Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(1): 2796-2802
Received: 05-11-2017
Accepted: 06-12-2017

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Integrated nutrient management growth, yield, protein content and economics of grain amaranth (*Amaranthus hypochondriacus*)

Debasis Mahata and Ashim Chandra Sinha

Abstract
A field experiment was conducted during the pre kharif season 2012 and 2013 at instructional farm of Uttarbanga Krishi Viswavidyalaya, Pundibari, West Bengal, to Evaluation of organic sources for nitrogen management in grain amaranth (*Amaranthus hypochondriacus*) in integrated nutrient management with 14 treatments. The field experiment was laid out in Randomized Block design with three replications. The treatment receiving organic sources of nitrogen significantly influenced the height of plant, leaf area index, dry matter accumulation, crop growth rate, T_{14} was found to be superior to other treatments and the yield components of grain amaranth were significantly differs with the combine sources organics than the sole application of organics over control treatment. The highest pooled seed yield of 16.9 q.ha^{-1} was recorded under T_{14} treatment followed by 14.6 q.ha^{-1} at T_{12} and T_8 respectively. The maximum higher net return accrued to T_8 and followed by accrued to T_{10} during both the year respectively. The higher benefit cost ratio at T_2, T_{10} and T_8 showed a high paying potential of Grain amaranth. So, we conclude that farmers of North Bengal can adopt grain amaranth in high or medium high land situation with the application of poultry manure instead of chemical fertilizer.

Keywords: grain amaranth, yield, protein, starch

Introduction

Heavy use of chemicals in agriculture has weakened the ecological base in addition to degrading the soil, water resources and quality of the food. At this juncture, a keen awareness has sprung on the adoption of “Organic Farming” as a remedy to cure the ills of modern chemical agriculture (Kunnal, 1997) [13]. It is very much essential to develop a strong workable and compatible package of nutrient management through organic resources for various crops based on scientific facts, local conditions and economic viability (Kannaiyan, 2000) [12]. Organic manures have carry over effect on succeeding crops. The responses of the succeeding crops in a cropping system are influenced greatly by the preceding crops and the inputs applied therein. The organic manure provides the required nutrition to the plants and reduces the environmental pollution. The organic manure provides the required nutrition to the plants and reduces the environmental pollution. Increase the microbial activity, anion and cation exchange capacity, organic matter and carbon content of the soil. Organic manure also improves the yield of crops as well as quality of the products. Organic products of various crops are acceptable in the foreign market because consumers of the foreign countries are preferring products from organic farming. Suitable for experiment entitled “Studieson organic sources for nitrogen management in Grain amaranth (*Amaranthus hypochondriacus*)” was conducted during the years of 2012 and 2013 at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar on sandy loam soils under sub-tropical par-humid to tropical humid climate of *terai* region of West Bengal, Grain amaranth (*Amaranthus hypochondriacus*) is an ancient crop originating from Central and South America. The high nutritional value of amaranth seeds, functional potential, brief growth cycle, adaptability to unfavorable climate and soil condition and the food use of the entire plant is the reason for increasing research interest in this pseudocereal (Pospisil *et al*., 2006; Capriles *et al*., 2008) [15, 6]. Amaranth grain is reported to have high levels of lysine, a nutritionally critical amino acid, ranging from 0.73 to 0.84% of the total protein content (Bressani *et. al* 1987) [4]. The limiting amino acid is usually reported to be leucine (Singhal and Kulkami 1988) [17], although some reports indicate that threonine actually may be the amino acid which is more biologically limiting than leucine (Bressani *et. al* 1987) [4]. Amaranth leaves are also a wonderful astringent, and make a great wash for skin problems like eczema, and a wonderful acne remedy. Amaranth also makes an effective mouthwash for treating mouth sores, swollen gums, and sore throat. Amaranth leaves have been found to be a good home remedy for hair loss and premature graying. Therefore, considering the above situation needs to the application of various organic manures to counteract the adverse soil condition and to improve the yield of grain amaranth in North Bengal agro-climatic region with the following objectives: To study the growth parameters of buck wheat and Grain amaranth as influenced by organic sources of nitrogen. Effect of organic sources of nitrogen on yield and yield components of grain amaranth. To study the qualitative traits (protein) as influenced by organic sources of nitrogen. To find out the economics of grain amaranth production.

