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Impact of planting geometry and nutrient strategies on growth and yield of grain amaranth (*Amaranthus hypochondriacus* L.)

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Abstract
A field experiment was carried out at Navsari Agricultural University, Navsari, Gujarat during the *rabi* season of 2019-20 to study the effect of spacing and nutrient management on growth parameters, yield attributes and yield of grain amaranth. Grain amaranth grown at spacing 45 cm between row resulted in higher plant height (121.71 cm), stem girth (3.69 cm), spike length (44.49 cm), length of spikelets (10.74 cm), number of spikelets/spike (62.41), seed yield (1403.28 kg/ha) and stover yield (2841.27 kg/ha). Moreover, among nutrient management treatments, 50% RDF + 50% RDN through bio-compost resulted in higher higher plant height (123.50 cm), stem girth (3.79 cm), spike length (45.12 cm), length of spikelets (10.92 cm) and number of spikelets/spike (63.30), seed yield (1462.50 kg/ha) and stover yield (2961.02 kg/ha). Growing grain amaranth at 45 cm spacing and applying 50% RDF + 50% RDN through bio-compost results in better growth and higher yield.

Keywords: Amaranth, spacing, nutrient management, bio-compost

Introduction

Amaranthus also known as third millennium crop belongs to family Amaranthaceae. It is richer in protein, dry matter and ash than cereals and is an excellent source of protein, fiber, fat and minerals (Bodroza *et al*., 2003) [1]. It is rich source of protein (16%) and contains amino acids like lysine (5%), cystine (4.0%), methionine (4.0%), isoleucine (3.0%) and leucine (4.7%). It is used in making porridge, laddoos, breads, biscuits, flakes and crackers. Grain amaranth cultivation in Gujarat has increased to a great extent and during last 10 years there has been a notable increase in the area, production and productivity of Rajgira. In Banaskantha and Kheda districts the area under amaranthus is increasing as this crop replaces wheat and potato due to water scarcity. Amaranthus is cultivated in an area of 12,000 hectare in Gujarat. It is either cultivated as a sole crop or as a border crop in Lucerne or cumin fields or as a mixed crop with vegetables and mustard (Raiger *et al*., 2023) [7]. In grain amaranth cultivation, the optimal planting density varies significantly across different regions, based on factors such as environmental conditions, production systems, and the specific variety cultivated. There is a significant interaction between environment and plant population density on grain yield. Their results indicate that site-specific planting densities should be adopted to optimize yield under different environmental conditions. The plant nutrient deficiency is evidently increasing in Indian soils and the irrational use of fertilizers has enhanced soil imbalance especially in terms of NPK ratio (Lakhran *et al*, 2015) [3]. Integrated nutrient management approach involves use of inorganic fertilizer and organic manure can be entrusted in longer run in building up soil fertility besides increasing growth and yield, (Patel *et al*., 2018) [6].

Materials and Methods

The experiment was conducted during *rabi* season of the year 2019-20 at the college farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari. Navsari is categorized under agro-ecological situation-III of South Gujarat Heavy Rainfall Zone which has warm summer, mild winter and humid monsoon with heavy rainfall. During the crop period, The maximum temperature ranged between 27.5 to 34.4 °C and minimum temperature ranged between 8.4 to 19.3 °C, respectively. Moreover, the range of morning and evening relative humidity lied between 76.4 to 91.3 per cent and 39.4 to 68.6 per cent, respectively. The soil of the plot was clayey in texture with 7.68 pH, 0.38 dS/m EC and 0.52% organic carbon. Moreover, the soil was low in available N (238.6 kg/ha), high in available P_2O_5 (50.8 kg/ha) and very high available potassium (356.2 kg/ha). The experiment consisted of two factors *viz.* spacing and integrated nutrient management. Factor A *i.e.* Row Spacing has two treatments: S_1: 30 cm and S_2: 45 cm. Factor B *i.e.* Integrated Nutrient Management has 6 treatments: T_1: Control, T_2: 100% RDF (60:40, N:P kg/ha), T_3: 75% RDF + 25% RDN through bio-compost, T_4: 75% RDF + 25% RDN through FYM, T_5: 50% RDF + 50% RDN through bio-compost and T_6: 50% RDF + 50% RDN through FYM. The experiment was laid in Randomized block design with factorial concept consisting of 12 treatment combinations in 3 replications. The gross plot size was 4.0 m x 3.6 m while net plot size was 3.0 m x 2.7 m. Gujarat amaranth-2 variety was sown in November at seed rate 3 kg/ha by line sowing method.

