International Scholars Journals

International Journal of Agricultural Sciences ISSN: 2167-0447 Vol. 14 (8), pp. 001-009, August, 2024. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Impact of Organic Cultivation on Root Yield, Quality, and Soil Biological Health of Orange-Fleshed Sweet Potato (Ipomoea batatas L.)

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Accepted 21 July, 2024

A field experiment conducted for three consecutive years (2006-08) with different organic manures with or without bioagents revealed higher root yield with the application of green leaf manure (12606 kg/ha) as well as integrated use of organic and inorganic manures (12563 kg/ha). Quality characters like dry matter, starch, and β-carotene content were higher with the application of farmyard manures and other organic manures. At the end of three years, the soil organic carbon content was 0.38% in farmyard manure applied plots compared to 0.31% in control plot. The soil microbial biomass carbon content was increased with the application of organic manures and bioagents. At the end of three seasons, the initial levels of soil enzymes urease, β-glucosidase and phosphatase increased from 1248 to 1352 (µg NH4-Ng^{-1} soil d^{-1}), 10.7 to 20.0 (µg PNP g^{-1} soil h^{-1}) and 126 to 295 (µg PNP g^{-1} soil h^{-1}), respectively in various organic treatment systems. Bio-agents such as *Trichoderma, Azospirillum, Azotobacter* and phosphorus solubilizing bacteria population build up in the soil was observed when applied along with organic manures.

Keywords: Phosphatase, Quality, Root yield, Sweet potato, Urease, β-glucosidase.

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is an important tropical food crop with versatile utility. The tubers are used as a subsidiary food after boiling, baking and frying. Tubers are also form of an industrial raw material for the production of starch, alcohol, pectin etc. Besides energy provider, it is a good source of minerals and vitamins. Orange flesh sweet potatoes are rich in ß-carotene (precursor for vitamin A) (Sreekanth, 2008). Vitamin A deficiency is the major nutritional problem in the poverty prone communities in India. The strategy of increasing orange flesh sweet potato consumption helps to alleviate vitamin A deficiency, which causes night blindness (Anderson *et al*., 2007). The high yielding orange flesh varieties are fertilizer responsive. Research evidences indicate that the application of inorganic fertilizers increases root yield (Nedunchezhiyan and Srinivasulu Reddy, 2002) but hampers the quality of sweet potato (Nedunchezhiyan *et al*., 2003). Better sweet potato root quality was observed at optimum amount of nitrogen supply especially through organic sources (Nedunchezhiyan *et al*., 2003). Organic manuring of sweet potato improves soil health (Nedunchezhiyan and Srinivasulu Reddy, 2004).

Incorporation of organic manures influences soil enzymatic activity either because of the composition of the added materials themselves or because they increase microbial activity of the soil (Goyal *et al*., 1993). Soil enzymatic activity is responsible for forming stable organic molecules that contribute to the permanence of the soil ecosystem and for nitrogen (urease) and phosphorus (phosphatase) cycles (Pascual *et al*., 2002). β-glucosidase is considered as sensitive biological indicator of carbon content (Badiane *et al*., 2001). Soil microbial population which is partly responsible for soil enzyme activities could be improved through inoculation of microbes into the rhizosphere. However, their abundance depends on the source of organic and

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Table 1. Nutrient content of organic sources

Organic source	2006			2007			2008		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
FYM	0.48	0.12	0.39	0.51	0.11	0.36	0.49	0.12	0.34
Glyricidia sepium	2.34	0.31	2.01	1.98	0.22	1.77	2.22	0.27	1.82
Vermicompost	1.88	0.27	1.05	1.76	0.21	0.86	1.72	0.22	0.92

inorganic nutrients (Pramanik *et al*., 2007). Keeping in view of the above an investigation was carried out to study the impact of organic production of orange flesh sweet potato on root yield, quality and soil health.

