Biological Forum – An International Journal **15(9): 315-321(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Effect of Organic Sources of Nutrients on Soil characteristics, Nutritional Quality and Economics of Grain Amaranth (*Amaranthus hypochondriacus* L.)

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(Received: 24 June 2023; Revised: 21 July 2023; Accepted: 26 August 2023; Published: 15 September 2023)
(Published by Research Trend)

ABSTRACT: A field study was conducted during *Kharif* 2021 at Research Institute of Organic Farming (RIOF) field unit, University of Agricultural Sciences, Bangalore to investigate the influence of various organic nutrient sources on soil characteristics, nutritional quality of grain and the economic aspects of grain amaranth (*Amaranthus hypochondriacus* L.) cultivation. The field experiment was laid out in Randomized Complete Block Design (RCBD) consisting of twelve treatments, each replicated three times. Among the various organic nutrient sources tested, the combination of 50% N equivalent Farmyard Manure (FYM) and 50% N equivalent Pongamia cake (PC) resulted in the highest organic carbon content (0.66%) and the uptake of essential nutrients (58.7 kg ha^{-1} of nitrogen, 17.4 kg ha^{-1} of phosphorus, and 57.2 kg ha^{-1} of potassium), protein (12.98 g), calcium (414.98 mg), and iron (13.08 mg) per 100 grams of grain amaranth seeds. However, application of 100% N equivalent Pongamia cake (PC) significantly increased the crude fiber content (5.23 g) and oil content (7.14%) in the grain amaranth, whereas the lowest values were observed in the absolute control. Furthermore, Treatment 4, which involved the application of a microbial consortium to the soil at a rate of 1.5 kg ha^{-1}, demonstrated significantly higher populations of beneficial microorganisms, including bacteria, fungi, actinomycetes, nitrogen-fixing bacteria, and phosphate-solubilizing bacteria (45.52× 10^5 CFC/g of soil, 15.83× 10^4 CFC/g of soil, 19.13× 10^3 CFC/g of soil, 27.17 × 10^6 CFC/g of soil and 13.46× 10^6 CFC/g of soil, respectively) compared to the other organic nutrient sources. In terms of economic considerations, the application of 50% N equivalent Pongamia cake (PC) combined with 50% N equivalent Bio digestor liquid manure (BDLM) resulted in the highest net return and benefit-to-cost ratio (89511 Rs. ha^{-1}and 2.43 respectively).

Keywords: Amaranth, Organic nutrient sources, Pongamia cake (PC), Bio digestor liquid manure (BDLM), Microbial consortium, Nutritional quality, Grain yield and B:C ratio.

INTRODUCTION

The Green revolution helped in increasing food production by leaps and bounds, pulling millions out of the cycle of hunger and malnutrition. But this had a detrimental effect that we have been observing in recent days, the major among them being loss of soil fertility and loss of crop diversity. Hazardous application of chemical fertilizers to the soil led to problems like acidification, salinization, loss of soil microflora and in extreme cases desertification of once fertile soil. This brings back into focus the organic sources of nutrients that our ancestors used as fertilizers not so long ago. The popularisation of organic farming and increasing awareness about its health benefits vis versa the fertilizers and pesticides laden agricultural products have made it necessary to explore the use of various organic sources of nutrients for growing crops. Organic cultivation has many benefits such as higher prices for organic products, the use of organic fertilizers and pest control methods helps to reduce harmful chemical residues on crops. It also aids in improving the soil microflora which in turn helps to improve the mobilization and translocation of nutrients that would have been otherwise unavailable. The use of organic sources of nutrients also improves soil physical and chemical properties like organic carbon content, EC and nutrient content. Leaching and wash-off losses are very minimal when compared to inorganic fertilizers as they decompose slowly, are stable, are available throughout the crop growth period and leave a residual effect benefiting the succeeding crop. It has huge potential for expansion in cultivation as it is richer in protein, calcium and iron when compared to other cereals and even millets like ragi. Due to the fact that grain amaranth has a high protein as well as a high good fat content, there is a potential to use it as an energy food. Digestion and absorption of nutrients were found to be high in human feeding studies when milled and toasted amaranth products were used (Morales *et al*., 1988). The balance of healthy carbohydrates, fats, proteins and minerals makes amaranth the ideal potential crop to achieve a balanced diet with lower nutrient needs than other cereals. Additionally, it can be used by people suffering from celiac disease who cannot consume cereals with gluten, coming as a lifesaver and even providing a more nutritious alternative to commonly consumed cereals. Hence, there is a need to emphasize the adoption of scientific cultivation practices including the use of FYM, oil cakes, bio-fertilizers, etc., to cultivate grain amaranth. This could help us utilize organic sources of nutrients as an alternative to chemical fertilizers.