Materials and Methods

The field experiments were carried out at instructional farm of Uttar Banga Krishi Viswavidyalaya at Pundibari, Cooch Behar, West Bengal during the Early Pre-kharif seasons of 2012 and 2013. with 14 treatments. viz, T_1 = Control, T_2 = RDF (60:40:20), T_3 = Vermi Compost @ 2.5 t ha^{-1}, T_4 = Vermi Compost @ 5 t ha^{-1}, T_5 = Mustard Cake @ 2.5 t ha^{-1}, T_6= Mustard Cake @5 t ha^{-1}, T_7 = Poultry Manure @ 2.5 t ha^{-1}, T_8 = Poultry Manure @ 5 t ha^{-1}, T_9 = F.Y.M @ 8 t ha^{-1}, T_{10} = RDF +FYM @ 4 t ha^{-1}, T_{11} = Vermi Compost @ 2.5 t ha^{-1} + Mustard Cake @ 2.5 t ha^{-1}, T_{12} = Vermi Compost @ 2.5 t ha^{-1} + Mustard Cake @ 5 t ha^{-1}, T_{13} = Vermi Compost @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1} and T_{14} = Vermi Compost @ 2.5 t ha^{-1} + Mustard Cake @ 2.5 t ha^{-1} + Poultry Manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}. The farm is situated at $26^0$19'86"N latitude and $89^0$23'53" E longitude at an elevation of 43 meters above mean sea level. In upland situation with good drainage condition the investigations were undertaken. The soil of the experimental field was sandy loam in texture, a true representative of the *terai* region of West Bengal. The climate of *terai* zone is subtropical in nature with distinctive characteristics of high rainfall, high humidity and prolonged winter. There are broadly two dominant seasons in a year, extended winter or dry *Rabi* season and a long rainy season. The rainy season starts from 1^{st} week of May and continues up to last week of September having intermittent, drizzling and occasional heavy rainfall. The average rainfall of this zone varies between 2100 to 3300 mm. The maximum rainfall, *i.e.*, about 80% of the total, is received from south-west monsoon during the rainy months of June to September. The temperature range of this area varies from minimum of 7.1-8^0C to maximum of 24.8-32.2^0C. The area as a whole is humid and warm except having a short winter spell during December to February. This varied climatic situation makes the agro-ecological condition more complex and dynamic.

For measuring plant height Five plants were selected randomly from individual plot and properly tagged. Their heights were measured in centimeter from the ground level. Observation was taken at 20 day interval starting from 20 days after sowing. For calculation of DMA, destructive plant samples were taken from 50 cm row length of each plot at an interval of 20 days starting from 20 days after sowing and continue up to at harvest. From these sample plants the roots, green leaves and stem were separated and kept in brown paper packet and were allowed to dry in hot air oven at a temperature of 65ºc for 24 hours and continued till their constant weight were recorded and from this constant weight total dry matter production per square meter for each treatments was worked out. Leaf area index (LAI) is the ratio of leaf area to the area of ground cover. For LAI calculation, the destructive plant sample was taken from 50 cm row length of each plot. The green leaf laminas were separated from the destructive sample and 5 leaves were randomly selected. From the central portion of the selected leaves 10 cm size was cut by a sharp blade. The cut portion were kept in a small brown paper packet and allowed to dry in a hot air at a temperature of 65ºc for 24 hours and continued till a constant weight were recorded. The cut leaves were then weighted on a electronic balance. On the other hand, the green leaf lamina separated from the destructive sample were separately dried and weighted. There after using area weight (a/w) relationship of cut leaves, total leaf area were calculated for each treatment. Then according to the formula given by Watson, 1947 LAI was calculated at 20 days interval starting from 20 days after sowing.

