DOI : 10.5958/0974-0112.2020.00015.8

Indian J. Hort. 77(1), March 2020: 140-148

Organic management fosters yield, soil health and profit in dwarf white yam

G. Suja*, A.N. Jyothi, G. Byju, S.S. Veena, J. Sreekumar, M. Indira** and V. Ravi
ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 695017, Kerala

ABSTRACT

Organic farming is a safe alternative for sustainable production, clean food, soil and air. Field experiments were conducted in randomized block design over three consecutive seasons (2011-2014) in non-trailing genotype of white yam to compare the yield, quality and soil properties under conventional, traditional, organic and integrated system at ICAR-Central Tuber Crops Research Institute, Kerala. This was followed by on-farm trials for one year (2014-2015) at seven locations in two major yam growing districts of Kerala, to validate the on-station developed technology. At on-station, organic system (13.23 t/ha) performed better than chemical (12.18 t/ha) with 8.6% higher yield and insignificant effects on tuber quality. Organic plots showed higher pH (+0.412 unit), organic C (+22%), available N (+44%) and K (+7%), exchangeable Ca (+16%), Fe and Cu (+8%). The soil temperature, soil moisture, soil CO_2 flux and photosynthetically active radiation were also slightly promoted under organic management. The population of bacteria, fungi and actinomycetes were higher under organic (+12.87%, +58.69% and +48.85% respectively). Subsequently, the on-station developed organic technology comprising farmyard manure, green manure, neem cake, biofertilizers and ash tested on-farm confirmed that the yield and profit under organic management were higher by 21 and 38% respectively over conventional system. These results are valuable for the promotion of organic farming in non-trailing genotype of white yam for higher yield, profit and soil health.

Key words: *Dioscorea rotundata*, eco-friendly farming, productivity, soil properties, on-farm testing.

INTRODUCTION

The agro-technological revolution termed as green revolution led to significant increase in crop yields by adopting genetic crop improvement, chemical-intensive production practices including increased use of chemical inputs (fertilizers and pesticides), irrigation and intensive tillage (Henneron *et al*., 6). However, the results of intensive agricultural management, that advocated large chemical inputs and few carbon additions to the soil, was undesirable, especially with respect to resource use efficiency, sustainability and long term profitability. The problems, often referred to as post-green revolution problems include soil erosion, greenhouse gas emission, soil salinity, reduced soil organic matter, poor surface water quality, reduced water infiltration rates, pesticide pollution, desertification, loss of biodiversity, food contamination and adverse effects on human health.

Presently, alternative agricultural systems like organic farming, that are environmentally benign, less polluting, not much dependent on the nonrenewable fossil fuel based chemicals, fertilisers, pesticides etc., are popular. Organic farming is a sustainable alternative that focuses on soil health, environmental protection and human health by the non-use of chemical inputs and with maximum use of on-farm generated resources.

Root and tuber crops are important to agriculture, food security and income for 2.2 billion people in developing countries (Lebot, 7). Yams (*Dioscorea* spp.) are high energy tuberous vegetables with good taste and medicinal values. They are mostly used for their high content of carbohydrate (Enesi *et al*., 4). They also have a higher protein content and better balance of amino acids than many other root and tuber crops. They are staple crops in tropical countries, mainly West Africa, the Caribbean, Pacific Islands and Southeast Asia. Among edible yams, Asiatic yams like greater yam (*Dioscorea alata*) and lesser yam (*Dioscorea esculenta*) are common intercrops in many coconut growing regions of Asia. African white yam (*Dioscorea rotundata*), introduced in India, is gaining popularity among farmers due to its high yield potential (35-40 t/ha), wide adaptability in different agro-climatic locations, acceptable tuber quality, novel taste and flavor (Suja and Sreekumar, 17). The crop has good potential as a vegetable, subsidiary food item and industrial raw material. Yams are also important as sources of pharmaceutical compounds like saponins and sapogenins, which are precursors of cortesone and steroidal hormones (Estiasih *et al*., 5). The practice

*Corresponding author's E-mail: sujagin@yahoo.com
**Agricultural Research Station, Kerala Agricultural University, Thiruvalla, Kallungal P.O., Thiruvalla, Pathanamthitta 689 102, Kerala

of trailing in yams is a costly affair and contributes to approximately 30-35% of the production cost. Hence a non-trailing dwarf, bushy, non-climber variety of white yam, Sree Dhanya, suited to the different agro-climatic conditions of India, especially the homesteads in Kerala as well as in coastal and interior plains of southern regions of India, has been developed by ICAR-Central Tuber Crops Research Institute (CTCRI, 3).

