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Effect of different organic sources of nutrients on growth, yield and economics of grain amaranth (*Amaranthus hypochondriacus* L.)

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Abstract
A field study was conducted during *Kharif* 2021 at Research Institute of Organic Farming (RIOF) field unit, University of Agricultural Sciences, Bangalore to examine the response of grain amaranth (*Amaranthus hypochondriacus* L.) to different organic sources of nutrients. Among all the organic sources of nutrients Growth attributes like Plant height (165.7, 159.8,147.6and 115.0 cm), No. of leaves per plant (26.3, 25.5,24.1and 19.2), Leaf area per plant (2436, 2211, 2079and 1078 cm^2) and total dry matter accumulation per plant (71.1, 66.9,58.5 and 40.8 g $plant^{-1}$) and yield attributes like Panicle length (54.33, 52.33,48.50 and 38.33 cm), No. of fingers per panicle (37.67, 37.0, 35.67 and 25.33) and length of finger (22.13, 21.0, 20.37 and 15.30 cm), Grain yield (2127,2105,1972 and 1428 kg ha^{-1}), Stover yield (3596,3525,3417 and 2810 kg ha^{-1}) were recorded significantly higher with the application of 50% N equivalent FYM+ 50% N equivalent PC and which was found to be on par with application of 50%N equivalent PC + 50% N equivalent BDLM and 50% N equivalent PC + microbial consortium soil application. However Lower growth and yield attributes were recorded in Absolute control. Whereas, Higher Net returns and B:C ratio (89511 Rs. $ha^{-1}$and 2.43) were observed with the application of 50%N equivalent PC + 50% N equivalent BDLM.

Keywords: Nutrients, growth, yield, economics, grain amaranth, *Amaranthus hypochondriacus* L.)

Introduction
Grain amaranth (*Amaranthus* sp.) from the family Amaranthaceae is categorized as a pseudo cereal. They are plants, which form starchy seeds like cereals but are botanically assigned as dicotyledons. This crop has a long history and is native to the New World i.e., South America. Ancient civilization in those parts grew this pseudo-cereal extensively and had been a staple food. Its intensely coloured leaves, stems, and panicles have a mesmerizing effect and are a sight that evokes emotions that other crops cannot. The word "amaranth" means "everlasting or immortal" in Greek. Just as its name suggests the crop has endured the ravages of time and its distinctly beautiful appearance has helped to prevent the crop from slipping into obscurity. It is also grown for its aesthetic beauty in gardens. As the awareness about its nutritional qualities, especially its higher protein and lysine content gained traction it started to gain importance. It has re-emerged as one of the health care crops in many countries including India, especially among the urban health-conscious population. Grain amaranth requires fewer nutrients for its growth and development and has fewer pest and disease problems, which makes it fit well into the organic farming system. In recent years consumers are preferring organic products for their health benefits. For obtaining higher yields and increasing the productivity of the crop proper nutrient management is very much important. Nitrogen forms a basic input along with other nutrients for growth and development of crop. The increasing cost of fertilizers leads to a rise in the cost of production and thereby a reduction in profit. Leaves of amaranth can be used as a vegetable, the dried stover can be fed to cattle hence the entire crop has a myriad of uses. Hence as organic cultivation practices of grain amaranth have not been standardized, this study would help in achieving that. 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 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 inorganic nutrient treatment 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 PC (T_2); 100% N equivalent BDLM (T_3); Microbial consortium soil application (T_4); 50% N equivalent FYM+ 50% N equivalent PC (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 PC + 50% N equivalent BDLM (T_8); 50% N equivalent PC + 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 FYM was applied 15 days before sowing, pongamia cake and microbial consortia were applied on the day of sowing and the BDLM was applied to the treatments at 30 DAS and 60 DAS. One treatment was kept as check with application of recommended dose of fertilizer as per the package developed by UAS, Bangalore and another as absolute control, which was devoid of any external source of nutrient application. Grain amaranth variety KBGA-15 was sown at the spacing of 45 cm ×15 cm. Microbial consortium consisting of *Azopirillum*sps (Nitrogen fixer), Phosphorous solubilizing bacteria (PSB) and Vesicular arbuscular mycorrhiza (VAM) was used. 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. Observations on growth as well as yield attributes were recorded and all experimental data was analysed statistically and presented at five per cent level of significance for making comparison between treatments.