Crop growth rate can be calculated by the following formula-

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \ g\ m^{-2} day^{-1}$$

Where, W_1& W_2 were the dry weights of the shoot (stem and leaves) at two successive time intervals T_1 and T_2 respectively. This is the dry matter accumulation $unit^{-1}$ time and $unit^{-1}$ land area. Starch analysis: Reagent: Anthrone reagent: 0.4 per cent anthrone in concentrated sulphuric acid (H2SO4). Procedure: To 50 µl of aliquot prepared for starch estimation, 1 ml of double distilled water and to it 4 ml of anthrone reagent was added. The mixture was heated in water bath at 60°C for 10 min. After cooling O.D. was recorded at 620 nm against the reagent blank. Standard curve was prepared by using graded concentrations of anhydrous D-glucose. Starch content was calculated by multiplying glucose standard value by 0.9 (as 0.9 g of starch yield, 1.0 g of glucose as described by Hassid and Neufeld (1964). Protein analysis: 0.2 g of fresh seed was crushed in a previously chilled mortar with pestle in 0.8 ml of sodium phosphate buffer (pH 7.1). The grind tissue was centrifuged at 4ºC for 20 minutes at 10,000 rpm and the supernatant was used as crude protein. It was immediately stored frozen for further use.

Total protein was estimated following Lowry's method (1951).

The following chemical were prepared and stored.

Reagent A: 1g Na2CO3 in 50 ml of 0.1 (N) NaOH.

Reagent B: 0.25g CaSO4, 5H2O in 50 ml of 1% potassium sodium tartarate.

Reagent C: 50 ml reagent A + 1 ml reagent B.

Reagent D: 1 (N) Folin– Ciocaltaeu reagent.

During estimation 0.1 ml protein extract was pipetted into a test tube and by adding 0.9 ml of buffer the volume was made up to 1 ml. To this, 5 ml of reagent C was added and left for 10 minutes. After 10 minutes, 0.5 ml of reagent D was added, stirred well and incubated in dark for 30 min. The optical density was measured at 660 nm in a spectrophotometer against a reagent blank without protein extract. Quantity of protein was calculated with the help of the standard curve prepared with Bovine serum albumin (BSA)

Results and Discussion

Effect of treatments on plant height of grain amaranth

Plant height of grain amaranth was measured on five occasions starting from 20 DAS (days after sowing) till at harvest. The dates of observations were recorded at 20, 40, 60, 80 and at harvest. Plant height was significantly influenced by the nutrient management treatments at all the dates of recording observations during both the years of experimentation. It was seen from the data (Table 1) that the plant height of grain amaranth was increasing with increasing rate upto 60 DAS and then it was increasing with decreasing rate irrespective of the treatments.

At 20 DAS, the plant height varied from 10.1 cm & 11.1 cm under unfertilized control (T_1) and 17.2 cm & 18.5 cm under combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) during the years of 2012 & 2013, respectively.

At 40 DAS, the plant height varied from 23.3 cm & 23.5 cm. under unfertilized control (T_1) and 74.8 cm & 76.6 cm under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) and it was statistically *at par* with single application of Poultry manure @ 5 t ha^{-1} (T_8) during the years of 2012 & 2013, respectively.

At 60 DAS, the plant height varied from 29.7 cm & 31.0 cm. under unfertilized control (T_1) and 105.7 cm & 116.7 cm under combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) and it was statistically *at par* with the single application of Poultry manure @ 5 t ha^{-1} (T_8) during the years of 2012 & 2013, respectively.

At 80 DAS, the plant height varied from 39.8 cm & 42.9 cm, under unfertilized control (T_1) and 118.6 cm & 123.5 cm under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) and it was statistically *at par* with the single application of Poultry manure @ 5 t ha^{-1} (T_8) during the years of 2012 & 2013 respectively.

Significantly, the highest plant height was observed in combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) which was statistically *at par* with the single application of poultry manure @ 5 t ha^{-1} (T_8) during both the years of experimentation. Unfertilized control (T_1) recorded the shortest plant height during both the years of experimentation. Similar pattern of results were obtained at all the dates of taking observation.

It was further seen from the said table that the highest plant height, at harvest, was recorded to be 120.3 cm and 125.4 cm under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) which was statistically *at par* with the single application of poultry manure @ 5 t ha^{-1} (T_8) during both the years of experimentation. Unfertilized control (T_1) recorded significantly lower plant height (40.1 cm and 44.6 cm during 2012 and 2013, respectively). As soil of terai region is sandy loam with light textured, prevailing with high rainfall, causes leaching down of nutrients, that's why combined application of all the organic manures was added in treatment $T_{14.}$ The higher plant height might be due to synchronous and steady release of plant nutrients throughout the growth period. Pooled analysis also showed the similar trend as the individual years. These results are in conformity with the findings of Emede *et al*. (2012) [9], Ainika *et al*. (2011) [1] and Godonu *et.al*. (2011) [10].