Based on a decade of research in tropical tuber crops, it was conclusively proved that organic farming produced sustainable yield of quality tubers and higher profit besides maintaining soil health. Further, organic production techniques were developed in tropical tuber crops like elephant foot yam, trailing genotypes of yams and taro based on on-station and on-farm experimentation (Suja *et al*., 18; Suja and Sreekumar, 17; Suja, *et al*., 16). However, there is dearth of information on the impact of organic management in non-trailing genotype of white yam. Technologies for organic production of non-trailing dwarf white yam are currently lacking. Hence, the objectives of the present study were to compare the yield, tuber bio-chemical constituents, soil chemical properties, micro-climate as well as microbial count under organic vs conventional management in non-trailing dwarf white yam. The study also aims to develop organic production technologies in non-trailing white yam and validate the on-station developed technologies under on-farm conditions. These results on organic management further aim to promote non-trailing white yam as a vegetable in the kitchen gardens and homesteads.

MATERIALS AND METHODS

Experiment I: On-station experiment

Field experiments were carried out over three growing seasons (May-January) from 2011 to 2014 at the Farm of ICAR-Central Tuber Crops Research Institute (8°29'N, 76°57'E, 64 m altitude), Thiruvananthapuram, Kerala. The climate of the site is typical humid tropical with bimodal annual pattern of rainfall. The mean rainfall, relative humidity, maximum and minimum temperature during the growing seasons were 1176.4 mm, 80.1% and 31.2°C and 24.4°C respectively. The monthly total rainfall, monthly average maximum temperature (T max), minimum temperature (T min), and relative humidity during the crop growth period in the experimental years are depicted in Fig.1.

The soil is a typical acid Ultisol (pH: 5.26). At the start of the experiments, the soil was characterized as having medium organic C (0.65%), low available N (68.36 kg/ha), medium available P (10.88 kg/ha), and high available K (222.10 kg/ha). Cropping history of the experimental site is such that cassava was grown for one cycle followed by a green manure crop. Thus, before the start of this experiment a green manure crop of cowpea (*Vigna unguiculata*) was grown in the site and incorporated into the soil during May 2011. No chemical inputs were used in either the cassava or cowpea, and thus the site had been organically managed for one year before the commencement of the present research.

In this trial, dwarf white yam variety Sree Dhanya was used as a test crop. This is a non-climbing, dwarf and bushy variety of white yam that does not require staking. It is a seedling selection with

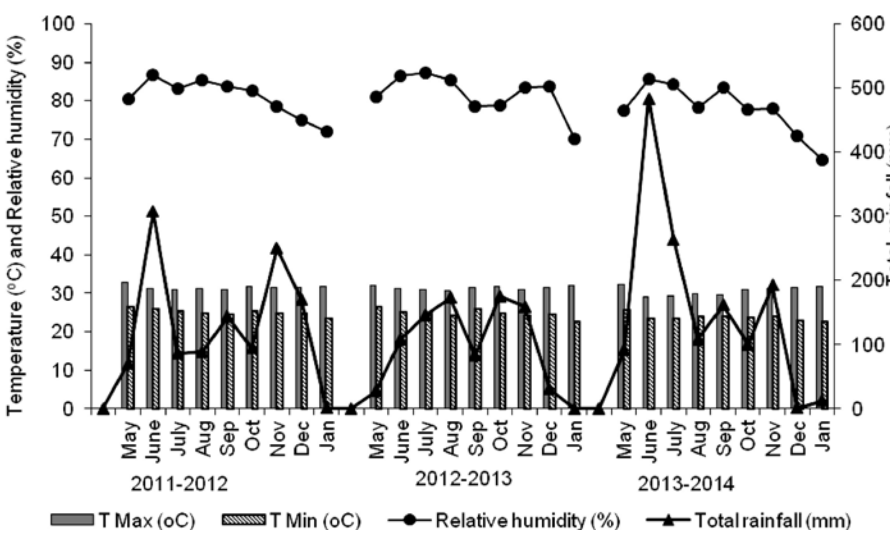

Fig. 1. Weather parameters during the crop growth period in the research station.

an average yield of 20 t/ha and potential yield of 39 t/ha. It has cylindrical brown-skinned, white-fleshed tubers with good cooking quality (CTCRI, 3). The dwarf white yam var. Sree Dhanya was tested under four production system treatments, conventional, traditional, organic and integrated systems, using a randomized complete block design with five replications over three consecutive growing seasons. The description of the different production systems are given in Table 1. The average content of nutrients in the differrent organic manures used are given in Table 2.

