

Production potential of intercropping spices in elephant foot yam (*Amorphophallus paeoniifolius*)

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ABSTRACT

A field experiment was conducted at Regional Centre of Central Tuber Crops Research Institute, Dumuduma, Bhubaneswar, Odisha, during 2010–11 to 2012–13, to study production potential of intercropping spices in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]. The experiment consisted of 7 treatments, viz. elephant foot yam (EFY) (sole crop), ginger (*Zingiber officinale* Rosc.) (sole crop), turmeric (*Curcuma longa* L.) (sole crop), EFY + ginger (1:1 in additive series), EFY + ginger (1:2 in additive series), EFY + turmeric (1:1 in additive series) and EFY + turmeric (1:2 in additive series), and was laid out in randomized block design with 4 replications. In intercropping, elephant foot yam full population was maintained. The intercrops were planted in intra-row spacing. Introduction of intercrops and increasing their population significantly increased pseudostem height and decreased pseudostem girth, canopy spread and production of leaflets in elephant foot yam. Incidence of collar rot was found decreased in the intercropping and minimum of 6.0% was observed in elephant foot yam + turmeric (1:2) intercropping. The intercropping systems showed superiority to sole cropping in total productivity and starch content, and reduction in calcium oxalate content. The highest corm equivalent yield (39.6 t/ha), gross (₹3,96,000) and net returns (₹2,33,000) and benefit: cost ratio (2.43) were noticed in elephant foot yam + ginger (1:2).

Key words : Collar rot, Corm-equivalent yield, Elephant foot yam, Intercropping, LER, Starch

Elephant foot yam a tuberous vegetable is gaining importance as a commercial crop. The botanically modified stem 'corm' is consumed as vegetable after boiling, baking and frying (Nedunchezhiyan *et al.*, 2002; Nedunchezhiyan *et al.*, 2006). Young leaves are also used as vegetable after chopping and boiling. Pickle, a delicacy recipe preferred by Indians is also prepared from elephant foot yam corms (Nedunchezhiyan and Misra, 2008). Corms are rich in minerals and vitamins (Nedunchezhiyan *et al.*, 2008). Long keeping quality of the tubers, less pests and diseases, and low labour requirement encourages farmers to grow elephant foot yam crop in spite of the long duration (8 months). The crop is planted at wider spacing and it takes 3 months to fully cover the ground. A long umbrella shaped crop canopy (a tripartite dissected leaf on single pseudostem) allows intercrops to be grown in the wider interspaces. Short-duration pulses like greengram, blackgram and cowpea were profitable intercrops and synergistic effect of the above was noticed in elephant foot

yam (Nedunchezhiyan and Byju, 2005). In Kerala, during initial stage, farmers grow cucumber or *Amaranthus* as intercrop and harvest within 60–75 days after sowing (Ravindran and Nedunchezhiyan, 2008). However, long-duration intercrops reduces corm yield proportional to their duration (Nedunchezhiyan and Byju, 2005). Elephant foot yam corm yield was found to be reduced at various degrees when intercropped with okra and vegetable cowpea (Chattopadhyay *et al.*, 2008).

Information on the effect of shade loving long duration spice crops like ginger and turmeric as intercrops in elephant foot yam is not available. Hence, present investigation was carried out to study the effect of intercropping spices in elephant foot yam on the growth, yield, quality, disease incidence, system productivity and profitability.

MATERIALS AND METHODS

A field experiment was conducted at Regional Centre of Central Tuber Crops Research Institute, Dumuduma (20° 14' 50" N and 85° 47' 06" E), Bhubaneswar during 2010–11 to 2012–13. The soil had pH 6.7, organic carbon 0.32%, available nitrogen 268 kg/ha, available phosphorus 19.5 kg/ha and available potassium 185 kg/ha before the experiment. Water-holding capacity of the soil was 18.4%.

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The climate of the region is characterized by hot and humid summer and cold and dry winter. The average annual rainfall was 1,400 mm in 55 days. The average maximum temperature ranged between 29.0 and 38.9°C, whereas the average minimum temperature between 14.9 and 26.7°C. July and August were the highest rain-receiving months.

