Integrated Nutrient Management: A Pathway to Enhanced Growth and Yield in *Amaranthus tricolor* L.

Abstract

The present study was conducted to determine the effect of different levels of manures, fertilizer, and biofertilizers application, either alone or in combination on seed germination, vigor, and yield of Amaranthus. Recommended rates of organic manures *viz.*, farmyard manure (5 t/ha) and vermicompost (2.5 t/ha) biofertilizers i.e., *Azotobacter* and *Phosphate solubilizing bacteria* @ 200g per 10 kg of seed were integrated with the recommended dose of fertilizer @ 60: 40: 20 kg/ha NPK. The experiment was designed with twelve treatments with three replications that were laid out in a randomized complete block design. Results revealed that the treatment T_{12} which consists of half dose of NPK + half dose of vermicompost + Azotobacter and PSB observed early emergence of seeds (3.60 days) along with higher germination percentages (84.53 percent) as well as vigorous seedlings in terms of vigor index-1 (5.75) and vigor index-2 (5.56). The crop was harvested three times at a height of 20 cm and by the application of treatment T_{12}, plants take minimum time for harvest i.e., 21.65, 30.65, and 41.16 days along with the highest yield i.e., 0.50, 1.15, and 0.85 kg per plot at first second and third harvest respectively. Therefore, it is clear that combining inorganic fertilizers with organic manures could increase soil health in addition to enhancing growth and facilitating consistent nutrition for the Amaranthus crop.

Keywords: Amaranthus, Germination, Integrated Nutrient Management, Vigour, Yield.

Introduction

Vegetables are essential components of our daily diet, with a recommended intake of at least 300 grams per person per day, including 125 grams of leafy vegetables. Leafy vegetables, often dubbed 'mines of minerals,' contribute significantly to our nutritional intake, offering vitamins, minerals, protein, carotene (vitamin A), iron, and ascorbic acid (vitamin C) [1]. Among these, Amaranthus stands out as a widely consumed vegetable across India [2]. Derived from the Greek word 'Anthos' meaning everlasting or unwilting, Amaranthus, also known as 'Chaulai' or the 'poor man's vegetable,' belongs to the genus Amaranthus, family Amaranthaceae, which comprises 65 genera and 850 species worldwide. *Amaranthus tricolor* L., extensively cultivated in Bengal historically [3], holds cultural and agricultural significance in South India as well [4]. Originating in India [5], Amaranthus demonstrates centers of diversity in Central and South America, India, and Southeast Asia, with secondary diversity in West Africa and East Africa [6]. Its attributes as a C4 plant, coupled with its short-duration growth and high yield per unit area, make it suitable for crop rotation. The nutritive value of Amaranthus is noteworthy, offering energy, carbohydrates, fat, protein, vitamins, and trace elements [7]. However, its performance hinges directly on soil nutrient status managed through organic and inorganic fertilizers. While chemical fertilizers have been traditionally employed, their adverse effects on soil health, ecosystem balance, and human health, coupled with escalating costs and availability issues, necessitate the exploration of alternative nutrient sources. Organic manures, composts, vermicomposts, crop residues, green manures, and biofertilizers present viable alternatives, offering cost-effectiveness and availability. Integrated Nutrient Management (INM) emerges as a promising approach, leveraging organic and chemical fertilizers alongside biofertilizers to sustain crop yield while enhancing fertilizer efficiency and soil health [8]. This study, titled "Integrated Nutrient Management: A Pathway to Enhanced Growth and Yield in *Amaranthus tricolor* L.," aims to explore this approach, recognizing the diversity in nutrient sources and their implications for improved crop performance.

Materials and Methods

The experiment was conducted during the *kharif* season at the Nursery area, Department of Horticulture, College of Agriculture, Indore, Madhya Pradesh, India. The experiment field was prepared by two deep ploughing with disc plough and planking to bring the field to a good tilth condition. Each experimental unit was demarcated and the layout was drawn as per the plan finally, the field was divided into 39 plots (2.25 m X 1.05 m each plot) having irrigation channels and paths. There were thirteen treatments and each treatment was allocated randomly in each plot. The thirteen treatments, T1: Control (No use of Fertilizers and manures), T2: Recommended dose of NPK (60,40,20), T3: 100% FYM (5 tonnes/ha), T4: 100% Vermicompost (2.5 tonnes/ha), T5: Azotobacter (200g/10 kg seed) + PSB (200g/10 kg seed), T6: 75% Recommended dose of fertilizers + 25% Vermicompost, T7: 75% Recommended dose of fertilizers + 25% FYM, T8: 75% Recommended dose of fertilizers + 25% Vermicompost + Azotobacter + PSB, T9: 75% Recommended dose of fertilizers + 25% FYM + Azotobacter + PSB, T10: 50% Recommended dose of fertilizers + 50% Vermicompost, T11: 50% Recommended dose of fertilizers + 50% FYM, T12: 50%0 Recommended dose of fertilizers + 50% Vermicompost + Azotobacter + PSB, T13: 50% Recommended dose of fertilizers + 50% FYM + Azotobacter + PSB were evaluated in randomized block design with the three replications. Before sowing in the plots, seeds were treated with thiram @ 2.5 g/kg and then with Azotobacter and Phosphate solubilizing bacteria@ 200g/10 kg seed. FYM @ 5 tonnes/ha and vermicompost @ 2.5 tonnes/ha were incorporated in the field at the time of field preparation as per treatments. Half dose of nitrogen @ 60 kg/ha and a full dose of phosphorus @ 40 kg/ha and potassium @ 20 kg/ha was also given as per treatment in the plots as basal dose and the remaining quantity of nitrogen was applied as top dressing at each foliage cutting. By maintaining row to row distance of 45 cm, seeds were sown in the plots @ 2 kg/ha in the third week of July. Gradually thinning was done at 5 cm height to achieve a final spacing of 15 cm between the plants. All cultural operations were performed as per recommendations. The statistical analysis was carried out as per the procedure [9].

