EFFECTS OF AMENDING COMPOST AND GREEN MANURE WITH PHOSPHATE ROCK ON QUALITY OF AMARANTH

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ABSTRACT

A study was conducted in Iringa, Tanzania to evaluate the effects of crotalaria green manure and compost applied alone or amended with Minjingu Phosphate Rock (MPR) as sources of N and P and their effects on vegetable quality attributes. The field experiment was conducted using a split plot design with three replications. Crop species formed main plots, while fertilizer treatments constituted the subplots. Two amaranth species (*Amaranthus cruentus* and *Amaranthus hypochondriacus*) were used. The treatments included crotalaria (*Crotalaria ochroleuca*), crotalaria + MPR, compost, compost + MPR and NPK, which was used as a standard. Results indicated that amendment of compost or crotalaria with MPR enhanced P supply by 22% and 100%, respectively. The tested materials significantly increased vitamin C, vitamin A and crude protein content of amaranth. Plants from plots treated with crotalaria had significantly higher levels of protein, calcium, vitamins C and A contents, compared to those fertilized with compost. There were significant and positive correlations between soil available N, P, and uptake with protein, calcium, iron, vitamin C and A content of amaranth. Due to the role of Ca in cell wall synthesis, it probably influenced the keeping quality of amaranth. The high Ca content in MPR amended treatments increased the evaluated keeping quality attributes of amaranth. It is therefore recommended that the tested organic materials be adopted as sources of N and P in the organic production of amaranth. Application of crotalaria and compost should be supplemented with P sources such as MPR in order to increase their P contents.

Key words: Organic farming, Minjingu phosphate rock, Vegetables, Quality

INTRODUCTION

Vegetables are good sources of vitamins, minerals and proteins, all of which contribute to the good health of people (Tindall, 1983). Apart from their nutritive values, vegetables are also sources of income. Amaranth (*Amaranthus* spp.) is among the most commonly grown vegetable in Tanzania. It is grown using both conventional and organic farming methods. For optimum yields, amaranth demands high levels of soil nitrogen (N) and phosphorus (P) (Tindall, 1983). This implies that the sole use of organic materials for production of this vegetable crop in areas with low soil P, such as Southern Highlands of Tanzania, may not supply adequate amounts of P thus requiring additional source (Nziguheba et al., 2002). Phosphate rock (PR) is acceptable for use in organic farming due to its natural and slow P releasing characteristics (Walker et al., 2006). However, rock phosphate is more effective when applied to perennial crop species than to the short-term annual crops like amaranth. This is because the release of P increases with the time of contact between soil and PR. Amendment of organic materials with PR increase soil available P through enhanced dissolution caused by the released acids from the decomposing matters (Deshpande et al., 1988).

The claims that quality of organically grown food is superior to those grown conventionally are still under debate due to inadequate scientific evidence. Normally, the quality of a food product refers to its desirability, edibility, appearance, safety, and its nutritional content. It is based on the beneficial or harmful chemical components and its behaviour over time under storage conditions (Raupp, 1998). The quality of horticultural produce can be affected during plant growth, post-harvest handling, storage and processing. For example, conditions favourable to water loss after harvest result in a rapid loss of vitamin C, especially in leafy vegetables (Lee and Kader, 2000).

The use of fertilizers affects the quality of agricultural products including nutritional composition (Roinila and Granstedt, 1995). Nitrogen fertilizers at high rates tend to increase nitrate accumulation, and decrease the content of vitamin C in many fruits and vegetables (Babik et al., 2002). However, most studies have only related fertilizers with yield or nutritional value responses without clear relationship with the availability of soil nutrients. The difference between availability of nutrients from organic and inorganic sources and their relationship with quality of vegetables is not very clearly understood. Since the plant roots absorb nutrients in simple ionic forms like NO_3^- and NH_4^+, there is no difference whether they are derived from organic or mineral sources (Giller, 2002).

The objective of the present study was to evaluate the effects of crotalaria green manure and compost applied alone or in combination with Minjingu Phosphate Rock (MPR) on availability of soil N and P and quality of amaranth vegetables.