The gross plot size (size of each replicate plot including border plants) was 5.25 × 3.00 m (28 plants), accommodating 10 plants for sampling (net plot), excluding the border plants. In each year, the crop was planted in May. It was mainly rainfed and harvested after nine months. In the organic farming plots, green manure cowpea was sown in between the pits immediately after planting yams. The green matter was incorporated at 50% flowering stage of cowpea. The quantity of green matter incorporated was 20.6, 29.6 and 20.0 t/ha in 2011, 2012 and 2013, respectively.

Tubers from the net plot were harvested on 9 February 2012, 14 February 2013 and 14 February 2014 and fresh weight of tubers from the net plot were recorded and tuber yield was expressed in t/ha. Proximate analyses of tubers for dry matter, starch, sugar, ash and fibre were done using standard procedures. Soil samples were collected from 0-15 cm depth, air dried under shade, passed through 2 mm sieve and stored in air tight containers. The pH, organic C, available N, P and K, exchangeable Ca, Mg, Fe, Zn and Cu status of the above prepared soil samples were estimated by standard analytical methods. For microbial analyses, soil samples were collected from the rhizosphere region of three dwarf white yam plants per replication pooled and mixed well. The powdered soil was sieved through a wire mesh. The soil, thus, prepared was used for the determination of microbial plate count of bacteria, fungi and actinomycetes by standard procedures. Soil CO_2 flux, soil temperature, soil moisture and photosynthetically active radiation (PAR) were measured at the grand growth period (4 MAP) of the crop using LI-8100 A Automated Soil CO_2 Flux System.

Two way analysis of variance (ANOVA) for randomized block design (analysing the data from different years separately) was used to compare treatment differences for the different plant and soil parameters using SAS statistical software (SAS, 12). Combined BARTLETT analysis over years was also done to enable comparisons between the years. Thus, pooled analysis of yield data of three seasons was done. The critical difference (CD) test was used at the 0.05 level of probability to test differences between treatment means.

Experiment II. On-farm validation

The organic production system developed on-station was validated through on-farm experiments in seven locations in two major growing districts of southern India, viz., Thiruvananthapuram and Kollam during 2014-2015. The climate of the on-farm sites was hot tropical with bimodal rainfall pattern. The mean maximum and minimum temperature was 35°C and 20°C respectively and the relative humidity was high, being 90-95%, especially during the monsoon

Table 1. Components of production systems used in the study for dwarf white yam cultivation.

Type	Description
Conventional	FYM @ 10 t/ha + NPK @ 80:60:80 kg/ha
Traditional	Farmers' practice (FYM @ 15 t/ha and ash @ 1.5 t/ha)
Organic	FYM @ 15 t/ha + green manuring to generate 15-20 t/ha of green matter in 45-60 days + neem cake @ 1 t/ha + ash @ 1.5 t/ha + biofertilizers (*Azospirillum* @ 3 kg/ha and mycorrhiza @ 5 kg/ha)
Integrated	FYM @ 10 t/ ha + NPK @ 40:30:80 kg/ha + biofertilizers (*Azospirillum* @ 3 kg/ha and mycorrhiza @ 5 kg/ha)

Table 2. Nutrient content of organic manures used in the study.

Organic manures	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Farmyard manure	0.50	0.20	0.28	0.08	0.075	1465.00	70.00	40.00	3.00
Green manure	3.45	0.57	2.02	0.41	0.39	1324.77	509.03	78.10	11.83
Neem cake	1.50	1.00	1.20	1.75	0.65	850.00	40.00	15.00	12.00
Ash	0.6	1.60	7.11	15.00	1.3	5125.00	2850.00	625.00	122.00

season. The average annual rainfall was 1500 mm. The soil of the on-farm sites were acidic (pH: 5.35), rated as low for organic C (0.42%), available N (102.55 kg ha^{-1}) and P (8.55 kg ha^{-1}) and high for available K (295.75 kg ha^{-1}).