For measuring Days to the first seedling emergence daily observations were taken, until the first foliage leaf appeared. Germination percent was recorded according to ISTA, 2011. Vigour index I and II were computed using the formula [10], and expressed in the whole number. Five random plants were selected and properly tagged in each replication for every treatment to collect the data related to the number of days taken to achieve 20 cm height as harvesting of greens were done at 20 cm height. The greens obtained from each plot and replication at the first, second, and third harvest at 20 cm height were weighted and the Yield /plot (kg) was worked out.

$$\text{Germination percentage} = \frac{\text{Number of germinating seeds} \times 100}{\text{Total number of seeds}}$$

$$\text{Vigour Index} - 1 = \frac{\text{Germination percentage} \times \text{Seedling length (cm)}}{100}$$

$$\text{Vigour Index} - 2 = \text{Seedling dry weight (g)} \times \text{Germination percentage}$$

Results

The results of the experiments are presented in Table 1. There is a significant effect of Integrated Nutrient Management on all the traits viz. Number of days taken for germination, germination percentage, Vigor index-1 and-2, number of days taken to harvest and yield (kg per plot). Treatment combination T_{12} showed a minimum of 3.60 days for germination, which was followed by 4.10 days due to the treatment combination T_{13} while a maximum of 6.51 days was recorded due to the application treatment T_1. Similarly, a maximum 84.53 germination percentage was also observed due to the application of treatment T_{12} which was succeeded by 78.19 percent by the use of treatment T_{13} meanwhile the minimum of 58.74 percent germination was recorded in treatment T_1. Following this, the maximum value of vigor index-1 (5.75) and vigor index-2 (5.56) was also observed in T_{12} followed by the 5.38 (vigor index-1) and 4.85 (vigor index-2) by the application of T_{13}. At the same time, minimum values of vigor index-1 (1.93) and Vigor index- (1.01) were observed by the use of treatment T_1 (control). Moreover, by the use of treatment, T_{12} plant took a minimum of 21.65, 30.65, and 41.16 days to attain 20 cm height for all three consecutive first, second, and third harvest respectively It was followed by the application of treatment T_{13} by which plants took 23.69, 32.9 and 43.86 days for first, second and third harvest respectively at 20 cm height while the application of treatment T_1 took maximum 32.25, 44.90 and 59.84 days for all the three harvests respectively. Similarly, a maximum yield of 0.50 kg per plot, 1.15 kg per plot, and 0.85 kg per plot was also observed by the application of treatment T_{12} at all three harvests. This was succeeded by T_{13} by which 0.38 kg per plot, 0.99 kg per plot, and 0.74 kg per plot yield was obtained at each harvest while the application of treatment T_1 yielded a minimum of 0.15 kg per plot, 0.20 kg per plot, and 0.18 kg per plot greens at each harvest respectively.

Discussion

The overall performance of Amaranthus is better in the treatment combination T_{12}. It might be due to the positive response of the crop toward the nutrition available from different sources like fertilizer, vermicompost, and biofertilizers. The availability of effective microorganisms through biofertilizers along with nutrients supplied by vermicompost and chemical fertilizers which change the soil plant ecosystem in terms of soil health and growth and development of the plant consequently increased the yield and its attributing traits of amaranthus [11]. Biofertilizers stimulate plant growth by providing necessary nutrients as a result of their colonization at their rhizosphere (*Azotobacter, Azospirillum, Pseudomonas, Phosphate solubilizing bacteria,* and *Cyanobacteria*) or by symbiotic association (*Rhizobium, Mycorrhizae or Frankia*) [12].