Table 1: Effect of treatments on plant height of grain amaranth

Treatments	Plant height (cm.)														
	20 DAS			40 DAS			60 DAS			80 DAS			At harvest		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_1	10.1	11.1	10.6	23.3	23.5	23.4	29.7	31.0	30.4	39.8	42.9	41.3	40.1	44.6	42.3
T_2	14.2	14.1	14.2	32.7	34.8	33.7	40.3	52.4	46.4	71.1	69.7	64.9	62.5	67.3	70.4
T_3	13.5	13.1	13.3	24.6	27.8	26.2	32.7	34.3	33.5	59.0	57.0	56.4	55.2	57.5	58.0
T_4	15.2	15.2	15.2	37.8	36.6	37.2	48.3	55.3	51.8	76.0	75.2	70.4	70.3	70.6	75.6
T_5	14.2	13.3	13.7	30.6	31.5	31.1	38.7	40.0	39.4	67.4	64.9	61.8	60.4	63.2	66.2
T_6	15.8	15.5	15.6	46.6	49.6	48.1	57.7	61.4	59.5	85.0	87.8	84.6	82.5	86.8	86.4
T_7	13.6	13.2	13.4	29.6	31.3	30.5	35.7	37.2	36.4	65.2	60.1	59.3	58.5	60.2	62.7
T_8	16.2	16.0	16.1	50.2	51.7	51.0	67.6	72.0	69.8	91.9	95.0	94.3	95.5	93.2	93.4
T_9	14.1	14.2	14.1	33.3	35.6	34.4	45.7	53.6	49.6	74.1	72.2	69.0	67.3	70.7	73.2
T_{10}	15.5	15.2	15.4	40.8	39.2	40.0	54.8	56.6	55.7	76.8	76.6	74.4	72.3	76.5	76.7
T_{11}	16.2	16.0	16.1	48.7	50.6	49.6	60.7	66.9	63.8	91.0	91.7	89.3	87.7	90.9	91.4
T_{12}	16.5	16.2	16.4	50.3	58.5	54.4	73.3	75.3	74.3	103.8	104.6	102.8	100.3	105.3	104.2
T_{13}	15.5	15.4	15.5	42.7	41.3	42.0	55.7	56.7	56.2	82.2	80.7	79.8	79.0	80.6	81.5
T_{14}	17.2	18.5	17.8	74.8	76.6	75.7	105.7	116.7	111.2	118.6	123.5	121.0	120.3	125.4	122.9
S.Em(±)	1.03	0.89	0.76	2.00	2.08	1.64	2.76	2.96	2.82	3.47	3.38	3.04	3.51	3.38	3.42
CD (P=0.05)	3.02	2.60	2.21	5.85	6.08	4.78	8.06	8.66	8.24	10.14	9.88	8.89	10.26	9.88	9.99

Effect of treatments on crop growth rate (CGR) of grain amaranth

Periodical observations revealed that crop growth rate (CGR) of grain amaranth was slow during the initial period (20-40 DAS) of growth irrespective of treatments and years of experimentation (Table 2). It started to increased since 20-40 DAS and reached at its maximum during the period, 40-60 DAS. Then it decreased progressively with the age of the crop in all the treatment combinations till maturity during both the years. The reproductive phase of the crop coincided with the third period (40-60 DAS) of observation and it was natural that crop growth rate was at its maximum in that phase when there was fullest manifestations of all the vegetative parts of the plant alongwitht flower initiation. At the later stages when the crop was in ripening phase and had no further vegetative growth showed a decline in crop growth rate. At these stages grain filling took place partly by translocation from storage in vegetative parts and partly by synthesis with limited foliage.

At 20-40 DAS, the crop growth rate varied from 1.69 g m^{-2} d^{-1} & 2.50 g m^{-2} d^{-1} under unfertilized control (T_1) and 4.81 g m^{-2} & 4.97 g m^{-2} under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) during the years of 2012 & 2013, respectively.