The on-farm experiment was conducted as a randomized block design with three treatments (conventional, traditional and organic) replicated at seven farm locations (one replicate plot for each treatment at each farm location). The plot size was 5.25 × 3.00 m. For the on-farm trials, dwarf white yam var. Sree Dhanya was planted during June 2014 and harvested in February 2015. Tubers were harvested, fresh weights were recorded and yields were expressed in t/ha. At harvest, surface soils (0-15 cm) were collected from each site and analysed for pH, organic C, available N, P, K, and microbial plate count of bacteria, fungi and actinomycetes by standard methods. Total cost of cultivation and gross returns were calculated from average input cost and labour cost for all operations and average market price of the produce, respectively during the period of investigation. Based on this net income and benefit:cost ratio (B:C ratio) were computed as follows:

Net income (₹/ha) = Gross income – Gross cost of cultivation

B : C ration = Gross income ÷ Gross cost

Data of the on-farm experiment were analyzed by ANOVA for randomized block design, treating the seven locations as replicates.

RESULTS AND DISCUSSION

In the on-station experiment, during the first and second years, the yam tuber yields of organic farming (12.60, 12.28 t/ha) were similar to that of conventional practice (12.23, 13.01 t/ha). In the third year, the yield in the organic farming system was 31% higher than in the conventional practice, but this difference was not statistically significant (Table 3). While a decline in yield was observed by the third year in conventional, traditional and integrated systems, the yield in the organic system increased by the third year, though these differences among the years were not statistically different. The average of tuber yield during the three years of the experiments revealed that there was no significant difference among the production systems, even though the yield in the organic system was 8.6% higher than that of conventional systems (Table 3). Tuber length and girth remained unaffected.

Similarly, the indication of an increased yield (though not statistically significant) in the organic over the conventional production systems observed in this study was inconsistent with the majority of reports comparing yields in conventional and organic systems reporting that crop yields under organic management were 20-40% lower than conventional systems (Ponti *et al.*, 10; Seufert and Ramankutty, 14). On the basis of meta-analysis of 362 published papers on organic-conventional comparative crop yields, Ponti *et al.* (10) reported that organic yields of individual crops were on an average 80% of conventional yields and yield gap varied between crops and regions. In general, the intensity of farming in the prevailing conventional system affected the yield (Ramesh *et al.*, 11). Hence, in areas of intensive farming system, conversion to organic agriculture decreased yield depending on the intensity of external chemical input use before conversion (Ramesh *et al.*, 11). It is interesting to note that in the present study, the yield of dwarf white yam in organic management was 8.6% higher than in the conventional system. Yams are ethnic vegetables and dwarf white yam, which is, especially, grown in homesteads, are usually grown with low chemical inputs and with applications of organic wastes and manures that are available with the small and marginal holder farmers.

Biochemical parameters of tubers, dry matter, starch, sugar, ash and fibre, were not significantly influenced by the various practices (Table 4).

The major chemical properties of soil were not significantly influenced due to various production systems throughout the course of experimentation, except available K in the first year and pH in the

Table 3. Yield of dwarf white yam in different production systems in the on-station experiment.

Production system	Tuber yield (t/ha)				Tuber length (cm)	Tuber girth (cm)
	2011-12	2012-13	2013-14	Mean	Mean	Mean
Conventional	12.23	13.01	11.30	12.18	26.33	19.42
Traditional	12.11	13.65	10.07	11.94	24.40	18.60
Organic	12.60	12.28	14.79	13.23	24.11	19.79
Integrated	10.23	12.33	11.05	11.20	25.60	18.13
CD (P = 0.05)	N.S	N.S	N.S	N.S	N.S	N.S

N.S = Not significant.

