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Effect of multi-tier cropping systems on light interception in elephant foot yam with respect to yield

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Abstract
A field experiment was conducted during summer, 2019 and 2020 to study the effect of multi-tier cropping systems in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] for efficient resource utilization and profitability in coastal Andhra Pradesh. The experiment was carried out with ten treatments in three replications. The experiment consist of different multi-tier cropping systems with elephant foot yam grown as main crop along with eighteen intercrops grown in different treatments. The results revealed that among the different multitier cropping systems, elephant foot yam when grown as sole crop (T_{10}) recorded superior values for light interception at 30, 60, 90, 120 and 150 DAP and superior yield when compared to other multitier cropping systems during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis.

Keywords: Elephant foot yam, multi-tier cropping systems, light interception, yield

Introduction
Tuber crops have been classified as the third most important food crops after cereals and legumes. Elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] also known as "King of tuber crops" belongs to the family araceae. It is most popular and widely cultivated member of edible aroids. It is native of South-East Asia and is indigenous to tropical Asia and Africa and is considered as a famine food in the pacific islands. It is gaining popularity (importance in tropical countries) not only as a food security crop but also as a starchy vegetable having high nutritive and medicinal values (O' Hair and Asokan, 1986) [1].
India ranks first in world acreage (10.2 million hectare) and is the second largest producer of vegetables in the world, with an annual production of 105.40 million tonnes. Our requirement of vegetables has been increased to about 128.5 million tonnes to meet the nutritional requirement of an estimated 1220 million population expected by 2030-31 (Sankaranarayanan *et al*. 2011). Economy of the country is to be improved through agriculture and horticulture by better utilization of natural resources and other inputs. Thus, production per unit area of land, time and inputs should be increased by improving efficiency of the rate and extent to which natural resources are harvested for conversion to economic produce. This is possible through intensive cropping involving crop mixers wherever feasible. This will not only improve the crop production in sustainable way but also economize the crop production.
Multi-tier or Multi-storied or Multi-layer cropping system is the method of growing two or more crops of different heights simultaneously on same piece of land in a certain period. In multi-tier systems, the possibility of more efficient use of resources like sunlight, nutrients and water is leading to increased biological diversity and higher production stability. In addition, the root systems of the component crops are also located at distant zones so as to explore the soil for moisture and nutrients. Intercrops were observed to serve as an insurance against the menace of pests and diseases, vagaries of weather, market fluctuations and help to increase the net profit to growers. The objective of any cropping system is efficient utilization of all resources *viz*., land, water and solar radiation, maintaining stability in production and obtaining higher net returns. The efficiency is measured by the quantity of produce obtained per unit resource used in a given time.
The most efficient practice would probably be to grow these crops in multi-tier cropping systems during summer season. An ideal elephant foot yam based multi-tier vegetable cropping should aim to produce higher economic returns and yield per unit area, offer greater stability in production to meet the domestic needs of the farmer and also ensure stable income per unit area. Growing the short duration crops with elephant foot yam are very useful because they supply food, additional income especially when the elephant foot yam crop cannot yet be

harvested, they may fix nitrogen and supply other nutrients to the top soil, protect the soil from the direct impact of rainfall and reduce the speed of run-off water thus reducing soil erosion and they also reduces the weed growth during early stages of the elephant foot yam development. Hence the present study entitled "Studies on multi-tier cropping systems in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] for efficient resource utilization and profitability in coastal Andhra Pradesh"

Material and Methods

A field experiment entitled "Studies on multi-tier cropping systems in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] for efficient resource utilization and profitability in coastal Andhra Pradesh" was carried out during summer (2019-20 and 2020-21) seasons at College farm, College of Horticulture, Venkataramannagudem. The experiment was carried out with ten treatments with three replications in a randomized block design. The experiment consist of ten multi-tier treatments (T_1 - Elephant Foot Yam + Ridge Gourd + Green Chilli, T_2 - Elephant Foot Yam + Bitter Gourd + Coriander, T_3 - Elephant Foot Yam + Bottle Gourd + Fenugreek, T_4 - Elephant Foot Yam + Snake Gourd + Sorrel, T_5 - Elephant Foot Yam + Indeterminate Tomato + Radish, T_6 - Elephant Foot Yam + Yard Long Bean + Onion, T_7 - Elephant Foot Yam + Sweet Corn + Cow Pea, T_8 - Elephant Foot Yam + Okra + Carrot, T_9 -Elephant Foot Yam + Cluster Bean + Palak, T_{10} - Elephant Foot Yam (sole crop). The present investigation was carried out with variety Gajendra. The experimental area was divided into 5 m x 5 m sized plots. One meter wide irrigation channels were provided between two replications. After ploughing thoroughly and harrowing, the corms are planted vertically at a spacing of 60 cm × 60 cm and at a depth of 5 to 7.5 cm. Size of the corm weighing 500 g per pit was used. The cultivation practices of main crop and intercrops were given under table 1. The data recorded were tabulated and were statistically analyzed by adopting the standard RBD procedures outlined by Panse and Sukatme (1985) [2]. The mean values were tested for significance at 5% level of probability. The critical difference values were calculated at 5% level of probability.

