LAND USE AND WEED CONTROL EFFICIENCY OF INTERCROPPING IN ELEPHANT FOOT YAM

ILAKIYA, T.[1*] – SWARNAPRIYA, R.[2] – PUGALENDHI, L.[1] – GEETHALAKSHMI, V.[1] – LAXMANAN, A.[1] – SATHEES KUMAR, K.[3,4]

[1]*Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India*

[2]*Floriculture Research Station, Thovalai 629302, Tamil Nadu, India*

[3]*Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741252, West Bengal, India*

[4]*SRM College of agricultural sciences, SRMIST, Chengalpattu 603 201, Tamil Nadu, India*

[*]*Corresponding author*
e-mail: ilakiyatamil@gmail.com; phone: +91-5099-9448

(Received 13th Mar 2023; accepted 1st Jun 2023)

Abstract. Elephant foot yam, the king of tubers is a long duration tropical tuber crop with multifaceted uses. It is a slow growing crop especially in the initial phases and there is a time lapse of two months or more for the spread of its canopy due to slower sprouting. The interspaces remain fallow and therefore, may be successfully exploited for the cultivation of short-term vegetable crops. To achieve maximum land use efficiency and to control weed growth, the field experiments were conducted at Horticultural College and Research Institute, Coimbatore, India for two seasons, 2021 and 2021/22. Four short-duration vegetables, *viz.*, cluster bean, amaranthus, radish and fenugreek were grown in the inter-spaces of elephant foot yam and compared to its solo crop. At initial stages, the growth parameters of elephant foot yam were higher in solo crop whereas, at later stages, the cluster bean intercropping fared better. Weed control efficiency was greater in the cluster bean intercropping system at 90, 120, 150 and 180 days after planting. A higher yield of elephant foot yam 46.54 t/ha and 38.37 t/ha was obtained at season I and season II respectively in the cluster bean intercropped treatment. The land equivalent ratio was at its maximum (1.66 and 1.61) in the cluster bean intercropping system, indicating that the system is very productive. Thus, for increasing the productivity and profitability, it is suggested for elephant foot yam intercropping with cluster bean. Furthermore, planting elephant foot yam in summer (season I) is preferred since it resulted in higher yield (46.54 t/ha).
Keywords: *land equivalent ratio, production, profitability, tuber crop, weed control*

Introduction

Amorphophallus paeoniifolius, more often referred to as elephant foot yam, is a tuberous vegetable crop that is produced in tropical and subtropical climates (Choudhary et al., 2012). It is a member of the Aeraceae family, and it is also known as Jimikand or Suran. In many Asian nations, elephant foot yam is grown and consumed as a staple meal (Mursyidin et al., 2022). In India, elephant foot yam is a significant contributor to the diets of tribal people, especially in rural regions where it is abundantly accessible. Owing to its yield potential and desirability as a starchy tuber with good nutritional and therapeutic properties, it is not only grown as a crop for food security but also as a crop for commercial purposes (Dey and Ghosh, 2010). A hundred-gram fresh weight tuber of elephant foot yam contain high starch content (11-28 percent), sugar (0.7-1.7 percent), vitamin C (17.1 mg), calcium (161.08 mg), and micronutrient like iron (3.43 mg), manganese (0.19-0.65 mg), zinc (0.12-1.92 mg) and other minerals in sufficient amount (Singh et al., 2016). The elephant foot yam is regarded as the king of tubers due to its

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

multifarious uses. It is grown extensively in Andhra Pradesh, Chhattisgarh, Bihar, West Bengal, Gujarat, Kerala, Jharkhand, Tamil Nadu, Uttar Pradesh, Maharashtra, and also in the Northeastern States of India (Suja et al., 2012). Weeds are the possible stumbling blocks for better yields and higher quality in tuber crops as they compete with the roots for the applied resources. The weed roots may occasionally penetrate into the subterranean storage organs of tuber crops, lowering the quality of the food. The time lapse between planting and sprouting and the slower spread of canopy during the initial growth phases in elephant foot yam make it sensitive to weed development (Nedunchezhiyan et al., 2018). In wider-spaced plantations, weed infestation in the early stages of crop growth produces a significant decrease in yield. Various pest and disease-causing organisms use weeds as alternate hosts. Weeds impede the growth and development of elephant foot yam by competing for light, nutrients, space, and water both above and below ground. Therefore, weed management is essential, particularly during the first two to three months of crop development.

Under, these circumstances, growing short duration vegetables in the interspaces of elephant foot yam might limit weed development in the early stages. Intercropping, also known as companion planting, is the practice of growing more than one crop species in the same area at the same time (Maitra et al., 2021). Based on the environmental, economic, and ecological advantages that it offers, intercropping is becoming one of the management strategies to increase land use efficiency (LUE) (Khanal et al., 2021). It seeks to identify the synergistic and facilitative interactions among species in order to optimize resource collection and use, as well as yield and profit per unit land area (Arshad et al., 2020). Intercropping also lowers the cost of weeding and makes the whole system more productive and profitable. So, this study was conducted with the objective of increasing LUE as well as to look at how well weeds are minimized in a system where elephant foot yam is cultivated with other crops.