Results and Discussion

Growth attributes

Among the organic sources of nutrients, growth parameters *i.e*., plant height (165.70 cm), number of leaves (26.33), leaf area (2435.67 cm^2 $plant^{-1}$) and Dry matter accumulation (71.1 g $plant^{-1}$) at harvest were significantly higher (Table 1) with application of 50% N equivalent FYM+ 50% N equivalent PC. But it was found on par with application of50%N equivalent PC + 50% N equivalent BDLM (T_8), 100% N equivalent PC (T_2), 50% N equivalent PC + microbial consortium soil application (T_9).

The reason for significantly higher growth attributes were recorded with application of 50% N equivalent FYM+ 50% N equivalent PC could be attributed to application of PC (Pongamia cake) which supplies all other nutrients and organic carbon, which play vital role in nutrient cycling and water retention in the soil. The higher plant height could also be due to synchronous and steady release of plant nutrients throughout the growth period (Mahata and Sinha., 2018) [5]. All these factors help in improving the availability of nutrients leading to higher height (Osman *et al*., 2009) [8]. Higher number of leaves in T_5might be due to the fact that nitrogen and other major nutrients by the crop was met by slow release of nutrients by FYM along with pongamia cake. Better growth and development observed under high nitrogen rate suggest that increasing plant nitrogen to an optimum rate enables the plants to produce their potential number of leaves (Olaniyi *et al*., 2008) [7]. Further, the above results were in line with study by Naveen and Mevada (2012) [6] who stated that prolonged availability of nutrients might increase plant height, number of leaves. Higher leaf area and total dry matter obtained in the same treatment was a result of steady supply of nutrients from organic sources which have accelerated the synthesis of chlorophyll and amino acids associated with major photosynthetic processes of plant. The research findings are in accordance with the study conducted by Dongre (2011) [2], Salman Khan (2018) [13] and Parmar and Patel (2009) [9].

Yield and Yield attributes

Among the different organic sources of nutrients, application of T_5: 50% N equivalent FYM + 50% N equivalent PC resulted in significantly higher yield attributes such as panicle length (54.33), Number of fingers per panicle (37.67) and Length of finger (22.13 cm)but it was significantly on par with the treatment T_8: 50% N equivalent PC + 50% N equivalent BDLM, T_2: 100% N equivalent PC (T_2), T_9: 50% N equivalent PC + microbial consortium soil application (Table 2 and fig.1).

It was observed that application of different organic sources of nutrients had a significant impact on the grain yield per hectare (Table 3 and fig. 2). Among the different organic treatments application of 50% N equivalent FYM + 50% N equivalent PC recorded significantly higher Grain yield, Stover yield and Harvest Index (2127, 3596 kg ha^{-1} and 0.37) which was found to be on par with the control RDF@ 60: 40: 40 kg ha^{-1} N: P: K + 10 t ha^{-1} FYM (2260, 3915 kg ha^{-1} and 0.37 respectively). Among the different organic treatments' application of 50% N equivalent PC + 50% N equivalent BDLM (2105, 3525 kg ha^{-1} and 0.37), 100% N equivalent PC (2005, 3497 kg ha^{-1} and 0.36), 50% N equivalent PC + microbial consortium soil application (1972, 3417 kg ha^{-1} and 0.37), 50% N equivalent FYM +50% N equivalent BDLM (1907, 3392 kg ha^{-1} and 0.36), and 50% N equivalent FYM + Microbial consortium soil application (1880, 3230 kg ha^{-1} and 0.37) were found to be on par with the treatment with the highest yield. The lowest Grain yield, Stover yield and Harvest Index were observed in absolute control (1428, 2810 kg ha^{-1} and 0.34).

The reason for increasing higher yield and yield attributes in treatments involving PC might be due to better availability of major nutrients which are required in larger quantity thus directly help the plant to register higher growth factors like plant height, number of leaves, leaf area and total dry weight. Slow release of N increases its availability over a prolonged period as observed by Saha *et al*., 2011 [12] in case of rice. Increased yield components like higher panicle length, Grain yield and stover yield were reported by Elbehri *et al.*, (1993) [3] in grain amaranth. They opined that higher grain and stover yield might be due to cumulative effect of vegetative growth as evident from higher plant height, leaf area index and dry matter production. Echoing similar results were reported by Chaudhari *et al.* (2009) [1] and Ganesh (2011) [4]. The above results could be 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. All the yield attributing characters were adversely affected in absolute control due to severe lack of nutrients when compared to other treatments. From the results of the experiment, it could be concluded that organic sources of nutrients, especially involving oil cakes in various levels can be used to obtain good results in grain amaranth.

