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Vermicompost Enhances the Yield and Quality of Red Amaranth Subjected to Acidic Soil

Munmun Saha^{1*}, Kamrun Nahar Mousomi¹, Abu Rashed Md. Maukeeb², Shimul Mondal³

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ABSTRACT

The study was conducted to evaluate the vermicompost enhances the yield and quality of red amaranth subjected to acidic soil. Five treatments namely, control (T1), cowdung (T2), compost (T3), vermicompost (T4) and lime+100% recommended inorganic fertilizer dose (T5) were considered in acidic soil for the fulfilment of experimental objectives. The experiment was laid out in a randomized complete block design with three replications in the southern part of Bangladesh. All the treatments gave significantly higher yield ($p < 0.05$) while it was compared to the control. Highest yield of red amaranth was observed from the treatment of vermicompost (7.79 tha⁻¹) followed by lime (5.79 tha⁻¹), compost (5.52 tha⁻¹) and cowdung (4.73 tha⁻¹). The result showed that the effects of vermicompost were more efficient in terms of vigorous production, nutrient contents as well as in the maintenance of soil pH for the potential cultivation of red amaranth compared to the other management. Besides these, the nutrients content of red amaranth was also observed and found that the Ca, Mg, K, P, S and Fe were substantially higher in vermicompost except the Zn and B. Mg, K and P content were highly ($r^2 > 0.9$) correlated with the yield. Only vermicompost and lime enhanced 7% and 0.3% of pH over the control. Therefore, in acidic soil the vermicompost would be the best alternative for Red amaranth production.

INTRODUCTION

Red amaranth (*Amaranthus tricolor* L.) cultivation is a big challenge in the Northeastern part of Bangladesh where acidic soil (pH < 6) is a common problem that deteriorates the crop's yield as well as quality. A report on the status of acidic soil subjected to organic matter management revealed that acidic soil remained buffer by the application of organic matter (Jiang et al., 2018). However, in Bangladesh soils, the organic matter content is very low (< 1.5) and is being gradually depleted (Ullah et al., 2008) day by day. Only the use of balanced chemical fertilizer, high yield level could not be maintained over the years because of deterioration in soil physical and biological environments (Khan et al., 2008). Although in small quantities the organic manures contain plant nutrients as compared to the fertilizers, the presence of growth promoting principles like enzymes and hormones, besides plant nutrients make them essential for improvement of soil fertility and productivity (Bhuma, 2001). Available reports also indicate that combined effects of NPKS (25%) and vermicompost (75%) have given higher yield of tomato, cabbage, okra compared to recommended dose of full amount NPKS and control (Islam et al., 2017; Farzana et al., 2019; Akhter et al., 2019). Response of red amaranth to cowdung application is also evident (Sanni, 2016). The organic manure is easily available to the farmers and its cost is low compared to that of inorganic fertilizers.

Red amaranth (*Amaranthus tricolor* L.) is now widely grown as vegetables both in tropics and sub-tropics of the world. It can be grown throughout the year and can be harvested in a very short time. In Bangladesh, *Amaranthus*

tricolor L. is a commonly cultivated vegetables in winter season. It also contains various volatile compounds, polyphenols, antioxidant, antimalarial, and antiviral compounds, which prevent cancer, cardiovascular diseases, diabetes, etc. (Jiang et al., 2011; Khandaker et al., 2008; Shukla et al., 2010). It was reported that amaranth contains protein, ascorbic acid, and mineral nutrients of Ca, Fe, Mg, P, K, and Na, which are considered as the nutritional value in vegetables (USDA, 1984). The cultivation of red amaranth is increasing day by day in Bangladesh (BBS, 2010) although its production is lower than other amaranth producing countries (Talukder, 1999). The chemical fertilizers are used as a supplemental source of nutrients, however farmers do not apply it in a balanced proportion (BARC, 2012). Targeting high yield is the most logical way to raise production from the limited land resources which is why a vast area of acidic soils in the southern belt of Bangladesh should be considered under production. The above-discussed factors in accordance of consideration, this study was undertaken to assess the effects of organic and inorganic fertilizers on yield response of red amaranth to the acid soil and to compare the effects of organic and inorganic fertilizer.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at the research field of the Department of Agricultural Chemistry, Sylhet Agricultural University, Bangladesh during December 20, 2018 to February 5, 2019. The soil was the Agro-ecological Zone of Northern and Eastern Piedmont Plains (AEZ-

¹ Department of Agricultural Chemistry, Sylhet Agricultural University, 3100, Bangladesh

² Department of Agricultural Chemistry, Khulna Agricultural University, 9100, Bangladesh

³ Department of Soil Science, Bangladesh Agricultural Research Institute, Gazipur, 1702, Bangladesh

* Corresponding author's e-mail: munmun.agchm@sau.ac.bd

Table 1: Analysis on the chemical properties of initial soil sample

pH	OM%	OC%	Total N%	P (µg g-1)	K (meq 100g-1)	Ca (meq 100g-1)	Mg (meq 100g-1)	S (µg g-1)	B (µg g-1)
5.2	2.1	1.2	0.14	11	0.14	5.1	1.8	13.5	0.3

OM: Organic Matter; OC: Organic Carbon; meq: Milli equivalent

22) under the “Pritim Pasha” soil series. The experimental soil was collected from a depth of 0-15 cm prior to the application of fertilizers to determine the physical and chemical properties of soil. The physical and chemical characteristics of the collected soil were determined by Hunter method (1984) (Table 1).

Experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The total number of experimental plots were fifteen (15) having the size of 0.48m² (80 cm × 60 cm) of each plot. The treatments were control (T1), cowdung (T2), compost (T3), vermicompost (T4), and lime+100% recommended inorganic fertilizer dose (T5). The whole amount of TSP, MoP, Gypsum, Cowdung, Compost, Vermicompost and half of urea were applied during final land preparation three days before seed sowing. The remaining amount of urea was applied in the third weeks after seed sowing. In the lime treated plots, lime was applied 15 days before applying organic amendments. Seeds of locally cultivated ‘Altapeti’ red amaranth variety (local name-Lalsak) were sown in broadcasting method and the seed rate is 1 kg ha⁻¹ (BARI, 2005). The application rate of chemical fertilizers, organic fertilizers and lime is given in the Table 2 and Table 3.

Intercultural operations

Single weeding and sprinkler irrigation was done at 18 and 20 days after sowing seeds. After one week of seed germination, the extra plants were thinned out from each plot. No control measures were taken because of being no severe disease or pest infestation were observed in the field.

Data collection and Statistical analysis

At harvest, the whole plot was harvested, ten plants were randomly selected from each plot to record the data and the plants were oven dried at 80 °C for 72 hours. Data

on plant height, number of leaves plant⁻¹, shoot and root length, shoot and root fresh and dry weight, total plant population and yield were recorded during harvest. In an acid mixture (1:3 ratio of perchloric: nitric acid) the soil and plant samples were digested to determine iron (Fe), zinc (Zn), potassium (K) and phosphorus (P). By using a spectrophotometer, the phosphorus (P) was determined by phosphomolybdate blue method. By using an atomic absorption spectrometer (AAS) the composition of cations in samples were determined. Soil pH was measured by making a 1:10 ratio of soil: solution and waiting for exactly 10 minutes. The statistical analyses of the recorded data were done by using Rstudio software and Sigma plot 14.0 version and the means were separated by using Least Significant Difference (LSD) Test.

RESULTS

Total Plant Population

Total plant population means the total number of plants per plot. The effect of different organic and inorganic fertilizers on the total plant population of Red amaranth was significantly ($p < 0.05$) higher. The highest total plant population (337) were obtained from the vermicompost followed by cowdung, compost and lime and the lowest total plant population (223.67) was found in control treatments, respectively (figure 1). Our result indicates that vermicompost is probably more effective for reducing the effect of acid soil that may maintain the proper plant population.

Number of leaves per plant

The effect of different organic and inorganic fertilizers on the number of leaves per plant of red amaranth was significant. The maximum number of leaves per plant (10.03) was recorded from vermicompost and the minimum (6.47) number of leaves per plant was recorded from the control treatments (figure 1). The rest of the treatments also followed similarly of the total plant

Table 2: Application rate of organic and inorganic fertilizers in each plot of experimental field

Name of the Fertilizers	Application rate	Application rate in each plot
Cowdung	5 tha-1	240 g
Compost	5 tha-1	240 g
Vermicompost	4 tha-1	192 g
Lime	0.98 tha-1 or 4 kg decimal -1	47.41 g
Recommended dose of inorganic fertilizer	150-23-17-4 kg ha-1 of N-P-K-Gypsum, respectively	7.2-1.1-0.8-0.192 g of N-P-K-Gypsum, respectively

Table 3: Chemical component of organic and inorganic fertilizers

Organic and inorganic fertilizers	Ca	Mg	N	P	K	Fe	Zn	S	B
Cowdung	0.87	0.52	1.1	0.24	0.56	0.36	0.01	0.11	0.012
Compost	2.29	1.38	0.89	0.11	0.88	0.36	0.048	0.46	0.018
Vermicompost	1.16	0.97	1.93	0.83	0.9	0.36	0.019	0.27	0.016
Lime	39.84	0.001	0.58	0.08	0.01	0.31	0.001	0.04	0.013

population number.

