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Effect of spacing and nutrient management on quality parameters and nutrient uptake of grain amaranth (*Amaranthus hypochondriacus* L.)

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Abstract

A field experiment was conducted at the Research-cum-instructional farm, College of Agriculture, Raipur (C.G.) during Rabi 2020-21 and 2021-22. The experiment was laid out in Split Plot Design with three replications. The treatments comprised of three spacing levels as main plot factor i.e. S₁: 40 x 20 cm, S₂: 50 x 20 cm, S₃: 60 x 20 cm, and eight levels of nutrient management as sub plot factor, viz. N₀: Control, N₁: 75% RDN, N₂: 100% RDN, N₃: 125% RDN, N₄: 75% RDN + Foliar spray of 19:19:19 NPK at 40 and 60 DAS, N₅: 75% RDN + Foliar spray of cow urine (10%) + Vermiwash (10%) at 40 and 60 DAS, N₆: 100% RDN + Foliar spray of 19:19:19 NPK at 40 and 60 DAS, N₇: 100% RDN + Foliar spray of cow urine (10%) + Vermiwash (10%) at 40 and 60 DAS. Grain amaranth variety, Chhattisgarh Rajgira-1, was taken as test crop. Recommended dose of nutrient applied to the crop was 60:40:20 kg N, P₂O₅ and K₂O ha⁻¹. Based on the results of two-year research it was found that quality parameters of grain amaranth were generally less responsive to spacing and nutrient management, as protein, oil, carbohydrate, and ash contents remained statistically unaffected, although slightly higher values were observed under wider spacing (60 x 20 cm) and integrated nutrient treatments. However, protein yield and oil yield were significantly influenced, with maximum values recorded at 50 x 20 cm spacing combined with 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS, followed by 125% RDN, indicating the importance of optimal plant density and balanced nutrient supply. Nutrient content (N, P, and K) in grain and stover was not markedly affected by spacing, but was significantly enhanced by nutrient management, with 100% RDN + foliar spray consistently recording the highest values. Similarly, nutrient uptake by grain, stover, and total plant was maximized under 50 x 20 cm spacing and improved further with integrated nutrient application, reflecting better resource utilization, efficient assimilate partitioning, and enhanced photosynthetic activity, while control treatments recorded the lowest values.

Keywords: Nanourea, conventional urea, growth, LAI, yield and wheat

Introduction

Global food security is increasingly threatened by rapid population growth, climate change, and declining natural resources, with food production needing to rise by over 50% by 2050. In countries like India, heavy dependence on major cereals such as rice, wheat, and maize, along with shrinking freshwater resources, has raised concerns about sustainability and nutritional security, as cereal-based diets often lack essential micronutrients. Crop diversification with resilient and nutrient-rich crops is therefore essential. Grain amaranth (*Amaranthus hypochondriacus* L.), a C4 plant, is a promising alternative due to its nutrient rich, as well as its dual use as both grain and leafy vegetable. Amaranth is widely recognized as a “superfood” owing to its superior nutritional composition, including high protein content with a well-balanced amino acid profile, particularly rich in lysine, which is generally limiting in cereals. It is also an excellent source of iron, calcium, and antioxidants, and its gluten-free nature makes it suitable for individuals with celiac disease (Rastogi and Shukla, 2013; Yadav *et al.*, 2021) [11, 18]. The seeds are rich in starch, constituting about 62% in *Amaranthus hypochondriacus* (Saunders and Becker, 1984) [13], making them suitable for diverse food applications. The oil content ranges from 4.8 to 8.1%, characterized by its light color, stability at low temperatures, and high unsaturation, along with the presence of beneficial omega fatty acids (He and Corke, 2003) [3].

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Grain amaranth contains 14.5–15.1% protein (Rodas and Bressani, 2009) [12], which is higher than most cereal grains and closely aligns with WHO recommendations for a balanced human diet. Owing to its nutritional richness, amaranth is utilized in various forms across regions, including bakery products, snacks, and traditional foods such as laddoos in India, chapattis in the Himalayan region, and satto in Nepal (Oke, 1983) [9]. Despite these advantages, its productivity remains low under Indian conditions, largely due to inadequate agronomic practices. Among these, plant spacing and nutrient management are critical for optimizing resource use, growth, yield, and quality. Balanced fertilization with nitrogen, phosphorus, and potassium (NPK), along with integrated use of organic inputs such as cow urine and vermiwash, can improve nutrient use efficiency and sustain soil health. These organic sources are rich in nutrients, beneficial microbes, and plant growth regulators, and their foliar application in combination with water-soluble fertilizers like 19:19:19 NPK has shown promising results. However, limited information is available on the combined effect of spacing and nutrient management on grain amaranth, particularly under the agro-climatic conditions of Chhattisgarh. Therefore, the present study was undertaken to evaluate the effect of spacing and nutrient management on the quality and nutrient uptake of grain amaranth (*Amaranthus hypochondriacus* L.).

