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Yield maximization of grain Amaranth (*Amaranthus hypochondriacus* L.) through application of bio-stimulants

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Abstract

The experiment was carried out during kharif season 2024 at M block, field unit of All India Co-ordinated Research Network on Potential Crops, Zonal Agricultural Research Station, University of Agricultural Sciences, Bangalore, Karnataka, India. The experiment consists of eleven treatment combinations which were replicated thrice in RCBD. Treatments comprised of varying levels of RDF (50, 75 and 100 per cent) and the application of bio-stimulants viz., microbial consortia as soil application and vermiwash and seaweed extract as foliar spray. Among the different treatments, application of 100% RDF + Seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS recorded significantly higher growth, yield and yield parameters viz., plant height (152.8 cm), number of leaves plant⁻¹ (23.45), total dry matter production (104.8 g plant⁻¹), panicle length (42.60 cm), number of fingers panicle⁻¹ (37.21), length of finger (16.62 cm), grain yield (1758 kg ha⁻¹) and stover yield (6100 kg ha⁻¹) of grain amaranth over RDF. Significantly, higher protein (13.90%) and oil content (8.40%) and higher amino acid content lysine, methionine, cystine, isoleucine and leucine (6.60, 4.60, 5.80, 4.90 and 6.20 g / 100 g of protein, respectively) were recorded with application of 100% RDF + Seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS which was found on par with 100% RDF + Vermiwash @ 5% foliar application (13.80% and 8.10%) at 30 and 45 DAS and 100% RDF + PSB + VAM + Azatobacter soil application (13.30% and 7.75%) Notably, this particular treatment also proved the most financial rewarding, generating higher gross returns (₹ 1,40640 ha⁻¹), net returns (₹ 105283 ha⁻¹) and benefit cost ratio of 3.99 outperforming all other treatment options. These findings emphasize the potential of bio-stimulants in maximizing grain yield of grain amaranth for higher economic benefit for farmers.

Keywords: Grain amaranth, bio-stimulants, grain yield, quality and economics

Introduction

Grain Amaranth (*Amaranthus hypochondriacus* L.) a quick growing and upcoming subsidiary food crop of the future, belongs to the family Amaranthaceae and genus Amaranthus. The genus *amaranthus* has more than 60 species of which some are grown for leaf purpose and seeds of which are black in colour. Three species (*Amaranthus hypochondriacus*, *Amaranthus caudatus* and *Amaranthus cruentus*) are grown for grain purpose and seeds of which are in golden yellow colour. The seeds are very nutritious and popularly called as 'Dantina Beeja' in Kannada and 'Rajgira' in Hindi. It is a hardy plant with thick stalks and suitable for arid and semiarid tropics. It has resistance against pests, diseases and has a highly competitive ability which permits its cultivation with minimum crop management.

About 5000 years ago, pre-Columbian civilizations grew thousands of hectares of this pseudo-cereal which was used along with maize and beans. The native Aztecs community of South America relied on amaranth seeds as an important staple food. After Spanish invasion, maize crop with which amaranth co-evolved and developed into a major world crop. By the middle of 20th century, the cultivation of grain amaranth had declined to the point, where it has grown only in small plots in Mexico, the Andean highlands and in the Himalayan foothills of India and Nepal (Dinesh Adhikary *et al.*, 2020) [5]. After knowing the biochemistry in the beginning of 21st century, the nutritional qualities especially the higher protein and lysine content of grain amaranth was known and the crop started gaining importance and re-emerged as one of the

health care crop in many countries including India.

Amaranth seed is known to be very nutritious with high protein content (14-16%) and quality due to the presence of higher lysine, at a total concentration of 29.67 g/100 g protein of the total protein content (Neelesh kumar *et al.*, 2018) ^[13]. The starch component of amaranth is distinctive and high swelling power with a gel characteristic which has significance in specialized food and industrial applications. Amaranth grain contains 6 to 10 per cent oil which is predominantly unsaturated (76%) and is high in linoleic acid which is necessary for nutrition.