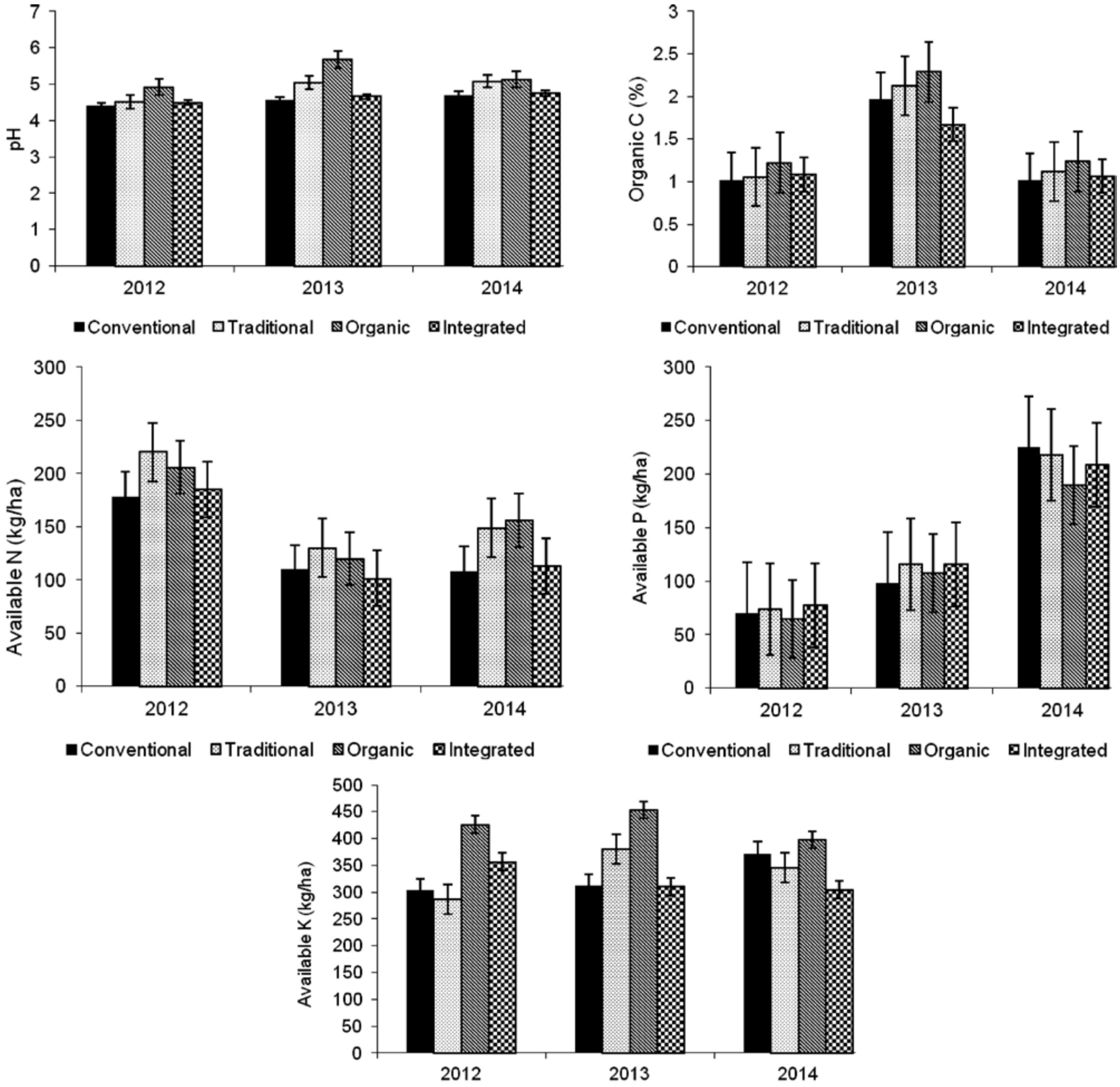

Fig. 2. Effect of production systems on the major chemical properties of the soil during three years of cultivation of dwarf white yam at the on-station site.

Table 4. Impact of production systems on the biochemical characters of dwarf white yam in the on-station experiment (Mean of three years).

Production systems	Dry matter (%)	Starch (% FW)	Sugar (% FW)	Ash (% DW)	Fibre (% DW)
Conventional	28.36	19.88	1.24	2.97	1.15
Traditional	27.81	20.12	1.16	3.11	1.18
Organic	27.39	19.64	1.19	3.33	1.22
Integrated	27.35	19.44	1.22	2.84	1.32
CD (P = 0.05)	N.S	N.S	N.S	N.S	N.S

N.S = Nnot significant.

second season, which were significantly higher in organic plots (Fig. 2). When compared to the initial value in all the treatments by the end of third year there was improvement in organic C, available N, P and K. Of the production systems, organic management favoured all these attributes. We were more interested in the increase/decrease of these parameters in organic over conventional system and hence, we found that by the third year, pH increased by 0.412 unit, organic C by 22%, available N by 44% and K by 7% under organic management over conventional plots (Fig. 3).