Materials and Methods

A field experiment was conducted at Research cum Instructional farm of College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur during rabi season of 2020-21 and 2021-22. The experiment was conducted using a split plot design with three replications. The main plot treatments consisted of three spacing levels: S₁ (40 × 20 cm), S₂ (50 × 20 cm), and S₃ (60 × 20 cm). The sub-plot treatments included eight nutrient management levels: N₀ (control), N₁ (75% recommended dose of nitrogen, RDN), N₂ (100% RDN), N₃ (125% RDN), N₄ (75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 days after sowing, DAS), N₅ (75% RDN + foliar spray of cow urine (10%) + vermiwash (10%) at 40 and 60 DAS), N₆ (100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS), and N₇ (100% RDN + foliar spray of cow urine (10%) + vermiwash (10%) at 40 and 60 DAS). The experimental site was clay loam in texture having pH 7.5, EC 0.26 dSm⁻¹, organic carbon 0.54% and soil available N, P and K, 208.75, 23.28 and 240.67 kg ha⁻¹, respectively. The grain amaranth variety 'Chhattisgarh Rajgira-1' was used as the test crop at a seed rate of 3.0 kg ha⁻¹. Recommended dose of nutrient 60:40:20 kg N, P₂O₅, and K₂O per hectare applied in the form of Urea, SSP (Single Super Phosphate) and MOP (Muriate of potash). The entire dose of phosphorus and potassium was applied at sowing as basal, while nitrogen was applied in two splits-one at basal and the remaining at 30 DAS. Calculation for the required amount of Urea, SSP and MOP was done as per the treatment details, for 75% RDN (45:30:15 kg N, P₂O₅, K₂O ha⁻¹), 100% RDN (60:40:20 kg N, P₂O₅, K₂O ha⁻¹) and 125% RDN (75:50:25 kg N, P₂O₅, K₂O ha⁻¹) applied accordingly. Foliar spray of 19:19:19 NPK (2%), cow urine (10%) and vermiwash (10%) was executed twice at 40 and 60 DAS as per the treatment with the help of a knapsack sprayer during evening hours. Whereas the control plot received no application of fertilizer or foliar spray. Protein content was estimated by converting nitrogen content using a factor of 6.25, and protein yield was calculated by multiplying protein content with seed yield. Oil content was determined using the Soxhlet extraction method with petroleum ether, and oil yield was computed by multiplying oil content with seed yield. Carbohydrate content was estimated by the

Anthrone method through acid hydrolysis, color development, and spectrophotometric measurement at 630 nm using a standard curve, while ash content was determined by incinerating samples in a muffle furnace at 550 ± 25°C and calculating residue weight. Nitrogen content in grain and stover was analyzed using the Kjeldahl digestion, distillation, and titration method, whereas phosphorus content was determined by the vanadomolybdate yellow color method using spectrophotometry, and potassium content by flame photometry after diacid digestion. Nutrient uptake (N, P, and K) by grain and stover was calculated by multiplying respective nutrient content with yield, and total uptake was obtained by summing grain and stover uptake.

Results

Quality parameters

Protein content

Data presented on Table 1 clearly revealed that protein content of grain amaranth was not significantly affected by spacing, nutrient management, or their interaction, with values remaining narrow (10.14–10.16%) across treatments; however, slightly higher values were observed under 60 × 20 cm spacing and 100% RDN + foliar spray of 19:19:19 NPK, and the lowest under control.

Protein yield

Protein yield of grain amaranth was significantly influenced by spacing, nutrient management, and their interaction (Table 1). Among spacings, 50 × 20 cm recorded the highest protein yield (109.24 kg ha⁻¹), followed by 40 × 20 cm (101.63 kg ha⁻¹), while the lowest was under 60 × 20 cm (90.08 kg ha⁻¹). Nutrient management showed that 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS produced the highest protein yield (133.54 kg ha⁻¹), followed by 125% RDN (123.63 kg ha⁻¹), whereas the control recorded the lowest (45.42 kg ha⁻¹). The interaction effect indicated that the combination of 50 × 20 cm spacing with 100% RDN + foliar spray of 19:19:19 NPK resulted in the maximum protein yield across years.

