Indian Journal of Agricultural Sciences **90** (8): 1402–10, August 2020/Article
https://doi.org/10.56093/ijas.v90i8.105904

Conservation agriculture in elephant foot yam (*Amorphophallus paeniifolius*) + banana (*Musa* AAB) system for higher productivity and profit: Results of an on-farm validation trial

K REMYA[1] and G SUJA[2]

ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala 695 017, India

Received: 14 September 2018; Accepted: 27 November 2019

ABSTRACT

Field experiment was conducted in a farmer's field at Alathara, Kattela, Thiruvananthapuram, Kerala, during 2016-2017, to evaluate and identify varieties of elephant foot yam [*Amorphophallus paeniifolius* (Dennst. Nicolson)] adapted to conservation agriculture, to validate the resource conservation technologies for elephant foot yam in banana (*Musa* ABB) (var. *Nendran*) based system and to assess its impact on growth, yield, soil physico-chemical-biological properties, system productivity and profitability. Four varieties of elephant foot yam (Gajendra, Sree Padma, Sree Athira and Peerumade Local) were tested under two practices, viz. farmer's practice (FP) and conservation agriculture (CA) practice, replicated thrice in split plot design, with varieties in main plots and practices in sub plots.The effect of varieties, practices and varieties × practices interaction was not significant for corm yield and bunch yield of banana. However, among the varieties, Sree Padma produced the highest fresh corm yield (1.9 kg/plant and 17.1 t/ha respectively). The bunch yield of banana (12.2 kg/plant and 30.5 t/ha respectively) was also highest under intercropping with elephant foot yam var. Sree Padma. Conservation agriculture out yielded farmer's practice by 46.9% with respect to elephant foot yam yield and 4.2% for banana yield. Among the varieties × practices interaction, Sree Padma under conservation practice was the most productive (fresh corm yield and bunch yield of 23.1 t/ha and 31.7 t/ha respectively). The major, secondary and micronutrient status of the soil, except available Mn, physical properties of the soil, actinomycetes count, acid phosphatase and urease enzyme activities remained identical in the various treatments, indicating the equal efficiency of conservation agriculture to the existing farmer's practice. Available Mn status was higher under conservation practice with Sree Padma var. The conservation treatment proved to be the most productive (by 11.1% over FP) and profitable (by 41.2% over FP) as revealed from the highest tuber equivalent yield (75.8 t/ha), production efficiency (252.6 kg/ha/day), gross income (₹ 2273615/ha), net income (₹ 1743 454/ha) and B:C ratio (4.3). Among the treatment combinations, highest productivity (86.5t/ha) and profitability (net income of ₹ 2065307/ha; B:C ratio of 4.9), was realized from Sree Padma variety of elephant foot yam intercropped with Nendran banana under conservation agriculture.

Key words: Banana, Conservation agriculture, Economics, Elephant foot yam, Production efficiency, Soil properties, Tuber equivalent yield

Indian agriculture has made a significant transformation from a food deficit-subsistence farming system to a food surplus-commercialized system with over four times increase in the food grain production during the last five decades. However, it is facing many challenges too, like stagnating net cropped area, plateauing yield levels, deterioration of soil quality, degradation of natural resources, reduction in per capita land availability and the adverse effects of climate change.

Conservation agriculture and resource conservation technologies are gaining increased attention worldwide as a viable option for sustainable agriculture, as a potential adaptation strategy to impart climate resilience. It is based on three core inter-linked principles of minimum soil disturbance, permanent soil cover (by crop residues, mulching or cover crops) and crop diversification.

Based on a part of Ph D thesis of the first author from Kerala University.

[1]Ph D Scholar (e mail: sujagin@yahoo.com), [2]Principal Scientist, Division of Crop Production, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is an important tuberous vegetable having high nutritive value, good taste and cooking quality. It has also medicinal values and used in pharmacological industry due to the presence of various nutraceuticals (Reguet *et al*.1999). The *Nendran* banana also known as French plantain (*Musa* AAB) is an important cash crop in South India particularly in Kerala and southern districts of Tamil Nadu. The banana variety *Nendran* is widely cultivated in many parts of South India. Fully ripe fruits of these varieties serve as dessert delicacy. The mature raw fruits of *Nendran* are used for making chips and for culinary purposes. The starchy flour extracted from mature fruits also serves as weaning food for infants. These crops with a duration of 10-12 months take four to five months to develop the canopy and to fully cover the inter space. Further these are highly susceptible to bunchy top virus disease, nematode infestation and to wind damage causing total crop loss to farmers (Nayar and Suja 2004).

Raising hardier crops especially tropical tuberous vegetables like elephant foot yam, in association with bananas and plantains augments net income from unit area per unit time, enables better utilization of resources, serves as an insurance against total crop loss and ensures food and nutritional security to resource poor farmers. The productivity and profitability of such association has been reported (Nayar and Suja 2004). There is sufficient biomass addition and nutrient recycling and scope for low/minimum tillage in this crop combination.