MATERIALS AND METHODS

The present investigation was carried out at Research Institute of Organic Farming field unit, with the organic nutrient treatments being administered at M block, GKVK, University of Agricultural Sciences, Bangalore, during late *Kharif* 2021. RCBD design was adopted in the experiment with three replications. The experiment comprised of 12 treatments *viz*., 100% N equivalent FYM (T_1); 100% N equivalent Pongamia cake (T_2); 100% N equivalent BDLM (T_3); Microbial consortium soil application (T_4); 50% N equivalent FYM+ 50% N equivalent Pongamia cake (T_5); 50% N equivalent FYM + 50% N equivalent BDLM (T_6); 50% N equivalent FYM + Microbial consortium soil application (T_7); 50%N equivalent Pongamia cake + 50% N equivalent BDLM (T_8); 50% N equivalent Pongamia cake + microbial consortium soil application (T_9); 50% N equivalent BDLM + microbial consortium soil application (T_{10}); Absolute control (T_{11}); Control (RDF) (T_{12}). Well decomposed Farm Yard Manure (FYM) was applied 15 days before sowing, pongamia cake and microbial consortia were applied on the day of sowing and the Bio Digestor Liquid Manure (BDLM) was applied to the treatments at 30 and 60 DAS. One treatment was kept as check with application of Recommended Dose of Fertilizer (RDF) as per the package developed by UAS, Bangalore and another treatment as absolute control, which was devoid of any external source of nutrient application. Microbial consortium consisting of *Azopirillum* sps (Nitrogen fixer), Phosphorous solubilizing bacteria (PSB) and Vesicular Arbuscular Mycorrhiza (VAM) was applied at the rate of 1.5 kg ha^{-1} as per the treatment. Grain amaranth variety KBGA-15 was sown at the spacing of 45 cm ×15 cm. FYM was applied at the rate of 7.5 t ha^{-1} to each treatment except absolute control. Other cultural operations were followed as per the recommendation of the crop. All the observations were recorded and data was analysed statistically and presented at five per cent level of significance for making comparison between treatments.

Crude protein was determined by Kjeldahl's digestion distillation method. Plant samples (0.5 g) were digested in digestion flasks using sulphuric acid and the digestion mixture (K_2SO_4 + $CuSO_4$ + Se in the ratio of 100:20:1). After complete digestion, the digested materials were distilled in alkaline medium and the liberated ammonia was trapped in four per cent boric acid solution containing mixed indicator. The trapped ammonia was titrated against standard sulphuric acid. The crude protein content was computed by multiplying the per cent nitrogen content with factor 6.25 (Jackson, 1967).

Crude fibre of the sample was estimated by using moisture and fat free samples and expressed as g per 100g of sample. The sample was boiled with H_2SO_4 followed by NaOH. The residue was dried in a desiccator and weighed.

$$\text{Per cent of crude fibre (g 100g}^{-1}\text{)} = \frac{\text{Loss in weight on ignition}}{\text{Weight of sample used (g)}} \times 100$$

$$= \frac{(W_2 - W_1)}{\text{Weight of the sample used (g)}} \times 100$$

W_1= Weight of the ashing dish;

W_2= Weight of the sample in desiccator

Calcium in the plant sample digest is estimated by titrating against standard Versenate solution using Patton Reeders indicator for calcium (Piper, 1966). After making suitable dilution of di-acid extract, the samples were fed to the atomic absorption spectrophotometer using appropriate hallow cathode lamp.