Oil content

It is evident from Table 2 that oil content of grain amaranth was not significantly affected by spacing, nutrient management, or their interaction, with values remaining narrow (6.03–6.25%) across treatments; however, slightly higher values were observed under 60 × 20 cm spacing and 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS, and the lowest under control.

Oil yield

A perusal of Table 2 shows that oil yield of grain amaranth was significantly influenced by spacing and nutrient management, with the highest yield recorded under 50 × 20 cm spacing (66.80 kg ha⁻¹) and the lowest under 40 × 20 cm spacing (55.84 kg ha⁻¹). Among nutrient treatments, the maximum oil yield was obtained with 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS (84.03 kg ha⁻¹), followed by 125% RDN (76.64 kg ha⁻¹) and 100% RDN + cow urine + vermiwash (75.78 kg ha⁻¹), while the control recorded the lowest yield (25.79 kg ha⁻¹). The interaction between spacing and nutrient management was non-significant.

Carbohydrate content

Data presented in Table 3 revealed that carbohydrate content of grain amaranth was not significantly affected by spacing, nutrient management, or their interaction, with values ranging from 60.73–63.28% across spacings and 58.22–63.94% across nutrient treatments; slightly higher values were observed under

60 × 20 cm spacing and 125% RDN, while the lowest was recorded under control.

Ash content

Findings presented in Table 3 suggest that ash content of grain amaranth was not significantly affected by spacing, nutrient management, or their interaction, with values ranging from 2.68–2.86% across spacings and 2.38–3.28% across nutrient treatments; slightly higher values were observed under 60 × 20 cm spacing and 100% RDN + foliar spray of 19:19:19 NPK, while the lowest was recorded under control.

Nutrient uptake

Nitrogen content in grain (%)

Table 4 illustrates that nitrogen content in grain of grain amaranth was not significantly influenced by spacing, nutrient management, or their interaction during both the years and on mean basis, with values remaining within a narrow range (1.60–1.67%); however, slightly higher values were observed under 60 × 20 cm spacing and 100% RDN + foliar spray of 19:19:19 NPK, while the lowest values were recorded under control.

Nitrogen content in stover (%)

From the data given in Table 4 it can be inferred that nitrogen content in stover of grain amaranth was not significantly influenced by spacing, nutrient management, or their interaction during both the years and on mean basis, with values remaining within a narrow range (1.47–1.56%); however, slightly higher values were observed under 50 × 20 cm and 60 × 20 cm spacing and 100% RDN + foliar spray of 19:19:19 NPK, while the lowest values were recorded under control.

Phosphorus content in grain (%)

The data in Table 5 indicates that phosphorus content in grain of grain amaranth was not significantly influenced by spacing, nutrient management, or their interaction during both the years and on mean basis, with values ranging narrowly from 0.34 to 0.40%; however, slightly higher values were observed under 60 × 20 cm spacing and 100% RDN + foliar spray of 19:19:19 NPK, while the lowest values were recorded under control.

Phosphorus content in stover (%)

Phosphorus content in stover of grain amaranth was not significantly influenced by spacing, nutrient management, or their interaction during both the years and on mean basis, with values ranging from 0.15 to 0.21% (Table 5). However, slightly higher values were observed under 60 × 20 cm and 50 × 20 cm spacing and 100% RDN + foliar spray of 19:19:19 NPK, while the lowest values were recorded under control.

Potassium content in grain (%)

The examination of Table 6 indicates that potassium content in grain of grain amaranth was not significantly affected by spacing, nutrient management, or their interaction during both the years and on mean basis, with values ranging from 0.52 to 0.57%; however, slightly higher values were observed under 60 × 20 cm spacing and 100% RDN + foliar spray of 19:19:19 NPK, while the lowest values were recorded under control.

Potassium content in stover (%)

Table 6 illustrates that potassium content in stover of grain amaranth was not significantly affected by spacing, nutrient management, or their interaction during both the years and on mean basis, with values ranging from 1.31 to 1.43%; however, slightly higher values were observed under 60 × 20 cm spacing and 100% RDN + foliar spray of 19:19:19 NPK, while the

lowest values were recorded under control.

Nitrogen uptake (kg ha⁻¹)

Data presented in Table 7 revealed that nitrogen uptake by grain, stover, and total uptake of grain amaranth was significantly influenced by spacing and nutrient management during both the years and on mean basis. Among spacings, 50 × 20 cm recorded the highest uptake (grain: 17.1–17.8; stover: 34.7–37.9; total: 51.8–55.7 kg ha⁻¹), followed by 40 × 20 cm, while the lowest was observed under 60 × 20 cm. Nutrient management also showed a significant effect, with 100% RDN + foliar spray of 19:19:19 NPK recording the highest uptake (grain: 20.7–21.6; stover: 40.9–44.1; total: 61.6–65.7 kg ha⁻¹), followed by 125% RDN and 100% RDN + foliar spray of cow urine + vermiwash, whereas the control recorded the lowest values. The interaction effect was significant for grain nitrogen uptake, with the highest values consistently observed under 100% RDN + foliar spray of 19:19:19 NPK across all spacings, generally at par with 125% RDN (and cow urine + vermiwash in some cases), while the control recorded the lowest uptake in all spacings.