Results and Discussion

The results from the field experiment during the summer season of the years 2019, 2020 and pooled analysis on light interception at (30, 60, 90, 120 and 150 DAP) and yield per plot and hectare are given below and tabulated in Table 2 and 3.

Light Interception at 30 DAP

At 30 DAP, highest light interception (70.57%, 75.50%, 72.96%) was recorded with elephant foot yam when grown as sole crop (T_{10}) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis. Lowest light interception at 30 DAP (63.90%, 62.57%, 63.23%) was recorded with elephant foot yam + yard long bean + onion (T_6) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis.

Light Interception at 60 DAP

At 60 DAP, significantly highest light interception (69.73%, 72.07%, 70.90%) was recorded with elephant foot yam when grown as sole crop (T_{10}) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis. Lowest light interception at 60 DAP (20.13%, 24.00%, 22.06%) was recorded with elephant foot yam + bottle gourd + fenugreek (T_3) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis.

Light Interception at 90 DAP

At 90 DAP, highest light interception (65.07%, 65.33%, 65.20%) was recorded with elephant foot yam when grown as sole crop (T_{10}) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis. Lowest light interception at 90 DAP (14.13%, 14.20%, 14.16%) was recorded with elephant foot yam + bottle gourd + fenugreek (T_3) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis.

Light Interception at 120 DAP

At 120 DAP, highest light interception (64.23%, 64.30%, 64.26%) was recorded with elephant foot yam when grown as sole crop (T_{10}) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis. Lowest light interception at 120 DAP (32.17%, 32.87%, 32.52%) was recorded with elephant foot yam + bottle gourd + fenugreek (T_3) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis.

Light Interception at 150 DAP

At 150 DAP, highest light interception (72.87%, 74.53%, 73.70%) was recorded with elephant foot yam when grown as sole crop (T_{10}) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis. Lowest light interception at 150 DAP (60.67%, 62.33%, 61.50%) was recorded with elephant foot yam + indeterminate tomato + radish (T_5) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis.

The maximum light interception at 30, 60, 90, 120 and 150 DAP was reported in elephant foot yam when grown as sole crop. The increase in light interception might be due to the absence of pandal arrangement, no surrounding intercrops which led to more availability of sunlight directly to the sole crop. The lowest light interception was recorded in T_3 (elephant foot yam + bottle gourd + fenugreek) upto 120 DAP where bottle gourd was grown on pandals above elephant foot yam. Bottle gourd with dense foliage hinders the light interception and thereby recorded lower values. At 150 DAP, all the cucurbitaceous vegetables grown on pandals reached senescence and did not hinder the light interception which did not affected the yield. This proves that elephant foot yam is suitable for growing under shade in pandal system and in open field conditions.

Yield per plot (kg)

Maximum yield per plot (117.89 kg, 123.65 kg, 120.77 kg) was recorded with elephant foot yam when grown as sole crop (T_{10}) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis. Minimum yield per plot (76.12 kg, 79.00 kg, 77.55 kg) was recorded with elephant foot yam + yard long bean + onion (T_6) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis respectively.

Maximum yield per hectare (471.55 q, 500.18 q, 485.86 q) was recorded with elephant foot yam when grown as sole crop (T_{10}) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis. Minimum yield per hectare

(304.47 q, 325.77 q, 315.12 q) was recorded with elephant foot yam + yard long bean + onion (T_6) during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis.

These findings are in accordance with the results obtained by Raj *et al*. (2014) [3] in elephant foot yam cropping systems; Ravikiran *et al*. (2015) [4] in elephant foot yam cropping systems and Samima *et al*. (2020) [5] in elephant foot yam cropping systems.