MATERIALS AND METHODS

The field experiment was conducted at the Tanzania Tree Seed Agency (TTSA) centre located at 70 49’ S and 350 41’ E at an altitude of 1548 m above sea level. The experiment was conducted from September 2000 to September 2002, and was repeated three times. Soil characterization was conducted at the beginning of the experiment. Soil samples were randomly collected at a depth of 20 cm to represent the experimental area. Samples for laboratory analysis were air-dried, ground and sieved to pass through a 2 mm sieve. Samples were analysed for soil texture, soil bulk density, soil pH, total N, extractable P, organic C, exchangeable levels of K, Mg, Ca, Al and cation exchange capacity (CEC). Results are presented in Table 1.

Table 1. Physical and chemical properties of the soils used in the study

Soil characteristic	Value/class	Remark*
PH (H_20) 1:2.5	5.8	Medium
Organic carbon (%)	0.54	Low
Total N (%)	0.28	Medium
Extractable P (ppm)	4.26	Low
Exchangeable bases (cmol/kg)		
Ca^{2+}	2.39	Low
Mg^{2+}	0.52	Medium
K+	0.34	Medium
Al^{3+}	0.05	Low
CEC (cmol/kg)	6.43	Low
Clay (%)	13	
Silt (%)	14	
Sand (%)	73	
Textural class	Sandy loam	
Bulk density	1.58	

* According to Landon (1991)

Experimental Design and Preparation of Materials

The field experiment was laid out in a split plot design with three replications. Crop species constituted the main plots, while fertilizer treatments formed the subplots. Two commonly grown amaranth species, *Amaranthus cruentus* and *Amaranthus hypochondriacus* were used. Fertilizer treatments included: (i) control (no fertilizer material added), (ii) compost, (iii) compost + MPR, (iv) crotalaria green manure, (v) crotalaria green manure + MPR, and (vi) NPK (standard).

Compost was prepared using the heap method as described by the Henry Doubleday Research Association (HDRA) (1998). Materials used included crop residues mainly from chopped maize stalks, fruit and vegetable scraps from mangoes, oranges, passion fruits, pineapples, chilli, and tomatoes, dairy cattle manure, wood ash, a thin layer of top-soil and green grass. Minjingu phosphate rock was added to the layers in one of the compost heaps to make phospho-compost.

Seeds of *Crotalaria ochroleuca* were directly sown on the experimental plots at a rate of 50 kg/ha. Crotalaria plants were uprooted at flowering stage, chopped and incorporated into the soil. The MPR (49 kg P/ha) was broadcast evenly on the green manure at the time of incorporation into the soil, to come up with green manure + MPR treatment. The rate of application for green manure and compost was based on N content of these materials and N requirement of amaranth crop. Seeds of *A. cruentus* and *A. hypochondriacus* were sown at a spacing of 30 cm between rows and 15 cm within rows. Plots used were 3 m wide and 3 m long, giving a plot size of 9 m^2. Weeding and irrigation were done when necessary.

Data Collection and Analysis

Soil samples were collected from the plots after each harvest. The soil samples were analysed for available levels of N and P. Tissue concentrations of N and P in the plant materials were determined following procedures outlined by Okalebo et al. (1993). These values were then used to compute N and P uptake.

Ten amaranth plants randomly picked from each treatment were used for quality analysis. Vitamin C content was determined using the 2,6-dichlorophenol-indophenol method (Plumer, 1974). Vitamin A was determined by the spectrophotometric method (AOAC, 1995). Iron and Ca contents were determined using the atomic absorption spectrophotometric method (AOAC, 1995). Nitrogen content was determined by using the automated Kjeldahl method (AOAC, 1995). Nitrogen content values were multiplied by a factor 6.25 to obtain crude protein. For keeping quality, amaranth leaf samples were washed, blanched, dried, packaged in polyethylene bags and then stored at room temperature for 28 days. Vitamin C content before and after storage was considered as the main indicator of keeping quality as proposed by Raupp (1998).