Phosphorus uptake (kg ha⁻¹)

The result depicted in Table 8 demonstrates that phosphorus uptake by grain, stover, and total uptake of grain amaranth was significantly influenced by spacing and nutrient management during both the years and on mean basis. Among spacings, 50 × 20 cm recorded the highest uptake (grain: 3.9–4.0; stover: 4.2–4.8; total: 8.1–8.8 kg ha⁻¹), followed by 40 × 20 cm, while the lowest was observed under 60 × 20 cm. Nutrient management also showed a significant effect, with 100% RDN + foliar spray of 19:19:19 NPK recording the highest uptake (grain: 5.0–5.1; stover: 5.3–6.0; total: 10.3–11.1 kg ha⁻¹), followed by 125% RDN and 100% RDN + foliar spray of cow urine + vermiwash, whereas the control recorded the lowest values. The interaction effect between spacing and nutrient management was found to be non-significant.

Potassium uptake (kg ha⁻¹)

Potassium uptake by grain, stover, and total uptake of grain amaranth was significantly influenced by spacing and nutrient management during both the years and on mean basis (Table 9). Among spacings, 50 × 20 cm recorded the highest uptake (grain: 5.7–5.9; stover: 31.2–34.1; total: 36.9–40.0 kg ha⁻¹), followed by 40 × 20 cm, while the lowest was observed under 60 × 20 cm. Nutrient management also showed a significant effect, with 100% RDN + foliar spray of 19:19:19 NPK recording the highest uptake (grain: 7.2–7.4; stover: 37.6–40.5; total: 44.8–47.8 kg ha⁻¹), followed by 125% RDN and 100% RDN + foliar spray of cow urine + vermiwash, whereas the control recorded the lowest values. The interaction effect was significant for grain potassium uptake, with 100% RDN + foliar spray of 19:19:19 NPK consistently recording the highest values across spacings, generally at par with 125% RDN (and cow urine + vermiwash in some cases), while the control recorded the lowest uptake; however, interaction effects for stover and total uptake were non-significant.

Discussion

Quality parameters

Protein content of grain amaranth was not significantly affected by spacing or nutrient management, though slightly higher values occurred under wider spacing (60 × 20 cm) and 100% RDN + foliar spray of 19:19:19 NPK, likely due to reduced competition and improved nitrogen assimilation; narrower spacing showed marginally lower values (Modhvadia *et al.*, (2007) ^[7]; Vaghela, 2018 ^[16]). Protein yield, however, was

significantly influenced by both factors, with highest yields at 50 × 20 cm spacing and 100% RDN + foliar spray, followed by 125% RDN and 100% RDN + cow urine + vermiwash, highlighting the role of optimal plant density and nitrogen supply (Dehariya *et al.*, 2019) ^[1]. Oil content did not vary significantly, but numerically higher values were seen under wider spacing and foliar nutrient application, possibly due to better photosynthate allocation. Oil yield, in contrast, increased significantly at 50 × 20 cm spacing and with 100% RDN + foliar spray, followed by cow urine + vermiwash treatments, reflecting enhanced seed formation and lipid accumulation; control plots showed the lowest yields (Gajbhiye *et al.*, (2015) ^[2]; Khurana *et al.*, (2016) ^[4]). Carbohydrate and ash contents were statistically unchanged, but tended to be higher under wider spacing and nutrient-rich treatments, likely due to improved photosynthetic efficiency and mineral uptake, whereas control plots recorded the lowest values (Pandey *et al.*, 2014; Sharma *et al.*, 2019; Ojha *et al.*, 2013; Verma *et al.*, 2017) ^[10, 14, 8, 17].