Impact of light interception on yield

Light interception played a very efficient role in plant growth, yield as well as quality in elephant foot yam. The higher the light interception the more the growth and yield. Elephant foot yam is a shade loving plant, growing under pandal system did not affect the yield of elephant foot yam in some treatments. Elephant foot yam when grown under pandals with bottle gourd and fenugreek as well with sweet corn cowpea showed on par values to the sole crop treatment with respect to growth and yield parameters. The light interception attribute plays a very important role as it helps in improving the photosynthesis process and thus photosynthetic assimilates prepared moves to the growing meristematic regions quickly thus helping in good growth of petioles, number of leaves, plant height and plant canopy which finally leading to good corm formation and development in terms of size gives more yield. Hence from the above it can be concluded that elephant foot yam when grown as sole crop absorbed more sunlight and produced more yield when compared to elephant foot yam grown in other multi-tier treatments.

Table 1: Cultivation practices of main crop and intercrops

S. No	Crop	Time of sowing / Transplanting		Spacing
		2019	2020	
I.	Main crop Elephant foot yam	15.02.2019	14.02.2020	60 cm× 60 cm
II.	Inter crops			
1.	Ridge gourd	15.02.2019	14.02.2020	1.5 m × 1.5 m
2.	Green chilli	15.02.2019	14.02.2020	30 cm × 30 cm
3.	Bitter gourd	15.02.2019	14.02.2020	1.5 m × 1.5 m
4.	Coriander	15.02.2019	14.02.2020	10 cm × 10 cm
5.	Bottle gourd	15.02.2019	14.02.2020	1.5 m × 1.5 m
6.	Fenugreek	15.02.2019	14.02.2020	10 cm × 10 cm
7.	Snake gourd	15.02.2019	14.02.2020	1.5 m × 1.5 m
8.	Sorrel	15.02.2019	14.02.2020	10 cm × 10 cm
9.	Indeterminate tomato	15.02.2019	14.02.2020	45 cm × 45 cm
10.	Radish	15.02.2019	14.02.2020	10 cm × 10 cm
11.	Yard long bean	15.02.2019	14.02.2020	45 cm × 45 cm
12.	Onion	15.02.2019	14.02.2020	15 cm × 15 cm
13.	Sweet corn	15.02.2019	14.02.2020	45 cm × 45 cm
14.	Cow pea	15.02.2019	4.02.2020	30 cm × 30 cm
15.	Okra	15.02.2019	14.02.2020	45 cm × 45 cm
16.	Carrot	15.02.2019	14.02.2020	10 cm × 10 cm
17.	Cluster bean	15.02.2019	14.02.2020	45 cm × 45 cm
18.	Palak	15.02.2019	14.02.2020	10 cm × 10 cm

Table 2: Effect of multi-tier cropping systems on light interception at 30, 60 and 90 DAP in elephant foot yam

Treatments	Light interception (%) at 30 DAP			Light interception (%) at 60 DAP			Light interception (%) at 90 DAP		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1-EFY+RG+GC	70.10	72.80	71.45	53.77	61.00	57.38	51.13	52.93	52.03
T_2-EFY+BiG+Co	68.30	70.17	69.23	55.40	55.27	55.33	43.60	41.53	42.56
T_3-EFY+BoG+Fg	66.17	68.00	67.03	20.13	24.00	22.06	14.13	14.20	14.16
T_4-EFY+SG+So	64.63	66.00	65.37	24.73	25.27	25.00	33.40	31.93	32.66
T_5-EFY+IT+Rd	70.43	64.93	67.75	62.77	44.93	53.85	63.20	51.97	57.58
T_6-EFY+YLB+O	63.90	62.57	63.23	53.80	63.90	58.85	53.00	51.67	52.33
T_7-EFY+SC+CP	69.93	66.20	68.06	63.53	61.20	62.36	62.03	54.87	58.45
T_8-EFY+Ok+Ca	70.40	70.97	70.68	65.73	66.07	65.90	62.67	61.47	62.06
T_9-EFY+CB+P	70.27	71.13	70.70	69.17	69.73	69.45	63.60	64.77	64.18
T_{10}-EFY	70.57	75.50	72.96	69.73	72.07	70.90	65.07	65.33	65.20
S.Em±	0.29	0.62	1.57	0.76	0.62	3.71	1.00	0.82	2.02
C.D. at 5%	0.86	1.86	5.03	2.26	1.84	1.80	2.97	2.44	6.46