MATERIALS AND METHODS

A field experiment was conducted for consecutive three years during 2006-2008 on Typic Rhedustalfs at Regional Centre of Central Tuber Crops Research Institute (20º 14' 50" N and 85º 47' 06" E), Dumuduma, Bhubaneswar, Orissa, India. The experiment was laid out in randomized block design (RBD) with three replications. The experiment consisted of eight treatments and the treatments are based on source of nitrogen supply. T_1 traditional production (no manure and fertilizer), T_2 conventional production (recommended organic manure and inorganic fertilizer), T_3 farmyard manure (FYM) based organic production (OP) (100% N through FYM), T_4 green leaf manure (GLM) (*Glyricidia sepium* (Jacq.) Walp leaves) based organic production (100% N through GLM), T_5 vermicompost (VC) based organic production (100% N through VC), T_6 biofertilizers (*Azospirillum, Azotobacter* phosphorus solubilizing bacteria and *Trichoderma*) + 50% N through FYM, T_7 biofertilizers (*Azospirillum, Azotobacter* phosphorus solubilizing bacteria and *Trichoderma*) + 50% N through GLM, T_8 biofertilizers (*Azospirillum, Azotobacter* phosphorus solubilizing bacteria and *Trichoderma*) + 50% N through VC. The recommended dose of fertilizer was FYM 5 t/ha + 50:25:50 kg NPK/ha.

Organic manures were applied based on N requirement. The total N requirement was calculated by considering N content in 5 t FYM + 50 kg fertilizer N. Nutrient content of organic manures were analysed before application in each year (Table 1). *Azospirillum, Azotobacter* phosphorus solubilizing bacteria and *Trichoderma* fresh cultures obtained from Microbiology laboratory, Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar were applied into the soil (5 kg/ha each). *Trichoderma* enriched FYM was applied in organic farming. For *Trichoderma* enriching the FYM, 1 kg of *Trichoderma* formulation was mixed with one ton of FYM. Maintained 60-65% moisture by sprinkling water on the mixture and then it was covered with polythene after heaping. The heap was turned once in 10 days and sprinkled little water to maintain 60-65% moisture. The enriched FYM was used after a month. The genotype ST 14 (orange flesh) was studied in this experiment. Neem (*Azadirachta indica*) based plant protection measures were carried out in all the treatments except treatment T_1 and T_2. In treatment T_2 fenthion 500 g a.i./ha (0.05%) was used as plant protection chemical. No plant protection measure was done in T_1. The gross plot size of each treatment was 6.0 x 6.0 m. Each plot was surrounded by 30 cm height bund. Channel/furrow width of 1 m was maintained around the plots to prevent run off water crossing over the plot. The treatment T_2 plots were kept in lower side 10 m away from other treatments in the same field. For three years the treatments were allotted in the same plot (fixed plot).

Before conducting the experiment, maize (*Zea mays*) was cultivated without chemicals for two seasons (2004 and 2005) as test crop for conversion into organic field. The soil physicochemical characters were analyzed before and after three years of the experiment. Coarse sand, fine sand, silt and clay were determined by Bouyoucos hydrometer method (Kanwar and Chopra, 1967). pH and EC were determined in a 1:2 soil:water suspension using Beckman pH meter (Jackson, 1967) and Solubridge method (Jackson, 1967), respectively. Organic carbon was determined by the method of Walkley and Black (Jackson, 1967). Available N, P and K were estimated by potassium permanganate method (Subbiah and Asija, 1956), Brays I method (Brays and Kurtz, 1945) and flame photometer method (Jackson, 1967), respectively. Soil microbial biomass carbon was determined by fumigation method (Vance *et al*., 1987). Urease, phosphatase and β-glucosidase were analysed by following the methods of Broadbent et al. (1958), Eivazi and Tabatabai (1977; 1988), respectively.