Nutrient content and uptake

Nitrogen, phosphorus, and potassium contents in both grain and stover of grain amaranth were largely unaffected by spacing, indicating that nutrient concentration is more dependent on genotype and nutrient availability than plant density. Minor

numerical increases—grain K at wider spacing (60 × 20 cm) and grain N at narrower spacing (40 × 20 cm)—likely reflect micro-environmental effects due to altered competition for resources (Modhwadia, 2004) ^[6]. Nutrient management, however, significantly influenced both content and uptake. The treatment 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS consistently recorded the highest N, P, and K in grain and stover, followed by 125% RDN. Adequate nutrient supply during critical growth stages ensures balanced metabolism, efficient nutrient partitioning, and enhanced photosynthetic activity, whereas nutrient-deficient control plots exhibited the lowest values. Nitrogen, phosphorus, and potassium uptake by grain, stover, and total plant were significantly higher at 50 × 20 cm spacing, likely due to an optimal balance between plant population and individual growth, which promotes better root development, canopy coverage, and nutrient acquisition. Integrated nutrient management enhanced uptake by improving rhizospheric nutrient availability and assimilate translocation. Interactions between spacing and nutrient management were generally non-significant, reinforcing that nutrient enrichment plays a more decisive role in determining chemical quality than plant density Singh *et al.*, 2018^[15]; Meena *et al.*, (2021) ^[5].

Table 1: Protein content and protein yield of grain amaranth as influenced by various spacing and nutrient management treatments during 2020-21 and 2021-22

Spacing	Protein content (%)			Protein yield (kg ha ⁻¹)		
	2020-21	2021-22	Mean	2020-22	2021-22	Mean
S ₁ : 40 x 20 cm	10.13	10.14	10.14	99.86	103.39	101.63
S ₂ : 50 x 20 cm	10.15	10.16	10.15	106.99	111.48	109.24
S ₃ : 60 x 20 cm	10.17	10.16	10.17	88.21	91.94	90.08
SEm±	0.03	0.03	0.03	1.28	0.99	1.14
CD (P=0.05)	NS	NS	NS	5.03	3.90	4.46
Nutrient management						
N ₀ : Control	10.01	10.02	10.02	45.00	45.84	45.42
N ₁ : 75% RDN	10.06	10.07	10.07	76.10	79.82	77.96
N ₂ : 100% RDN	10.13	10.14	10.14	101.80	107.03	104.42
N ₃ : 125% RDN	10.24	10.25	10.25	120.98	126.27	123.63
N ₄ : 75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	10.15	10.16	10.16	104.72	109.24	106.98
N ₅ : 75% RDN + foliar spray of CU+VW at 40 and 60 DAS	10.08	10.09	10.09	88.96	92.86	90.91
N ₆ : 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	10.32	10.33	10.33	132.14	134.94	133.54
N ₇ : 100% RDN + foliar spray of CU+VW at 40 and 60 DAS	10.21	10.22	10.22	117.10	122.15	119.63
SEm±	0.07	0.07	0.07	2.36	2.42	2.39
CD(P=0.05)	NS	NS	NS	6.72	6.92	6.82
Interaction (SxN)	NS	NS	NS	S	S	S

Table 2: Oil content (%) and oil yield (kg ha⁻¹) of grain amaranth as influenced by various spacing and nutrient management treatments during 2020-21 and 2021-22

Treatment Spacing	Oil content (%)			Oil yield (kg ha ⁻¹)		
	2020-21	2021-22	Mean	2021-22	2021-22	Mean
S ₁ : 40 x 20 cm	6.03	6.15	6.09	59.82	62.58	61.2
S ₂ : 50 x 20 cm	6.13	6.25	6.19	65.18	68.42	66.8
S ₃ : 60 x 20 cm	6.22	6.35	6.29	54.43	57.25	55.84
SEm±	0.08	0.09	0.09	0.79	1.07	0.92
CD(P=0.05)	NS	NS	NS	3.102	4.182	3.642
Nutrient Management						
N ₀ : Control	5.65	5.76	5.71	25.42	26.16	25.79
N ₁ : 75% RDN	5.89	6.01	5.95	44.54	47.04	45.79
N ₂ : 100% RDN	5.92	6.05	5.99	59.56	63.22	61.39
N ₃ : 125% RDN	6.33	6.46	6.40	74.66	78.61	76.64
N ₄ : 75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	6.22	6.35	6.29	64.10	67.49	65.80
N ₅ : 75% RDN + foliar spray of CU+VW at 40 and 60 DAS	6.09	6.21	6.15	53.68	56.51	55.10
N ₆ : 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	6.47	6.58	6.53	82.78	85.28	84.03
N ₇ : 100% RDN + foliar spray of CU+VW at 40 and 60 DAS	6.43	6.56	6.50	73.74	77.65	75.70
Sem±	0.12	0.12	0.12	1.74	1.81	1.78
CD(P=0.05)	0.35	0.33	0.34	4.98	5.17	5.08
Interaction (SxN)	NS	NS	NS	NS	NS	NS