Plant height

Different organic fertilizers significantly influenced the plant height of red amaranth. All the treatments showed significantly higher ($p < 0.05$) plant height than the control. The highest (43.06 cm) and lowest (26.95 cm) plant heights were recorded from vermicompost and the control treatments, respectively. The compost, cowdung, lime+100 inorganic fertilizers gave 33.82 cm, 31.60 and 36.57 cm, respectively (figure 1)

Shoot and root length

The shoot length is an important yield contributing parameter of red amaranth. After the harvest of the crop, the shoot length and root length were measured. Application of different treatments performed

significantly ($p < 0.01$) and varied widely over the control. The highest shoot and root length (32.82cm and 10 cm) were obtained from vermicompost and the lowest shoot and root length (20.77 cm and 6.19cm) were found in control treatments, respectively.

Fresh weight

Fresh weight for all the treatments over control significantly increased ($p < 0.05$). However, the highest and the lowest shoot fresh weight (102.35g and 72.73g) that were obtained from vermicompost and control. After vermicompost; lime + 100% recommended fertilizer gave the higher level of fresh weight (92.25g) followed by compost (80.27g) and cowdung (80.27g). Fresh weight in crop plants indicate the proper growth and development by maintaining cell turgidity.

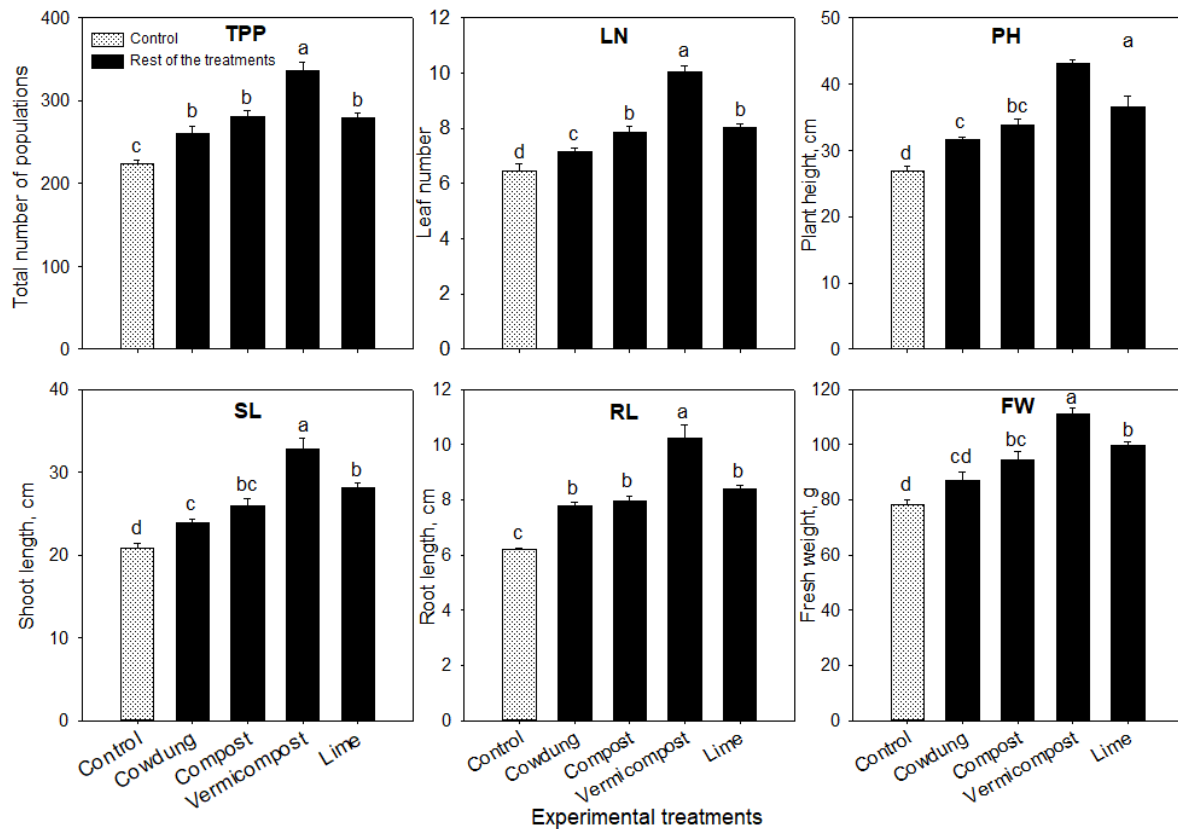


Figure 1: Morphological characters of red amaranth for different organic and inorganic nutrient sources. Different letters indicate significant treatment differences ($p < 0.05$), whiskers indicate individual \pm standard error of the mean. The sample number, $n=3$.

Root shoot dry weight

By various treatments, the highest root dry weight was obtained from the compost (1.10g) followed by vermicompost (0.9g), lime (0.71g) and cowdung (0.63). Only compost and vermicompost gave a significantly higher yield ($p < 0.05$) than the control. On the other hand, shoot dry weight under vermicompost showed a maximum level of dry weight compared to the control. Lime and compost gave a similar level of shoot dry weight. Our results indicate vermicompost maintains a

higher level of shoot and root dry weight compared to other treatments (figure 2).