In Recent years Plant Bio-stimulants are normally used in agriculture with the aim of reducing the use of chemical inputs, to increase production and to re-establish the natural equilibrium in agro-ecosystems. These substances are also applied to enhance crop productivity and nutritional quality of agricultural foods. Bio-stimulant formulations are mixtures of different substances such as, humic and fulvic acids, protein hydrolysates, extracts of plants or seaweeds, silicon, chitosan, inorganic compounds, beneficial fungi (i.e. *Arbuscular mycorrhizal* fungi; AMF and *Trichoderma spp.*) and plant growth-promoting bacteria (Ngoroyemoto *et al.*, 2019) ^[14]. Bio-stimulants influence development in all the different phases of the crop's life cycle, starting from seed germination up to maturity. They are known to improve the efficiency of the plant's metabolism to induce yield increase and enhanced crop quality. Hence, the present study has been planned to enhance the productivity and quality of grain amaranth.

Materials and Methods

The experiment was carried out during *kharif* 2023 and 2024 for two consecutive seasons at M block, Zonal Agricultural Research station, University of Agricultural sciences, Bangalore Karnataka, India. The experiment consists of eleven treatment combinations which were replicated thrice in RCBD. Treatments comprised of varying levels of RDF (50, 75 and 100 per cent) and the application of bio-stimulants viz., microbial consortia as soil application and vermiwash and seaweed extract as foliar spray. The soil of the experimental site was red sandy loam grouped under the class of *Alfisols*. Composite soil samples from 0-15 cm depth were collected from the experimental plot before the imposition of treatments and they were analyzed for physical and chemical properties of soil. The values obtained along with the methods employed for their estimation are presented in Table 1. The soil of experimental site was neutral in reaction (6.45), low in available nitrogen (244 kg ha⁻¹), medium in available phosphorus (39 kg ha⁻¹) and available potassium (233 kg ha⁻¹). The organic carbon content was 0.41% and electrical conductivity was 0.30 dS m⁻¹.

Farm yard manure (FYM) @ 7.5 t ha⁻¹ was applied 15 days before sowing. Fertilizer viz., nitrogen, phosphorus, potassium were applied to all the plots as per the treatments. PSB + VAM + *Azotobacter*, vermiwash and seaweed extract being the experimental material, PSB + VAM + *Azotobacter* was applied through soil mode as per the treatments. Full dose of phosphorus, potassium, (60:40:40 N: P2O5: K2O) along with 50 per cent of nitrogen for each treatment was applied as basal dose and remaining 50 per cent nitrogen dose was top dressed at 30 days after sowing as per the treatments. Soil application of PSB + VAM + *Azotobacter* @ 5 kg ha⁻¹ was applied at the time of

sowing. Foliar spray of vermiwash and seaweed each @ 5ml L⁻¹ was done at 30 and 45 days after sowing as per the treatments. In order to record the various morphological observations, samples consisting of five plants were selected at random from each net plot and observations on various growth and yield parameters were recorded at 30, 60 DAS and at harvest. The experimental data collected on plant growth parameters, yield components were subjected to Fisher's method of "Analysis of Variance" (ANOVA) as outlined by Gomez and Gomez (1984) ^[7]. Wherever F- test was significant, for comparison between the treatment means, an appropriate value of critical difference (CD) was worked out. All the data was analyzed and the results were presented and discussed at a probability level of five per cent.

Results and Discussion

Growth attributes of grain amaranth

Among the different treatments 100% RDF + Seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS (T₉) recorded significantly higher plant height, no. of leaves per plant and dry matter production per plant (152.8 cm, 23.45 and 104.8 g/plant, respectively) which was found to be on par with 100% RDF + Vermiwash @ 5% foliar application (145.6 cm, 22.44 and 100.10 g/plant, respectively) at 30 and 45 DAS (T₆) and 100% RDF + PSB + VAM + *Azotobacter* soil application (139.8 cm, 22.15 and 98.11 g/plant, respectively) (T₃). Whereas, lower plant height, no. of leaves per plant and dry matter production per plant (105.0 cm, 13.25 and 58.81 g/plant, respectively) were seen in absolute control (T₁). This could be due to the positive impact of seaweed extract which is rich in nutrient content, growth promoting hormones and beneficial components have significant role in plant's physiological processes leading to improved nutrient uptake, enhanced photosynthesis and better growth (Gaurav Kumar and Dinabandhu Sahoo, 2011) ^[6]. Similarly, this might be due to rich array of bioactive compounds such as cytokinins, auxins and gibberellins in seaweed extract which play crucial roles in promoting plant growth and development. By improving nutrient uptake and assimilation, seaweed extracts ensure presence of antioxidants and plant growth regulators which helps to mitigate oxidative stress and enhance the plant's tolerance to environmental stresses, further supporting healthy leaf growth (Kumar *et al.* 2012) ^[11].