At 40-60 DAS, the crop growth rate varied from 3.25 g m^{-2} d^{-1} & 3.74 g m^{-2} d^{-1} under unfertilized control (T_1) and 5.20 g m^{-2} d^{-1} & 5.25 g m^{-2} d^{-1} under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) and it was statistically *at par* with single application of Poultry manure @ 5 t ha^{-1} (T_8) during the years of 2012 & 2013, respectively.

At 60-80 DAS, the crop growth rate varied from 1.67 g m^{-2} d^{-1} & 1.27 g m^{-2} d^{-1} under unfertilized control (T_1) and 2.07 g m^{-2} & 2.50 g m^{-2} under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) during the years of 2012 & 2013, respectively.

At 80-at harvest, the crop growth rate varied from 1.10 g m^{-2} d^{-1} & 0.84 g m^{-2} d^{-1} under unfertilized control (T_1) and 3.20 g m^{-2} d^{-1} & 2.76 g m^{-2} d^{-1} under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) and it was statistically *at par* with the single application of poultry manure @ 5 t ha^{-1} (T_8) during both the years of experimentation. These results are in conformity with the findings of Ainika *et al*., (2011) [1] and Chaudhari *et. al*. (2010) [7].

Table 2: Effect of treatments on crop growth rate of grain amaranth

Treatments	Crop growth rate (CGR) (g m^{-2} day^{-1})											
	20-40 DAS			40-60 DAS			60-80 DAS			80- At harvest		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_1	1.69	2.50	2.10	3.25	3.74	3.50	1.67	1.27	1.47	1.10	0.84	0.97
T_2	2.15	3.05	2.60	3.60	4.17	3.89	1.48	1.77	1.62	2.66	1.51	2.09
T_3	1.75	2.90	2.32	3.41	3.82	3.61	2.25	1.64	1.95	1.44	1.38	1.41
T_4	2.37	3.11	2.74	3.90	4.24	4.07	1.55	1.92	1.73	2.82	1.60	2.21
T_5	1.99	3.00	2.50	3.51	3.97	3.74	2.32	1.79	2.05	1.78	1.49	1.63
T_6	3.40	3.31	3.35	4.15	4.55	4.35	1.64	2.07	1.86	3.06	1.89	2.47
T_7	1.95	3.00	2.47	3.51	3.88	3.69	2.30	1.74	2.02	1.70	1.39	1.55
T_8	4.26	4.00	4.13	4.24	4.81	4.53	1.76	2.20	1.98	3.09	1.99	2.54
T_9	2.25	3.05	2.82	3.90	4.19	4.05	2.42	1.82	2.12	1.83	1.58	1.71
T_{10}	2.75	3.20	3.14	4.12	4.48	4.30	1.59	1.97	1.78	2.94	1.69	2.31
T_{11}	3.86	3.99	3.92	4.20	4.78	4.49	2.59	2.14	2.36	2.18	1.75	1.96
T_{12}	4.49	4.01	4.25	4.99	4.99	4.99	1.83	2.30	2.07	3.17	2.21	2.69
T_{13}	3.00	3.22	3.11	4.15	4.50	4.32	2.56	2.07	2.31	2.10	1.74	1.92
T_{14}	4.81	4.97	4.89	5.20	5.25	5.22	2.07	2.50	2.28	3.20	2.76	2.98
S.Em(±)	0.220	0.143	0.115	0.156	0.150	0.147	0.103	0.136	0.118	0.138	0.104	0.117
CD (P=0.05)	0.644	0.418	0.335	0.456	0.438	0.431	0.301	0.397	0.346	0.404	0.304	0.343

Effect of treatments on test weight of grain amaranth

In general, test weight were more in 2013 than in 2012 irrespective of organic sources for nitrogen management treatments (Table 3).

Significantly, the highest test weight was recorded with the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) might be due to higher plant height (Table 4.1.1 and Fig 4.1.1), Leaf area index (Table 4.1.2 and Fig 4.1.2), DMA(Table 4.1.3 and Fig 4.1.3), CGR(Table 4.1.4 and Fig 4.1.4), NAR(Table 4.1.5 and Fig 4.1.5) and yield components (Table 4.1.2.1, 4.1.2.2 & 4.1.2.3). followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) which was statistically *at par* with the single application of poultry manure @ 5 t ha^{-1} (T_8) during both the years of experimentation. Unfertilized control (T_1) recorded the lowest test weight during both the years of experimentation.