Fat was estimated as crude ether extract using moisture free sample. The solvent was removed by evaporation and the residue of fat was weighed

$$\text{Fat content (g 100g}^{-1}\text{)} = \frac{\text{Weight of ether extract}}{\text{Weight of sample taken}}$$

RESULTS AND DISCUSSION

A. Effect of treatments on soil characteristics of grain amaranth

Total nitrogen, phosphorus and potassium uptake by grain amaranth (kg ha^{-1}) as influenced by organic nutrient management practices are presented in Table 1. Total nitrogen uptake by grain amaranth was found to differ significantly due to different organic nutrient management practices. Overall higher total nitrogen, phosphorus and potassium uptake (62.8, 18.6 and 59.1 kg ha^{-1} NPK, respectively) was found with control (RDF) (T_{12}) among the organic sources of nutrients application of 50% N equivalent FYM + 50% N equivalent PC had higher total nitrogen, phosphorous and Potassium uptake (58.7, 17.4 and 57.2 kg ha^{-1} NPK, respectively) as compared to other treatments but was found on par with application of 100% N equivalent PC (56.7, 17.0 and 54.6 kg ha^{-1} NPK, respectively) and 50% N equivalent PC + 50% N equivalent BDLM (57.7, 16.7 and 55.9 kg ha^{-1} NPK, respectively). Significantly lower total Nitrogen, phosphorus and potassium uptake (39.5, 10.8 and 44.8 kg ha^{-1}NPK, respectively) was observed with absolute control.

Significantly higher total uptake of nutrients (nitrogen, phosphorous and potassium) was application of 50% N equivalent FYM + 50% N equivalent PC. This might be due to the nutrient applied overall improvement in crop growth, vigour, production and translocation of sufficient photosynthate resulting in well-developed roots and favourable root microflora increasing nutrient availability. Long-term nutrient releasing capability of the organic sources was confirmed by earlier studies (Adekayode and Ogunkoya 2011). Higher total uptake of nutrients with application of 50% N equivalent FYM + 50% N equivalent PC could also be due to increased dry matter accumulation in leaf, stem and grain (Chaudhari *et al*., 2009). Similarly, Pratap *et al*. (2010) reported that the higher total dry matter accumulation might be attributed to the higher residual nutrient build-up and slow sustained release of nutrients in the organic sources of nutrients treated plot which reflected in the higher yield.

The data recorded on soil chemical properties like pH, EC (electrical conductivity), OC (Organic Carbon) and available NPK after harvesting the crop is presented in Table 2.

It was observed that electrochemical properties like pH, EC and OC of the soil after harvest of the crop did not differ significantly among treatments. The treatments imposed with 100% N equivalent FYM recorded numerically higher pH (6.81) and OC (0.67%). Whereas, Control (RDF) recorded lower pH (6.30) and OC (0.59%) Numerically higher EC was observed with application 100% N equivalent FYM (0.29dSm^{-1}).

Similarly, Application of 100 % N equivalent through FYM recorded highest available nitrogen, phosphorous and potassium (324.49, 35.60 and 246.67 kg ha^{-1} NPK, respectively) in soil after harvest of the crop. However, lowest available nitrogen, phosphorous and potassium were present in absolute control (273.48, 27.95 and 212.17 kg ha^{-1} NPK, respectively). This might be due to the fact that application of FYM leads to slow mineralization of nutrients and also has better residual effect. Application of FYM to the field increased the available nitrogen, phosphorous and potassium of the soil after the crop harvest as compared to initial level of soil available N, P and K as reported by Raju *et al*. (1991).

Significantly higher microbial population of bacteria, fungi and actinomycetes in soil was observed after harvesting of grain amaranth crop influenced by different organic nutrient management practices as shown in Table 4.