The experiment was laid out in randomized block design with 4 replications. The experiment consisted of 7 treatments, viz. T₁, elephant foot yam (EFY) (sole crop); T₂, ginger (sole crop); T₃, turmeric (sole crop); T₄, EFY + ginger (1:1 in additive series); T₅, EFY + ginger (1:2 in additive series); T₆, EFY + turmeric (1:1 in additive series); and T₇, EFY + turmeric (1:2 in additive series). The gross plot size was 9.0 m × 9.0 m and the net plot size was 4.5 m × 4.5 m. Elephant foot yam was planted at 90 cm × 90 cm, ginger and turmeric at 25 cm × 25 cm spacing for sole cropping. In intercropping, elephant foot yam full population was maintained. The intercrops were planted in intra-row spacing. In 1:1 ratio, 1 plant of ginger or turmeric was planted between 2 plants of elephant foot yam (intercrop spacing 90 cm × 90 cm). In 1:2 ratio, 2 plants of ginger/turmeric were planted between 2 plants of elephant foot yam (intercrop spacing 90 cm × 45 cm). All the crops were planted in ridge and furrow system. The variety 'Gajendra', 'Surabhi' and 'Suroma' of elephant foot yam, ginger and turmeric, respectively, was used in this experiment. Recommended dose of fertilizer was applied to all the sole crops. In intercropping, elephant foot yam was given full dose of fertilizers and intercrops were given fertilizers based on net area sown. The recommended dose of fertilizers for elephant foot yam are: FYM @ 25 t/ha + N-P₂O₅-K₂O @ 80-40-100 kg/ha, for ginger - FYM @ 30 t/ha + N-P₂O₅-K₂O @ 75-20-40 kg/ha, and for turmeric - FYM @ 40 t/ha + N-P₂O₅-K₂O @ 30-12-48 kg/ha. The FYM and full P were applied during the last ploughing. Half dose of N and K were applied 1 month after planting (MAP) and the remaining half dose was applied 1 month after the first dose. Corms and rhizomes were treated with cowdung slurry (1 kg fresh cowdung dissolved in 1 litre water) + *Trichoderma viridi* (5 g/kg of seed) mixture. Weeding followed by earthing up was carried out 25, 50 and 75 days after planting. The crop was raised under protective irrigation. Elephant foot yam, ginger and turmeric were harvested at 8 months after planting.

Elephant foot yam produces on an average 2–3 pseudostems/plant or hill when whole corms are planted. Usually second pseudostem emerges at 3 months after planting. Growth observations on plant height and canopy spread were recorded from the first pseudostem at 3 months after planting and the second pseudostem at 5 months after planting. However, observations on number of leaflets, leaf area index (LAI) and dry matter partition-

ing were taken considering the whole plant/hill at 3, 5 and 8 months after planting (harvest). Corm yield was recorded at harvest (8 months after planting). Quality characters of corms such as dry matter, starch, total sugar and calcium oxalate were analysed (AOAC, 1980) at harvest. Growth and yield parameters of the intercrops were also recorded. Cost of cultivation and returns were calculated as per prevailing rates of inputs and output during the cropping period. Benefit: cost ratio was also calculated.

The land-equivalent ratio (LER) was used as the criterion for measuring the resource use efficiency of intercropping over sole cropping and it was calculated as suggested by Willey (1979). When the value of LER is greater than 1, intercropping favours the growth and yield of the spices. When LER is lower than one, intercropping negatively affects the growth and yield of crops grown in mixtures (Caballero *et al.*, 1995).

The data were subjected to analysis of variance (ANOVA) for RBD using Genstat software. The homogeneity of error variance was tested using Bartlett's χ^2 -test. As the error variance was homogeneous, pooled analysis was done. Comparison of treatment means for significance at 5% was done using the critical differences (CD) as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth dynamics

The pseudostem height of elephant foot yam was significantly greater under elephant foot yam + turmeric (1:2) intercropping than that under sole cropping throughout the crop-growth period. This might be owing to the increased competition for light from the intercrop and etiolation of the main crop is a common feature under intercropping. At early stage, ginger and lower population of turmeric did not exhibit much competition for light. Maximum pseudostem girth of elephant foot yam was noticed in sole cropping of elephant foot yam. Introduction of intercrops and increasing their population significantly reduced the pseudostem girth. Minimum pseudostem girth was observed in elephant foot yam + turmeric (1:2) intercropping. In this treatment the competition for light was maximum as indicated by greater pseudostem height. Pseudostem girth and height are inversely related.