On-station field experiments conducted at ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) for two years indicated that conservation chemical practice was productive and profitable for elephant foot yam + banana intercropping system. However the technology required validation in actual farming situation. Hence, the objectives of the present study were to evaluate and identify varieties of elephant foot yam adapted to conservation agriculture, to monitor the effect of conservation agriculture on the growth, yield, soil physico-chemical-biological properties, system productivity and profitability and to validate the resource conservation technologies for elephant foot yam + banana (var. *Nendran*) system.

MATERIALS AND METHODS

Field experiments was conducted during 2016-2017 in a farmer's field at Alathara, Kattela, Sreekariyam, Thiruvananthapuram, Kerala, India. The site experiences a typical humid tropical climate with bimodal annual pattern of rainfall.The total annual rainfall received during May 2016 to March 2017 was 854.1 mm, maximum and minimum temperatures were 30.8ºC and 23.9ºC, and relative humidity was 81.2%.The experimental soil was clayey in texture with pH 5.1, high status of organic C (1.3%), available P (35.2 kg/ha) and available K (308.9 kg/ha) and low available N (144.6 kg/ha).

The experiment was laid out in split plot design in a banana (var. *Nendran*) field, with four varieties of elephant foot yam (Gajendra, Sree Padma, Sree Athira and Peerumade Local) in main plots and two practices (farmer's practice (FP) and conservation agriculture (CA) in sub plots and replicated thrice. Description of practices and nutrient management options are given in Tables 1 and 2.

Gajendra is a variety released from Vegetable Research Station, Rajendra Nagar, under the aegis of All India Co-ordinated Research Project (AICRP) on Tuber Crops, which is a selection from local collections of Kovvur, West Godavari district, Andhra Pradesh. It produces an average yield of 42.0 t/ha (potential yield of 55.0 t/ha) in 180-210 days (AICRP2012). Sree Padma is a selection from indigenous germplasm collection from Wyanad, Kerala with an average yield of 42.0 t/ha and potential yield of 80.2 t/ha, released from ICAR-CTCRI. Sree Athira is a hybrid selection released from ICAR-CTCRI, Thiruvananthapuram, that matures in 9-10 months and yielding 40.5 t/ha (CTCRI 2006).Peerumade local is a local high yielding variety with good market preference and excellent cooking quality, procured from Peermade Development Society, Pothupara, Idukki district, Kerala.

The gross plot size was 8 m × 4 m accommodating 8 banana at a spacing of 2 m × 2 m and 32 elephant foot yam plants at a spacing of 90 cm × 90 cm. Banana was planted in pits of 50 cm^3 and elephant foot yam in 60 × 60 × 45 cm^3 sized pits.

The growth characters of elephant foot yam, such as plant height, leaf spread and girth of pseudostem were measured from three plants at 3, 4, 5 and 6months after planting (MAP), mean values were computed and expressed in cms. Growth characters of banana, such as plant height, girth of pseudostem, number of total leaves were measured from three plants at 4 and 6 MAP. Tubers of elephant foot yam and bunches of banana were harvested, fresh weights were recorded and expressed in t ha^{-1}. The soil samples were collected from the experimental plots at various intervals,

Table 1 Description of treatments

Treatment	Tillage + nutrient management + weed management practices
Farmer's practice (FP)	Conventional tillage** + mulching + application of manures and fertilizers + hand weeding
Conservation agriculture (CA)	Conservation practices such as minimum tillage#, crop residue retention, green manuring + chemical method of weed management$+ need based application of manures and fertilizers based on soil testing*

**Conventional tillage: Two ploughings, digging of entire area before pit preparation, two weedings.# Minimum tillage: One ploughing, digging for pit formation alone, one weeding, $Pre-emergence application of Oxyfluorfen @ 0.2 kg ai/ha within 6 days of planting, *Based on Aiyer and Nair (1985) 78% N, 0 P and 25% K of the POP recommendation of NPK to both the crops, Crop residue addition in CA @ 7 t/ha, Fresh biomass from green manure cowpea in CA was 1.15 t/ha.

Table 2 Description of nutrient management options

Treatments	Nutrient management mode	Banana	Elephant foot yam
Farmer's practice (FP)	Without soil testing	FYM @ 25 t/ha, Neem cake @ 4.4 t/ha, Bone meal @ 0.6 t/ha, ash @ 4.4 t/ha, Musoorie phosphate 2000 kg/ha, Muriate of potash 1500 kg/ha	Neemcake @ 3 t/ha, Poultry manure @ 2.6 t/ha, Bone meal @ 1.5 t/ha
Conservation agriculture (CA)	Chemical based on soil testing	FYM @ 25 t/ha, NPK @ 148:0:75 g/plant	FYM @ 21.5 t/ha, NPK @ 78:0:25 kg/ha

prior to the experiment, 3 MAP, 6 MAP and harvest stage and analyzed for pH, organic C (Jackson 1973), available N (Subbiah and Asija 1956), P and K (Jackson 1973), exchangeable Ca, Mg, available Fe, Mn, Zn and Cu by standard procedures (Sims and Johnson 1991).