Economics

Among the organic nutrient management practices, the cost of cultivation was highest with application of 100% N equivalent through FYM (Rs. 48,325 ha^{-1}) and overall, the lowest cost of cultivation was recorded with absolute control (Rs. 25,489 ha^{-1}). Overall, the gross returns were found be highest in Control (RDF) (Rs.1,35,600 ha^{-1}), among the organic nutrient management practices, the Gross returns was highest with application of 50% N equivalent FYM+ 50% N equivalent PC (Rs. 1,27,620 ha^{-1}) and lowest was recorded with absolute control (Rs. 85,860 ha^{1}).Overall, the highest net returns of Rs. 1,03,013 per ha was obtained with Control (RDF), among the organic nutrient management practices, the net returns were highest Rs.89,511 with application of 50% N equivalent PC + 50% N equivalent BDLM. and lowest net return of Rs. 60,371 per ha was obtained with absolute control (Table 4 and fig. 3). Higher B: C ratio of 2.92 was recorded with Control (RDF). While among the organic nutrient management practices, the Higher B: C ratio (2.43) was observed with application of 50% N equivalent PC + 50% N equivalent BDLM. Overall, the lowest B:C ratio (1.28) was obtained with application 100% N equivalent through FYM. Among the different organic nutrient management practices, higher cost of cultivation was observed in application of 100% N equivalent through FYM (Rs. 48,325 ha^{-1}). Higher cost of cultivation was recorded in these treatments mainly due to its increased cost as it has low N content hence had to applied in larger quantities pushing cost higher.

Maximum net return of Rs1,03,013per ha was obtained with application of RDF (Control), among the organic nutrient management practices, the net returns was highest Rs.89511per ha with application of 50% N equivalent PC + 50% N equivalent BDLM. Lowest net return of Rs. 60371 per ha was obtained with absolute control. Maximum net return can be attributed to higher grain yield and lower cost of cultivation. This led to higher net returns because of higher yield of grain amaranth, and was sold at higher price in the market. Among the organic nutrient management practices, 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.

Similar results were earlier reported by Patel *et al.* (2005) [10] and Mahata and Sinha (2018) [5] who reported similar trend of results in Grain Amaranth. The above results were also found to be in conformity with the findings of Pratap *et al.* (2010) [11].

Table 1: Influence of different organic sources of nutrients on growth attributess of grain amaranth

Treatments	Plant height (cm)	Number of leaves	Leaf area (cm^2 $plant^{-1}$)	Total DMP (g $plant^{-1}$)
T_1: 100% N equivalent FYM	138.33	19.87	1350.13	45.6
T_2: 100% N equivalent PC	153.40	24.17	2162.20	62.7
T_3: 100% N equivalent BDLM	140.90	20.93	1507.03	53.1
T_4: Microbial consortium soil application	136.67	19.33	1381.50	46.2
T_5: 50% N equivalent FYM+ 50% N equivalent PC	165.70	26.33	2435.67	71.1
T_6: 50% N equivalent FYM + 50% N equivalent BDLM	145.13	23.07	1879.90	57.4
T_7: 50% N equivalent FYM + Microbial consortium soil application	143.00	21.30	1803.50	56.9
T_8: 50%N equivalent PC + 50% N equivalent BDLM	159.77	25.53	2211.10	66.9
T_9: 50% N equivalent PC + microbial consortium soil application	147.60	24.07	2079.00	58.5
T_{10}: 50% N equivalent BDLM + microbial consortium soil application	140.00	20.47	1502.50	48.0
T_{11}: Absolute control	115.00	19.17	1077.13	40.8
T_{12}: Control (RDF)	171.67	31.10	2855.53	80.7
F-test	*	*	*	*
S.Em ±	3.88	0.89	62.53	1.36
CD @ 5%	11.39	2.62	183.42	3.99

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

Table 2: Panicle length, number of fingers per panicle and length of finger of grain amaranth as influenced by different organic nutrient management practices

Treatments	Panicle length (cm)	Number of fingers per panicle	Length of finger (cm)
T_1: 100% N equivalent FYM	44.18	32.00	17.77
T_2: 100% N equivalent PC	50.87	36.33	20.77
T_3: 100% N equivalent BDLM	45.27	33.00	18.73
T_4: Microbial consortium soil application	41.62	31.00	16.03
T_5: 50% N equivalent FYM+ 50% N equivalent PC	54.33	37.67	22.13
T_6: 50% N equivalent FYM + 50% N equivalent BDLM	47.03	34.33	19.73
T_7: 50% N equivalent FYM + Microbial consortium soil application	46.33	33.33	18.70
T_8: 50%N equivalent PC + 50% N equivalent BDLM	52.33	37.00	21.00
T_9: 50% N equivalent PC + microbial consortium soil application	48.50	35.67	20.37
T_{10}: 50% N equivalent BDLM + microbial consortium soil application	44.20	32.67	18.63
T_{11}: Absolute control	38.33	25.33	15.30
T_{12}: Control (RDF)	57.87	40.00	26.10
F-test	*	*	*