Table 3: Carbohydrate content (%) and ash content (%) of grain amaranth as influenced by various spacing and nutrient management treatments during 2020-21 and 2021-22

Spacing	Carbohydrate content (%)			Ash content (%)		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean
S ₁ : 40 x 20 cm	60.16	61.29	60.73	2.63	2.74	2.69
S ₂ : 50 x 20 cm	61.33	62.47	61.90	2.78	2.88	2.83
S ₃ : 60 x 20 cm	62.69	63.86	63.28	2.81	2.91	2.86
SEm±	0.28	0.28	0.28	0.03	0.03	0.03
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient Management						
N ₀ : Control	57.68	58.76	58.22	2.31	2.45	2.38
N ₁ : 75% RDN	61.49	62.64	62.07	2.48	2.56	2.52
N ₂ : 100% RDN	60.67	61.80	61.24	2.44	2.51	2.48
N ₃ :125% RDN	63.35	64.53	63.94	3.05	3.14	3.10
N ₄ : 75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	61.16	62.30	61.73	2.90	2.99	2.95
N ₅ : 75% RDN + foliar spray of CU+VW at 40 and 60 DAS	61.42	62.58	62.00	2.64	2.72	2.68
N ₆ : 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	62.80	63.97	63.39	3.23	3.33	3.28
N ₇ : 100% RDN + foliar spray of CU+VW at 40 and 60 DAS	62.57	63.73	63.15	2.86	3.04	2.95
SEm±	0.66	0.67	0.67	0.08	0.08	0.08
CD (P=0.05)	1.87	1.90	1.89	0.23	0.22	0.23
Interaction (SxN)	NS	NS	NS	NS	NS	NS

Table 4: Nitrogen content of grain and stover of grain amaranth as influenced by various spacing and nutrient management treatments during 2020-21 and 2021-22

Treatments	Nitrogen content (%)					
	Grain			Stover		
Spacing	2020-21	2021-22	Mean	2020-21	2021-22	Mean
S ₁ : 40 x 20 cm	1.62	1.64	1.63	1.50	1.52	1.51
S ₂ : 50 x 20 cm	1.62	1.64	1.63	1.52	1.54	1.53
S ₃ : 60 x 20 cm	1.63	1.65	1.64	1.52	1.54	1.53
SEm±	0.005	0.004	0.0045	0.017	0.017	0.017
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
N ₀ : Control	1.60	1.61	1.605	1.47	1.49	1.48
N ₁ : 75% RDN	1.61	1.63	1.62	1.50	1.52	1.51
N ₂ : 100% RDN	1.62	1.64	1.63	1.52	1.54	1.53
N ₃ :125% RDN	1.64	1.66	1.65	1.53	1.55	1.54
N ₄ : 75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	1.62	1.64	1.63	1.51	1.54	1.525
N ₅ : 75% RDN + foliar spray of CU+VW at 40 and 60 DAS	1.61	1.63	1.62	1.49	1.51	1.5
N ₆ : 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	1.65	1.67	1.66	1.54	1.56	1.55
N ₇ : 100% RDN + foliar spray of CU+VW at 40 and 60 DAS	1.63	1.65	1.64	1.53	1.55	1.54
SEm±	0.01	0.01	0.01	0.02	0.02	0.02
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (SxN)	NS	NS	NS	NS	NS	NS

Table 5: Nitrogen content of grain and stover of grain amaranth as influenced by various spacing and nutrient management treatments during 2020-21 and 2021-22

Treatments	Phosphorus content (%)					
	Grain			Stover		
Spacing	2020-21	2021-22	Mean	2020-21	2021-22	Mean
S ₁ : 40 x 20 cm	0.35	0.36	0.36	0.17	0.18	0.18
S ₂ : 50 x 20 cm	0.36	0.37	0.37	0.18	0.19	0.19
S ₃ : 60 x 20 cm	0.37	0.38	0.38	0.18	0.19	0.19
SEm±	0.005	0.006	0.01	0.003	0.003	0.003
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
N ₀ : Control	0.34	0.36	0.35	0.15	0.16	0.16
N ₁ : 75% RDN	0.35	0.37	0.36	0.16	0.17	0.17
N ₂ : 100% RDN	0.36	0.36	0.36	0.18	0.19	0.19
N ₃ :125% RDN	0.38	0.39	0.39	0.19	0.20	0.20
N ₄ : 75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	0.36	0.36	0.36	0.18	0.19	0.19
N ₅ : 75% RDN + foliar spray of CU+VW at 40 and 60 DAS	0.36	0.36	0.36	0.16	0.18	0.20
N ₆ : 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	0.39	0.40	0.40	0.20	0.21	0.21
N ₇ : 100% RDN + foliar spray of CU+VW at 40 and 60 DAS	0.37	0.37	0.37	0.19	0.20	0.20
SEm±	0.01	0.01	0.01	0.01	0.01	0.01
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (S x N)	NS	NS	NS	NS	NS	NS