The treatment which received 100% RDF + Seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS (T₉) recorded higher total dry matter production. This could be due to the fact that application of seaweed extracts improves the efficiency of photosynthesis by enhancing chlorophyll content, stomatal conductance and carbon assimilation rates which results in greater biomass production as more carbon dioxide is converted into organic matter through enhanced metabolic activities within the plant. It also enhances the plant's resilience to environmental stresses such as drought, salinity and pathogens, which limit biomass accumulation. By improving the plant's nutrient uptake efficiency and enhancing its tolerance to stress, seaweed extracts also ensures more energy towards biomass production. The above result was similar to the findings of Kalaivanan and Venkatesalu (2012) ^[8] and Balamurugan and Sasikumar (2013) ^[1].

Table 1: Growth attributes of grain amaranth as influenced by application of bio-stimulants

Tr. No.	Treatments	Plant height (cm)	No. of leaves plant ⁻¹	Total dry matter production (g plant ⁻¹)
T ₁	Absolute control	105.0	13.25	58.81
T ₂	100% RDF	133.5	19.96	86.01
T ₃	100% RDF + PSB + VAM + <i>Azotobacter</i> – SA	139.8	22.15	98.11
T ₄	75% RDF + PSB + VAM + <i>Azotobacter</i> - SA	136.6	20.12	89.12
T ₅	50% RDF + PSB + VAM + <i>Azotobacter</i> - SA	132.5	17.20	70.02
T ₆	100% RDF + Vermiwash @ 5% - FA	145.6	22.44	100.1
T ₇	75% RDF + Vermiwash @ 5% - FA	132.6	19.56	81.78
T ₈	50% RDF + Vermiwash @ 5% - FA	126.4	17.62	73.06
T ₉	100% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	152.8	23.45	104.8
T ₁₀	75% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	126.4	19.31	80.35
T ₁₁	50% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	135.8	18.00	78.02
	S.Em ±	5.13	0.68	3.05
	CD @ 5%	15.13	2.02	9.00

Note: Recommended FYM @ 7.5 t ha⁻¹ is common for all treatments SA- Soil application of PSB + VAM + *Azotobacter* of each @ 5 kg ha⁻¹
FA- Foliar application of vermiwash and seaweed extract applied at 30 and 45 DAS

Yield attributes of grain amaranth

Panicle length was found to be significantly influenced by different soil and foliar application of bio-stimulants. Significantly higher panicle length, no. of fingers per panicle and length of fingers (42.60 cm, 37.21 and 16.62 cm, respectively) were recorded with 100% RDF + Seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS (T₉) which was found on par with 100% RDF + Vermiwash @ 5% foliar application (41.28 cm, 34.08 and 16.62 cm, respectively) at 30 and 45 DAS (T₆) and 100% RDF + PSB + VAM + *Azotobacter* soil application (40.37 cm, 33.22 and 13.84 cm, respectively) (T₃). However, lower panicle length (28.07 cm, 11.88 and 8.70 cm, respectively) were seen in absolute control (T₁). This might

be due to seaweed extracts which provide a rich source of nutrients and trace elements that improve nutrient uptake by the plants particularly, nitrogen, phosphorus and potassium, which are vital for reproductive development. Furthermore, these extracts enhance photosynthetic efficiency and chlorophyll content, increasing the plant's capacity to harness solar energy for the development of longer panicles (Devi and Mani, 2013) [4]. These findings are similar with the results reported by Satapathy *et al.* (2014) [16] who observed that improved photosynthetic efficiency, chlorophyll content and overall metabolic activity, which contribute to better assimilation of carbon and nutrients needed for finger elongation.