S.Em ±	2.04	1.01	0.89
CD @ 5%	6.00	2.95	2.63

DAS- Days after sowing, RDF- Recommended dose of fertilizers, FYM-Farmyard manure, BDLM-Bio digester liquid manure, PC-Pongamia cake

Table 3: Grain yield, stover yield and harvest index of grain amaranth as influenced by different organic nutrient management practices

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index
T_1: 100% N equivalent FYM	1834	3224	0.36
T_2: 100% N equivalent PC	2005	3497	0.36
T_3: 100% N equivalent BDLM	1842	3224	0.36
T_4: Microbial consortium soil application	1745	3171	0.35
T_5: 50% N equivalent FYM+ 50% N equivalent PC	2127	3596	0.37
T_6: 50% N equivalent FYM + 50% N equivalent BDLM	1907	3392	0.36
T_7: 50% N equivalent FYM + Microbial consortium soil application	1880	3230	0.37
T_8: 50%N equivalent PC + 50% N equivalent BDLM	2105	3525	0.37
T_9: 50% N equivalent PC + microbial consortium soil application	1972	3417	0.37
T_{10}: 50% N equivalent BDLM + microbial consortium soil application	1837	3253	0.36
T_{11}: Absolute control	1428	2810	0.34
T_{12}: Control (RDF)	2260	3915	0.37
F-test	*	*	*
S.Em ±	88	22	0.01
CD @ 5%	259	65	0.03

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

Table 4: Cost of cultivation, gross returns, net returns and B: C ratio of Grain Amaranth as influenced by different organic nutrient management practices

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1: 100% N equivalent FYM	48325	110040	61715	1.28
T_2: 100% N equivalent PC	38125	120300	82175	2.16
T_3: 100% N equivalent BDLM	35895	110520	74645	2.08
T_4: Microbial consortium soil application	33258	104700	71442	2.15
T_5: 50% N equivalent FYM+ 50% N equivalent PC	42568	127620	85052	2.00
T_6: 50% N equivalent FYM + 50% N equivalent BDLM	41258	114420	73162	1.78
T_7: 50% N equivalent FYM + Microbial consortium soil application	40125	113280	73155	1.82
T_8: 50%N equivalent PC + 50% N equivalent BDLM	36789	126300	89511	2.43
T_9: 50% N equivalent PC + microbial consortium soil application	34895	118320	83435	2.40
T_{10}: 50% N equivalent BDLM + microbial consortium soil application	32589	110220	77631	2.38
T_{11}: Absolute control	25489	85860	60371	2.37
T_{12}: Control (RDF)	35287	135600	103013	2.92

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

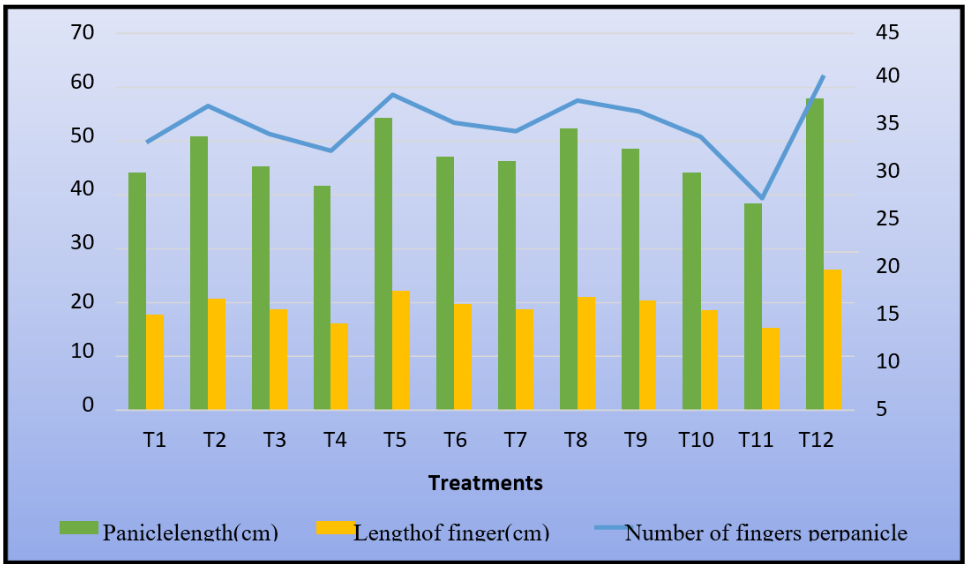

Fig 1: Panicle length, length of panicle and number of fingers per panicle of grain amaranth as influenced by different organic nutrient management practices