Microbial plate counts were made by following serial dilution technique (Travors and Cook, 1992). *Azospirillum* specific medium (5 g mallic acid, 0.5 g K_2HPO_4, 4 g KOH, 0.1 g $MgSO_4$, 0.02 g NaCl, 0.01 g $CaCl_2$, 0.05 g $FeSO_4$, 0.002 g Na_2MoO_4, 0.002 g bromothymol blue, 0.01 g $MnSO_4$, 2 g agar and 1.0 litre distilled water), *Azotobacter* specific medium (290 g sucrose, 1 g K_2HPO_4, 0.5 g $MgSO_4$, 0.5 g NaCl, 0.001 g Na_2MoO_4, 0.01 g $FeSO_4$, 2 g $CaCO_3$, 15 g agar and 1.0 litre distilled water), phosphorus solubilizing bacteria specific medium (10 g glucose, 0.5 g yeast, 0.5 g NH_4SO_4, 0.2 g KCl, 0.2 g NaCl, 0.001 g $MgSO_4$, 5 g $Ca_3(PO_4)_2$ and 1.0 litre distilled water) and *Trichoderma* specific medium (0.2 g $MgSO_4$, 0.9 g K_2HPO_4, 1.0 g NH_4NO_3, 0.15 g KCl, 0.25 g chloramphenicol, 0.3 g ridomil, 0.15 g rose Bengal, 3.0 g glucose, 15.0 g agar and 1.0 litre distilled water) were prepared and plated on the glass Petri dish. 0.1 ml from 10^1 to 10^6 dilution was poured on the surface of Petri dish with the help of a micropipette and was evenly spread with the help of a sterile spreader and incubated at 30±2ºC. Colony count was carried out daily up to 15 days. The physicochemical character of the experimental field was presented in the Table 2.

Quality characters of tubers such as dry matter, starch and total sugar (Moorthy and Padmaja, 2002) and β-carotene (Goodwin, 1980) were analyzed at harvest.

Sustainable yield index (SYI) with respect to yield was worked out as follows,

$SYI = Y_{mean} – SD/Y_{max}$

Where, Y_{mean} mean yield from a practice over years, SD standard deviation and Y_{max}

maximum yield obtained with any practice. If SYI is <0.33 unsuitable, 0.33-0.66 moderately sustainable and >0.66 sustainable.

The data were subjected to the analysis of variance (ANOVA) appropriate the design using GENSTAT programme. Test of significance of the treatment difference was done on the basis of F test (Gomez and Gomez, 1984). The the treatments were compared with the least significant difference (LSD) at a 5% level of probability.

RESULTS AND DISCUSSION

Root yield

Discernable variation in root yield was observed due to system of production (Table 3). Maximum tuber yield was

Table 2. Physico-chemical properties of the experimental site

Particular	Value
1. Mechanical analysis	
Coarse sand (%)	41.3
Fine sand (%)	28.1
Silt (%)	8.7
Clay (%)	21.9
Soil texture	Sandy clay loam
Family	Typic Rhedustalfs
Bulk density (g/cc)	1.5
2. Bio-chemical analysis	
Soil pH	5.2
Electrical conductivity (dS/m)	0.032
Organic carbon (%)	0.34
Available nitrogen (N kg/ha)	140
Available phosphorus (P kg/ha)	19.2
Available potassium (K kg/ha)	147
Urease (µg NH4-N/g soil/d)	1248
Phosphatase (µg PNP/g soil/h)	10.7
β-glucosidase (µg PNP/g soil/h)	126
Azospirillum (cfu/g of soil)	5×10^5
Azotobacter (cfu/g of soil)	3×10^5
Posphorus solubilising bacteria (PSB) (cfu/g of soil)	3×10^5
Trichoderma (cfu/g of soil)	2×10^4
Soil microbial biomass (µg/g of soil)	173.6

obtained with green leaf manure (*Glyricidia sepium* leaves) based organic production (12607 kg/ha). *Glyricidia sepium* leaves decompose quickly thus it is possible that nutrients were available to the sweet potato plant quickly. The root yield (12563 kg/ha) of conventional method (organic and inorganic source of N) of sweet potato production was at par with green leaf manure based organic production (Table 3) and it was the next best treatment. Plant gets nutrients throughout the growing period when there is integrated use of inorganic (immediately available) and organic (slow mineralisation) source of nutrients which leads to higher yield attributes and yield in sweet potato (Nedunchezhiyan and Srinivasulu Reddy, 2002). The sweet potato root yield of vermicompost based organic production was statistically comparable with both green leaf manure based as well as conventional method of production. Among organic production types, root yield of sweet potato in FYM based organic production was lower. Low nutrient content and slow mineralisation of FYM affects plant uptake during critical stages (Nedunchezhiyan and Srinivasulu Reddy, 2002).