Materials and Methods

This experiment was done in the college orchard at the Horticultural College and Research Institute located at Coimbatore, Tamil Nadu, India (11° 02' N, 77° 03' E). The trial was conducted over two seasons, from April to December 2021 and from September 2021 to May 2022. Weather conditions varied slightly over two growing seasons (*Figure 1*). The mean maximum temperatures, varied from 28.4°C to 35.16°C in the first season and from 28.4°C to 34.64°C in the second season. During the first season, the daily minimum temperatures ranged from 20.89°C to 24.58°C. During the second season, the minimum temperatures ranged from 20.67°C to 24.58°C. In terms of the yearly precipitation, the first season received 636.50 millimeters, while the second season received 738.60 millimeters. The study consisted of four short duration vegetable crops which were compared with solo crop of elephant foot yam and are as follows: T_1 - Elephant Foot Yam (Sole crop); T_2 - Elephant Foot Yam + Cluster Bean; T_3 - Elephant Foot Yam + Radish; T_4 - Elephant Foot Yam + Amaranthus; and T_5 - Elephant Foot Yam + Fenugreek. Each treatment was replicated four times and were organised in a randomized block design with a plot size of 10 m^2. The soil that was the subject of the investigation was Typic Haplustalfs with texture class of sandy clay loam, that has 6.81 and 6.59 pH and contains 0.38% and 0.35% of organic carbon, 276 kg/ha and 253 kg/ha of available nitrogen, 26 kg/ha and 24 kg/ha of available phosphorus and 412 kg/ha and 389 kg/ha of available potassium at season I and season II, respectively. Elephant foot

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

yam variety Co-1 was used for the study and was planted at a distance of 90 cm between rows and 60 cm between plants as per the specification of TNAU crop production guide 2020. A total of 80:60:100 kg of NPK per hectare of fertilizer was given, where 40:60:50 kg of NPK were applied after 45 days of sowing and the remaining 40 kg of N and 50 kg of K were top dressed one month later. Once a week, irrigation was supplied through drip irrigation. In the inter-spaces between the elephant foot yam, crops like cluster bean (45 × 30 cm), radish (20 × 10 cm), amaranthus (20 × 15 cm), and fenugreek (20 × 15 cm) were planted as per the treatment specification.

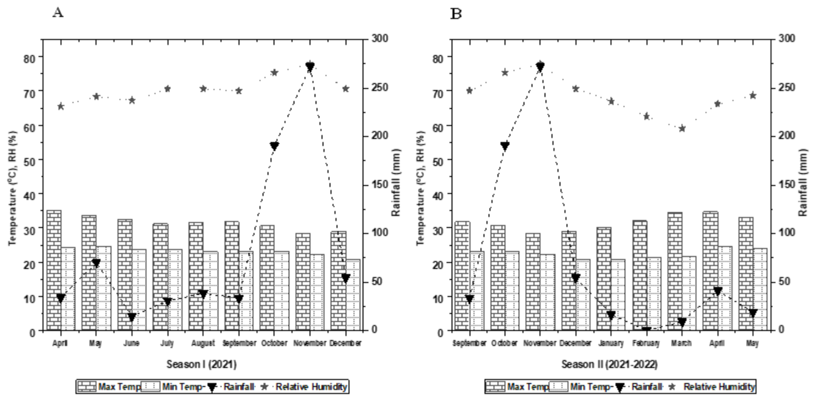

***Figure 1.** Meteorological observation during growing Season I (a) and Season II (b) of elephant foot yam*

Weed samples were collected randomly from three locations, at 60, 90, 120, 150 and 180 days following planting, using a quadrate of 0.25 m^2 and converted into weed population/m^2. Following that, the weeds were dried in an oven and the results were reported as the weed dry weight per m^2. As proposed by Mani et al. (1968), the weed control efficiency (WCE) was determined by using the following formula, and expressed in percent:

$$WCE = [(DMC-DMT)/DMC]*100 \qquad (Eq.1)$$

where, DMC - dry matter of weeds in control (in solo crop); DMT - dry matter of weeds in treatment (in intercrop).

Five plants were randomly chosen from each plot to serve as the sample unit for the biometric observations. At 60, 90, 120, 150 and 180 days after planting (DAP), the plant height, pseudostem girth, canopy spread (N-S), (E-W), fresh weight and dry weight of the whole plant were measured. According to Ravi et al. (2010) and Williams (1946) the leaf area and leaf area index (LAI) were computed. The total leaf area that was measured was then divided by the entire ground area that was occupied by each plant to arrive at the leaf area index as per the following formula:

$$LAI = \text{Total leaf area of the plant / Ground area occupied by the plant} \qquad (Eq.2)$$

The crop growth rate (CGR) of elephant foot yam was estimated using the formula given by Watson (1947).

$$CGR = [(W_2-W_1)/\rho\ (t_2-t_1)] \qquad (Eq.3)$$

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

where, W_1 -whole plant weight at time t_1 - W_2 - whole plant weight at time t, ρ -Ground area. CGR is expressed in g m^{-2} day^{-1}.

The land equivalent ratio (LER), which compare the productivity of intercrops to that of the sole crops, was calculated using the following formula given by Ofori and Stern (1987).

$$LER = [Y_{aa}/ Y_a] + [Y_{bb}/Y_b] \quad \text{(Eq.4)}$$

where, Y_{aa} - yield of intercropped elephant foot yam; Y_a - yield of monocropped elephant foot yam; Y_{bb} - yield of intercrop in elephant foot yam; Y_b - yield of a intercrop when grown as a monocrop. When the LER is more than 1, the intercrop is more productive than the solo crop, but when it is less than 1, the solo crop is more productive than the intercrop.