With increasing age (up to 5 months after planting), canopy spread and production of leaflets increased irrespective of sole and intercropping systems (Table 1). Significantly higher canopy spread, leaflets/plant and leaf-area index (LAI) of elephant foot yam were noticed in sole cropping of elephant foot yam (Table 1). This might be due to less/lack of competition for light, nutrients and other resources under sole cropping, which probably might have provided favourable physical environment that

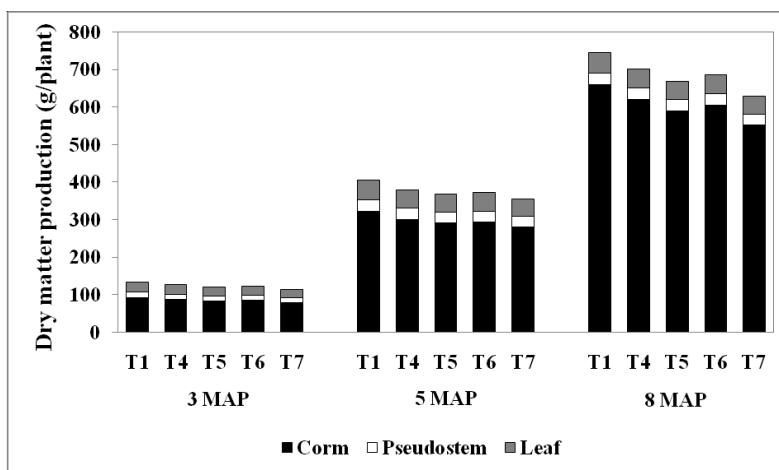
led to higher canopy spread and production of leaflets. Leaf area/plant of ginger and turmeric was higher in intercropping than their respective sole crops. This might be due to lesser intra-species competition in intercropping than sole cropping. However, when population of intercrops increased the leaf area/plant was decreased. Intercrops exhibited significantly higher leaf-area index under sole cropping owing to higher plant population on unit area basis.

Elephant foot yam canopy spread and production of leaflets decreased under intercropping. The lowest canopy spread and leaflets production was noticed in elephant foot yam + turmeric (1:2). Decreased growth attributes of base crop in intercropping is well documented (Saikia *et al.*, 2003; Kour *et al.*, 2014). Pooled data of dry-matter production and partitioning revealed that pseudostem and leaf dry matter increased up to 5 months after planting, then after the increase was negligible (Fig. 1). Corm dry-matter increased rapidly after 3 months. The maximum increase was between 3 and 5 months after planting. At all the stages, lower dry-matter was observed in pseudostem and higher dry-matter in corms. Leaf dry-matter was higher than pseudostem. Significantly higher total dry-matter accumulation/plant of pseudostem, and leaf, corm was observed in sole cropping of elephant foot yam. However, dry-matter of pseudostem was almost similar in all the treatments at all the stages. Similarly, leaf dry-matter was comparable under elephant foot yam + ginger (1:1),

elephant foot yam + ginger (1:2) and elephant foot yam + turmeric (1:1) at all the stages. Elephant foot yam + ginger (1:1) at all the stages, elephant foot yam + ginger (1:2) at 5 months after planting and elephant foot yam + turmeric (1:1) at 5 and 8 months after planting resulted in same corm dry-matter production. The total dry-matter accumulation under elephant foot yam + ginger (1:1) and elephant foot yam + turmeric (1:1) were comparable. This indicated that intercrops at higher population affected leaf, corm and total dry-matter accumulation. The rate of total dry-matter accumulation was not affected by intercrops at early stage, but affected at later stage (Table 2). The rate of total dry-matter accumulation was drastically reduced under elephant foot yam + turmeric (1:2) between 5 and 8 months after planting.

Collar rot

In elephant foot yam, collar rot caused by *Sclerotium rolfsii* is one of the major diseases. Collar rot infection starts 2 months after planting and continues till harvest. It causes breaking of pseudostem completely at collar region and yield loss. Greater incidence of collar-rot was found in sole cropping (Table 2). Intercropping had significantly reduced collar rot incidence. Reduction of collar rot incidence was higher with turmeric than ginger. The roots and rhizomes exudates of turmeric released in the rhizosphere might have been affected the growth and multiplication of *Sclerotium rolfsii*. Intercrop population was found to be



	3 MAP				5 MAP				8 MAP			
	Pseudostem	Leaf	Corm	Total	Pseudostem	Leaf	Corm	Total	Pseudostem	Leaf	Corm	Total
SEm±	0.52	0.78	2.01	3.92	0.90	1.59	9.93	10.97	1.04	1.40	20.36	20.94
CD (P=0.05)	NS	NS	6.2	12.1	NS	4.9	30.6	33.8	NS	4.3	62.7	64.5

MAP: Month after planting;

Fig. 1. Dry-matter production and partitioning (g/plant) in elephant foot yam as influenced by spices intercropping (pooled data of 3 years) treatment details are presented in the Materials and Methods

Table 1. Growth dynamics of elephant foot yam (EFY) and intercrops in elephant foot yam + spices intercropping (pooled data of 3 years)