Application of biofertilizers along with 50% of N through any organic source registered significantly higher tuber yield over traditional farming (no manure and fertilizers and plant protection chemicals) but significantly lower than 100% N application (Table 3). Application of biofertilizers can not replace 50% of nutrient requirements, but may be 25-30%. It was indicated by the level of yield reduction in biofertilizer treatments. The yield reduction was 2.8-9.1% with biofertilizers along with 50% N through organic sources when compared to 100% N through organic sources. Nedunchezhiyan and Srinivasulu Reddy (2002) and Saikia and Borah (2007) reported *Azospirillum* can replace one-third N requirements. The lowest yield was obtained with traditional method of cultivation where no manure and fertilizer were applied. Though sweet potato is grown in marginal and low fertility soil, it responds to application of nutrients (Nedunchezhiyan and Srinivasulu Reddy, 2002).

Sustainability yield index presented in the Table 3 indicated that all the production systems investigated were sustainable (SYI >0.66) except traditional method (SYI 0.63). Continuous mining in traditional system caused reduction in SYI. Higher SYI in conventional system perhaps might be use of both organic manure and inorganic fertilizers. The highest SYI was observed in green leaf manure based production system. This might be quick decomposition of green leaf manure and release of nutrients in critical stages apart from addition of organic matters into the soil.

Quality characters

Sweet potato is mainly grown for its starchy root. The dry matter content of sweet potato is very essential for post

Table 3. Root yield and sustainable yield index of orange fleshed sweet potato under various production systems

Treatment	Root yield (kg/ha)				Sustainable yield index (SYI)
	2006	2007	2008	Mean	
Traditional production	8250	8550	8310	8370	0.63
Conventional production	11860	13020	12810	12563	0.92
FYM based OP	11220	11050	12000	11423	0.84
Green leaf manure based OP	12560	12960	12300	12607	0.95
Vermicompost based OP	12010	12110	12000	12040	0.92
Biofertilizers + 50% FYM N	11350	10950	11020	11107	0.84
Biofertilizers + 50% GLM N	11640	11450	11300	11463	0.87
Biofertilizers + 50% VC N	11420	11220	11160	11267	0.86
LSD (*P*=0.05)	783	256	1013	607	-

Table 4. Quality characters of orange flesh sweet potato fresh tubers (pooled data of 3 years)

Treatment	Dry matter (%)	β-carotene (mg/100 g of tuber)	Starch (%)	Total sugars (%)
Taditional production	24.0	14.03	20.3	2.7
Cconventional production	25.0	14.58	21.5	2.3
FYM based OP	25.6	14.87	22.0	2.5
Green leaf manure based OP	25.3	14.53	21.2	2.3
Vermicompost based OP	24.8	14.60	21.3	2.3
Biofertilizers + 50% FYM N	24.9	14.41	21.4	2.4
Biofertilizers + 50% GLM N	24.9	14.35	21.0	2.3
Biofertilizers + 50% VC N	24.7	14.30	20.6	2.4
LSD (*P*=0.05)	0.8	0.58	0.8	0.1

Table 5. Bio-agents population (cfu/g of soil) after three years as influenced by production systems of sweet potato

Treatment	*Azotobacter*	*Azospirillum*	PSB	*Tricoderma*
Traditional production	2×10^5	2×10^5	2×10^5	2×10^4
Conventional production	2×10^6	8×10^5	6×10^5	3×10^4
FYM based OP	8×10^6	7×10^6	8×10^5	16×10^6
Green leaf manure based OP	9×10^5	7×10^5	1×10^5	3×10^4
Vermicompost based OP	12×10^5	14×10^5	2×10^5	3×10^4
Biofertilizers + 50% FYM N	15×10^6	10×10^6	12×10^6	12×10^6
Biofertilizers + 50% GLM N	8×10^6	9×10^6	9×10^6	8×10^6
Biofertilizers + 50% VC N	8×10^6	9×10^6	11×10^6	8×10^6