Prior to statistical analysis, data on weeds were transformed using square roots. STAR software was used for the analysis of data. An analysis of variance was carried out on the collected data. The treatment means were differentiated based on the difference that was statistically significant (Gomez and Gomez, 1984).

Results and Discussion

Weed flora

The weed flora (*Figure 2*) observed in elephant foot yam during the two seasons were *Acalypha indica, Parthenium hysterophorus, Alternanthera pungens, Euphorbia hirta, Boerhavia diffusa, Corchorus olitorius, Cardamine hirsuta, Chenopodium album, Tribulus terrestris, Trianthema portulacastrum, Portulaca oleraceae, Cyperus rotundus, Digitaria sanguinalis, Dactylotenium aegyptium* and *Cynodon dactylon*.

Figure 2. *Broad leaved (1-11), sedge (12) and narrow leaved (12-15) weeds identified in elephant foot yam*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

Weed density, weed biomass and weed control efficiency

All the treatments had exhibited a significant ($p<0.05$) effect on the weed count, dry matter of weeds (*Tables 1, 2, 3*) and weed control efficiency (*Table 4*) in both seasons.

Table 1. *Effect of intercropping in broad leaved weed density (no/m²) and weed biomass (g/m²) (Pooled data of season I &II*

Treatments	Broad leaved weed density (no/m²)					Broad leaved weed biomass (g/m²)				
	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP
T_1 - Elephant Foot Yam (EFY)	7.85[a] (61.13)	7.07[a] (49.58)	5.72[a] (32.29)	4.83[a] (22.89)	3.82[a] (14.11)	5.66[a] (31.52)	5.07[a] (25.24)	4.03[a] (15.76)	3.61[a] (12.53)	2.81[a] (7.40)
T_2 - EFY + Cluster bean	5.50[d] (29.77)	4.34[e] (18.34)	3.69[e] (13.15)	3.65[d] (12.85)	3.19[d] (9.68)	3.91[e] (14.77)	3.05[e] (8.83)	2.64[e] (6.51)	2.64[e] (6.48)	2.37[d] (5.11)
T_3 - EFY + Radish	5.34[e] (28.01)	4.85[d] (23.06)	4.64[c] (21.06)	4.12[c] (16.47)	3.57[bc] (12.27)	3.75[d] (13.58)	3.49[c] (11.72)	3.43[d] (11.26)	3.00[d] (8.54)	2.68[b] (6.68)
T_4 - EFY + Amaranthus	5.76[c] (32.70)	5.01[c] (24.64)	4.28[d] (17.83)	4.20[bc] (17.21)	3.48[c] (11.65)	4.13[c] (16.57)	3.71[d] (13.28)	3.06[c] (8.90)	3.09[c] (9.15)	2.55[c] (6.06)
T_5 - EFY + Fenugreek	6.31[b] (39.35)	5.35b (28.14)	4.94[b] (23.90)	4.32[b] (18.23)	3.59[b] (12.40)	4.55[b] (20.17)	3.85[b] (14.36)	3.58[b] (12.29)	3.36[b] (10.94)	2.71[ab] (6.85)
C.D [5%]	1.65	1.52	1.49	1.42	1.45	1.32	1.29	1.25	1.21	1.28

Original value in parenthesis was subjected to√ X+0.5 transformation

Table 2. *Effect of intercropping in narrow leaved weed density (no/m²) and weed biomass (g/m²) (Pooled data of season I & II)*

Treatments	Narrow leaved weed density (no/m²)					Narrow leaved weed biomass (g/m²)				
	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP	60 DAP	90 DAP	120 DAP	150 DAP	180 DAP
T_1 - Elephant Foot Yam (EFY)	5.25[a] (27.73)	6.75[a] (45.08)	7.17[a] (50.93)	7.46[a] (55.23)	5.86[a] (33.96)	3.45[a] (11.49)	4.32[a] (18.17)	4.68[a] (21.47)	4.88[a] (23.29)	3.87[a] (14.50)
T_2 - EFY + Cluster bean	3.63[d] (12.88)	4.60[e] (20.71)	5.64[e] (31.43)	6.66[d] (43.99)	5.17[c] (26.44)	2.35[d] (5.09)	3.06[e] (8.92)	3.67[d] (13.02)	4.32[d] (18.18)	3.33[d] (10.71)
T_3 - EFY + Radish	3.21[e] (9.98)	5.48[d] (29.93)	6.31[d] (39.44)	7.09[c] (49.82)	5.46[b] (29.49)	2.14[e] (4.14)	3.54[d] (12.12)	4.07[c] (16.15)	4.64[c] (21.06)	3.57[c] (12.35)
T_4 - EFY + Amaranthus	3.78[c] (13.97)	5.80[c] (33.38)	6.51[c] (42.16)	7.15[bc] (50.72)	5.59[b] (30.99)	2.55[c] (6.03)	3.79[c] (13.90)	4.19[c] (17.11)	4.69[bc] (21.48)	3.73[b] (13.50)
T_5 - EFY + Fenugreek	4.30[b] (18.24)	6.08[b] (36.70)	6.71[b] (44.69)	7.29[ab] (52.68)	5.62[b] (31.23)	2.90[b] (8.02)	3.96[b] (15.30)	4.37[b] (18.73)	4.82[ab] (22.73)	3.77[ab] (13.73)
C.D [5%]	1.15	1.22	1.38	1.40	1.31	0.98	1.02	1.32	1.24	1.18

