exert significant response on protein content (Table 3). However, iron ($FeSO_4$) applied @ 10 kg ha^{-1} led to marginal improvement in protein content than no iron (Fe_0).

Economics

Economic analysis of the data (Table 4) showed that line sowing was more effective in realizing higher net returns and benefit: cost ratio. Net return and B:C ratio were maximum with 60 kg N ha^{-1}. The higher net return and benefit:cost ratio under these treatments was owing to more grain yield.

CONCLUSION

It can be concluded from the study that to earn higher net return from amaranth, line sowing (45 cm x 15 cm) be followed and the crop need to be fertilized with nitrogen @ 60 kg and $FeSO_4$ @ 10 kg ha^{-1} keeping common dose of phosphorous @ 40 kg ha^{-1}.

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