Table 6: Potassium content in grain and stover of grain amaranth as influenced by various spacing and nutrient management treatments during 2020-21 and 2021-22

Treatments	Potassium content (%)					
	Grain			Stover		
Spacing	2020-21	2021-22	Mean	2020-21	2021-22	Mean
S ₁ : 40 x 20 cm	0.53	0.54	0.54	1.35	1.37	1.36
S ₂ : 50 x 20 cm	0.54	0.54	0.54	1.36	1.38	1.37
S ₃ : 60 x 20 cm	0.55	0.56	0.555	1.37	1.39	1.38
SEm±	0.01	0.01	0.01	0.02	0.02	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
N ₀ : Control	0.52	0.53	0.53	1.31	1.33	1.32
N ₁ : 75% RDN	0.53	0.54	0.54	1.33	1.35	1.34
N ₂ : 100% RDN	0.53	0.54	0.54	1.36	1.38	1.37
N ₃ :125% RDN	0.55	0.56	0.56	1.39	1.41	1.4
N ₄ : 75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	0.54	0.55	0.55	1.36	1.39	1.375
N ₅ : 75% RDN + foliar spray of CU+VW at 40 and 60 DAS	0.53	0.53	0.53	1.34	1.36	1.35
N ₆ : 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	0.56	0.57	0.57	1.41	1.43	1.42
N ₇ : 100% RDN + foliar spray of CU+VW at 40 and 60 DAS	0.54	0.55	0.55	1.38	1.40	1.39
SEm±	0.01	0.01	0.01	0.02	0.02	0.02
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (S x N)	NS	NS	NS	NS	NS	NS

Table 7: Nitrogen uptake (kg ha⁻¹) of grain amaranth as influenced by various spacing and nutrient management treatments during 2020-21 and 2021-22

Treatments	Nitrogen uptake (kg ha ⁻¹)								
	Grain			Stover			Total		
Spacing	2020-21	2021-22	Mean	2020-21	2021-22	Mean	2020-21	2021-22	Mean
S ₁ : 40 x 20 cm	15.8	16.5	16.2	31.4	35.1	33.3	47.2	51.7	49.5
S ₂ : 50 x 20 cm	17.1	17.8	17.5	34.7	37.9	36.3	51.8	55.7	53.8
S ₃ : 60 x 20 cm	14.1	14.7	14.4	29.3	33.0	31.1	43.4	47.7	45.5
SEm±	0.1	0.2	0.2	0.4	0.9	0.6	0.5	1.0	0.7
CD(P=0.05)	0.5	0.6	0.6	1.6	3.3	2.5	1.9	3.8	2.9
Nutrient management									
N ₀ : Control	7.2	7.3	7.3	16.3	17.4	16.9	23.5	24.8	24.1
N ₁ : 75% RDN	12.2	12.8	12.5	24.6	29.0	26.8	36.8	41.7	39.3
N ₂ : 100% RDN	16.3	17.1	16.7	33.4	37.5	35.4	49.6	54.6	52.1
N ₃ :125% RDN	19.4	20.2	19.8	38.6	41.3	40.0	58.0	61.5	59.8
N ₄ : 75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	16.8	17.5	17.1	34.2	39.2	36.7	50.9	56.7	53.8
N ₅ : 75% RDN + foliar spray of CU+VW at 40 and 60 DAS	14.2	14.9	14.6	28.7	32.7	30.7	42.9	47.6	45.2
N ₆ : 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	20.7	21.6	21.1	40.9	44.1	42.5	61.6	65.7	63.6
N ₇ : 100% RDN + foliar spray of CU+VW at 40 and 60 DAS	18.7	19.5	19.1	37.8	41.4	39.6	56.5	60.9	58.7
SEm±	0.4	0.4	0.4	0.9	1.2	1.0	1.1	1.5	1.3
CD(P=0.05)	1.1	1.1	1.1	2.5	3.3	2.9	3.0	4.2	3.6
Interaction (S x N)	S	S	S	NS	NS	NS	NS	NS	NS

Table 8: Phosphorus uptake (kg ha⁻¹) of grain amaranth as influenced by various spacing and nutrient management treatments during 2020-21 and 2021-22