Results and Discussion

Growth Parameters

Plant Height

Plant height at 60 DAS and at harvest (110.04 cm, 121.71 cm, respectively) was recorded with when grain amaranth was sown at a row spacing of 45 cm (S_2) which was significantly higher than plant height of plants sown at row spacing of 30 cm (S_1). Patel *et al*. (2013) [3] found similar results in grain amaranth. Among the nutrient management treatments, a significantly greater plant height was recorded under the combined application of organic and inorganic nutrient sources. Application of 50% RDF + 50% RDN through bio-compost (T_5) recorded the highest plant height at 60 DAS and at harvest (111.53 cm, 123.50 cm, respectively) but it was found statistically at par with treatments 75% RDF + 25% RDN through bio-compost (T_3), 75% RDF + 25% RDN through FYM (T_4) and 50% RDF + 50% RDN through FYM (T_6). Significantly lower plant height at 60 DAS and at harvest (96.53 cm, 107.22 cm, respectively) was recorded under control (T_1). This increase can be attributed to the enhanced availability of nitrogen and phosphorus supplied through chemical fertilizers, which likely stimulated photosynthetic activity and facilitated the efficient translocation of photosynthates from source to sink, thereby promoting plant growth. Concurrently, the application of biocompost, serving as a source of plant nutrients and organic matter, contributed to the improvement of soil physical properties by enhancing water retention capacity, soil aeration, and microbial activity. These favourable soil conditions collectively supported increased plant height. Moreover, the interaction effect of spacing and nutrient management on plant height at 60 DAS and at harvest was non-significant.

Stem Girth

Stem girth at 60 DAS (2.62 cm) and at harvest (3.69 cm) was recorded with row spacing of 45 cm (S_2) which was significantly higher than that of plants sown at row spacing of 30 cm (S_1). Moreover, application of 50% RDF + 50% RDN through bio-compost (T_5) resulted in maximum stem girth at 60 DAS (2.67) which was significantly higher over control but remained at par with treatments 100% RDF (60:40, N:P kg/ha) (T_2), 75% RDF + 25% RDN through bio-compost (T_3), 75% RDF + 25% RDN through FYM (T_4) and 50% RDF + 50% RDN through FYM (T_6). Maximum stem girth at harvest (3.79) was recorded with application of 50% RDF + 50% RDN through bio-compost (T_5) which was significantly higher over control but remained at par with treatment 75% RDF + 25% RDN through bio-compost (T_3) and 50% RDF + 50% RDN through FYM (T_6). The observed increase in stem girth of grain amaranth may be attributed to the optimal supply of nitrogen. Nitrogen being a fundamental structural component of plant cells, played a crucial role in regulating key physiological processes, including cell division and elongation. Moreover, nitrogen application enhanced the photosynthetic efficiency of leaves, leading to increased production and availability of photosynthates, which in turn contributed to improved stem development. Stem girth was not affected significantly by interaction of spacing and nutrient management.

Table 1: Effect of spacing and nutrient management on plant height (cm) and stem girth (cm) of grain amaranth at 60 DAS and at harvest.