Data collected from each experiment was analysed using the MSTAT-C statistical package (Michigan State University, 1991). The analysis of variance (ANOVA) procedures were applied as described by Steel and Torrie (1980). Duncan's Multiple Range Test at P=0.05 was used to separate means. Simple correlation coefficients between different soil fertility parameters against quality parameters were also determined.

RESULTS AND DISCUSSION

Effect of Treatments on Availability of N and P in Soil and Uptake by Amaranth Plants

Fertilizer materials significantly (P<0.05) improved availability of N and P in the soil (Table 2). Plots treated with NPK had the highest available N and P that is ascribed to higher solubility and hence higher rate of release of mineral N and P compared to the organic amendments. Variation in the rate and timing of releasing P among fertilizer materials could explain the high CV (%) values observed on soil available P. The level of variation decreased in subsequent crop cycles due to build up of P in the organic treatments.

Crotalaria was more effective in increasing soil N than compost probably due to its higher N content. However, there were lower available N levels in the plots treated with crotalaria + MPR compared to those treated with crotalaria alone. This may have resulted from the influence of P on the rate of crotalaria decomposition and release of N. In the presence of PR more P was available thus enhanced provision of energy to the microbes involved in decomposition (Somado et al., 2002). It is also possible that P enhanced more root development and root mass, which influenced more N uptake.

Table 2. Effect of treatments on N and P availability in soil and uptake by amaranth plants

	Available N (mg/kg)		Available P (mg/kg)		N uptake (kg/ha)	P uptake (kg/ha)
Treatment	1st crop	3rd crop	1st crop	3rd crop	3rd crop	3rd crop
Species						
A. cruentus	13.23a	18.29a	14.33a	44.44a	83.28a	10.97a
A. hypochondriacus	10.08a	17.37a	15.35a	47.17a	92.89a	9.53a
SE +	1.01	1.63	4.68	1.70	7.68	0.99
Fertilizer types						
Compost	7.91c*	11.77c	11.28b	37.01bc	54.42d*	7.23d
Compost + MPR	9.45c	13.03c	11.48b	45.15b	66.57d	10.58c
Crotalaria	12.95b	20.34b	7.17b	17.95cd	98.36c	8.85cd
Crotalaria + MPR	9.17c	13.91c	13.63b	34.59bc	117.60b	13.14b
NPK	21.31a	38.25a	39.97a	129.93a	164.91a	19.89a
Control	9.14c	9.69c	5.49b	10.20d	24.64e	1.82de
Mean	11.65	17.83	14.84	45.81	88.08	10.25
SE +	1.17	2.12	4.01	6.72	6.44	0.79
CV (%)	25	29	66	36	18	19
$LSD_{0.05}$	3.44	6.24	11.82	19.83	18.99	2.32

* = Means in the same column followed by the same letter are not significantly different at P=0.05 according to DMRT. *A. cruentus* = *Amaranthus cruentus, A. hypochondriacus* = *Amaranthus hypochondriacus,* MPR = Minjingu Phosphate Rock, SE = Standard error

This was reflected by the higher N uptake by plants treated with crotalaria + MPR. Soil available P in plots treated with crotalaria alone did not differ significantly from the control probably due to its low P content (Gachene et al., 1999). Amendment of compost or crotalaria with MPR increased soil availability and plant uptake of P. This could be due to increased MPR dissolution enhanced by the decomposing organic matter and the formation of Ca and organic matter complexes (Van Straiten, 2002). This is also in agreement with the results reported by Samina et al. (2002), who obtained maximum P uptake by rice plants, with the application of green manure plus rock phosphate.

Effects of Fertilizer Materials on Nutritional Quality of Amaranth

Amaranth plants from plots treated with NPK and crotalaria had significantly higher protein content than those from plots treated with compost and the control (Table 3). This trend suggests that crude protein content was associated with the ability of the fertilizer materials to supply plant nutrients particularly N. These variations were consistent to the results on soil available N and P (Table 2).