Yield

Variation among the treatments corresponding to red amaranth's yield was highly significant ($p < 0.001$). The highest yield (7.79 t/ha) was found in vermicompost followed by lime (5.79 tha⁻¹), compost (5.52 tha⁻¹) and cowdung (4.73tha⁻¹) and the lowest yield (3.64t ha⁻¹) was recorded in control (figure 2).

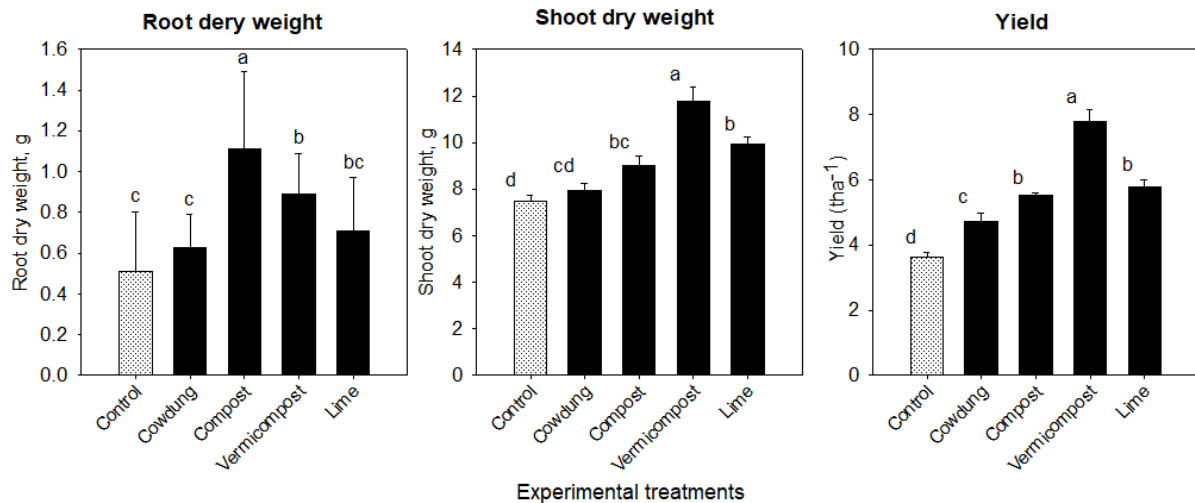


Figure 2: Yield of red amaranth for different organic and inorganic nutrient sources. Different letters indicate significant treatment differences ($p < 0.05$), whiskers indicate individual standard deviation of the mean. NS = Not significant, **indicates significant at 1% level of probability. Figures in a column having the same or no letter(s) do not differ significantly.

Nutrient Composition

Ca

Calcium content of red amaranth resulting from the effect of different organic and inorganic fertilizers was statistically significant ($p < 0.05$). The highest (2.11%) Ca was obtained from the plants treated with vermicompost and the minimum (1.48%) Ca was recorded from the plants under control treatment.

Mg

The maximum and minimum Mg contents were obtained from the plant treated with vermicompost (1.04%) and control (0.56%) treatments, respectively.

K

The highest amount of potassium content (3.56%) was recorded from the treatment of vermicompost and the lowest amount of potassium (2.02%) was recorded from the control treatment (Table 4). Vermicompost application showed a higher amount of potassium compared with other organic fertilizers.

P

Phosphorus content of red amaranth varied from 0.43 to 0.84% due to the application of different organic and inorganic fertilizers. The maximum and minimum P content in red amaranth were obtained from the plants treated with vermicompost (0.84%) and the plants under control treatment (0.43%), respectively.

S

Significant variation was observed in S content due to different organic and inorganic fertilizer applications. The highest amount of sulphur content (0.38%) was obtained from vermicompost and the lowest amount of sulphur content (0.15%) was recorded from the control

treatment (Table 4).

B

Micronutrient content was also significantly affected by both organic and inorganic amendments. Intrinsicly B availability is low in acidic soil and high rainfall deteriorates the situation with the leaching of B that become adsorbed to Fe and Al oxides. The amount of B content varied from 20 to 52 $\mu\text{g g}^{-1}$. The maximum and minimum B contents were obtained from compost (52 $\mu\text{g g}^{-1}$) treated plants and the plants under control treatment (20 $\mu\text{g g}^{-1}$), respectively.

Zn and Fe

Significant variations were observed in the Zn and Fe content of red amaranth due to the application of different organic and inorganic amendments. The highest Zn and Fe content of red amaranth (93.70 $\mu\text{g g}^{-1}$ and 990.17 $\mu\text{g g}^{-1}$) were obtained from the treatment of cowdung and vermicompost and the lowest Zn and Fe content (50.00 $\mu\text{g g}^{-1}$ and 766.33 $\mu\text{g g}^{-1}$) were found in control treatments, respectively (Table 4). Solubility of nutrients in the soil can also be increased due to the substantial increase of Zn and Fe content with liming. The negative charge of OM in the soil becomes higher and gets hydrated, because of increased pH after liming.