Treatment	Elephant foot yam						Intercrops							
	Pseudostem height (cm)		Pseudostem girth (cm)		Canopy spread (cm)		Leaflets/plant		Leaf-area index		Leaf-area/plant (cm ²)		Leaf-area index	
	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP
EFY (sole crop)	80	96	13	18	98	126	336	536	0.84	1.53	-	-	-	-
Ginger (sole crop)	-	-	-	-	-	-	-	-	-	-	1,494	3,037	2.39	4.86
Turmeric (sole crop)	-	-	-	-	-	-	-	-	-	-	1,713	3,325	2.74	5.32
EFY + ginger (1:1 additive series)	83	104	12	16	93	122	312	498	0.78	1.42	1,645	3,372	0.91	1.87
EFY + ginger (1:2 additive series)	84	106	12	15	90	118	306	490	0.77	1.40	1,556	3,105	0.43	0.86
EFY + turmeric (1:1 additive series)	85	108	11	14	88	114	302	482	0.76	1.38	2,146	4,221	1.19	2.35
EFY + turmeric (1:2 additive series)	90	118	10	13	86	111	290	472	0.73	1.35	2,045	4,032	0.57	1.12
SEm±	2.3	2.7	0.3	0.3	2.3	3.9	11.0	15.5	0.019	0.039	39.5	75.0	0.039	0.052
CD (P=0.05)	7	8	1	1	7	12	34	48	0.06	0.12	122	232	0.12	0.16

MAP, Month after planting

Table 2. Dry-matter production rate, yield attributes and yield of elephant foot yam and intercrops under elephant foot yam (EFY) + spices intercropping (pooled data of 3 years)

Treatment	Elephant foot yam						Intercrops						LER				
	Rate of total dry matter production (g/g)		Collar-rot incidence (%)		Corm diameter (cm)		Corm yield (g/plant)		Corm yield (t/ha)		Rhizome yield/plant (g)			Rhizome yield (t/ha)		Elephant foot yam equivalent yield (t/ha)	
	3-5 MAP	5-8 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP		3 MAP	5 MAP	3 MAP	5 MAP
EFY (sole crop)	1.42	0.84	9.6	17.6	20.4	3000	36.0	-	-	-	-	-	-	-	-	-	
Ginger (sole crop)	-	-	-	-	-	-	-	-	-	-	68.1	10.2	35.8	1.00			
Turmeric (sole crop)	-	-	-	-	-	-	-	-	-	-	83.4	13.1	19.7	1.00			
EFY + ginger (1:1 additive series)	1.37	0.85	9.1	17.0	19.4	2830	34.0	2.7	2.7	90.2	1.1	38.1	1.06				
EFY + ginger (1:2 additive series)	1.44	0.81	8.8	15.4	18.1	2740	32.9	2.5	2.5	77.8	1.9	39.6	1.10				
EFY + turmeric (1:1 additive series)	1.39	0.84	7.3	16.5	18.9	2775	33.3	3.2	3.2	180.3	2.2	36.6	1.02				
EFY + turmeric (1:2 additive series)	1.44	0.77	6.0	14.2	16.6	2560	30.8	2.8	2.8	143.2	3.3	35.8	1.00				
SEm±	0.025	0.019	0.36	0.45	0.55	85	0.84	0.06	0.06	2.46	0.19	1.10	-				
CD (P=0.05)	NS	0.06	1.1	1.4	1.7	262	2.6	0.2	0.2	7.6	0.6	3.4	-				

MAP, Months after planting; LER, land-equivalent ratio; NS, not significant

inversely related to collar rot incidence in elephant foot yam. Significantly lower incidence of collar-rot was noticed in elephant foot yam + turmeric (1:2) intercropping.

Yield

Higher corm length, diameter and yield/plant were noticed in sole cropping of elephant foot yam (Table 2). This was on a par with elephant foot yam + ginger (1:1). This was due to higher growth, dry matter production and partitioning in the absence of/ lesser competition in these treatments (Table 1; Fig. 1). Greater yield attributes led to higher corm yield in these treatments. The corm yield in elephant foot yam + ginger intercropping was just 5.5% lesser than sole elephant foot yam. Intercropping in elephant foot yam resulted in lesser corm length, diameter and yield/plant than the sole cropping. Intercrops reduced the corm yield of elephant foot yam according to their population. Among the intercropping treatments, elephant foot yam + ginger (1:1) resulted in higher corm yield and it was on a par with elephant foot yam + ginger (1:2) and elephant foot yam + turmeric (1:1).