Table 3. Effects of fertilizer materials on nutritional quality of amaranth in the third crop cycle

Treatment	Crude protein content (%)	Calcium (mg/100g)	Iron (mg/100g)	Vitamin C (mg/100g)	Vitamin A (µg beta-carotene/100g)
Species					
A. cruentus	21.77a	422.66a	6.41a	37.53a	1835.90a
A. hypochondriacus	23.91a	468.57a	8.13a	42.49a	1994.07a
SE +	0.25	13.55	0.51	2.99	17.34
Fertilizer types					
Compost	18.89c	433.80bc*	7.20bc	36.05c	1910.65d
Compost + MPR	20.04c	426.69c	6.40cd	38.33bc	1956.43d
Crotalaria	24.67b	470.46abc	7.38bc	42.93abc	2018.38c
Crotalaria + MPR	24.48b	480.76ab	8.29ab	46.99ab	2136.00b
NPK	28.52a	495.85a	8.97a	49.55a	2242.56a
Control	20.46c	366.11d	5.36d	26.16d	1225.92e
Mean	22.84	445.61	7.27	40.00	1914.99
SE +	0.74	16.36	0.47	2.97	20.38
CV (%)	8	9	16	18	12
$LSD_{0.05}$	2.19	48.25	1.39	8.77	60.11

* Means in the same column followed by the same letter are not significantly different at *P*=0.05 according to DMRT. *A. cruentus = Amaranthus cruentus, A. hypochondriacus = Amaranthus hypochondriacus,* MPR = Minjingu Phosphate Rock, SE = Standard error.

This was supported by the highly significant ($P<0.01$) positive correlation between uptake and soil available N and P with crude protein contents of amaranth (Table 4). This is expected since N and P are constituents of proteins and amino acids in plants (Tandon, 1995). Therefore, the higher uptake of N and P in amaranth plants would mean higher protein synthesis.

Calcium content in the edible portions of amaranth plants for all fertilizer treatments was significantly higher than the control. According to West et al. (1987), raw amaranth contains 410 mg/100 g calcium. This suggests that all fertilizer materials were effective in increasing Ca to adequate levels.

Amaranth plants treated with compost + MPR had the lowest iron content. This might be attributed to reduced iron uptake caused by high concentration of phosphate and calcium ions, which were supplied by the MPR, in the soil nutrient medium (Lingle et al., 1963 as cited by Mengel and Kirkby, 1978). According to West et al. (1988), average iron content in the edible portion of raw amaranth is 8.9 mg/100 g, which compares well with iron content values in plants treated with NPK (8.97 mg/100 g) and crotalaria + MPR (8.3 mg/100 g). Increased Ca and Fe might have resulted from increased soil fertility, especially soil available N. This can also be explained by the significant correlation between uptake and soil available N and iron content. Mzee (2001) observed increased Ca concentration in rice following addition of N compared with the treatment without N. This result could be attributed to the enhanced uptake of Ca caused by increased vegetative growth influenced by N.

All fertilizer treatments significantly ($P<0.05$) increased vitamins C and A content in amaranth plants. The NPK, crotalaria and crotalaria + MPR treatments did not differ significantly ($P<0.05$), but had higher vitamin C content than the compost treatments.

Table 4. Correlation between soil nutrients, nutrient uptake and nutritional quality of amaranth

Parameters	Soil available N	Soil available P	N uptake at harvest	P uptake at harvest
1. Vitamin A	0.450**	0.466**	0.595**	0.568**
2. Vitamin C	0.467**	0.459**	0.749**	0.676**
3. Ca	0.415*	0.388*	0.705**	0.593**
4. Fe	0.435**	0.434**	0.700**	0.586**
5. Crude protein	0.728**	0.549**	0.830**	0.653**

*, ** = Significant at P=0.05 and P=0.01. n = 36. Error df = n-2

According to West et al. (1988), raw amaranth contains 50 mg/100 g vitamin C, which does not differ much from the levels obtained in the plants treated with NPK and crotalaria. The higher vitamin C content in these treatments could be attributed to higher soil available N in plots treated with NPK and crotalaria (Table 2). By increasing N levels, leafy vegetables develop more vitamin C content (Locascio et al., 1984). Water-soluble vitamins such as vitamin C, contain C, H, N and S. The N, S, and P from the soil, together with the sugar obtained after photosynthesis reaction, help plants to synthesize vitamins, fats, proteins, starch and a variety of essential materials for plants (Mou and Ryder, 2004). Therefore, low soil availability and uptake of N, S or P may affect vitamin contents in plants. This is also supported by the highly significant (P<0.01) correlation between the soil available N and P, uptake and vitamin A and C content in amaranth (Table 4). Similarly, Habben (1973) found that by increasing N rates beta-carotene content increased in carrots.