harvest processing. In human beings deficiency of vitamin A causes night blindness. β-carotene is a precursor of vitamin A. Orange fleshed sweet potatoes are one of the sources of β-carotene. The genotype ST 14 had the highest content of 13.83 mg of β-carotene /100 g fresh root (Vimala *et al*., 2006). Marked variation in quality characters were noticed due to production systems (Table 4). Dry matter, β-carotene and starch content in roots were higher in 100% N through any one of the sources than 50% N through any one of the sources + biofertilizers application. Root dry matter content was higher in FYM or GLM based organic production. β-carotene content of the root, though governed by the genetic factor, agronomic factors like source and quantity of nutrients significantly influenced the content. β-carotene content were higher in 100% N than 50% N + biofertilizers application. Among organic sources, FYM based organic production yielded higher β-carotene content roots. Nedunchezhiyan *et al*. (2003) also reported similar findings in alfisols. Starch content in roots was higher in FYM based organic production than other systems. Conventional production system (both organic and inorganic fertilizer) followed it. Dry matter, β-carotene and starch content in roots were lower in

traditional system of production where no manure and fertilizer was applied. However, traditional system of production of sweet potato recorded higher sugar content in roots (Table 4).

Bio-agents population

The microbiological status of the soil has often been proposed as an early and sensitive indicator of soil ecological stress or restoration processes in both natural and agro-ecosystems (Dick and Tabatabai, 1993; Dick, 1994; Badiane *et al*., 2001). Microbial colony counting by dilution plate method revealed that considerable population of *Azospirillum, Azotobacter,* PSB and *Trichoderma* were found in native soils (Table 5). When FYM was applied, more bio-agents population built up was noticed (*Azospirillum, Azotobacter,* PSB and *Trichoderma*) compared to vermicompost and green leaf manuring (Table 5). Application of *Trichoderma, Azospirillum, Azotobacter* and PSB increased their population irrespective of organic sources (Table 5). However, it was relatively higher with farmyard manure application than other source of organic manuring (Table 5), at the end of three seasons of cropping. Pramanik *et al*. (2007) also recorded more number of microbes in cow dung compost. Higher *Trichoderma* population was found when FYM enriched *Trichoderma* was applied (Table 5).

Green leaf manured plots showed relatively less increase of bio-agents. Similarly, the inorganic fertilizer applied treatment also the increase of microbial population was less (Table 5). Relatively lower quantity of organic matter addition in former and inorganic fertilizer nutrients in latter affected the bio-agents population. Continuous cropping of sweet potato with out addition of manures and fertilizers (traditional system of production) reduced the microbial population considerably after three years, when compared to initial population (Table 1 and 5).

Post harvest soil nutrients status

At the end of three seasons, discerning changes in bulk density, pH and organic carbon status of post harvest soil were noticed with reference to system of production (Table 6). Noticeable decrease in bulk density in farmyard based organic production was observed. A little increase of bulk density was observed with traditional production system (T_1). Also, slight decrease of pH and organic carbon status were registered in traditional farming. Decomposition of organic matters in organic manures lead to formation of ammonium (NH4+) ions and humic acids (Komilis and Ham, 2006). Presence of carboxylic and phenolic groups in humic acids caused lowering of pH while ammonium ions increased the pH of the system. Combined effect of these oppositely charged ions actually regulates the pH and a shift of pH towards neutrality. Higher organic carbon status was found in post harvest soils after three years when organic manures were used (Table 6) Significantly higher amounts of organic carbon after three years of experimentation were observed when full dose of N was applied through FYM. Conventional system of production was the next best. Application of full dose of N through green leaf manuring and vermicompost followed it. Higher organic carbon in these treatments was due to higher amount of organic matter application. Organic manures have a positive impact on soil quality (Badiane *et al*., 2001). The initial bulk density, pH and organic carbon status of the soil were 1.52, 5.2 and 0.34% respectively.

Soil microbial biomass carbon (SMBC) content was found to be higher in FYM based production system (Table 6). This was due to higher microbial population (Table 5) and organic carbon (Table 6). In long term field experiments, Witter *et al*. (1993) found a larger SMBC in plots where farmyard manure had been applied in each year than unfertilized plots. Soil systems receiving more organic matter tend to harbour higher levels of microbial biomass carbon with greater microbial activity (Sparling, 1985; Bhattacharyya *et al*., 2005). The size of soil microbial biomass carbon depends on organic carbon of the soil (Lovell and Jarvis, 1996). Application of bio-agents was found to increase soil biomass carbon content.