Original value in parenthesis was subjected to√ X+0.5 transformation

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

Table 3. *Effect of intercropping in sedge leaved weed density (no/m^2) and weed biomass (g/m^2) (Pooled data of season I & II*

	Sedge leaved weed density (no/m^2)					Sedge leaved weed biomass (g/m^2)				
	60 DAP	**90 DAP**	**120 DAP**	**150 DAP**	**180 DAP**	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**	**180 DAP**
T_1 - Elephant Foot Yam (EFY)	6.20^a (22.73)	7.43^a (45.08)	8.40^a (50.93)	7.54^a (55.23)	5.95^a (33.96)	3.53^a (11.49)	4.21^a (18.17)	4.92^a (21.47)	4.34^a (23.29)	3.26^a (14.50)
T_2 - EFY + Cluster bean	4.66^c (9.98)	4.73^d (20.71)	6.17^d (31.43)	6.58^d (43.99)	5.41^c (26.44)	2.47^c (5.62)	2.52^e (8.92)	3.38^e (13.02)	3.78^c (18.18)	2.98^c (10.71)
T_3 - EFY + Radish	4.23^d (12.88)	5.87^c (29.93)	7.13^c (39.44)	6.90^{bc} (49.82)	5.60^b (29.49)	2.33^d (5.09)	3.21^c (12.12)	4.08^d (16.15)	3.90^c (21.06)	3.11^b (12.35)
T_4 - EFY + Amaranthus	4.73^c (13.97)	5.83^c (33.38)	7.28^c (42.16)	6.78^c (50.72)	5.63^b (30.99)	2.47^c (5.63)	3.10^d (13.90)	4.20^c (17.11)	3.82^c (21.48)	3.12^b (13.50)
T_5 - EFY + Fenugreek	5.13^b (18.24)	6.25^b (36.70)	7.59^b (44.69)	7.05^b (52.68)	5.66^b (31.23)	2.78^b (8.02)	3.40^b (15.30)	4.48^b (18.73)	4.10^b (22.73)	3.15^b (13.73)
C.D [5%]	1.72	1.58	1.87	1.52	1.35	0.78	0.65	0.89	0.98	0.59

Original value in parenthesis was subjected to$\sqrt{X+0.5}$ transformation

Table 4. *Effect of intercropping on Weed control efficiency (%) (Pooled data of season I & II)*

Treatments	**Weed control efficiency (%)**				
	0 – 60 DAP	**60- 90 DAP**	**90-120 DAP**	**120-150 DAP**	**150 – 180 DAP**
T_1 - Elephant Foot Yam (EFY)	0.00	0.00	0.00	0.00	0.00
T_2 - EFY + Cluster bean	56.73	66.57	51.26	30.34	27.29
T_3 - EFY + Radish	62.11	48.45	29.16	18.83	13.08
T_4 - EFY + Amaranthus	51.44	43.89	29.87	18.03	11.57
T_5 - EFY + Fenugreek	37.57	35.88	17.31	7.79	7.08

At every stage of crop development, weed count and weed dry matter were much lower in all the intercropped treatments than in the monocropped elephant foot yam. Introducing intercrops in elephant foot yam, when the field is freshly prepared, will avoid untimely weeding associated with hand-hoeing. The latter method has an advantage over chemical control at our current level of development because of the need for herbicide training. In general, the elephant foot yam's weed dynamics were more pronounced during the plant's early development stages (up to 150 DAP). While in later stages, up to harvest, the weed dynamics are lessened as a result of the shade effect produced by the canopy and architecture of elephant foot yam leaves (Singh et al., 2016; Kumar et al., 2020). It was possible that shading prevents the germination of some weed species by inducing secondary dormancy in their seeds. This might be the result of a change in the light quality

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

generated by the canopy. The dominating weed species that are found in both seasons include *Trianthema portulacastrum* (broad leaved), *Cyperus rotundus* (narrow leaved), and *Cynodon dactylon* (sedge). The pooled analysis for two seasons showed that weed density ranged between 3.19 to 7.83 no/m^2 (broad leaved); 3.21 to 7.46 no/m^2 (narrow leaved) and 4.23 to 8.40 no/m^2 (sedge), whereas, weed biomass ranged between 2.37 to 5.66 g/m^2 (broad leaved); 2.14 to 5.66 g/m^2 (narrow leaved) and 2.33 to 4.92 g/m^2 (sedge) Among the treatments, lower weed count and weed biomass for all the categories, *viz.*, broad-leaved, narrow-leaved, and sedge weeds, were observed in elephant foot yam intercropped with cluster bean at 90, 120, 150 and 180 DAP for both the seasons. At the initial stage, the broad-leaved weeds were more prevalent than narrow-leaved and sedge weeds. This is in confirmatory to the findings of Singh et al. (2021). Intercropping was found to suppress weed growth at early crop growth stages. The smothering effect of intercrops on weeds led to lower dry matter production, which in turn resulted in lower nutrient uptake by weeds. Therefore, crop weed competition is reduced in intercropping systems. According to the findings of many research, increasing the species variety of crops grown in an intercropping system is claimed to retain a highly asymmetric competitive advantage over weeds, which in turn results in a lower weed biomass. Crops and weeds are competitors for the resources that are available, and reducing the presence of weeds will eventually lead to greater production. In the present study, weeds took advantage of the initial stagnant development rate and wider spacing of solo cropped elephant foot yam (T_1), resulting in the greatest weed biomass and weed density.