Correlation between yield/yield component and nutrient composition

A simple correlation was followed between the nutrient elements and yield to understand the effect of nutrients element on the yield. Our result showed that Mg, K and P are highly correlated with yield compared to Ca, Fe and S (Figure 3). This result indicated that organic fertilizers and lime are highly correlated with the yield and vermicompost is the most responsible treatment.

Table 4: Nutrient contents of Red amaranth under different sources of organic and inorganic nutrients.

Treatments	Ca(%)	Mg(%)	K(%)	P(%)	S(%)	Zn(ppm)	Fe(ppm)	B(ppm)
T1	1.48d	0.56e	2.02e	0.43d	0.15d	50.00d	766.33d	20.00d
T2	1.83b	0.69d	2.38d	0.61 c	0.20c	93.70a	886.33b	29.00c
T3	1.62c	0.81c	2.73c	0.71b	0.27b	72.00c	832.67c	52.00a
T4	2.11a	1.04a	3.56a	0.84a	0.38a	83.45b	990.17a	37.00b
T5	1.63c	0.73b	3.01b	0.64bc	0.21c	75.45c	852.67c	26.33 c
CV (%)	3.44	4.72	3.92	6.07	8.64	3.55	1.38	8.59
LSD	0.11	0.07	0.20	0.07	0.04	5.01	22.43	5.32
Level of significance	**	**	**	**	**	**	**	**

NS = Not significant, **indicates significant at 1% level of probability. Figures in a column having same or no letter(s) do not differ significantly. Treatment T1=Control, T2=Cowdung, T3=Compost, T4=Vermicompost, T5= Lime+100% recommended fertilizers. Values are \pm standard error, n=3.

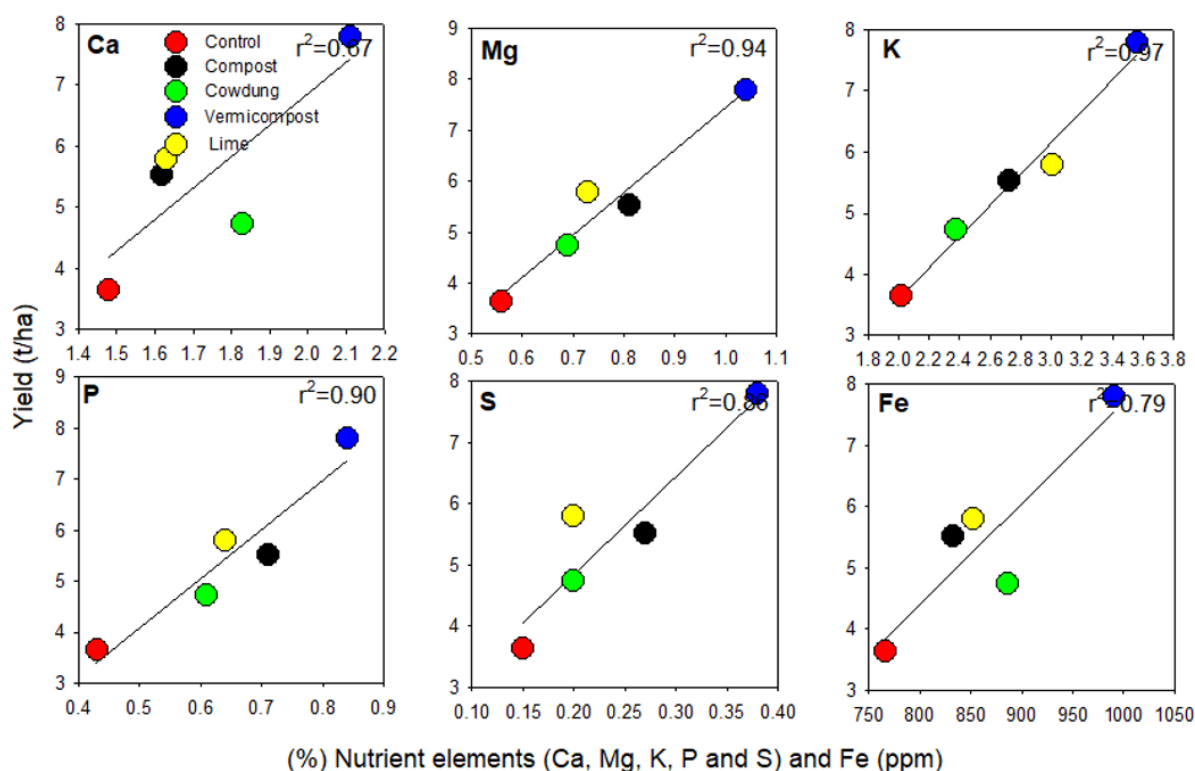


Figure 3: A correlation between yield and nutrient elements subjected to five different treatments. Red, black, green, blue and yellow colors indicate control, compost, cowdung, vermicompost and lime +100% recommended fertilizers.