Treatments	Plant height (cm)		Stem girth (cm)	
	60 DAS	At harvest	60 DAS	At harvest
(A) Spacing (S)				
S_1: 30 cm	101.96	112.89	2.50	3.33
S_2: 45 cm	110.04	121.71	2.62	3.69
S.Em. ±	1.27	1.81	0.03	0.05
C.D. at 5%	3.75	5.31	0.10	0.15
(B) Integrated nutrient management (T)				
T_1: Control (0 kg/ha)	96.53	107.22	2.33	3.03
T_2: 100% RDF (60:40, N:P kg/ha)	104.31	114.88	2.53	3.40
T_3: 75% RDF + 25% RDN through bio-compost	107.91	119.63	2.60	3.61
T_4: 75% RDF + 25% RDN through FYM	106.11	116.99	2.58	3.50
T_5: 50% RDF + 50% RDN through bio-compost	111.53	123.50	2.67	3.79
T_6: 50% RDF + 50% RDN through FYM	109.61	121.60	2.64	3.71
S.Em. ±	2.21	3.13	0.06	0.08
C.D. at 5%	6.49	9.19	0.18	0.26
C.V.%	5.12	6.55	6.09	6.20
Interaction (S x T)	NS	NS	NS	NS

Yield Parameters

Yield attributing characters were significantly influenced by row spacing and nutrient management. Plants grown at 45 cm row spacing (S_2) recorded higher spike length (44.49 cm), length of spikelets (10.74 cm), number of spikelets/spike (62.41) and test weight (0.55) over Plants grown at 30 cm row spacing (S_1). This is attributed to lower competition among plants and higher availability of space, light, moisture and nutrients. These findings are in accordance with those reported by Patel *et al*. (2013) [5] and Vaghela *et al*. (2018) [8]. Among the INM treatments 50% RDF + 50% RDN through bio-compost (T_5) recorded significantly higher spike length (45.12 cm), length of spikelets (10.92 cm) and number of spikelets/spike (63.30) which was at par with treatments T_3 and T_6 in case of spike length, with treatments T_3, T_4 and T_6 in case of length of spikelets and with treatments T_2, T_3, T_4 and T_6 for number of spikelets/spike. Moreover, test weight was not significantly influenced by INM treatments. The application of nitrogen significantly enhances vegetative and reproductive growth by accelerating protein synthesis and promoting efficient dry matter partitioning during the reproductive stage, thereby contributing to increased spike length. Moreover, the combined use of organic and inorganic nutrient sources ensures sustained and balanced nutrient availability throughout the crop cycle, facilitating optimum photosynthate accumulation and translocation to the developing spike. This consistent nutrient supply from early growth stages not only improves photosynthetic efficiency but also enhances the availability of essential metabolites and assimilates required for the development of reproductive structures, ultimately resulting in increased spike length, greater spikelet length, and a higher number of spikelets per spike. Yield parameters were not influenced significantly by interaction between spacing and nutrient management.

Table 2: Yield parameters of grain amaranth as influenced by spacing and nutrient management.

Treatments	Length of spike (cm)	Length of spikelets (cm)	Number spikelets/spike	Test weight (g)
(A) Spacing (S)				
S_1: 30 cm	38.97	9.78	57.97	0.52
S_2: 45 cm	44.49	10.74	62.41	0.55
S.Em. ±	0.56	0.15	0.89	0.007
C.D. at 5%	1.63	0.44	2.63	0.02
(B) Integrated nutrient management (T)				
T_1: Control (0 kg/ha)	35.98	9.12	55.15	0.50
T_2: 100% RDF (60:40, N:P kg/ha)	40.64	10.03	59.12	0.53
T_3: 75% RDF + 25% RDN through bio-compost	43.00	10.49	61.13	0.54
T_4: 75% RDF + 25% RDN through FYM	41.53	10.26	60.08	0.53
T_5: 50% RDF + 50% RDN through bio-compost	45.12	10.92	63.30	0.55
T_6: 50% RDF + 50% RDN through FYM	44.09	10.72	62.38	0.55
S.Em. ±	0.96	0.25	1.55	0.01
C.D. at 5%	2.83	0.76	4.56	NS
C.V.%	5.66	6.2	6.33	5.59
Interaction (S x T)	NS	NS	NS	NS

Seed Yield (kg/ha)