It would further be seen from the said table that the highest test weight (1.82 g and 1.84 g during 2012 and 2013, respectively) was recorded to be under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) (1.61 g and 1.64 g during 2012 and 2013, respectively) which was statistically *at par* (1.45 g and 1.47 g during 2012 and 2013, respectively) with the single application of poultry manure @ 5 t ha^{-1} (T_8). Unfertilized control (T_1) recorded significantly the lowest test weights (1.30 g and 1.33 g during 2012 and 2013 respectively) It would further be seen that higher weight of 1000-seeds were obtained in the treatments where N, P, & K level was more or less optimum through inorganic or organic sources.

Effect of treatments on seed yield of grain amaranth

The seed yield of grain amaranth was, in general, more in 2013 than in 2012 irrespective of organic sources for nitrogen management treatments (Table 3).

Significantly, the highest seed yield was obtained in combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) which was statistically at par with the single application of poultry manure @ 5 t ha^{-1} (T_8) during both the years of experimentation. Unfertilized control (T_1) recorded the lowest seed yield during both the years of experimentation.

It would further be seen from the said table that the highest seed yield (16.7 q ha^{-1} and 17.2 q ha^{-1} q ha^{-1} during 2012 and

2013 respectively) was recorded under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) (15.0 q ha^{-1} and 16.1 q ha^{-1} q ha^{-1} during 2012 and 2013 respectively) which was statistically *at par* (13.8 q ha^{-1} and 14.8 q ha^{-1} q ha^{-1} during 2012 and 2013 respectively) with the single application of poultry manure @ 5 t ha^{-1} (T_8). Unfertilized control (T_1) recorded significantly the lowest seed yield (3.8q ha^{-1} and 4.7 q ha^{-1} during 2012 and 2013, respectively). Pooled analysis also showed the similar trend as the individual years. Combined application of FYM, vermicompost, mustard cake and poultry manure or their integrated use had influenced seed yield of grain amaranth during both the years (Godonu *et.al*., 2011) [10], Rathor *et al*., (2004) [16] and Emede *et al*. (2012) [9].

Effect of treatments on Stem yield of grain amaranth

The stem yield of grain amaranth was, in general, more in 2013 than in 2012 irrespective of organic sources for nitrogen management treatments (Table 3).

Significantly, the highest stem yield was observed in combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) which was statistically *at par* with the single application of poultry manure @ 5 t ha^{-1} (T_8) during both the years of experimentation. Unfertilized control (T_1) recorded the lowest stem yield during both the years of experimentation.

It would further be seen from the said table that the highest stem yield (28.8 q ha^{-1} and 29.0 q ha^{-1} during 2012 and 2013, respectively) was recorded under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) (27.1 q ha^{-1} and 28.3 q ha^{-1} during 2012 and 2013, respectively) which was statistically *at par* (26.2 q ha^{-1} and 26.9 q ha^{-1} during 2012 and 2013, respectively) with the single application of poultry manure @ 5 t ha^{-1} (T_8). Unfertilized control (T_1) recorded significantly the lowest stem yield (16.0 q ha^{-1} and 18.1 q ha^{-1} during 2012 and 2013 respectively). Pooled analysis also showed the similar trend as the individual years. The increase in stem yield of grain amaranth due to the different sources of organic treatments could be ascribed to the overall improvement in crop growth, vigour, production and translocation of sufficient photosynthate. The results corroborated the experimental findings of Chaudhari *et. al.* (2010) [7] and Emede *et al*. (2012) [9].