DISCUSSION

Organic matters may overcome the problem of acid soil for Red amaranth production

Soil organic matters are applied to the acid soil for replenishing the soil pH which is crucial for the smooth growth and development of vegetable crops. It is reported that acid soils with plant residue compost, urban waste compost and manure have all been used to increase soil pH (Alter and Mitchell 1992; Hue, 1992; Watt et al., 1991). The mechanism behind the increasing soil pH is the specific absorption of organic anions that correspond to the release of hydroxyl ions (Hue, 1992). Other findings showed that low pH reduced crop yield greatly which can be solved by the application of compost (Halim et al., 2018). Our findings also showed that acid soil treated after organic matter, especially vermicompost enhanced plant population, leaf no., plant height, fresh weight,

dry weight and yield significantly. Thus, the application of vermicompost significantly increased plant height for the improvement of soil physical properties (Jahan et al., 2014). This result might be due to plant growth regulators and other plant growth influencing materials produced by microorganisms present in vermicompost (Grappelli et al., 1987). Significant variations in root fresh and dry weight of red amaranth were observed from the effect of different organic fertilizers. A similar result was found that the average yield of *Amaranthus* species was enhanced by vermicompost application (Uma and Malathi, 2009). Moreover, the soil's physical properties; particularly soil porosity, structure, water holding capacity and supplied other plant growth promoting substances improved due to vermicompost. The highest and lowest root fresh and dry weights were obtained from compost (9.83g and 1.11g) and control treatment (5.57g and 0.51g),

respectively (figure 1 and figure 2) and these indicate the effects of vermicompost are more efficient than chemical and other organic fertilizers for the production of red amaranth. Bongkyoon (2004) reported that the effect of vermicompost application was more favorable than the effects of the application of chemical fertilizers. Our result also shows that vermicompost enhances 7% pH over control (Appendix A) in acid soil which may play a great role in smoothing red amaranth production in acid soil.

Vermicompost enhances Ca, Mg, K and S which denotes the good quality of red amaranth

Calcium is a very important mineral in human metabolism, making up about 1-2% of an adult human's body weight. It was evident that vermicompost applications showed higher calcium content than other organic or inorganic fertilizer applications. In a similar study, it was observed that calcium content was higher in vermicompost compared to other compost applied in crop production (Singh, 2009). Besides Ca, Magnesium deficiency can lead to a significant amount of chlorosis, and drooping leaves (Soetan et al., 2010) in many types of vegetables. Many critical physiological and biochemical processes in plants are adversely affected by Mg deficiency, leading to impairments in growth and yield (Cakmak and Yazici, 2010). Mg content of red amaranth ranged from 0.56 to 1.04%, which was statistically significant than the control especially compared to the vermicompost. Not only Ca and Mg, Potassium also increased in red amaranth leaves under the treatments of organic matter, especially vermicompost in our experiment. In acidic conditions cation exchange capacity (CEC) decreases, thereby inducing K deficiency in soil (Slattery et al., 1999). Because of liming, acidic ions become neutralized and alleviate K⁺ absorption inhibition (Silva et al., 2008). Potassium is an important plant nutrient and is good for human health as diets having high potassium are associated with improved blood pressure control and improved kidney function. (Mateljan, 2015). In addition Phosphorus content is enhanced by vermicompost on Amaranthus production (Uma and Malathi, 2009).

In the case of vermicompost, P content was found double that in control plots. However, cowdung, compost and lime +100% recommended fertilizers applications also showed a significant increase in P content than in the control treatment. It indicates the ready availability of P in the soil after organic and inorganic fertilizers application in acidic soil. We also showed that a higher amount of sulphur was found under the treatment

of vermicompost compared to the control, cowdung, compost and lime-treated soil. Our result was supported by (Kmetova and Kovacik, 2014) who found that the impact of vermicompost on the yield of maize (*Zea mays L.*) to the phenological growth stages, was significantly higher compared to other chemical fertilizers.

Higher yield, nutrient elements are strongly corelated

To know the specific relationship among yield, leaf number, plant height and nutrient elements in red amaranth, we calculated the correlation between yield and nutrients elements and found that higher yield strongly correlated to the nutrient elements. Mg, K and P were highly correlated with the yield. Anac et al. (2007) found that K enhances the yield quality, test and vitamins content in spinach where balance fertilizers play an important role. A report suggested that effect of phosphorus rates on growth, yield, and postharvest quality of tomato significantly increased subjected to the calcareous soil (Zhu, 2017). Beside K and P, Magnesium deficiency in acid soil is another crucial element for sustainable crop production which may deteriorate the yield and quality of crops (Wang et al., 2020).

Our overall discussion explicit that vermicompost could be the best alternative than the other organic matter like cowdung and compost in order to the yield, quality and soil improvement. The post soil (Appendix A) analysis also reveals that vermicompost added more nutrient elements to the soil which is very much essential for subsequent crop production.