The physical properties like bulk density, particle density, water holding capacity and porosity were done by Keen Raczkowskii box method (Gupta and Dakshinamoorthy 1980) and microbial count of bacteria, fungi and actinomycetes were done by serial dilution method (Sherman and Cappuccino 2005). Dehydrogenase enzyme activity of the soil was estimated by determination of triphenylformazan (TPF) production according to Klein *et al*. (1971). Acid phosphatase (phosphomonosterase) activity was determined by the procedures of Tabatabai and Bremner (1969). A modified assay of urease activity based on Broadbent *et al*. (1958) was used for estimating the urease activity in the soil.

Total cost of cultivation and gross returns were calculated from the average input cost and average market price of the produce during the period of investigation. The net return (₹/ha) was worked out by subtracting the gross cost from gross income. The benefit:cost ratio (B:C ratio) was computed by dividing the gross income by the gross cost. The total tuber equivalent yield and production efficiency of the various treatments were worked out as per Nedunchezhiyan *et al*. (2007). The analysis of variance of data was done using SAS (2010) by applying analysis of variance technique (ANOVA) for split plot design. Wherever significant difference among treatments was detected through ANOVA, critical differences (CD) are provided for effective comparison of means.

RESULTS AND DISCUSSION

Growth dynamics

The effect of varieties, practices and varieties × practices interaction was not significant for almost all the growth attributes of elephant foot yam and banana, except pseudostem girth. This indicates that varieties performed similarly under conservation agriculture. However, among the varieties, Gajendra was the tallest throughout the growth phase (Table 3). The varieties showed significant variation in pseudostem girth at 5 MAP and 6 MAP. The pseudostem girth of Gajendra was significantly higher at 5 MAP and on par with Sree Athira at 6 MAP.

Of the two treatments, conservation treatment favoured the plant growth, especially by greater plant height and pseudostem girth at most stages. Higher retention of residues in the conservation treatment might have resulted in more proliferation of root system and better growth. Moreover the effect of mulching combined with greater weed control due to application of herbicides might have favoured crop growth in the conservation practice.The effect of varieties, practices and varieties × practices significantly influenced the pseudostem girth of banana at 4 MAP (Table 3). The pseudostem girth of banana was higher when intercropped with Sree Padma variety of elephant foot yam, irrespective of the practices.

Yield

The effect of varieties, practices and varieties × practices interaction was not significant for corm yield and bunch yield of banana (Table 4). Similar results of almost identical response of varieties to organic and conventional

Table 3 Effect of treatments on pseudostem girth (cm) of elephant foot yam and banana

Treatment	Elephant foot yam		Banana
	5 MAP	6 MAP	4 MAP
Varieties			
Gajendra	15.44	15.78	35.43
Sree Padma	11.97	13.33	43.50
Sree Athira	11.92	15.06	35.75
Peerumade Local	12.83	14.44	35.65
CD (P=0.05)	2.035	1.252	4.194
Practices			
Conservation agriculture (CA)	13.50	14.97	36.21
Farmers practice (FP)	12.58	14.33	38.95
CD (P=0.05)	NS	NS	1.064
Varieties × practices			
Gajendra CA	15.56	15.67	33.65
Gajendra FP	12.44	15.89	37.21
Sree Padma CA	12.50	13.67	41.79
Sree Padma FP	13. 00	13.50	45.21
Sree Athira CA	15.33	15.44	33.29
Sree Athira FP	11.50	14.67	38.21
Peerumade Local CA	11.33	15.11	36.12
Peerumade Local FP	12.17	13.78	35.17
CD (P=0.05)	NS	NS	4.254

Table 4 Effect of resource conservation treatments on the productivity of elephant foot yam and banana

Treatment	Elephant foot yam			Banana	
	Corm yield		Corm dry matter production (t/ha)	Bunch yield	
	kg/plant	t/ha		kg/ plant	t/ha
Varieties					
Gajendra	1.75	15.09	3.45	11.83	29.58
Sree Padma	1.99	17.10	3.69	12.18	30.45
Sree Athira	0.77	6.59	0.97	11.43	28.58
Peerumade Local	1.80	15.44	2.88	11.32	28.30
CD (P=0.05)	NS	NS	1.842	NS	NS
Practices					
Conservation Agriculture (CA)	1.88	16.13	2.90	11.93	29.82
Farmers' practice (FP)	1.28	10.98	2.58	11.45	28.63
CD (P=0.05)	NS	NS	NS	NS	NS
Varieties × practices					
Gajendra CA	1.65	14.15	2.28	12.40	31.00
Gajendra FP	1.86	16.03	4.61	11.26	28.15
Sree Padma CA	2.68	23.08	4.68	12.69	31.72
Sree Padma FP	1.29	11.13	2.65	11.67	29.18
Sree Athira CA	0.57	4.88	0.86	11.33	28.33
Sree Athira FP	0.96	8.29	1.08	11.53	28.83
Peerumade Local CA	2.60	22.40	3.79	11.31	28.28
Peerumade Local FP	0.99	8.48	1.96	11.33	28.33
CD (P=0.05)	NS	NS	NS	NS	NS

management was reported earlier in elephant foot yam (Suja *et al*. 2016) and taro (Suja *et al*. 2017). However, among the varieties, Sree Padma produced the highest fresh corm yield (1.9 kg/plant, 17.1 t/ha respectively). Varieties differed significantly for corm dry matter production and all the varieties, except Sree Athira, had higher corm dry matter yield.