It was observed that Microbial consortium soil application at 1.5kg ha^{-1} recorded higher bacteria, fungi, actinomycetes, N-fixers and PSB (45.52 × 10^5 CFC/g of soil, 15.83 × 10^4 CFC/g of soil, 19.13 × 10^3 CFC/g of soil, 27.17 × 10^6 CFC/g of soil and 13.46 × 10^6 CFC/g of soil, respectively). Absolute control (T_{11}) recorded significantly lowest microbial population of bacteria (26.07 × 10^5 CFC/g of soil), fungi (8.33 × 10^4 CFC/g of soil), actinomycetes (11.13 × 10^3 CFC/g of soil), N-fixers (11.88 × 10^6 CFC/g of soil) and, PSB (7.59 × 10^6 CFC/g of soil) in soil at harvest. Significant higher microbial population (bacteria, fungi, actinomycetes, N-fixers and PSB was observed with microbial consortium soil application. This helped in increasing the microbial population as it acted as a reservoir for beneficial microbes which utilized the organic matter for their growth and multiplication. Application of organic manures like neem cake, bio-compost and vermicompost harboured more microbes in soil than the NPK application. The above results were also found to be similar with the findings of Prakash *et al*. (2008); Glick (2012); Sakhubai *et al*. (2014).

B. Effect of treatments on nutritional quality of grain amaranth

Crude protein, crude fibre, oil content, Ca and Fe content in Grain Amaranth seeds as influenced by different sources of organic nutrients are presented in Table 4.

On analysis it was observed that crude protein, crude fibre, oil content was significantly impacted by different sources of organic nutrients whereas Ca, and Fe content in Grain Amaranth seeds were non-significant. Nevertheless, numerically higher values of Calcium (414.98 mg), Iron (13.08 mg) and protein content (12.98 g) per 100 gm of grain amaranth seeds were observed with application of 50% N equivalent FYM+ 50% N equivalent PC. Further lowest protein content was observed in absolute control (11.53 g). However, significantly higher crude fibre content (5.23 g) and oil content (7.14 %) was seen with application of 100% N equivalent PC, significantly lower crude fibre (4.54 g) and oil content (5.75 %) was observed in absolute control.

Higher protein content in seed might be due to root enlargement, improved microbial activities resulting in higher availability and uptake of nitrogen (Naveen and Mevada 2012). Neeraja and Patel (2015) opined that the higher protein content in grains was due to the higher vegetative growth and yield attributing characters, which could have helped to increase the nitrogen uptake. Higher fibre content was due to the higher due higher fibre content in PC when compared to other treatments which was reflected in the treatment. On the same lines higher oil and sulphur content in PC helped in increasing the oil content significantly when compared to other treatments (Mahata and Sinha 2018).

C. Effect of treatments on grain yield and economics of grain amaranth

It was observed that application of different organic sources of nutrients had a significant impact on the grain yield per hectare. Whereas, test weight did not vary significantly among the different organic sources of nutrients. Numerically, application of 50% N equivalent FYM + 50% N equivalent PC recorded higher 10 ml seeds weight (7.90 g). Whereas, absolute control recorded lower 10 ml seed weight (7.49 g).

Among the different organic treatments application of 50% N equivalent FYM + 50% N equivalent PC recorded significantly higher grain yield (2105 kg ha^{-1}), Net returns (Rs. 89,511) and B:C ratio (2.43). However, lower grain yield (2105 kg ha^{-1}), net return (Rs. 60,371 ha^{-1}) was obtained with absolute control. Whereas, overall, the lowest B:C ratio (1.28) was obtained with application 100% N equivalent through FYM.

The reason for increasing higher yield might be due to better availability of major nutrients which are required in larger quantity. It also due to beneficial response of the crop due to microbial consortia. Microbes colonize the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plants. Vesicular Arbuscular Mycorrhiza is known to enhance the uptake and transport mineral nutrients from the soil directly into host plant roots. Combined effect of FYM, pongamia cake, BDLM and microbial consortia had significant positive influence in various treatments (Ainika *et al.*, 2011).

Table 1: Total nitrogen, phosphorus and potassium uptake by grain amaranth as influenced by different organic nutrient management practices.