The slight increase in pH under organic management over chemical management at the end of three years is attributable to factors such as changes in fertilizer practices, effect of green manure and wood ash. Application of urea normally tends to acidification of soil (Barak *et al*., 1). Long term effects of chemical fertilizers can include leaching of nitrate and sulphate, which will leach some base cations, causing acidification, unless the nitrate and sulphate supply in the fertilizer is balanced by base cations eg., calcium nitrate or calcium sulphate. So, even urea, which has a temporary high pH effect around the prill, has a medium capacity to acidify the soil. Mono ammonium phosphate and di ammonium phosphate has still more acidification potential and ammonium sulfate even more. Elimination of urea and other fertilizers in the organic system hindered the further lowering of pH in the present study. The addition of green manure in the organic system might have provided an additional source of cations possibly from lower soil depths, that are released at the soil surface through leaching and decomposition of nutrients. In addition, evidence exists to confirm the liming effect of Ca input from the various organic manures like farmyard manure (0.08%), green manure (0.41%), neem cake (1.75%) and ash (15%) that might have enhanced the soil pH slightly under organic management (Suja et al., 16; Seena Radhakrishnan and Suja, 13. Ash, especially, has strong alkaline reaction and a neutralizing effect on soil acidity.

Increases in soil organic C and available N are expected to result from the use of organic manures, especially the addition of 20 t/ha of green matter. This is in accordance to the report of Parmar et al. (9) that long term use of farmyard manure and vermicompost resulted in better yield, soil quality and greater amount of carbon stock and carbon sequestration under tomato-cauliflower-radish/pea cropping pattern.

Soils under organic systems have higher K levels due to direct result of inputs (Clark *et al*., 2). The secondary and micronutrient status after three years of cropping indicated that it was not significantly influenced by production systems. However, organic management enhanced the exchangeable Ca by 16%, available Fe and Cu status of the soil by 8% over conventional practice (Table 5).

Calcium content of organic inputs used in the study, farmyard manure, green manure, neem cake and ash might have contributed to higher exchangeable Ca status under organic management. The organic compounds are mainly produced by microbial and root processes and serve to enhance the solubility of micronutrient ions, especially Fe, Cu, Mn and Zn, that might otherwise react in the soil to form insoluble compounds unavailable to plants. Because soil pH strongly influences availability of most micronutrients, proper pH management is a

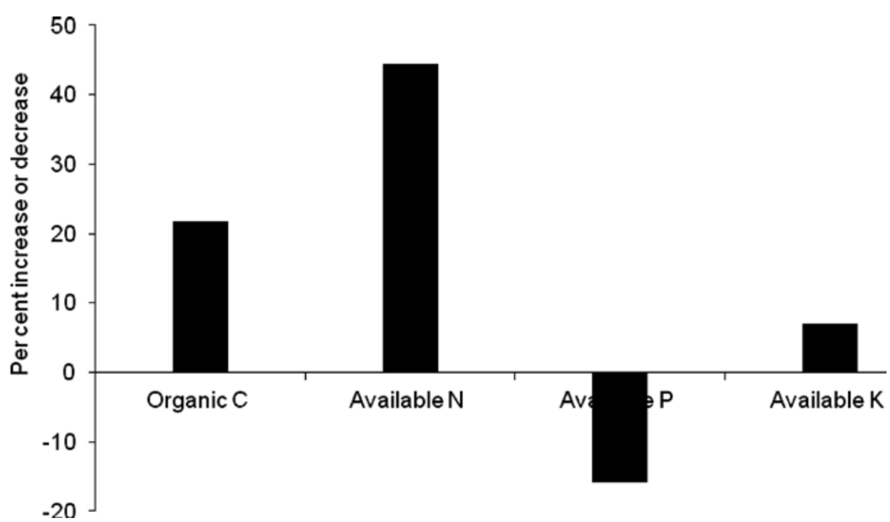

Fig. 3. Percent change in major soil chemical properties under organic management system in the on-station experiment.

Table 5. Impact of production systems on the secondary and micronutrient status of soil under three years of cultivation of dwarf white yam at the on-station site.

Production systems	Exch. Ca (cmol/kg)	Exch. Mg (cmol/kg)	Avail Fe (mg/kg)	Avail Zn (mg/kg)	Avail Cu (mg/kg)
Conventional	1.92	1.04	46.10	4.29	0.678
Traditional	2.28	0.87	44.90	4.11	0.638
Organic	2.22	0.96	49.90	4.12	0.740
Integrated	1.86	0.92	50.80	4.07	0.646
CD (P = 0.05)	N.S	N.S	N.S	N.S	N.S
Initial values	1.12	0.60	23.99	2.78	0.65

N.S = Not significant.

key cultural practice. As soil acidity decreases, the availability of Fe, Mn, Zn, Cu, and B increases.