The bunch yield of banana (12.2 kg/plant, 30.5 t/ha respectively) was also highest under intercropping with elephant foot yam var. Sree Padma. Conservation agriculture out-yielded farmer's practice by 46.9% with respect to elephant foot yam yield and 4.2% for banana yield.

Higher productivity under conservation practice was obviously due to ideal soil environment on account of residue retention, green manuring and better weed control using herbicides, which facilitated favourable conditions for moisture conservation, greater nutrient availability, moisture and light to the component crops of the system (Singh *et al*. 2014; Prasad *et al*. 2014; Shekhar *et al*. 2014; Kumar *et al*. 2016). Among the varieties x practices interaction, Sree Padma under conservation practice was the most productive (fresh corm yield, dry corm yield and bunch yield of 23.1 t/ha, 4.7 t/ha, 31.7 t/ha respectively).

Soil properties

*Physical indicators:*The physical properties of the soil as influenced by practices and varieties × practices interaction are given in Table 5. The bulk density, particle density, water holding capacity and porosity of the soil was unaffected by the practices and varieties × practices interaction. This is expected as perceptible changes in soil physical properties occur only under long-term minimum tillage, residue retention and conservation practices. However, conservation agriculture resulted in slightly lower particle density and higher water holding capacity and porosity.

Chemical indicators: The chemical properties of the soil as influenced by practices and varieties × practices interaction are given in Fig 1, 2 and 3, Tables 6 and 7.The trend in the status of major chemical properties as influenced by the treatments is illustrated in Fig 1 and 2. There was a drop in pH from the initial value in both the practices by the end of crop growth (Fig 1). Organic C content after a slight drop in the second stage of sampling enhanced progressively, especially under conservation practice by 6% over farmer's practice by harvest. In general, there was an increasing trend in available N status in both the treatments, though it was in the low range. Available P status showed an increasing trend and available K declined by the end of the trial (Fig 1). The major, secondary and micronutrient status of the soil, except available Mn, remained identical in the various treatments tested, indicating the equal efficiency of conservation agriculture to the existing farmer's practice

Table 5 Physical properties of the soil as influenced by conservation vs farmer's practice in banana + elephant foot yam system

Treatment	Bulk density (g/cm^3)	Particle density (g/cm^3)	Water holding capacity (%)	Porosity (%)
Practices				
Conservation agriculture (CA)	1.09	2.03	42.80	48.84
Farmers' practice (FP)	1.09	2.17	39.81	47.65
CD (P=0.05)	NS	NS	NS	NS
Varieties × practices				
Gajendra CA	1.14	2.04	38.46	50.37
Gajendra FP	1.15	1.93	39.72	51.21
Sree Padma CA	1.04	2.12	38.85	43.22
Sree Padma FP	1.04	2.31	46.29	53.01
Sree Athira CA	1.05	1.93	40.65	51.64
Sree Athira FP	0.99	2.50	43.81	35.25
Peerumade Local CA	1.14	2.03	41.27	50.14
Peerumade Local FP	1.17	1.92	41.37	51.13
CD (P=0.05)	NS	NS	NS	NS