Treatments	Total uptake (kg ha^{-1})		
	N	P	K
T$_1$: 100% N equivalent FYM	47.5	14.3	48.8
T$_2$: 100% N equivalent PC	56.7	17.0	54.6
T$_3$: 100% N equivalent BDLM	50.7	15.1	48.7
T$_4$: Microbial consortium soil application	45.2	12.4	47.3
T$_5$: 50% N equivalent FYM+ 50% N equivalent PC	58.7	17.4	57.2
T$_6$: 50% N equivalent FYM + 50% N equivalent BDLM	50.9	15.3	50.2
T$_7$: 50% N equivalent FYM + Microbial consortium soil application	51.5	15.4	50.9
T$_8$: 50%N equivalent PC + 50% N equivalent BDLM	57.7	16.7	55.9
T$_9$: 50% N equivalent PC + microbial consortium soil application	54.6	15.7	52.6
T$_{10}$: 50% N equivalent BDLM + microbial consortium soil application	50.2	14.7	48.7
T$_{11}$: Absolute control	39.5	10.8	44.8
T$_{12}$: Control (RDF @ 60:40:40 kg ha N:P: K + 10 t ha^{-1} FYM)	62.8	18.6	59.1
F-test	*	*	*
S.Em ±	0.73	0.47	1.15
CD @ 5%	2.14	1.39	3.39

DAS- Days after sowing, RDF- Recommended dose of fertilizers, FYM-Farm yard manure, BDLM-Bio digestor liquid manure, PC-Pongamia cake

Table 2: Chemical properties and availability of major nutrients in soil after harvest of the grain amaranth as influenced by different organic nutrient management practices.

Treatments	pH	EC (dSm^{-1})	OC (%)	Available Nutrients (kg ha^{-1}) after harvest		
				N	P_2O_5	K_2O
T$_1$: 100% N equivalent FYM				324.49	35.60	246.67
T$_2$: 100% N equivalent PC	6.55	0.28	0.64	307.80	32.93	236.23
T$_3$: 100% N equivalent BDLM	6.38	0.24	0.64	314.50	34.67	244.47
T$_4$: Microbial consortium soil application	6.69	0.23	0.63	292.67	35.00	243.97
T$_5$: 50% N equivalent FYM+ 50% N equivalent PC	6.42	0.26	0.66	301.33	31.67	225.23
T$_6$: 50% N equivalent FYM + 50% N equivalent BDLM	6.54	0.24	0.65	314.67	34.10	239.90
T$_7$: 50% N equivalent FYM + Microbial consortium soil application	6.78	0.26	0.64	314.63	33.98	241.50
T$_8$: 50%N equivalent PC + 50% N equivalent BDLM	6.47	0.25	0.65	302.33	32.50	226.07
T$_9$: 50% N equivalent PC + microbial consortium soil application	6.49	0.24	0.64	308.63	33.17	238.33
T$_{10}$: 50% N equivalent BDLM + microbial consortium soil application	6.63	0.25	0.65	317.13	34.17	245.17
T$_{11}$: Absolute control	6.25	0.22	0.62	273.48	27.95	212.17
T$_{12}$: Control (RDF @ 60:40:40 kg ha N:P:K + 10 t ha^{-1} FYM)	6.30	0.26	0.59	299.33	31.20	222.67
F-test	NS	NS	NS	*	*	*
S.Em ±	0.08	0.01	0.03	1.74	0.83	1.93
CD @ 5%	-	-	-	5.12	2.44	5.65

DAS- Days after sowing, RDF- Recommended dose of fertilizers, FYM-Farm yard manure, BDLM-Bio digestor liquid manure, PC-Pongamia cake

Table 3: Soil microbial population at harvest of grain amaranth as influenced by different organic nutrient management practices.