Note: T_1:- Elephant Foot Yam + Ridge Gourd + Green Chilli, T_2:- Elephant Foot Yam + Bitter Gourd + Coriander, T_3:- Elephant Foot Yam + Bottle Gourd + Fenugreek, T_4:- Elephant Foot Yam + Snake Gourd + Sorrel, T_5:- Elephant Foot Yam + Indeterminate Tomato + Radish, T_6:- Elephant Foot Yam + Yard Long Bean + Onion, T_7:- Elephant Foot Yam + Sweet Corn + Cowpea, T_8:- Elephant Foot Yam + Okra + Carrot, T_9:- Elephant Foot Yam + Cluster Bean + Palak, T_{10}:- Elephant Foot Yam (sole).

Table 3: Effect of multi-tier cropping systems on light interception at 120 and 150 DAP in elephant foot yam

Treatments	Light interception (%) at 120 DAP			Light interception (%) at 150 DAP		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1-EFY+RG+GC	52.03	52.53	52.28	71.33	70.33	70.83
T_2-EFY+BiG+Co	43.27	42.83	43.05	72.43	72.33	72.38
T_3-EFY+BoG+Fg	32.17	32.87	32.52	64.33	64.67	64.50
T_4-EFY+SG+So	33.80	33.87	33.83	62.53	63.00	62.77
T_5-EFY+IT+Rd	59.53	54.27	56.90	60.67	62.33	61.50
T_6-EFY+YLB+O	54.00	61.20	57.60	64.00	65.00	64.50
T_7-EFY+SC+CP	60.00	53.20	56.60	65.67	67.00	66.33
T_8-EFY+Ok+Ca	63.63	60.77	62.20	68.20	69.20	68.70
T_9-EFY+CB+P	63.77	63.07	63.42	72.53	73.20	72.87
T_{10}-EFY	64.23	64.30	64.26	72.87	74.53	73.70
S.Em±	0.92	0.95	1.93	1.40	1.43	1.00
C.D. at 5%	2.75	2.84	6.17	4.16	4.26	2.88

Note: T_1:- Elephant Foot Yam + Ridge Gourd + Green Chilli, T_2:- Elephant Foot Yam + Bitter Gourd + Coriander, T_3:- Elephant Foot Yam + Bottle Gourd + Fenugreek, T_4:- Elephant Foot Yam + Snake Gourd + Sorrel, T_5:- Elephant Foot Yam + Indeterminate Tomato + Radish, T_6:- Elephant Foot Yam + Yard Long Bean + Onion, T_7:-Elephant Foot Yam + Sweet Corn + Cowpea, T_8:- Elephant Foot Yam + Okra + Carrot, T_9:- Elephant Foot Yam + Cluster Bean + Palak, T_{10}:- Elephant Foot Yam (sole).

Table 4: Effect of multi-tier cropping systems on yield per plot (kg) and hectare (q) in elephant foot yam

Treatments	Yield per plot (kg)			Yield per hectare (q ha^{-1})		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1-EFY+RG+GC	104.2	105.6	104.9	416.80	422.40	419.62
T_2-EFY+BiG+Co	94.16	95.24	94.70	376.65	398.03	387.34
T_3-EFY+BoG+Fg	102.61	106.27	104.44	410.44	423.78	417.11
T_4-EFY+SG+So	89.19	93.20	91.19	356.77	388.84	372.80
T_5-EFY+IT+Rd	78.71	82.03	80.37	314.83	339.06	326.94
T_6-EFY+YLB+O	76.12	79.00	77.55	304.47	325.77	315.12
T_7-EFY+SC+CP	115.89	118.36	117.12	463.54	487.72	475.63
T_8-EFY+Ok+Ca	83.48	88.00	85.74	333.90	365.07	349.48
T_9-EFY+CB+P	87.04	91.45	89.24	348.15	380.61	364.37
T_{10}-EFY	117.89	123.65	120.77	471.55	500.18	485.86
S.Em±	3.38	3.14	2.31	13.54	9.90	8.39
C.D. at 5%	10.06	9.34	6.63	40.25	29.42	24.08

Conclusion

From the present study it can be concluded that elephant foot yam when grown as sole crop (T_{10}) recorded superior values for light interception and yield when compared to other multitier cropping systems during both the years of experimentation (2019-20 and 2020-21) and in pooled analysis.

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