Effects of Fertilizer Materials on the Keeping Quality of Amaranth

Plants from all fertilizer treatments had significantly lower weight loss compared to the control (Table 5). The weight loss by amaranth, which is mostly due to loss of moisture, could be related to calcium content of the plants. Calcium has a significant influence on the strength of cell wall in plants. Although not significantly different, plants treated with crotalaria, crotalaria + MPR and NPK had lower weight loss as compared to other treatments due to higher Ca content (Table 3). In addition, there was a highly significant (P<0.01) negative correlation (r=-0.621) between calcium content in amaranth plants and weight loss.

Results indicate that there was a decrease of vitamin C content in the stored amaranth, which might have been caused by blanching and drying. Vitamin C is very heat labile. Subadra et al. (1997) reported similar results that ascorbic acid content in fresh samples of *Moringa oleifera* leaves was 143.6 mg/100 g, while after blanching dropped it to 38.7 mg/100 g; that is, 27% retention of the fresh sample. In the present results there was a significant correlation (r=0.623) between calcium and vitamin C content in stored amaranth, which suggests that the higher the calcium content the higher vitamin C content in the stored amaranth. In addition, there was significant negative correlation (r=-0.556) between weight loss and vitamin C content in the stored amaranth, suggesting inverse relationship between the two parameters whereby the increase of weight loss caused more decrease in vitamin C content. The significantly (P<0.05) higher vitamin C retention in vegetables treated with compost + MPR than in other treatments was probably due to enhanced Ca levels.

Table 5. Effects of fertilizer materials and species on keeping quality of amaranth

Treatments	Weight lost after 48 hrs (%)	Vit. C in fresh samples (mg/100 g dry wt)	Vit. C content after storage (mg/100 g dry wt)	Vit. C retention after storage (%)
Species				
A. cruentus	66.62a	393.20a	39.95a	10.71a
A. hypochondriacus	58.14a	492.38a	43.57a	9.12a
SE +	0.369	40.79	2.70	1.13
Fertilizer types				
Compost	60.83b*	365.95bc	33.36d	10.23b
Compost + MPR	61.62b	354.63bc	44.87bc	13.08a
Crotalaria	58.79b	441.70b	41.73c	9.52b
Crotalaria + MPR	55.03b	617.96a	52.17ab	8.66b
NPK	57.36b	575.83a	53.06a	9.41b
Control	80.65a	300.67c	25.34e	8.58b
Mean	62.38	442.79	41.76	9.91
SE +	2.55	32.80	2.55	0.69
CV (%)	10	18	15	17
$LSD_{0.05}$	7.52	96.77	7.54	2.03

* = Means in the same column followed by the same letter are not significantly different at *P*=0.05 according to DMRT, *A. cruentus = Amaranthus cruentus, A. hypochondriacus = Amaranthus hypochondriacus,* MPR = Minjingu Phosphate Rock, SE = Standard Error

CONCLUSIONS AND RECOMMENDATIONS

From the results it can be concluded that application of organic materials, significantly increased soil available N and P. Combination of phosphate rock with green manure or compost increased soil P supply compared to un-amended treatments. The results indicate a close relationship between soil available nutrients, plant uptake and quality attributes of the test vegetable crop. The difference between organic and inorganic sources could be based on their different abilities to release nutrients. Due to its high Ca content, MPR amended treatments increased the evaluated keeping quality attributes of amaranth vegetables.

Therefore, vegetable farmers should be advised to supplement the use of organic materials with Ca-rich P sources such as MPR to enhance their keeping quality and soil P supply. Further research on the evaluated materials is recommended to identify frequency of MPR application and sequence of crops to be grown in rotation with amaranth for better utilisation of the available nutrients.

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