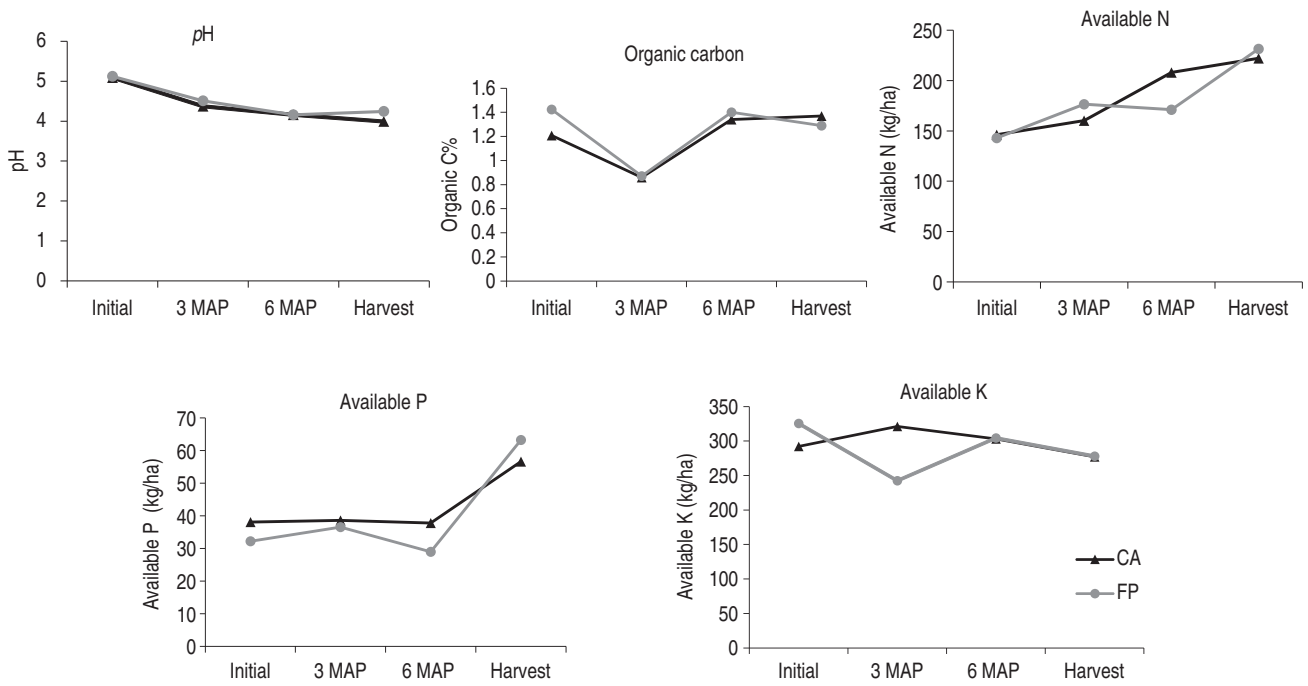

Fig 1 Effect of conservation vs farmer's practice on major chemical properties of the soil at various stages under banana + elephant foot yam system.

in banana + elephant foot yam system (Fig 3). This might be due to the addition of large quantities of various organic manures like FYM, poultry manure, neem cake, bone meal, ash apart from P and K containing chemical fertilizers in the farmer's practice. The farmer's system in the present study relied on injudicious and excess nutrient addition than needed for crop growth, especially in banana. However, it is worthy to mention that the two important soil chemical characteristics, soil organic C and CEC were improved under conservation practice in Gajendra variety owing to green manure cowpea addition, crop residue retention and slow rate in the breakdown of organic matter under conservation tillage practices (Lal *et al*. 2004; Palm *et al*. 2014; Tripathi *et al*. 2015) (Table 6). Available Mn status too was higher under conservation practice in Sree Padma var. which was on par with almost all the treatments, except Gajendra under the two practices (Table 7).

Biological indicators: The soil microbial count and the enzyme activities as influenced by practices and varieties × practices interaction is given in Table 8. The population of bacteria was significantly influenced by varieties × practices interaction and fungi by practices and varieties × practices interaction. The count of bacteria was highest under farmer's practice in Gajendra var. intercropped with banana, which was similar to that in Sree Padma under farmer's practice or conservation practice. In the case of fungal count, farmer's practice proved superior enhancing its population, especially when Sree Athira was the test variety. Dehydrogenase enzyme activity was significantly higher under farmer's practice. On the whole, farmer's

Table 6 Effect of varieties × practices on major chemical properties of the soil under banana + elephant foot yam system at the end of experimentation

Treatment	pH	Electrical conductivity (dS/m)	Organic C (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Gajendra CA	4.04	0.23	1.56	219.52	75.17	359.30
Gajendra FP	4.10	0.36	1.27	193.39	63.96	266.04
Sree Padma CA	3.80	0.42	1.33	209.07	34.61	203.54
Sree Padma FP	4.04	0.45	1.13	182.93	27.68	346.30
Sree Athira CA	3.86	0.52	1.25	227.88	57.91	328.46
Sree Athira FP	4.25	0.32	1.39	363.25	92.57	233.86
Peerumade Local CA	4.26	0.27	1.33	232.06	58.50	215.64
Peerumade Local FP	4.56	0.62	1.37	186.59	68.82	264.69
CD (P=0.05)	NS	NS	NS	NS	NS	NS