Intercropping caused a significant reduction in the weed population compared with control (solo-cropping). Among the intercropping systems, at both 2021 and 2021/22 seasons, cluster bean intercropping showed a higher weed control efficiency of 66.57%, 51.26%, 30.24% and 27.29% at 90, 120, 150 and 180 days, respectively. The higher weed control efficiency is due to the limitation of incoming photosynthetically active radiation (PAR) reaching weeds may potentially account for the lower species richness of weed populations in intercropping systems. The resources that were utilized by the intercrops were different from those that were used by the monoculture, which led to enhanced plant biomass and a reduction in weed development. This is in accordance with the findings of Rai et al. (2016). In comparison to intercropping systems, mean weed biomass and species richness in monocultures were substantially higher.

This may be because of the combination's synergistic effects as well as the overall increased crop density of the intercropping system as compared to the solo crop. Weedy check (T_1) resulted in considerably reduced weed control efficacy, which might be attributed to an uncontrolled weed population as a consequence of greater nutrition and moisture absorption, resulting in higher dry matter buildup of weeds. This is similar to the findings of Mori et al. (2022) in sorghum intercropping.

Crop growth attributes

Significant variations ($p < 0.05$) were observed for plant height, pseudostem girth, canopy spread (N-S, E-W), leaf area, leaf area index (*Figure 3*), fresh and dry weight of the plant and crop growth rate for elephant foot yam (*Figure 4*) among the different treatments for both the seasons.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