CONCLUSION

We were able to figure out the best effect of specific organic fertilizer. In this case, vermicompost was the best performer compared to cowdung, compost and lime + 100% recommended inorganic fertilizers who gave the highest plant height, number of leaves, shoot and root length, shoot fresh and dry weight, total plant population and yield. Vermicompost improved comparatively the yield and quality of Red amaranth in acid soil compared to the compost, cowdung and lime+100% recommended fertilizer. Vermicompost also increased 7% pH which is obviously important for the growth and development for red amaranth in acidic soil.

Therefore, it is suggested that farmers may use vermicompost (low production cost) in their crop fields which is easily available, nutrient rich, economically and environmentally suitable. We suggest that vermicompost would be the best alternative for Red amaranth production in acidic soil.

Appendix A Post harvest analysis of soil after harvesting the red amaranth crop

Treatment	pH	OM (%)	OM (%)	N (%)	Ca (g/kg)	Mg (g/kg)	K (g/kg)	P (ppm)	S (ppm)	Fe (ppm)
Control	5.52	3.04	3.04	0.161	2.08	0.4374	0.195	21	40.1	107
Cowdung	5.28	2.99	2.99	0.158	2.04	0.4374	0.312	22	37.3	120
Compost	5.5	2.72	2.72	0.144	2.04	0.4131	0.2964	28	50.7	119
Vermicompost	5.94	2.71	2.71	0.143	2.12	0.4617	0.429	26	53.9	106
Lime	5.54	2.64	2.64	0.139	2.08	0.4374	0.39	28	33.3	112

REFERENCES

- Abdul Halim, N.S., Abdullah, R., Karsani, S.A., Osman, N., Panhwar, Q.A., & Ishak, C.F. (2018). Influence of soil amendments on the growth and yield of rice in acidic soil. *Agronomy*, 8(9), p.165.
- Akhter, S., Islam, M. A., & Karim, M. R. (2019). Effects of nutrient management and netting on growth and yield of okra." *Fundamental and Applied Agriculture*, 4 (1), 627-631.
- Alter, D., & Mitchell, A. (1992). "Use of vermicompost extract as an aluminium inhibitor in aqueous solutions." *Communications in soil science and plant analysis*, 23(3-4), 231-240.
- Anaç, D., & Pierre Martin P. (Eds.). (2007). *Improved crop quality by nutrient management*, 86. Springer Science & Business Media.
- BARC. (2012). *Fertilizer Recommendation Guide*. Bangladesh Agricultural Research Council. Dhaka, Bangladesh.
- BARI Annual report. (2005). *Annual report of Bangladesh Agricultural Research Institute (BARI)*. Retrieved: <http://www.bari.gov.bd>
- BBS. (2010). *Yearbook of Agricultural Statistics of Bangladesh*. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Bangladesh. Dhaka, Bangladesh, pp. 100-109.
- Bhuma, M. (2001). Studies on the impact of humic acid on sustenance of soil fertility and productivity of green gram (VBNGG-2). M. Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, TN (INDIA).
- Brunner, W., & Blaser, P. (1989). Mineralization of soil organic matter and added carbon substrates in two acidic soils with high non-exchangeable aluminum. *Zeitschrift für Pflanzenernährung und Bodenkunde*, 152(4), 367-372.
- Cakmak, I., & Yazici, A. M. (2010). Magnesium: a forgotten element in crop production. *Better crops*, 94(2), 23-25.
- Farjana, S., Islam, M. A., & Haque, T. (2019). Effects of organic and inorganic fertilizers and mulching on growth and yield of cabbage (*Brassica oleracea* var. capitata L.). *Journal of Horticulture and Postharvest Research*, 2(2), 95-104.
- Grapeelli, A., Galli, E., & Tomati, U. (1987). Earthworm casting effect on *Agaricus bisporus* fructification. *Agrochimica*, 31(4-5), 457-462.
- Hue, N. V. (1992). Correcting soil acidity of a highly weathered Ultisol with chicken manure and sewage sludge. *Communications in soil science and plant analysis*, 23(3-4), 241-264.
- Islam, M. A., Islam, S., Akter, A., Rahman, M. H., & Nandwani, D. (2017). Effect of organic and inorganic fertilizers on soil properties and the growth, yield and quality of tomato in Mymensingh, Bangladesh. *Agriculture*, 7(3), 18.
- Jahan, F. N., Shahjalal, A. T. M., Paul, A. K., Mehraj, H., & Jamal Uddin, A. F. M. (2014). *Efficacy of vermicompost and conventional compost on growth and yield of cauliflower*. *Bangladesh Research Publications Journal*, 10(1), 33-38.
- Jiang, J., Wang, Y. P., Yu, M., Cao, N., & Yan, J. (2018). Soil organic matter is important for acid buffering and reducing aluminum leaching from acidic forest soils. *Chemical Geology*, 501, 86-94.
- Jiang, Y., Zhao, N., Wang, F., & Chen, F. (2011). Emission and regulation of volatile chemicals from globe amaranth flowers. *Journal of the American Society for Horticultural Science*, 136(1), 16-22.
- Kang, B. K. (2004). Effects of vermicompost on growth of fall-cropping potato in volcanic ash soil. *KOREAN JOURNAL OF CROP SCIENCE*, 49(4), 305-308.
- Khan, M.S., Shil, N.C., & Noor S. (2008). Integrated nutrient management for sustainable yield of major vegetable crops in Bangladesh." *Bangladesh Journal of Agriculture and Environment*, 4 (5), 81-94.
- Khandaker, L., Ali, M.B., & Oba, S. (2008). Total polyphenol and antioxidant activity of red amaranth (*Amaranthus tricolor* L.) as affected by different sunlight level. *Journal of the Japanese Society for Horticultural Science*, 77(4), 395-401.
- Kmet'ová, M., & Kováčik, P. (2014). The impact of vermicompost application on the yield parameters of maize (*Zea mays* L.) observed in selected phenological growth stages (BBCH-SCALE). *Acta fytotechnica et zootecnica*, 17(4), 100-108.
- Mateljan, G. (2015). *The World's Healthiest Foods: The Force for Change to Optimal with Health-promoting Foods and Nutrient-rich Cooking*. GMF Publishing.
- Sanni, K.O. (2016). Effect of compost, cow dung and NPK 15-15-15 fertilizer on growth and yield performance of Amaranth (*Amaranthus hybridus*)." *International Journal of Advances in Scientific Research*, 2(3), 76-82.
- Shukla, S., Bhargava, A., Chatterjee, A., Pandey, A.C., & Mishra B.K. (2010). Diversity in phenotypic and nutritional traits in vegetable amaranth (*Amaranthus tricolor*), a nutritionally underutilised crop. *Journal of the Science of Food and Agriculture*, 90(1), 139-144.
- Silva, T. R. B. D., & Lemos, L. B. (2008). Efeito da calagem superficial em plantio direto na concentração de cátions hidrossolúveis na parte aérea de culturas anuais. *Revista Brasileira de Ciência do Solo*, 32, 1199-1207.
- Singh, K. (2009). Microbial and Nutritional analysis of vermicompost, aerobic, and anaerobic compost. *Griffith University, Brisbane, Australia*.
- Singh, W. R., Pankaj, S. K., & Kalamdhad, A. S. (2015). Reduction of bioavailability and leachability of heavy metals during agitated pile composting of *Salvinia natans* weed of Loktak lake. *International Journal of Recycling of Organic Waste in Agriculture*, 4(2), 143-156.
- Slattery, W. J., Conyers, M. K., & Aitken, R. L. (1999). Soil pH, aluminum, manganese, and lime requirement. In 'Soil analysis: an interpretation manual'. (Eds KI Peverill, LA Sparrow, DJ Reuter) pp. 103-128.
- Soetan, K.O., Olaiya, C.O., & E. Oyewole, O. (2010). The importance of mineral elements for humans,