Table 2: Yield attributes of grain amaranth as influenced by application of bio-stimulants

Tr. No.	Treatments	Panicle length (cm)	Number of fingers panicle-1	Length of finger (cm)
T ₁	Absolute control	28.07	11.88	8.70
T ₂	100% RDF	36.82	29.17	12.53
T ₃	100% RDF + PSB + VAM + <i>Azotobacter</i> – SA	40.37	33.22	13.84
T ₄	75% RDF + PSB + VAM + <i>Azotobacter</i> - SA	37.06	31.00	13.48
T ₅	50% RDF + PSB + VAM + <i>Azotobacter</i> - SA	32.06	25.35	11.78
T ₆	100% RDF + Vermiwash @ 5% - FA	41.28	34.08	15.30
T ₇	75% RDF + Vermiwash @ 5% - FA	34.24	30.23	13.44
T ₈	50% RDF + Vermiwash @ 5% - FA	28.50	26.13	12.58
T ₉	100% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	42.60	37.21	16.62
T ₁₀	75% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	35.25	28.61	13.35
T ₁₁	50% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	29.58	26.28	11.60
	S.Em ±	1.77	1.95	0.98
	CD @ 5%	5.22	5.75	2.89

Note: Recommended FYM @ 7.5 t ha⁻¹ is common for all treatments SA- Soil application of PSB + VAM + *Azotobacter* of each @ 5 kg ha⁻¹
FA- Foliar application of vermiwash and seaweed extract applied at 30 and 45 DAS

Grain yield, stover yield and harvest index

Grain and stover yield were influenced by application of different bio-stimulants. Application of 100% RDF + seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS (T₉) recorded significantly higher grain yield (1758 and 6100 kg ha⁻¹, respectively) which was found on par with 100% RDF + Vermiwash @ 5% foliar application (1702 and 5906 kg ha⁻¹, respectively) at 30 and 45 DAS (T₆) and 100% RDF + PSB + VAM + *Azotobacter* soil application (1687 and 5854 kg ha⁻¹, respectively) (T₃) as compared to RDF. The yield increase was

14.37 per cent, 10.73 per cent and 9.75 per cent (T₉, T₆ and T₃, respectively) as compared to RDF. However, the lower grain yield (1049 and 3640 kg ha⁻¹, respectively) was recorded in absolute control (T₁).

Seaweed extract application has recorded significantly higher grain yield due to improved performance of growth and yield attributes. These extracts contain high content of plant growth regulators like auxins, cytokinins and gibberellins which plays crucial roles in stimulating cell division, elongation and overall plant growth which results in maximum grain production.

Findings of Kavitha *et al.* (2008) [9] were consistent with the above results. Yield parameters such as panicle length (cm), number of fingers panicle-1, length of fingers, grain yield plant⁻¹ and 10 ml seed volume weight were recorded significantly higher with soil and foliar application of bio-stimulants. This might be due to seaweed extract contains a wide range of micronutrients such as iron, zinc, manganese and magnesium which are vital for enzyme activation and metabolic processes within plants ensuring optimal physiological functions that ultimately leads to higher yields. The similar observations revealed by (Mitra and Mandal, 2012) [12] in rice crop.

The increased yield in grain amaranth resulting from the application of seaweed extract could be due to their roles in various physiological processes and enhancement of growth parameters which includes improved partitioning of carbohydrates from leaves to reproductive parts, which

ultimately leads to increased yield. These extracts improve the plant's tolerance to various environmental stresses including drought, salinity and temperature extremes. By enhancing stress resistance, seaweed extracts also helps crop to maintain their growth and productivity under adverse conditions, thereby increase the grain yield and also application of seaweed extract can stimulate beneficial microbial activity in the soil and improves nutrient availability and uptake by plants further enhances robust growth and yield Khan *et al.* (2009) [10] and Banjare *et al.* (2022) [2]. Whereas, harvest index of grain amaranth due to various soil and foliar application of bio-stimulants was found non-significant (Table 3). However, application of 100% RDF + Seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS (T₉) have recorded numerically higher value of harvest index (0.23). However, the lower harvest index (0.21) was recorded with absolute control (T₁).