Treatments	Soil microbial population				
	Bacteria (No. × 10^5 CFU/g of soil)	Fungi (No. × 10^4 CFU/g of soil)	Actinomycetes (No. × 10^3 CFU /g of soil)	N-fixers (No. × 10^6 CFU /g of soil)	PSB (No. × 10^6 CFU /g of soil)
T_1: 100% N equivalent FYM	36.30	14.00	15.33	22.66	11.57
T_2: 100% N equivalent PC	35.63	13.20	14.97	20.26	11.07
T_3: 100% N equivalent BDLM	36.87	14.23	17.03	22.71	11.13
T_4: Microbial consortium soil application	45.52	15.83	19.13	27.17	13.46
T_5: 50% N equivalent FYM+ 50% N equivalent PC	35.83	13.73	16.10	21.33	11.08
T_6: 50% N equivalent FYM + 50% N equivalent BDLM	36.97	12.80	15.33	22.07	11.03
T_7: 50% N equivalent FYM + Microbial consortium soil application	40.57	13.83	18.33	24.46	12.92
T_8: 50%N equivalent PC + 50% N equivalent BDLM	38.17	12.94	15.22	20.67	10.77
T_9: 50% N equivalent PC + microbial consortium soil application	39.67	14.85	16.11	23.57	12.07
T_{10}: 50% N equivalent BDLM + microbial consortium soil application	40.33	14.90	17.02	23.62	12.35
T_{11}: Absolute control	26.07	8.33	11.13	11.88	7.59
T_{12}: Control (RDF)	32.33	12.67	13.67	14.59	8.86
F-test	*	*	*	*	*
S.Em ±	1.38	1.11	1.33	1.13	0.66
CD @ 5%	4.05	3.15	3.89	3.32	1.94

NS- Non-significant, DAS- Days after sowing, RDF- Recommended dose of fertilizers, FYM-Farm yard manure, BDLM-Bio digestor liquid manure, PC-Pongamia cake

Table 4: Nutritional value of Grain Amaranth seed (per 100 gm) as influenced by different organic nutrient management practices.

Treatments	**Crude protein (g)**	**Crude fibre (g)**	**Oil (%)**	**Calcium (mg)**	**Fe (mg)**
T_1: 100% N equivalent FYM	12.80	5.17	6.92	406.37	13.00
T_2: 100% N equivalent PC	12.82	5.30	7.14	410.02	13.01
T_3: 100% N equivalent BDLM	12.35	4.83	6.72	404.03	12.93
T_4: Microbial consortium soil application	11.77	4.65	5.92	403.15	12.79
T_5: 50% N equivalent FYM+ 50% N equivalent PC	12.98	5.23	7.01	414.98	13.08
T_6: 50% N equivalent FYM + 50% N equivalent BDLM	12.65	4.84	6.77	405.95	12.97
T_7: 50% N equivalent FYM + Microbial consortium soil application	12.61	4.86	6.82	406.25	12.96
T_8: 50%N equivalent PC + 50% N equivalent BDLM	12.84	5.10	6.97	410.92	13.01
T_9: 50% N equivalent PC + microbial consortium soil application	12.68	4.90	6.89	408.93	13.00
T_{10}: 50% N equivalent BDLM + microbial consortium soil application	11.90	4.70	6.68	404.76	12.82
T_{11}: Absolute control	11.53	4.54	5.75	402.13	12.57
T_{12}: Control (RDF)	12.77	4.97	6.90	409.88	12.98
F-test	*	*	*	NS	NS
S.Em ±	0.10	0.11	0.06	1.89	0.03
CD @ 5%	0.28	0.32	0.18	-	-

NS- Non-significant, DAS- Days after sowing, RDF- Recommended dose of fertilizers, FYM-Farm yard manure, BDLM-Bio digestor liquid manure, PC-Pongamia cake

Table 5: Grain yield, 10 mL seed volume weight, Net returns and B:C ratio of grain amaranth as influenced by different organic nutrient management practices.