- domestic animals, and plants-A review. *African journal of food science*, 4(5), 200-222.
- Talukder, M.S.A. (1999). Effect of plant density on green yield and seed production in different amaranths. MS Thesis, BSMRAU, Salna, Gazipur.
- Ullah, M.S., Islam, M.S., Islam, M.A., & Haque, T. (2008). Effects of organic manures and chemical fertilizers on the yield of brinjal and soil properties." *Journal of the Bangladesh Agricultural University*, 6(2), 271-276.
- Uma, B., & Malathi, M. (2009). Vermicompost as a soil supplement to improve growth and yield of *Amaranthus* species." *Res. J. Agric. Biol. Sci.*, 5(6), 1054-1060.
- USDA ARS Nutrient Data Lab. (1984). Oxalic acid content of selected vegetables. Composition of foods: vegetables and vegetable products. Agricultural handbook No. 8-11, 1-18 <https://www.nal.usda.gov/legacy/fnic/usda-nutrient-data-laboratory>.
- Van der Watt, H. V. H., Barnard, R. O., Cronje, I. J., Dekker, J., Croft, G. J. B., & Van der WALT, M. M. (1991). Amelioration of subsoil acidity by application of a coal-derived calcium fulvate to the soil surface. *Nature*, 350(6314), 146-148.
- Wang, Z., Hassan, M. U., Nadeem, F., Wu, L., Zhang, F., & Li, X. (2020). Magnesium fertilization improves crop yield in most production systems: a meta-analysis. *Frontiers in plant science*, 1727.
- Zhu, Q., Ozores-Hampton, M., Li, Y., Morgan, K., Liu, G., & Mylavarapu, R. S. (2017). Effect of phosphorus rates on growth, yield, and postharvest quality of tomato in a calcareous soil. *HortScience*, 52(10), 1406-1412.