Treatments	Phosphorus uptake (kg ha ⁻¹)								
	Grain			Stover			Total		
Spacing	2020-21	2021-22	Mean	2020-21	2021-22	Mean	2020-21	2021-22	Mean
S ₁ : 40 x 20 cm	3.5	3.7	3.6	3.6	4.2	3.9	7.1	7.9	7.5
S ₂ : 50 x 20 cm	3.9	4.0	4.0	4.2	4.8	4.5	8.1	8.8	8.5
S ₃ : 60 x 20 cm	3.2	3.4	3.3	3.6	4.2	3.9	6.8	7.6	7.2
SEm±	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
CD(P=0.05)	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.6	0.6
Nutrient management									
N ₀ : Control	1.6	1.6	1.6	1.7	1.9	1.8	3.2	3.5	3.4
N ₁ : 75% RDN	2.6	2.9	2.8	2.7	3.3	3.0	5.3	6.1	5.7
N ₂ : 100% RDN	3.6	3.8	3.7	3.8	4.6	4.2	7.4	8.4	7.9
N ₃ :125% RDN	4.5	4.7	4.6	4.7	5.4	5.0	9.2	10.1	9.7
N ₄ : 75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	3.6	3.8	3.7	4.2	4.9	4.6	7.8	8.7	8.3
N ₅ : 75% RDN + foliar spray of CU+VW at 40 and 60 DAS	3.2	3.3	3.3	3.2	3.8	3.5	6.4	7.2	6.8
N ₆ : 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	5.0	5.1	5.1	5.3	6.0	5.7	10.3	11.1	10.7
N ₇ : 100% RDN + foliar spray of CU+VW at 40 and 60 DAS	4.2	4.4	4.3	4.8	5.3	5.1	9.0	9.7	9.4
SEm±	0.1	0.1	0.1	0.3	0.3	0.3	0.3	0.4	0.3
CD(P=0.05)	0.4	0.4	0.4	0.8	0.9	0.9	0.9	1.0	1.0
Interaction (S x N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 9: Potassium uptake (kg ha⁻¹) of grain amaranth as influenced by various spacing and nutrient management treatments during 2020-21 and 2021-22

Treatments Spacing	Potassium uptake (kg ha ⁻¹)								
	Grain			Stover			Total		
	2020-21	2021-22	Mean	2020-21	2021-22	Mean	2020-21	2021-22	Mean
S ₁ : 40 x 20 cm	5.3	5.4	5.4	28.4	31.7	30.1	33.7	37.2	35.5
S ₂ : 50 x 20 cm	5.7	5.9	5.8	31.2	34.1	32.6	36.9	40.0	38.5
S ₃ : 60 x 20 cm	4.8	5.0	4.9	26.5	29.8	28.1	31.3	34.8	33.1
SEm±	0.2	0.2	0.2	0.3	0.6	0.5	0.3	0.7	0.5
CD(P=0.05)	0.6	0.6	0.6	1.4	2.2	1.8	1.3	2.7	2.0
Nutrient Management									
N ₀ : Control	2.4	2.4	2.4	14.5	15.5	15.0	16.9	17.9	17.4
N ₁ : 75% RDN	4.0	4.2	4.1	21.8	25.7	23.7	25.8	29.9	27.9
N ₂ : 100% RDN	5.4	5.6	5.5	29.8	33.5	31.6	35.1	39.1	37.1
N ₃ : 125% RDN	6.5	6.8	6.7	35.0	37.5	36.2	41.5	44.3	42.9
N ₄ : 75% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	5.6	5.8	5.7	30.8	35.5	33.1	36.4	41.3	38.9
N ₅ : 75% RDN + foliar spray of CU+VW at 40 and 60 DAS	4.6	4.9	4.8	25.8	29.5	27.7	30.5	34.3	32.4
N ₆ : 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS	7.2	7.4	7.3	37.6	40.5	39.0	44.8	47.8	46.3
N ₇ : 100% RDN + foliar spray of CU+VW at 40 and 60 DAS	6.2	6.5	6.3	34.2	37.4	35.8	40.4	43.9	42.2
SEm±	0.1	0.1	0.1	0.8	1.1	0.9	0.8	1.2	1.0
CD(P=0.05)	0.4	0.4	0.4	2.3	3.1	2.7	2.3	3.3	2.8
Interaction (SxN)	S	S	S	NS	NS	NS	NS	NS	NS

Conclusion

Grain quality parameters of amaranth were not significantly influenced by spacing and nutrient management; however, protein and oil yields and nutrient uptake were significantly improved under 50 × 20 cm spacing combined with 100% RDN + foliar spray of 19:19:19 NPK at 40 and 60 DAS. Therefore, this combination is recommended for achieving better nutrient uptake and improved yield-related quality in grain amaranth.

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