Table 3: Grain yield, Stover yield and harvest index of grain amaranth as influenced by application of bio-stimulants

Tr. No.	Treatments	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index
T ₁	Absolute control	1049	3640	0.22
T ₂	100% RDF	1537	5333	0.22
T ₃	100% RDF + PSB + VAM + <i>Azotobacter</i> – SA	1687	5854	0.23
T ₄	75% RDF + PSB + VAM + <i>Azotobacter</i> - SA	1570	5448	0.22
T ₅	50% RDF + PSB + VAM + <i>Azotobacter</i> - SA	1358	4712	0.21
T ₆	100% RDF + Vermiwash @ 5% - FA	1702	5906	0.23
T ₇	75% RDF + Vermiwash @ 5% - FA	1501	5208	0.22
T ₈	50% RDF + Vermiwash @ 5% - FA	1396	4844	0.21
T ₉	100% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	1758	6100	0.23
T ₁₀	75% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	1534	5323	0.22
T ₁₁	50% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	1464	5080	0.21
	S.Em ±	57.06	197.65	0.008
	CD @ 5%	168.03	583.09	NS

Note: Recommended FYM @ 7.5 t ha⁻¹ is common for all treatments SA- Soil application of PSB + VAM + *Azotobacter* of each @ 5 kg ha⁻¹
FA- Foliar application of vermiwash and seaweed extract applied at 30 and 45 DAS

Quality parameters

Significantly, higher protein content (13.90%) and oil content (8.40%) were recorded with application of 100% RDF + Seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS (T₉) which was found on par with 100% RDF + Vermiwash @ 5% foliar application (13.80% and 8.10%) at 30 and 45 DAS (T₆) and 100% RDF + PSB + VAM + *Azotobacter* soil application (13.30% and 7.75%) (T₃). However, significantly lower protein (11.31%) and oil content (6.74%) were recorded with absolute control (T₁).

The significant increase in protein and oil content may be due to seaweed extracts typically contain phytohormones like cytokinin, auxins and gibberellins along with various micronutrients such as vitamins, minerals and amino acids which act synergistically to stimulate metabolic processes involved in protein and oil synthesis. Moreover, these extracts contain a wide range of micronutrients such as iron, zinc and manganese which act as cofactors for enzymes involved in protein and oil biosynthesis pathways. Similar results were obtained by Bhaskar *et al.* (1996) [3]. Devi and Mani (2013) [4] who reported that increment in quality parameters of rice were recorded with the combined application of seaweed saps and fertilizer.

Amino acid profile

The data on amino acid profile viz., lysine, methionine, cystine, isoleucine and leucine in seeds influenced by soil and foliar application of bio-stimulants is presented in Table 5. Significantly, higher amino acid content lysine, methionine, cystine, isoleucine and leucine (6.60, 4.60, 5.80, 4.90 and 6.20 g / 100 g of protein, respectively) was recorded with application of 100% RDF + Seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS (T₉) which was found on par with 100% RDF + Vermiwash @ 5% (6.20, 4.40, 5.50, 4.60 and 6.08 g / 100 g of protein, respectively) foliar application at 30 and 45 DAS (T₆) and 100% RDF + PSB + VAM + *Azotobacter* (5.70, 4.30, 5.20, 4.50 and 5.90 g / 100 g of protein, respectively) soil application (T₃). However, lower amino acid content (4.20, 2.80, 3.40, 2.80 and 3.81 g / 100 g of protein, respectively) was recorded in absolute control (T₁). This might be due to seaweeds contain diverse range of nutrients including growth-promoting substances such as hormones auxins, cytokinins and trace minerals. These extracts stimulate plant to uptake more soil nutrients and enhances its ability to synthesize amino acids leading to more balanced and enriched amino acid profile Patel *et al.* (2011) [15].