Post harvest soil available NPK indicated that in full dose of N applied production system had higher amount soil available NPK than other systems. Accumulation of organic matter and microbial biomass carbon in the soil serves as a labile reservoir of plant nutrients (Jenkinson and Ladd, 1981). Higher amount of available N content in the soil was noticed in 100% N supplied through FYM. Whereas, higher available P and K in post harvest soil were found in conventional system of crop production. This might be due to higher amount of P and K application in that particular treatment. External application of manures and fertilizers to replenish the depleting nutrients maintained higher fertility status than initial level. The lowest available NPK status was found in traditional system, where no manure and fertilizer was applied. Further the nutrient status in this treatment was lower than initial status indicating soil mining of sweet potato (Table 6).

Enzyme activities

Enzymes play a key role in soil nutrient cycling (Badiane *et al*., 2001). Enzyme activity was an index of soil productivity or microbial activity (Alef *et al*., 1995; Dick *et al*., 1996). Enzyme activity in soil results from the activity of accumulated enzymes as well as from enzymatic activities of proliferating micro-organisms (Kiss *et al*., 1975). Sources of accumulated enzymes are primarily microbial cells (Ladd, 1978), but can also be originated from plant and animal residues (Tabatabai, 1994). The urease, phosphatase and β-glucosidase activities were

Table 6. Post harvest bio-chemical status of the soil after 3 years

Treatment	Bulk density (g/cc)	pH	Organic carbon (%)	Microbial biomass carbon (µg/g of soil)	Urease (µgNH_4-N/g soil/d)	Phosphatase (µg PNP/g soil/h)	β-glucosidase (µg PNP/g soil/h)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1	1.53	5.1	0.31	172.4	1234	122	9.7	124	18.4	136
T_2	1.50	5.3	0.38	381.6	1330	295	19.1	176	22.5	196
T_3	1.48	5.4	0.40	620.4	1352	260	20.0	192	20.7	185
T_4	1.52	5.3	0.37	306.2	1338	282	19.2	168	21.8	172
T_5	1.49	5.2	0.37	318.3	1333	268	19.0	162	21.2	178
T_6	1.50	5.2	0.36	487.4	1288	204	16.1	156	19.9	153
T_7	1.51	5.2	0.36	429.6	1276	215	16.1	150	20.3	156
T_8	1.51	5.2	0.36	402.0	1264	200	15.8	148	20.0	160
LSD (*P*=0.05)	0.03	NS	0.01	12.4	96	22	1.7	8	0.9	11

higher with the full dose of N application system (Table 6). This may be due to higher levels of nitrogen and phosphorus application, higher microbial bio-agents population (Table 5) and microbial biomass carbon (Table 6). Application of organic manures increased the enzyme activities of the soil. Higher amounts of endoenzymes in the viable microbial populations increased levels of accumulated enzymes in the soil matrix. The enzymes in the organic manures may also directly contribute to enzyme activities (Dick and Tabatabai, 1984).

However, variation of enzyme activities between organic sources was related to their qualitative difference in the biogenic components and microbial biomass production. Urease and β-glucosidase activities were higher in FYM based production system (100% N). However, higher phosphatase activity was noticed in conventional system of production. This was due to higher amount of phosphorus application in conventional system compared to other treatments. Mulvaney and Bremner (1981) suggested that variation in the nature of organics invariably stimulated the production of urease and phosphatase in soil. The lowest levels of enzyme activities were with no fertilizer and manure application (traditional system of production) and this was as result of lower organic carbon, microbial bio-agent population and microbial biomass carbon status.

CONCLUSION

Quickly decomposable *Glyricidia* green leaf manuring or integrated use of organics and inorganic fertilizers produced higher yield but quality characters (dry matter, β-carotene and starch) were higher when FYM was used as source of Nitrogen. Higher amount of organic manure as source of N application increased the organic carbon level, which in turn increased microbial population, microbial biomass carbon and elevated the enzyme activities (urease, phosphatase and β-glucosidase) of the soil.

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