Table 3 shows that spacing has significant effect on seed yield. Crop grow at higher spacing *i.e.* 45 cm (S_2) produce significantly higher seed yield (1403.28 kg/ha) compared to narrow row spaced crop 30 cm (S_1) (1137.41 kg/ha). The plant-to-plant competition was less due to low plant density in S_2 which resulted in availability of sufficient solar radiation and moisture to an individual plant and leads to optimized plant growth, development and reproductive growth, which eventually increased seed yield. It is also observed from Table 3 that seed yield is influenced by INM treatments. Significantly higher seed yield (1462.50 kg/ha) was recorded on application of 50% RDF + 50% RDN through bio-compost (T_5) which remains statistically at par with treatments 75% RDF + 25% RDN through bio-compost (T_3) (1348.88 kg/ha) and 50% RDF + 50% RDN through FYM (T_6) (1415.58 kg/ha). Whereas, significantly the lowest seed yield (942.33 kg/ha) was recorded when no fertilizer was applied *i.e.* control (T_1). The increased grain yield of amaranth may be attributed to the timely and adequate availability of essential nutrients from both organic and inorganic sources, which facilitated efficient dry matter partitioning from source to sink during the reproductive stage. This, in turn, promoted greater accumulation of photosynthates in the spike. Additionally, the enhanced seed yield could be the result of the cumulative effects of macro- and micronutrients on vegetative growth, which improved overall photosynthetic efficiency. Furthermore, the combined application of organic and inorganic inputs likely enhanced carbohydrate and nitrogen metabolism, supported the synthesis of pectic substances and improved water metabolism and plant water relations. Similar results were also reported by Parmar and Patel (2009) [4] and Jangir *et al*. (2019) [2].

Straw Yield (kg/ha)

As per table significantly higher straw yield (2841.27 kg/ha) was recorded under higher spacing in crop 45 cm (S_2) than narrow row spaced crop 30 cm (S_1) (2270.71 kg/ha). This might be attributed to better utilization of moisture, solar radiation as well as nutrients owing to leaf better orientation which leads to higher photosynthesis and enhanced growth which in turn increases growth and yield parameters and thus resulted in higher straw yield. Moreover, significantly higher straw yield (2961.02 kg/ha) was obtained on application of 50% RDF + 50% RDN through bio-compost (T_5) which was statistically at par with treatment (T_3) 75% RDF + 25% RDN through bio-compost (2659.38 kg/ha) and (T_6) 50% RDF + 50% RDN through FYM (2800.40 kg/ha). Whereas, significantly the lowest straw yield (1898.71 kg/ha) was recorded under control where no nutrient inputs were applied (T_1). The enhancement in straw yield may be attributed to the consistent and sustained release of nutrients resulting from the integrated application of organic and inorganic fertilizers throughout the crop growth period. This balanced nutrient supply likely promoted optimal biomass accumulation, thereby contributing to increased straw yield. Additionally, the application of organic manures may have enhanced the efficiency of chemical fertilizers by improving soil properties and accelerating the humification process. The presence of humic substances, particularly humic acid, could have facilitated the availability of both native and applied nutrients, ultimately leading to improved plant growth, yield components and a significant increase in straw yield.

Table 3: Effect of spacing and nutrient management on seed and stover yield of grain amaranth

Treatments	Seed yield (kg/ha)	Straw yield (kg/ha)
(A) Spacing (S)		
S_1: 30 cm	1137.41	2270.71
S_2: 45 cm	1403.28	2841.27
S.Em. ±	36.61	70.84
C.D. at 5%	107.40	207.79
(B) Integrated nutrient management (T)		
T_1: Control (0 kg/ha)	942.33	1898.71
T_2: 100% RDF (60:40, N:P kg/ha)	1200.59	2455.30
T_3: 75% RDF + 25% RDN through bio-compost	1348.88	2659.38
T_4: 75% RDF + 25% RDN through FYM	1252.19	2561.15
T_5: 50% RDF + 50% RDN through bio-compost	1462.50	2961.02
T_6: 50% RDF + 50% RDN through FYM	1415.58	2800.40
S.Em. ±	63.42	122.71
C.D. at 5%	186.02	359.90
C.V.%	12.23	11.76
Interaction (S x T)	NS	NS

Conclusion
From the results of present field experiment, it can be concluded that growing grain amaranth at 45 cm spacing and applying 50% RDF + 50% RDN through bio-compost resulted in higher growth, seed yield and stover yield under South Gujarat agroclimatic condition.

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