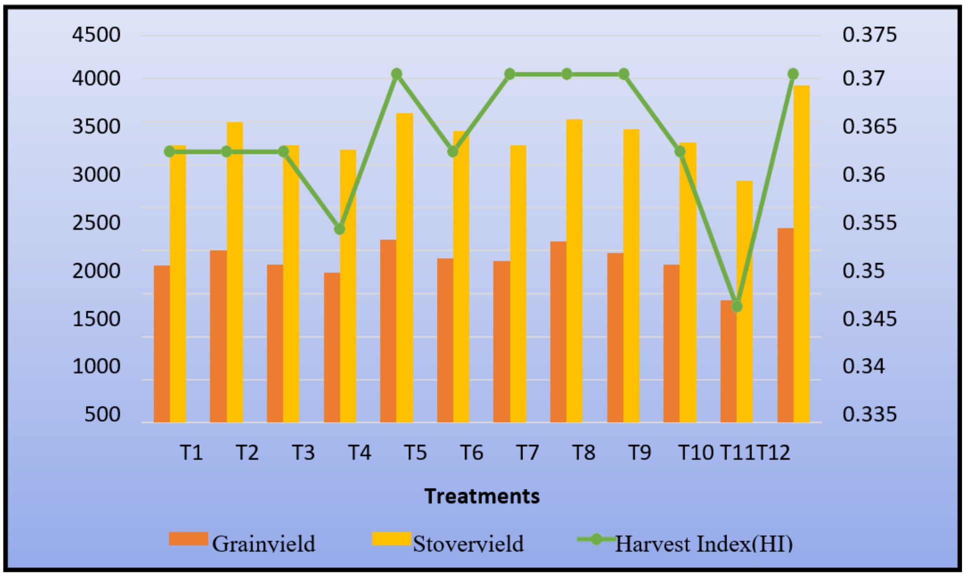

Fig 2: Grain yield, stover yield and harvest index of grain amaranth as influenced by different organic nutrient management practices

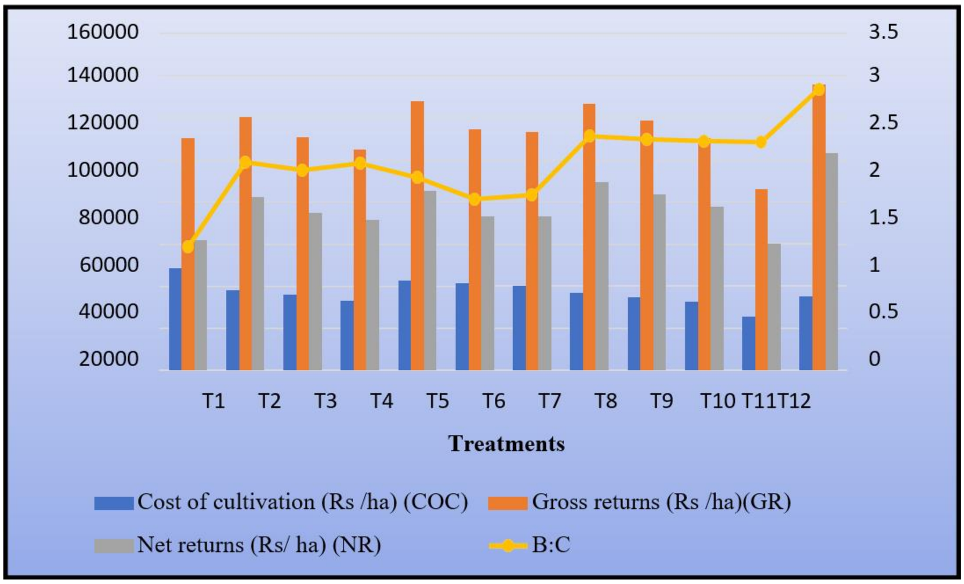

Fig 3: Cost of cultivation, gross return, net return and B:C ratio of grain amaranth

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