Table 4: Quality parameters of grain amaranth as influenced by application of bio-stimulants

Tr. No.	Crude protein (%)	Oil content (%)	Amino acid profile (g / 100 g of protein)				
			Lysine	Methionine	Cysteine	Isoleucine	Leucine
T ₁	11.31	6.74	4.20	2.80	3.40	2.80	3.81
T ₂	12.80	7.63	5.40	4.00	4.80	4.00	5.20
T ₃	13.30	7.75	5.70	4.30	5.20	4.50	5.90
T ₄	13.10	7.70	5.50	4.10	4.90	4.31	5.40
T ₅	12.50	7.01	5.00	3.75	4.10	3.59	4.50
T ₆	13.80	8.10	6.20	4.40	5.50	4.60	6.08
T ₇	12.70	7.30	5.00	3.80	4.40	3.70	4.80
T ₈	12.02	7.10	4.90	3.55	4.10	3.55	4.40
T ₉	13.90	8.40	6.60	4.60	5.80	4.90	6.20
T ₁₀	12.70	7.50	5.30	3.80	4.50	3.80	5.00
T ₁₁	12.35	7.20	5.10	3.61	4.20	3.60	4.70
	*	*	*	*	*	*	*
	0.483	0.283	0.202	0.146	0.176	0.149	0.194
	1.42	0.836	0.597	0.433	0.520	0.441	0.574

Note: Recommended FYM @ 7.5 t ha⁻¹ is common for all treatments SA- Soil application of PSB + VAM + *Azotobacter* of each @ 5 kg ha⁻¹

FA- Foliar application of vermiwash and seaweed extract applied at 30 and 45 DAS

Economics

Among the soil and foliar application of nutrients, higher cost of cultivation (₹ 35357 ha⁻¹) was recorded with application of 100% RDF + Seaweed extract @ 5 ml L⁻¹ foliar application at 30 and 45 DAS (T₉) followed by 100% RDF + Vermiwash @ 5% foliar application (₹ 35482 ha⁻¹) at 30 and 45 DAS (T₆) and

100% RDF + PSB + VAM + *Azotobacter* soil application (₹ 35732 ha⁻¹) (T₃). Higher cost of cultivation was recorded in these treatments mainly due to combined application of bio-stimulants which added more on it. However, lower cost of cultivation (₹ 29450 ha⁻¹) was recorded with absolute control (T₁) because of absence of cost on fertilizers.

Table 5: Economics of grain amaranth as influenced by application of bio-stimulants

Tr. No.	Treatments	Cost of cultivation (₹ ha ⁻¹)	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	B:C ratio
T ₁	Absolute control	29450	83920	54470	3.12
T ₂	100% RDF	33532	122960	89428	3.86
T ₃	100% RDF + PSB + VAM + <i>Azotobacter</i> – SA	35732	134960	99228	3.94
T ₄	75% RDF + PSB + VAM + <i>Azotobacter</i> - SA	34698	125600	90902	3.61
T ₅	50% RDF + PSB + VAM + <i>Azotobacter</i> - SA	34296	108640	74344	3.38
T ₆	100% RDF + Vermiwash @ 5% - FA	35482	136160	100678	3.94
T ₇	75% RDF + Vermiwash @ 5% - FA	34448	120080	85632	3.69
T ₈	50% RDF + Vermiwash @ 5% - FA	34046	111680	77634	3.43
T ₉	100% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	35357	140640	105283	3.99
T ₁₀	75% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	34323	122720	88397	3.67
T ₁₁	50% RDF + Seaweed extract @ 5 ml L ⁻¹ - FA	33921	117120	83199	3.71

Note: Recommended FYM @ 7.5 t ha⁻¹ is common for all treatments SA- Soil application of PSB + VAM + *Azotobacter* of each @ 5 kg ha⁻¹

FA- Foliar application of vermiwash and seaweed extract applied at 30 and 45 DAS

Conclusion

From the results of the present investigation, it can be concluded that foliar application of Seaweed extract @ 5 ml L⁻¹ at 30 and 45 DAS along with RDF found beneficial in improving the grain yield (1758 kg ha⁻¹), net returns (₹ 105283 ha⁻¹) and BC ratio (3.99), protein (13.90%) and oil content (8.40%) and essential amino acids in grain amaranth and was found on par with 100% RDF + Vermiwash @ 5% foliar application at 30 and 45 DAS and also with 100% RDF + PSB + VAM + *Azotobacter* soil application. Hence, bio-stimulants plays major role in improving yield and quality of grain amaranth.

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