No significant microenvironment (soil temperature, soil moisture, soil CO_2 and PAR) changes were observed under organic management, but favourable effects were discernible (Table 6). There was a slight increase in soil temperature due to the higher microbial activity, root metabolism and soil respiration consequent to the application of biofertilizers in organic and integrated systems. The soil moisture, soil CO_2 flux and PAR were also slightly promoted under organic management. Alternative soil management practices involving organic amendments were reported to have 20% higher soil CO_2 emissions (Montanaro *et al.*, 8). There was no significant effect on the soil microbial population under the various production systems (Table 6). The population of bacteria, fungi and actinomycetes were higher, (though not statistically significant) under organic system (+12.87%, +58.69% and +48.85% respectively). Suja *et al*. (18) and Suja and Sreekumar (17) also observed increased microbial population in cultivated organically managed soils under elephant foot yam and yams, respectively. Sheoran et al. (15) also recorded higher microbial population (39-47%) in organic farming over conventional farming, which resulted in better soil health and higher productivity.

In the present study, in the organic system, farmyard manure, green manure, neem cake and ash, were used to substitute chemical fertilisers. Of these, the most important component was green manuring with cowpea (incorporation of 15-20 t/ha of green matter). In the current research, organic farming was thus associated with higher levels of biological activity due to its versatile crop association involving legumes, decomposition of large quantity of organic manures to a greater extent than that in the chemical system, apart from the avoidance of pesticides and chemical fertilizers, which might have contributed to higher microbial population.

The on-farm validation was done to validate the on-station developed organic farming technologies. Trials were laid out in farmers fields (on-farm trials) at seven sites with three practices, conventional, traditional and organic, in Thiruvananthapuram and Kollam districts. In all the sites, organic management yielded the same as in conventional practice. However, the yields under organic management were 21% higher (though insignificant) over chemical based farming. Economic analysis indicated that organic management fetched added profit of ₹ 51,580/ha over chemical management in dwarf white yam (Table 7).

Thus, it can be concluded that organic farming comprising farmyard manure, green manure, neem cake, biofertilizers and ash is a feasible alternative

Table 6. Effect of production systems on micro-environment in dwarf white yam in the on-station experiment.

Production systems	Soil temperature (°C)		Soil moisture (m^3/m^3)		Soil CO_2 flux (μmol/m^2/s)		PAR (μmol/m^2/s)		Bacteria (x 10^6)	Fungi (x 10^4)	Actinomycetes (x 10^5)
	FN	AN	FN	AN	FN	AN	FN	AN	(cfu/g soil)		
Conventional	31.75	34.02	0.0560	0.0484	1.31	1.58	1301	1322	5.67	10.67	2.60
Traditional	31.43	33.55	0.0528	0.0435	1.96	1.00	1243	1415	4.80	10.60	2.53
Organic	32.87	36.70	0.0649	0.0547	1.80	1.50	1323	1324	6.40	16.93	3.87
Integrated	32.54	36.05	0.0544	0.0423	2.10	1.08	1165	1220	5.13	11.20	2.40
CD (P = 0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

FN-Forenoon; AN-Afternoon; NS = Not significant.

Table 7. Yield and economic analysis of farm level production of dwarf white yam under organic vs conventional systems.

Production systems	Yield (t/ha)	Gross income (₹/ha)	Total cost (₹/ha)		Gross costs (₹/ha)	Net income (₹/ha)	B:C ratio
			Labour	Inputs			
Conventional	13.49	404640	135000	133600	268600	136040	1.51
Traditional	13.76	412710	129000	141000	270000	142710	1.53
Organic	16.38	491520	141000	162900	303900	187620	1.62

B:C ratio-Benefit : cost ratio.

to conventional chemical intensive farming in non-trailing genotype of white yam for higher yield, profit and soil health. Organic management enhanced yield by 8-21% and profit by 38% with insignificant effects on tuber quality. Besides, the soil chemical properties, pH, organic C, available N, K, exchangeable Ca, Fe, and Cu, micro-environment and microbial count were also promoted.