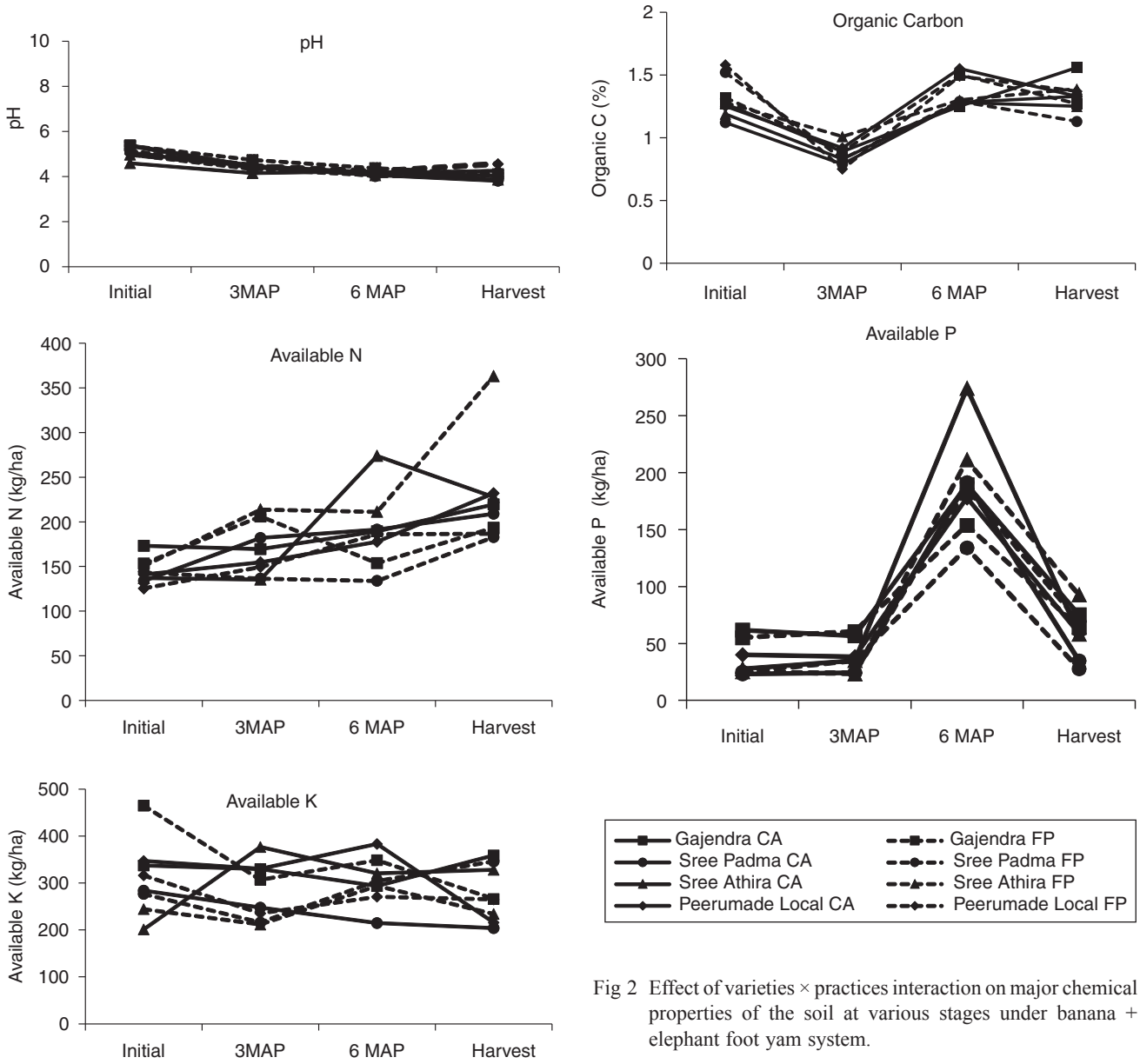

Fig 2 Effect of varieties × practices interaction on major chemical properties of the soil at various stages under banana + elephant foot yam system.

Table 7 Effect of varieties × practices on CEC, secondary and micronutrient status of the soil under banana + elephant foot yam system at the end of experimentation

Treatment	CEC	Exch. Ca	Exch. Mg	Available Fe	Available Mn	Available Zn	Available Cu
		(cmol/kg)			(ppm)		
Gajendra CA	17.07	3.11	2.02	15.71	13.37	8.03	5.94
Gajendra FP	14.67	2.47	2.47	9.31	13.13	5.27	4.62
Sree Padma CA	11.10	2.50	1.59	17.42	22.40	6.04	6.21
Sree Padma FP	13.06	2.48	1.60	19.84	21.89	3.46	5.59
Sree Athira CA	11.70	2.87	1.74	11.70	16.14	5.94	5.64
Sree Athira FP	14.57	3.03	1.77	18.51	20.13	6.77	5.31
Peerumade Local CA	15.13	2.35	1.81	13.57	18.33	5.66	5.68
Peerumade Local FP	15.85	2.95	1.72	16.09	16.41	8.93	6.53
CD (P=0.05)	NS	NS	NS	NS	7.574	NS	NS

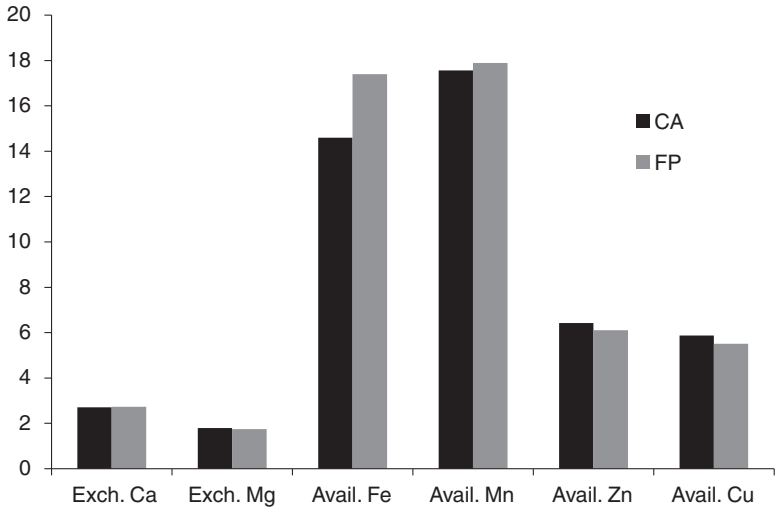

Fig 3 Effect of conservation vs farmer's practice on secondary and micronutrient status of the soil under banana + elephant foot yam system.

system showed an enhancement effect on soil microbial count and dehydrogenase enzyme activity mainly due to the substantial addition of different bio-resources along with chemical fertilizers as discussed earlier. The count of actinomycetes and the activity of enzymes, acid phosphatase and urease were not significantly affected by the practices or varieties × practices interaction.