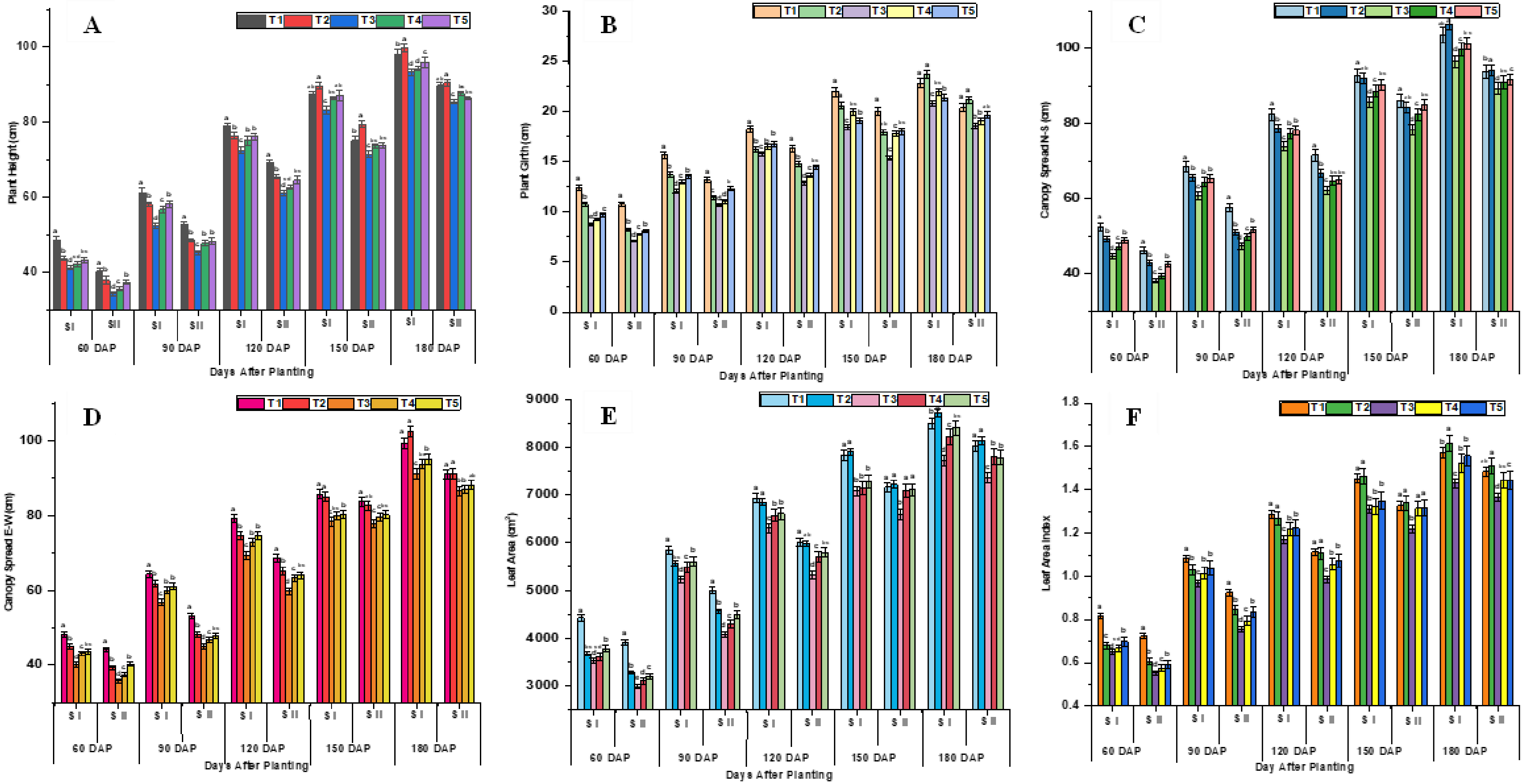

Figure 3. *Effect of intercropping on a) plant height b) pseudostem girth c) Canopy spread N-S d) canopy spread E-W, e) leaf area and f) leaf area index of elephant foot yam in season I and II (T1 – Elephant Foot Yam (EFY) – Sole crop; T2 – EFY + cluster bean; T3 - EFY + Radish; T4 - EFY + Amaranthus and T5 – EFY + Fenugreek)*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

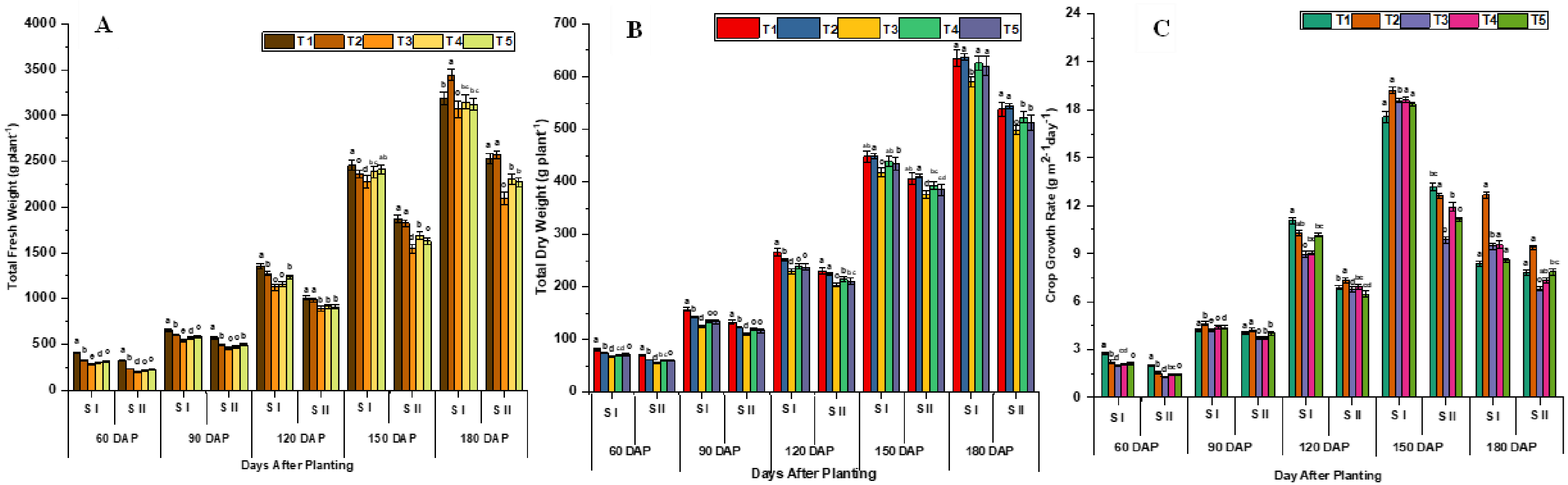

Figure 4. *Effect of intercropping on a) total fresh weight b) total dry weight and c) crop growth rate of elephant foot yam in season I and II (T1 – Elephant Foot Yam (EFY) – Sole crop; T2 – EFY + cluster bean; T3 - EFY + Radish; T4 - EFY + Amaranthus and T5 – EFY + Fenugre*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

Sole cropping of elephant foot yam was observed with maximum values for plant height, pseudostem girth, canopy spread (N-S, E-W) at 60, 90 and 120 DAP in both the seasons than other inter-cropped treatments. Increased growth rates in sole crop might be attributed to the less competition for space and nutrition as there were no associated intercrops. Later, at 150 and 180 days after planting, the treatment T_2 (Elephant foot yam + cluster bean) exhibited higher values. Intercropping with cluster bean increased the plant height and growth characteristics of elephant foot yam, because of the nitrogen fixation from the atmosphere by cluster bean through microbial symbiosis, that would have covered at least a portion of its growth. The similar findings were reported by Guo et al. (2022). Added, it improves the soil conditions for soil bacteria, which increased the root's ability to absorb more nutrients and water and, eventually, amps up the growth parameters. This was in accordance with findings of Kaluba et al. (2022) in their studies of cassava-legume intercropping.

Leaf area development in elephant foot yam persisted continuously up to 180 DAP before the plant began to senesce. The reduction in leaf area may be the result of assimilates being transported from the leaves to the growing sink (corms) when vegetative development ceases, which eventually leads to the senescence of the leaves. *Figure 2* showed that at 60, 90 and 120 DAP, T_1 (Elephant foot yam-sole crop) had a higher leaf area and later, at 150 and 180 DAP, elephant foot yam intercropped with cluster bean (T_2) had a higher leaf area than other treatments at both seasons. With respect to each plant's total leaf area, LAI confirmed a positive linear relationship. The treatments with more leaf area were noted to have proportionately greater LAI. The rate of photosynthesis by the plant is mostly determined by the leaf area of photosynthetically active leaves (Jo et al., 2022). A higher LAI helps photosynthesis intercept lighter, which results in a higher generation of dry matter (Raza et al., 2022).