Number of mother rhizomes and rhizome yield/plant were higher in intercropping than sole cropping of ginger and turmeric (Table 2). The treatment, elephant foot yam + ginger (1:1) resulted in higher number of mother rhizomes and rhizome yield/plant than elephant foot yam + ginger (1:2) and sole ginger. Similarly, elephant foot yam + turmeric (1:1) resulted in higher number of mother rhizomes and rhizome yield/plant than elephant foot yam + turmeric (1:2) and sole turmeric. This might be due to translocation of more photosynthates produced from larger leaf area of the plants in intercropping, where intra-species competition was less. Yield of ginger and turmeric was the

highest under sole cropping and reduced under intercropping due to lesser population (Table 2). The lowest yield of ginger and turmeric was noticed in elephant foot yam + ginger/turmeric 1:1 ratio (additive series) of intercropping.

System productivity

The intercropping systems showed superiority to sole cropping in total productivity (Table 2). The higher corm-equivalent yield under intercropping was owing to higher biomass production and efficient use of available growth resources under intercropping than sole cropping. Elephant foot yam + ginger (1:2) resulted in significantly higher corm equivalent yield. However, it was on a par with elephant foot yam + ginger (1:1) and elephant foot yam + turmeric (1:1) intercropping. The increase in corm-equivalent yield under elephant foot yam + ginger (1:2) was 10.0, 10.6 and 101.0% over sole cropping of elephant foot yam, ginger and turmeric, respectively. The LER values (Table 2) also indicated that intercropping systems were superior to sole cropping. The maximum LER was noticed in elephant foot yam + ginger (1:2) intercropping followed by elephant foot yam + ginger (1:1) and elephant foot yam + turmeric (1:1).

Quality and economics

Dry matter and total sugar content were not influenced by intercrops, but significant effect of intercrops on starch and calcium oxalate was observed (Table 3). Intercropping of elephant foot yam with ginger and turmeric resulted in higher starch content in corms than sole cropping of elephant foot yam. Significantly higher amount of starch content was noticed in elephant foot yam + turmeric (1:2) intercropping over sole cropping (Table 3). However, it

Table 3. Quality attributes of elephant foot yam (EFY) and economics of elephant foot yam + spices intercropping (pooled data of 3 years)

Treatment	Elephant foot yam corm				Cost of cultivation ($\times 10^3$ ₹/ha)	Gross return ($\times 10^3$ ₹/ha)	Net return ($\times 10^3$ ₹/ha)	Benefit: cost ratio
	Dry-matter (%)	Starch (% on fresh weight basis)	Total sugars (% on fresh weight basis)	Calcium oxalate (mg/100 g on fresh weight basis)				
EFY (sole crop)	22.0	15.4	1.35	86	150	360	210	2.40
Ginger (sole crop)	-	-	-	-	202	358	156	1.77
Turmeric (sole crop)	-	-	-	-	120	197	77	1.64
EFY + ginger (1:1 additive series)	21.9	16.3	1.33	84	158	381	223	2.41
EFY + ginger (1:2 additive series)	21.5	17.0	1.34	80	163	396	233	2.43
EFY + turmeric (1:1 additive series)	21.8	16.2	1.36	79	155	366	211	2.36
EFY + turmeric (1:2 additive series)	21.6	17.2	1.34	75	159	358	199	2.25
SEm \pm	0.48	0.42	0.026	1.3	-	-	-	-
CD (P=0.05)	NS	1.3	NS	4	-	-	-	-

NS, Not significant; selling price elephant foot yam, ₹10/kg; ginger ₹35/kg; turmeric ₹15/kg

was statistically at par with the other intercropping systems. Reduction in calcium oxalate (anti-nutritional factor) content was observed under intercropping than sole cropping of elephant foot yam. Significantly lower calcium oxalate content was noticed in elephant foot yam + turmeric (1:2) and it was statistically on par with elephant foot yam + turmeric (1:1). Alkaloids released by the turmeric and ginger in the rhizosphere might have influenced the calcium oxalate content.

All the intercropping systems except elephant foot yam + turmeric (1:2) fetched higher gross and net returns compared to sole cropping of elephant foot yam, ginger and turmeric (Table 4). The highest gross and net returns were noticed in elephant foot yam + ginger (1:2), followed by elephant foot yam + ginger (1:1) and elephant foot yam + turmeric (1:1). The highest benefit: cost ratio was observed in elephant foot yam + ginger (1:2) followed by elephant foot yam + ginger (1:1). This might be owing to yield advantages in the intercropping systems.

It can be concluded that intercropping of elephant foot yam with ginger and turmeric increased system productivity and starch content, decreased collar rot incidence and calcium oxalate content in elephant foot yam. Elephant foot yam + ginger (1:2 additive series) may be recommended for higher profit. Elephant foot yam + turmeric (1:2 additive series) may be recommended, where collar rot is a problem.

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