Treatment T_{12} has many growth-promoting hormones like indole -3- acetic acid (IAA), cytokinin, gibberellins, etc., and humic acid which could have been responsible for the faster germination of seed. Biofertilizers also promote seed germination and early development by excreting phytohormones such as auxins and gibberellines, etc. Besides, during metabolism the bacteria excrete organic acids (citric acid, malic acid, etc.) as well, thus helping nutrient uptake at a later stage of growth. It was reported that 10g inoculation of *Azotobacter* showed 100 percent germination and also reduced the average time taken to start germination [13]. This result is in agreement with the previous findings [14, 15] in Amaranthus. Additionally, Nitrogen especially nitrate stimulates the germination of Amaranthus [16, 17]. Previously it was reported that many weed species including Amaranthus nitrogenous compounds stimulate germination [18]. Similar findings in variations in germination percentage were also confirmed by previous researchers in Amaranthus [19, 15].

Vermicompost along with Biofertilizers produce or change the concentration of plant hormones, asymbiotic nitrogen fixation, and solubilization of mineral phosphate and other nutrients during germination which improves the seed vigor. This was in line with the previous findings [20, 20, 22] which stated that the seedling vigor index -1 and vigor index -2 increased with the combined application of inorganic fertilizers, organic manures, and biofertilizers.

Moreover, Biofertilizers and organic manures enrich the soil with organic matter content which increases the porosity of the soil which is beneficial to provide a congenial environment to roots for uptake of the available nutrients from the soil. The adequacy of manure decreased the number of days from planting to the first harvest and increased the number of harvests before senescence [23]. These findings are in accordance with previous researchers who observed a higher dose of nitrogen percentage of 20 % N from castor cake + 20 % N from vermicompost + 30 % N from poultry manure + 30 % N from FYM early harvest of the crop was possible [24].

Enhanced nitrogen content encourages increased growth and yield of crops [25, 26]. Since it is the main yield factor and is considered the characteristic constituent of functional plasma, an integral part of chlorophyll molecules, proteins, amino acids nucleic acids (RNA and DNA), nucleotides, phosphotides, alkaloids, enzymes, coenzymes, hormones, vitamins [27]. Due to the application of nitrogen through organic manures, inorganic fertilizers, and biofertilizers, plants received a sufficient amount of other essential elements throughout their growth period and nourished properly which improved the green leaves yield in the first cutting as well as in subsequent cuttings (second and third). These results are similar to the previous findings in Amaranthus [14].

Conclusion

Based on the aforementioned findings, it can be said that application of N: P: K @ 30:20:10 + half dose of vermicompost @1.25 tonnes per ha + Azotobacter @ 200 g/10kg seeds and PSB @ 200 g/10kg seeds was significantly effective in improving the germination, vigor, and yield of amaranthus along with soil physical conditions.

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Table 1: **Effect of Integrated Nutrient Management on Days taken for germination, Germination percentage, Vigour index, Number of days taken to harvest, yield kg/plot.**

Treatments	Days taken for germination	Germination percentage	Vigour index - 1	Vigour index - 2	Number of days taken at 20 cm height			yield kg/plot at 20 cm height		
					1st harvest	2nd harvest	3rd harvest	1st harvest	2nd harvest	3rd harvest
T_1	6.51	58.74	1.93	1.01	32.25	44.90	59.84	0.15	0.20	0.18
T_2	6.10	63.48	2.95	2.24	28.11	40.01	55.64	0.22	0.58	0.40
T_3	4.82	66.20	2.87	2.58	29.75	41.11	52.77	0.21	0.55	0.42
T_4	4.50	70.12	3.49	3.25	28.51	40.68	50.89	0.24	0.61	0.48
T_5	4.79	68.24	3.46	2.79	29.12	41.7	52.59	0.22	0.58	0.41
T_6	5.81	72.91	4.03	3.65	27.68	38.79	50.09	0.27	0.72	0.49
T_7	5.90	69.63	3.61	2.97	27.84	38.97	49.89	0.25	0.63	0.47
T_8	4.33	77.35	4.94	4.51	26.20	36.38	48.26	0.34	0.87	0.62
T_9	4.57	75.61	4.58	4.12	26.86	35.85	48.58	0.31	0.83	0.70
T_{10}	5.01	72.02	4.39	3.74	26.56	38.51	49.01	0.30	0.79	0.53
T_{11}	5.36	73.85	4.23	3.69	27.77	39.14	49.61	0.28	0.77	0.51
T_{12}	3.60	84.53	5.75	5.56	21.65	30.65	41.16	0.50	1.15	0.85
T_{13}	4.10	78.19	5.38	4.85	23.69	32.9	43.86	0.38	0.99	0.74
S. Em. ±	0.16	2.11	0.12	0.20	0.81	1.13	1.46	0.01	0.02	0.01
CD at 5%	0.47	6.17	0.36	0..59	2.37	3.29	4.26	0.02	0.06	0.04