In both the seasons, total fresh weight and dry weight of elephant foot yam was recorded highest in monocropped elephant foot yam at initial growth phases up to 120 DAP. Then after from 120 DAP up to 180 DAP, higher fresh and dry weight was recorded in cluster bean intercropping treatment (T_2). This impact may be related to the complementary nature of the cluster bean as companion crop and the superior use of biologically fixed nitrogen by the elephant foot yam in the later stages of its development. This is in confirmatory with the findings of Dwivedi et al. (2015). The shoot biomass production grew up to 180 DAP and then decreased. However, corm dry weight and total dry matter output increased steadily up to maturity.

The crop growth rate significantly increased up to 150 DAP and declined as it senesces. The mean growth rate of elephant foot yam was found to be increased from 0 to 60 DAP, 60 to 90 DAP, 90 to 120 DAP, and then peak between 120 and 150 DAP before beginning to fall. CGR was found maximum at T_1 (Elephant foot yam-sole crop) up to 90-120 DAP. Later T_2 -Elephant foot yam + cluster bean combination had a higher CGR compared to other treatments. The maximum CGR (120-150 DAP) was 1.227 and 1.148 in season I and season II, respectively, in treatment T_2. An increase in CGR in T_2 might be ascribed to the ideal growing conditions for the plant speeding up the plant's photosynthetic activity, which in essence provided substantial photosynthates for the plant to develop its root system, branches, and leaves per plant. Subsequently, This, in turn, caused an increase in the plant's total dry biomass, favouring a higher crop growth rate.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

Yield

The corm yield (*Table 5*) of elephant foot yam was found to be the highest (46.54 t/ha and 38.37 t/ha) in both seasons when intercropped with cluster bean, followed by solo cropping of elephant foot yam (45.11 t/ha and 36.42 t/ha). In cluster bean intercropping leaf area is higher in elephant foot yam, the larger leaf area resulted in the harvest of more light and thereby the production of photosynthate was higher in this treatment. The resources produced were relocated to bulking corms. Legumes are crops that replenish the soil, and the breakdown of their residue increases soil fertility, which in turn increases productivity. Chamkhi et al. (2022) also observed increased yield in legume-based intercropping. However, in intercropping radish, amaranthus, and fenugreek the yields were lower. Early growing phases in these three intercropping systems were not favourable as there was higher competition for resources and a wide range of cross-cultural interaction, which reduced the process of photosynthate partitioning from source to sink and decreased main crop yield (Chattopadhyay et al., 2008). Irrespective of the intercrops used, season I (April - December) yields better than season II (September-May). The marked-up difference in yield is due to the weather conditions that prevailed during the elephant foot yam growing season.

Table 5. *Effect of intercropping on yield and LER*

Treatments	Season I			Season II		
	Yield of main crop (t/ha)	Yield of inter crops (t/ha)	LER	Yield of main crop (t/ha)	Yield of inter crops (t/ha)	LER
T_1 - Elephant Foot Yam (EFY)	45.11^b	-	-	36.42^b	-	-
T_2 - EFY + Cluster bean	46.54^a	6.79	1.65	38.37^a	6.04	1.61
T_3 - EFY + Radish	42.52^d	11.74	1.31	33.05^d	10.85	1.27
T_4 - EFY + Amaranthus	44.33^{bc}	5.85	1.51	35.65^b	6.86	1.55
T_5 - EFY + Fenugreek	43.68^c	3.46	1.50	34.61^c	3.25	1.47
C.D [5%]	5.25	-	-	4.90	-	-

Land equivalent ratio (LER) (*Table 5*) is found above one, indicates the yield advantage of intercropping rather than monocropping. These results corroborate the findings of El-Ghobashy et al. (2018) who reported higher LER in maize and cowpea intercropping. Among the intercrops, elephant foot yam + cluster bean recorded the highest LER of 1.65 and 1.61 in season I and season II, respectively. LER values of 1.65 and 1.61 indicate a 65% and 61% yield advantage in two seasons respectively. The increased LER in this study is a result of inclusion of intercrops in the planting patterns and spatial arrangements and may have prevented the overlap of the peak growth periods of the two crops. These findings are in accordance with those of Salama and Abdel-Moneim (2021) who reported that maize - soyabean intercropping had better LER.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

Conclusion

The growth, yield, land equivalent ratio, weed density, weed biomass, and weed control efficiency of elephant foot yam were significantly impacted by the intercropping system in both seasons. Elephant foot yam was successfully grown with intercrops at high plant densities, occupying multiple horizons of the crop environment, and providing sufficient ground cover, which reduced competition from weed crops while maximising the use of the available resources. Weed control efficiency was found to be higher in intercropping systems. Cluster bean intercropping outperformed the other intercrops studied. The yield of elephant foot yam in both seasons were 46.54 t/ha and 38.37 t/ha in cluster bean intercropped treatment. The intercrops' land equivalent ratio was more than 1, which suggests higher yield productivity as compared to solo crops. Higher intercropping yields imply that farmers might produce more without cultivating more land. The findings made it very evident that elephant foot yam and cluster bean may be successfully intercropped for economic profit.