Table 3: Effect of treatments on yield and yield attributes of grain amaranth

Treatments	Yield											
	Test Weight (g)			Seed yield (q ha^{-1})			Stem Yield (q ha^{-1})			Harvest index		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_1	1.3	1.33	1.32	3.8	4.7	4.2	16.0	18.1	17.0	18.8	20.3	19.5
T_2	1.33	1.37	1.35	10.1	11.2	10.6	24.9	26.5	25.7	28.6	29.6	29.1
T_3	1.41	1.42	1.42	9.3	10.1	9.7	27.0	28.0	27.5	25.5	26.5	26.0
T_4	1.34	1.33	1.34	11.2	12.1	11.7	25.6	25.8	25.7	30.5	31.8	31.1
T_5	1.32	1.35	1.34	9.8	10.6	10.2	25.7	26.4	26.1	27.6	28.4	28.0
T_6	1.4	1.41	1.41	13.4	14.1	13.8	26.3	26.3	26.3	33.8	34.9	34.3
T_7	1.43	1.46	1.45	9.6	10.1	9.9	26.6	26.5	26.6	26.6	27.3	26.9
T_8	1.45	1.47	1.46	13.8	14.8	14.3	26.2	26.9	26.6	34.6	35.3	35.0
T_9	1.5	1.51	1.51	10.7	11.5	11.1	25.2	25.8	25.5	29.8	30.7	30.2
T_{10}	1.55	1.56	1.56	11.8	12.9	12.4	25.5	26.8	26.2	31.6	32.4	32.0
T_{11}	1.51	1.52	1.52	13.7	14.1	13.9	25.5	25.3	25.4	34.9	35.8	35.3
T_{12}	1.61	1.64	1.63	15.0	16.1	15.6	27.1	28.3	27.7	35.7	36.2	35.9
T_{13}	1.72	1.73	1.73	12.3	13.1	12.7	25.6	26.0	25.8	32.3	33.6	33.0
T_{14}	1.82	1.84	1.83	16.7	17.2	17.0	28.8	29.0	28.9	36.8	37.1	36.9
S.Em(±)	0.01	0.01	0.01	7.81	9.70	8.65	7.30	10.69	8.29	1.07	1.03	1.04
CD (P=0.05)	NS	0.02	0.02	22.83	28.34	25.28	21.33	31.23	24.23	3.12	3.00	3.04

Effect of treatments on harvest index of grain amaranth

In general, harvest index was higher in 2013 than in 2012 irrespective of organic sources of nitrogen management treatments (Table 3).

Significantly, the highest harvest index was observed in combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) which was statistically *at par* with the single application of poultry manure @ 5 t ha^{-1} (T_8) during both the years of experimentation. Unfertilized control (T_1) recorded the lowest harvest index during both the years of experimentation.

It would further be seen from the said table that the highest harvest index (36.8 % and 37.1 % during 2012 and 2013, respectively) with the to be under combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) (35.7 % and 36.2 % during 2012 and 2013, respectively) which was statistically *at par* (34.6 % and 35.3 % during 2012 and 2013 respectively) with the single application of poultry manure @ 5 t ha^{-1} (T_8). Unfertilized control (T_1) recorded significantly the lowest harvest index (18.8 % and 20.3 % during 2012 and 2013, respectively). Pooled analysis also showed the similar trend as the individual years. Similar results were also obtained by (Rathor *et al*., 2004) [16].

Effect of treatments on protein content of grain amaranth

The protein content of grain amaranth was influenced significantly at different levels of organic sources for nitrogen management treatments (Table 4).

Significantly, the highest protein Content was observed in combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) which was statistically *at par* with the single application of poultry manure @ 5 t ha^{-1} (T_8) during both the years of experimentation. Unfertilized control (T_1) recorded the lowest protein Content during both the years of experimentation.

It would further be seen from the said table that the highest protein Content (16.9 % and 17.2 % during 2012 and 2013, respectively) was recorded under the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}(T_{14}) followed by the combined application of vermi compost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} (T_{12}) (16.6 % and 16.4 % during 2012 and 2013, respectively) which was statistically *at par* (15.8 % and 16.3 % during 2012 and 2013, respectively) with the single application of poultry manure @ 5 t ha^{-1} (T_8). Unfertilized control (T_1) recorded significantly the lowest protein Content (12.4 % and 12.3 % during 2012 and 2013, respectively). Pooled analysis also showed the similar trend as the individual years. Similar results were recorded by Bavec. *et.al*. (2010) [2], Bejosano and Corke (1998) [3] and Olaniyi *et al*., (2008) [14].