System productivity and profitability

The net income and B:C ratio were significantly influenced by the treatments (Table 9). Conservation chemical treatment resulted in significantly higher net income and B:C ratio. The conservation chemical treatment proved to be the most productive and profitable as revealed from the highest tuber equivalent yield (75.8 t/ha), production efficiency (252.6 kg/ha/day), gross income (₹ 2273615/ha), net income (₹ 1743454/ha) and B:C ratio (4.3).The net return from conservation chemical treatment was higher by 41.2% over farmer's practice. This is due to the higher productivity (+11%) and lower cost of production (-34.7%) for land preparation and weed control in the conservation chemical treatment when compared to farmer's practice. Similar results of higher system productivity and profitability has been reported earlier in several conservation agriculture systems (Leinhard *et al*. 2014; Prasad *et al*. 2014). The farmer's system incurred a huge expenditure on account of purchased and off-farm generated organic manures like FYM, poultry manure, neem cake, bone meal, ash and chemical fertilizers.

Among the treatment combinations, highest productivity (tuber equivalent yield of 86.5 t/ha and production efficiency of 288.4 kg/ha/day) was realized from Sree Padma variety of elephant foot yam intercropped with Nendran banana under conservation chemical practice. The above treatment also proved to be the most profitable as revealed from the highest gross income (₹ 2595468/ha), net income (₹ 2065308/ha) and B:C ratio (4.9), closely followed by, but with almost similar returns in the conservation chemical treatment with Peerumade local variety (Table 9).

Thus it was proved beyond doubt that among the elephant foot yam varieties tested, Sree Padma was the most responsive to conservation agriculture under intercropping in banana var. *Nendran* as it was productive and profitable.

Table 8 Effect of conservation vs farmer's practice on soil microbial count and enzyme activities

Treatment	Bacteria (*10^6cfu/g)	Fungi (*10^4 cfu/g)	Actinomycetes (*10^5 cfu/g)	Dehydrogenase (µg TPF/g soil/h)	Acid phosphatase (µg p-nitro phenol/g soil/h)	Urease (µg urea/g soil/h)
Practices						
Conservation agriculture (CA)	48.2	8.27	2.47	16.12	257.00	66.54
Farmers' practice (FP)	75.9	13.97	2.35	23.46	251.00	66.53
CD (P=0.05)	NS	3.692	NS	3.124	NS	NS
Varieties × practices						
Gajendra CA	35.22	8.77	1.66	13.31	207.51	66.53
Gajendra FP	166.11	17.55	1.54	22.57	250.06	66.54
Sree Padma CA	109.55	5.11	3.11	21.77	254.26	66.55
Sree Padma FP	118.11	5.00	2.77	21.77	259.37	66.55
Sree Athira CA	35.09	16.44	2.33	17.13	275.59	66.53
Sree Athira FP	8.00	31.00	2.77	24.85	254.96	66.52
Peerumade Local CA	12.77	2.77	2.77	12.28	290.10	66.54
Peerumade Local FP	11.44	2.33	2.33	24.63	237.85	66.51
CD (P=0.05)	62.22	7.243	NS	NS	NS	NS

Table 9 System productivity and profitability of banana + elephant foot yam system as affected by conservation vs farmer's practice

Treatment	Yield (t/ha)		Tuber equivalent yield (t/ha)	Production efficiency (kg/ha/day)	Gross income (₹/ha)	Gross cost (₹/ha)	Net income (₹/ha)	B:C ratio
Practices	*Banana*	*EFY*						
Conservation agriculture (CA)	29.82	16.13	75.80	252.60	2046307	530160.50	1743454	4.30
Farmers practice (FP)	28.63	10.98	68.20	227.40	2273615	811429.00	1234878	2.52
CD (P=0.05)	NS	NS	NS	NS	NS	NS	266369.18	0.4545
Varieties × Practices								
Gajendra CA	31.00	14.15	76.13	253.76	2283871.00	530160.50	1753710.50	4.31
Gajendra FP	28.15	16.03	72.31	241.05	2169425.36	811429.00	1357996.36	2.67
Sree Padma CA	31.72	23.08	86.52	288.39	2595468.00	530160.50	2065307.50	4.90
Sree Padma FP	29.18	11.13	69.46	231.55	2083924.32	811429.00	1272495.32	2.57
Sree Athira CA	28.33	4.88	61.53	205.10	1845877.95	530160.50	1315717.45	3.48
Sree Athira FP	28.83	8.29	65.91	219.71	1977432.27	811429.00	1166003.27	2.44
Peerumade Local CA	28.28	22.40	78.97	263.25	2369241.67	530160.50	1839081.17	4.47
Peerumade Local FP	28.33	8.48	65.15	253.76	1954444.55	811429.00	1143015.55	2.41
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

ACKNOWLEDGEMENT

The authors are thankful to Dr G Byju, Principal Scientist (Soil Science), Division of Crop Production for the secondary and micro-nutrient analyses of soil samples, Dr (Mrs) S S Veena, Principal Scientist (Plant Pathology), Division of Crop Protection for the support in the enumeration of soil microbes and the Director, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, India, for providing facilities for carrying out the research work.