Treatments	Grain yield (kg ha^{-1})	10 mL seed volume weight (g)	Net returns (Rs. ha^{-1})	B:C ratio
T_1: 100% N equivalent FYM	1834	7.63	61715	1.28
T_2: 100% N equivalent PC	2005	7.78	82175	2.16
T_3: 100% N equivalent BDLM	1842	7.65	74645	2.08
T_4: Microbial consortium soil application	1745	7.63	71442	2.15
T_5: 50% N equivalent FYM+ 50% N equivalent PC	2127	7.90	85052	2.00
T_6: 50% N equivalent FYM + 50% N equivalent BDLM	1907	7.71	73162	1.78
T_7: 50% N equivalent FYM + Microbial consortium soil application	1880	7.69	73155	1.82
T_8: 50% N equivalent PC + 50% N equivalent BDLM	2105	7.81	89511	2.43
T_9: 50% N equivalent PC + microbial consortium soil application	1972	7.78	83435	2.40
T_{10}: 50% N equivalent BDLM + microbial consortium soil application	1837	7.64	77631	2.38
T_{11}: Absolute control	1428	7.49	60371	2.37
T_{12}: Control (RDF)	2260	7.98	103013	2.92
F-test	*	NS	-	-
S.Em ±	88	0.09	-	-
CD @ 5%	259	-	-	-

NS- Non-significant, DAS- Days after sowing, RDF- Recommended dose of fertilizers, FYM-Farm yard manure, BDLM-Bio digestor liquid manure, PC-Pongamia cake

All the yield attributing characters were adversely affected in absolute control due to severe lack of nutrients when compared to other treatments. However, Maximum net return can be attributed to higher grain yield and lower cost of cultivation. the higher B:C ratio (2.43) was observed with application of 50% N equivalent PC + 50% N equivalent BDLM, this was due to higher net returns compared to cost of cultivation. The above results were also found to be in conformity with the findings of Pratap *et al*. (2010); Mahata and Sinha (2018).

CONCLUSIONS

The study demonstrated that the choice of organic nutrient sources can affect soil characteristics, nutritional quality, and economic returns in grain amaranth cultivation. The microbial consortium treatment improved soil microbial activity, potentially enhancing soil health. Furthermore, specific nutrient combinations, such as the use of pongamia cake and Bio Digester Liquid Manure, showed promising economic benefits. Among the various organic nutrient sources tested, the combination of 50% N equivalent Farmyard Manure (FYM) and 50% N equivalent Pongamia cake (PC) resulted in the highest organic carbon content (0.66%) and the uptake of essential nutrients (58.7 kg ha^{-1} of nitrogen, 17.4 kg ha^{-1} of phosphorus, and 57.2 kg ha^{-1} of potassium), protein (12.98 g), calcium (414.98 mg), and iron (13.08 mg) per 100 grams of grain amaranth seeds. However, application of 100% N equivalent Pongamia cake (PC) significantly increased the crude fiber content (5.23 g) and oil content (7.14%) in the grain amaranth, whereas the lowest values were observed in the absolute control. Furthermore, Treatment 4, which involved the application of a microbial consortium to the soil at a rate of 1.5 kg ha^{-1}, demonstrated significantly higher populations of beneficial microorganisms, including bacteria, fungi, actinomycetes, nitrogen-fixing bacteria, and phosphate-solubilizing bacteria (45.52× 10^5 CFC/g of soil, 15.83× 10^4 CFC/g of soil, 19.13× 10^3 CFC/g of soil, 27.17 × 10^6 CFC/g of soil and 13.46× 10^6 CFC/g of soil, respectively) compared to the other organic nutrient sources. In terms of economic considerations, the application of 50% N equivalent Pongamia cake (PC) combined with 50% N equivalent Bio digestor liquid manure (BDLM) resulted in the highest net return and benefit-to-cost ratio (89511 Rs. ha^{-1} and 2.43 respectively).

FUTURE SCOPE

The scope of this study is multidimensional, encompassing soil science, agronomy, nutrition, and economics, with practical implications for sustainable and profitable grain amaranth cultivation. It contributes to the knowledge base in these fields and provides valuable insights for both researchers and practitioners in agriculture.

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How to cite this article: Gangadhar Eswar Rao, V. Venkatachalapathi, M.M. Venkatesha, R.N. Lakshmipathi and Kushal (2023). Effect of Organic Sources of Nutrients on Soil characteristics, Nutritional Quality and Economics of Grain Amaranth (*Amaranthus hypochondriacus* L.). *Biological Forum – An International Journal*, *15*(9): 315-321.