Table 4: Effect of treatments on protein content of grain amaranth

Treatments	Starch and Protein content (%)		
	Protein (%)		
	2012	2013	Pooled
T_1	12.4	12.3	12.3
T_2	13.5	13.9	13.7
T_3	12.4	12.8	12.6
T_4	14.1	14.2	14.2
T_5	13.5	13.2	13.3
T_6	15.0	15.2	15.1
T_7	13.3	13.1	13.2
T_8	15.8	16.3	16.1
T_9	13.9	14.1	14.0
T_{10}	14.3	14.6	14.4
T_{11}	15.6	15.4	15.5
T_{12}	16.6	16.4	16.5
T_{13}	14.6	14.9	14.8
T_{14}	16.9	17.2	17.0
S.Em(±)	0.55	0.54	0.33
CD (P=0.05)	1.62	1.57	0.95

Economics of grain amaranth

The data on economics of grain amaranth in relation to organic manures and chemical fertilizers have been presented in (Table 5).

The analyses on economics revealed that maximum gross return of Rs. 116900 ha^{-1} and Rs. 1204400 ha^{-1} were obtained with the combined application of vermicompost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1} *i.e.* T_{14} closely followed by Rs.
105000 ha^{-1} and Rs. 112700 ha^{-1} with vermicompost @ 2.5 t ha^{-1} + mustard cake @ 5 t ha^{-1} *i.e.* T_{12} during 2012 and 2013, respectively. Higher gross return was simply due to higher yield of both the crops in the sequence during both the years of experimentation. The results showed that all the organic treatments recorded higher gross returns as compared to chemically treated and control plots.

Among all the treatments, T_8 (poultry manure @ 5 t ha^{-1}) registered the heighest net return to the tune of Rs. 74955 ha^{-1} and Rs. 81955 ha^{-1}, respectively, in 2012 and 2013. This was followed by T_2 (Rs. 55802 ha^{-1} and Rs. 63336 ha^{-1}, respectively, in 2012 and 2013). The net returns were less in first year as compared to second year simply due to lesser yield for grain amaranth and ricebean in the first year. Among the organic manures, mustard cake recorded comparatively lower net returns in both the years might be due to higher unit price (Rs. 8.0 kg^{-1}) of mustard cake.

The highest benefit: cost ratio (3.75 and 4.20 during 2012 and 2013, respectively) was noticed in T_2 (100 % RDF) followed by T_{10} (3.37 and 3.74 during 2012 and 2013, respectively). This was owing to the less cost incurred in thise treatments. The results corroborate with the earlier findings of Panwar and Munda (2007) [18] and Rana and Rameshwar. (2003)

Table 5: Effect of treatments on economics of grain amaranth

Treatments	Cost of the treatments (Rs. ha^{-1})		General cost for grain amaranth cultivation (Rs. ha^{-1})		Total cost of cultivation grain amaranth (Rs.ha^{-1})		Gross return (Rs. ha^{-1})		Net return (Rs. ha^{-1})		Benefit: Cost ratio	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
T_1	-	-	11605	11605	13709	13709	26600	32900	14995	21295	1.29	1.83
T_2	3293	3459	11605	11605	17002	17168	70700	78400	55802	63336	3.75	4.20
T_3	10000	10000	11605	11605	23709	23709	65100	70700	43495	49095	2.01	2.27
T_4	20000	20000	11605	11605	33709	33709	78400	84700	46795	53095	1.48	1.68
T_5	20000	20000	11605	11605	33709	33709	68600	74200	36995	42595	1.17	1.35
T_6	40000	40000	11605	11605	53709	53709	93800	98700	42195	47095	0.82	0.91
T_7	5000	5000	11605	11605	18709	18709	67200	70700	50595	54095	3.05	3.26
T_8	10000	10000	11605	11605	23709	23709	96600	103600	74995	81995	3.47	3.80

T_{9}	8000	8000	11605	11605	21709	21709	74900	80500	55295	60895	2.82	3.11
T_{10}	7293	7459	11605	11605	21002	21168	82600	90300	63702	71236	3.37	3.74
T_{11}	30000	30000	11605	11605	43709	43709	95900	98700	54295	57095	1.31	1.37
T_{12}	50000	50000	11605	11605	63709	63709	105000	112700	43395	51095	0.70	0.83
T_{13}	14000	14000	11605	11605	27709	27709	86100	91700	60495	66095	2.36	2.58
T_{14}	39000	39000	11605	11605	52709	52709	116900	120400	66295	69795	1.31	1.38

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