REFERENCES

AICRP. 2012. *Description of Recommended Released Varieties under AICRP on Tuber Crops 1975-2011*. Technical Bulletin Series No. **51,** p 108. All India Co-ordinated Research Project on Tuber Crops, Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, India.

Aiyer R S and Nair K H. 1985. Soils of Kerala and their management. *Soils of India and Their Management*, 219 p. The Fertilizer Association of India, New Delhi.

Broadbent F E, Hill G N and Tyler K B. 1958. Transformations and movement of urea in soils. *Soil Science Society of America Proceedings* **22**: 302–7.

CTCRI. 2006. *Tuber Crop Varieties Released by the Central Tuber Crops Research Institute*, Technical Bulletin Series **24**, Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, India, pp 55-6.

Gupta R P and Dakshinamoorthy C. 1980. *Procedures for Physical Analysis of Soil and Collection of Agrometeorological Data*. Indian Agricultural Research Institute, New Delhi.

Jackson M L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd.

Klein D A, Loh T C and Goulding R L. 1971. A rapid procedure to evaluate dehydrogenase activity of soils low in organic matter. *Soil Biololgy and Biochemistry* **3**: 385–7.

Kumar V, Kumar M, Singh S K and Chandra S K. 2016. Yield and nutrient uptake of rice crop under conservation agriculture in Calciorthent. *Environment and Ecology* **34**(3): 1001-4.

Lal R, Griffin M, Apt J, Lave L Granger and Morgan M. 2004. Managing soil carbon. *Science* **304** (5,669): 393.

Leinhard P, Boulakia S, Legoupil J C, Gilard O and Seguy L. 2014. Conservation agriculture in South-east Asia. *Conservation Agriculture Global Prospects and Challenges*, pp 180-201. Jat R A, Sahrawat K L and Kassam A H (Eds). CABI, Wallingford, United Kingdom.

Nayar T V R and Suja G. 2004. Production potential of root and tubers in multiple cropping systems involving plantation crops. *Journal of Root Crops* **30**(2): 93–100.

Nedunchezhiyan M. 2007. Production and use-efficiency of greater yam (*Dioscore aalata*)-based intercropping system as influenced by intercrops and planting patterns. *Indian Journal of Agronomy* **52**(3): 216–19.

Palm C, Blanco-Canqui H, DeClerck F,Gatere L and Grace P. 2014. Conservation agriculture and ecosystem services: An overview. *Agriculture Ecosystems and Environment* **187**: 87–105.

Prasad D, Rana D S, Rana K S and Rajpoot S K.2014. Effect of tillage practices and crop diversification on productivity, resource-use efficiency and economics of maize (*Zea mays*)/ soybean (*Glycine max*)-based cropping systems. *Indian Journal of Agronomy* **59**(4): 534-41.

Regu A, Deepa V C.and Sundaram K A. 1999. Study on Soorana (*Amorphophallus paeoniifolius*) the king of tubers. *Tropical Tuber Crops in Food Security and Nutrition*, pp 10-4. Balagopalan C, Nayar T V R, Sundaresan S, Premkumar T, Lakshmi K R (Eds). Oxford and IBH Publishing Co. Pvt, Ltd. New Delhi.

SAS. 2010. *SAS Users Guide*. SAS Institute Inc. Cary, North Carolina, USA.

Shekhar C, Singh D, Singh A K, Nepalia V and Choudhary J. 2014. Weed dynamics, productivity and soil health under different tillage and weed control practices in wheat (*Triticum aestivum*)-maize (*Zea mays*) cropping sequence. *Indian Journal of Agronomy* **59**(4): 561–67.

Sherman N and Cappuccino J G. 2005. *Microbiology*: *A Laboratory Manual*, 6thEdn. **81**(3): 265–67.

Sims J T and Johnson G V. 1991. Micronutrient soil tests. *Micronutrients in Agriculture,* pp 427-76. Mortvedt J J, Cox F R, Shuman L M and Welch R M (Eds). Book Series No. 4, Soil Science Society of America, Madison.

Singh A, Kumar R and Kang J S. 2014. Tillage system, crop residues and nitrogen to improve the productivity of direct seeded rice and transplanted rice. *Current Agriculture Research* **2**: 14-29.

Subbiah B V and Asija L L. 1956. A rapid procedure for estimation of available nitrogen in soils.*Current Science* **25**: 259–60.

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 Horticulturae* **218**: 334–43, http://dx.doi.org/10.1016/j.scienta.2017.02.006.

Suja G, Jyothi A N and Byju G. 2016. Response of varieties of elephant foot yam to organic management. *Indian Journal of Agricultural Sciences* **86**(10): 1343–49.

Tabatabai M A and Bremner J M. 1969. Use of P-nitrophenol phosphate in assay of soil phosphatase activity. *Soil Biology and Biochemistry* **1**: 301–7.

Tripathi S C, Chander S and Meena R P. 2015. Effect of residue retention, tillage options and timing of N application in rice-wheat cropping system. *SAARC Journal of Agriculture* **13**(1): 37–49.