ACKNOWLEDGEMENTS

The authors thank the Director, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India, for providing facilities for carrying out the research work.

REFERENCES

1. Barak, P., Jobe, B., Krueger, A. R., Peterson, A. and Laird, A. 1997. Effects of long term soil acidification due to nitrogen fertilizer inputs in Wisconsin. *Plant Soil*, **197**: 61-69.
2. Clark, M. S., Horwath, W. R., Shennan, C. and Scow, K. M. 1998. Changes in soil chemical properties resulting from organic and low-input farming systems. *Agron. J.* **90**: 662-71.
3. CTCRI. 2006. *Tuber Crop Varieties Released by the Central Tuber Crops Research Institute*, Technical Bulletin Series No. 24 Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. 64 p.
4. Enesi, R. O., Hauser, S., Lopez-Montez, A. and Osonubi, O. 2018. Yam tuber and maize grain yield response to cropping system intensification in south-west Nigeria. *Arch. Agron. Soil Sci*. **64**: 953-66.
5. Estiasih, H.T., Apriliyanti, M. W., Afriliana, A. and Kusnadi, J. 2013. Physicochemical and bioactive characteristics of purple and yellow water yam (*Dioscorea alata*) tubers. *Int. J. PharmTech Res.* **5**: 1691-1701.
6. Henneron, L., Bernard, L., Hedde, M., Pelos, C., Villenave, C., Chena, C., Bertrand, M., Girardin, C. and Blanchart, E. 2015. Fourteen years of evidence for positive effects of conservation agriculture and organic farming on soil life. *Agron. Sustain. Dev*. **35**: 169-81.
7. Lebot, V. 2019. *Tropical Root and Tuber Crops: Cassava, Sweetpotato, Yams and Aroids*. 2nd Edn. Crop Production Science in Horticulture Series, CABI International, UK. 544 p.
8. Montanaro, G., Dichio, B., Bati, C. B. and Xiloyannis, C. 2012. Soil management affects carbon dynamics and yield in Mediterranean peach orchard. *Agric. Ecosyst. Environ*. **161**: 46-54.
9. Parmer, D. K., Thakur, D. R., Jamwal, R. S. and Aparna. 2016. Effect of long term organic manure application on soil properties, carbon sequestration, soil - plant carbon stock and productivity under two vegetable production systems in Himachal Pradesh. *J. Environ. Biol*. **37**: 333-39.
10. Ponti, T. D., Rijk, B. and van Ittersum, M. K. 2012. The crop yield gap between organic and conventional agriculture. *Agrl Syst*. **108**: 1-9.
11. Ramesh, P., Panwar, N. R., Singh, A. B., Ramana, S., Yadav, S. K., Shrivastava, R. and Subha Rao, A. 2010. Status of organic farming in India. *Curr. Sci*. **98**: 1190-94.
12. SAS. 2008. SAS Users Guide. SAS Institute Inc. Cary, North Carolina, USA.
13. Seena Radhakrishnan, A. R. and Suja, G. 2019. Nutrient release pattern of organic and inorganic resources used in *cassava production (Manihot esculenta Crantz). J. Plant Nutr.* **42**: 1301–15. https://doi.org/10.1080/01904167.2019.1617305.
14. Seufert, V. and Ramankutty, N. 2017. Many shades of gray-The context-dependent performance of organic agriculture. *Sci. Adv*. **3**: e1602638.

15. Sheoran, H. S., Phogat, V. K. and Dahiya, R. 2019. Effect of organic and conventional farming practices on soil microbial population. *J. Environ. Biol*. **40**: 125-29.

16. Suja, G., Byju, G., Jyothi, A. N., Veena, S. S. and Sreekumar, J. 2017. Yield, quality and soil health under organic vs conventional farming in taro. *Scientia Hort*., **218**: 334-43. http://dx.doi.org/10.1016/j.scienta.2017.02.006.

17. Suja, G. and Sreekumar, J. 2014. Implications of organic management on yield, tuber quality and soil health in yams in the humid tropics. *Int. J. Plant Prod*. **8**: 291–309.

18. Suja, G., Sundaresan, S., Susan John, K., Sreekumar, J. and Misra, R. S. 2012. Higher yield, profit and soil quality from organic farming of elephant foot yam. *Agron. Sustain. Dev*. **32**: 755–64.

Received : January, 2020; Revised : March, 2020;
Accepted : March, 2020