REFERENCES

[1] Arshad, M., Nawaz, R., Ahmad, S., Shah, G. A., Faiz, F., Ahmad, N., Irshad, M. A., Ranamukhaarachchi, S. L. (2020): Growth, yield and nutritional performance of sweet sorghum and legumes in sole and intercropping influenced by type of legume, nitrogen level and air quality. – Polish Journal of Environmental Studies 29(1): 533-543. http://dx.doi.org/10.15244/pjoes/104461.

[2] Chamkhi, I., Cheto, S., Geistlinger, J., Zeroual, Y., Kouisni, L., Bargaz, A., Ghoulam, C. (2022): Legume-based intercropping systems promote beneficial rhizobacterial community and crop yield under stressing conditions. – Industrial Crops and Products 183: 114958. http://dx.doi.org/10.1016/j.indcrop.2022.114958.

[3] Chattopadhyay, A., Mukhopadhyay, S. K., Rajib, N. (2008): Short duration vegetables as intercrops in elephant foot yam in the gangetic alluvium of West Bengal: analysis of growth, yield, and economics. – Journal of Root Crops 34(1): 10-14.

[4] Choudhary, V. K., Kumar, P. S., Kanwat, M., Sangeetha, A. (2012): Influence of NPK Fertilization on Nutrient Uptake. Growth and Yield of Elephant Foot Yam in Laterite Soils of Arunachal Pradesh. – Madras Agricultural Journal 99(10-12): 747-750.

[5] Dey, Y. N., Ghosh, A. K. (2010): Pharmacognostic evaluation and phytochemical analysis of the tuber of *Amorphophallus paeoniifolius*. – Int J Pharm Res Dev 2(9): 44-49.

[6] Dwivedi, A., Dev, I., Kumar, V., Yadav, R. S., Yadav, M., Gupta, D., Singh, A., Tomar, S. S. (2015): Potential role of maize-legume intercropping systems to improve soil fertility status under smallholder farming systems for sustainable agriculture in India. – International Journal of Life Sciences Biotechnology and Pharma Research 4(3): 145.

[7] El-Ghobashy, Y. E., Shams, A. S., Lamlom, M. M. (2018): Maximizing land use efficiency by intercropping cowpea with some maize cultivars under different maize planting geometries. – Agricultural Sciences 9(12): 1601. http://dx.doi.org/10.4236/as.2018.912112.

[8] Gomez, K. A., Gomez, A. A. (1984): Statistical procedures for agricultural research. – John Wiley & Sons.

[9] Guo, S., Li, S., Huang, G. (2022): Effects of Different Intercropping Models on Growth and Yield Traits of Maize in Red Soil Dryland. – Research on World Agricultural Economy 3(2455-2022-693): 1-8.

[10] Jo, S. G., Kang, Y. I., Om, K. S., Cha, Y. H., Ri, S. Y. (2022): Growth, photosynthesis, and yield of soybean in ridge-furrow intercropping system of soybean and flax. – Field Crops Research 275: 108329. https://doi.org/10.3390/agronomy13020413.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

[11] Kaluba, P., Mwamba, S., Moualeu-Ngangue, D. P., Chiona, M., Munyinda, K., Winter, E., Stützel, H., Chishala, B. H. (2022): Performance of Cassava under Lime, Fertilizer, and Legume Intercropping on Exhausted Land in Northern Zambia. – International Journal of Agronomy 1: 1-17. http://dx.doi.org/10.1155/2022/3649355.
[12] Khanal, U., Stott, K. J., Armstrong, R., Nuttall, J. G., Henry, F., Christy, B. P., Mitchell, M., Riffkin, P. A., Wallace, A. J., McCaskill, M., Thayalakumaran, T. (2021): Intercropping-evaluating the advantages to broadacre systems. – Agriculture 11(5): 453. https://doi.org/10.3390/agriculture11050453.
[13] Kumar, J. S., Sunitha, S., Sreekumar, J., Nedunchezhiyan, M., Mamatha, K., Das, B., Sengupta, S., Kamalkumaran, P. R., Mitra, S., Tarafdar, J., Damodaran, V. (2020): Integrated weed management in elephant foot yam. – Indian Journal of Weed Science 52(1): 69-73. http://dx.doi.org/10.5958/0974-8164.2020.00012.X.
[14] Maitra, S., Hossain, A., Brestic, M., Skalicky, M., Ondrisik, P., Gitari, H., Brahmachari, K., Shankar, T., Bhadra, P., Palai, J. B., Jena, J. (2021): Intercropping-A low input agricultural strategy for food and environmental security. – Agronomy 11(2): 343. https://doi.org/10.3390/agronomy11020343.
[15] Mani, V. S., Gautam, K. C., Chakraborty, T. K. (1968): Losses in crop yield in India due to weed growth. – International Journal of Pest Management 14(2): 142-158.
[16] Mori, C. K., Arvadiya, L. K., Sisodiya, R. R. (2022): Effect of intercropping and weed management practices on yield and weed parameters of Rabi sorghum (*Sorghum bicolor* L.) Under South Gujarat condition. – The Pharma Innovation Journal 11(3): 857-861.
[17] Mursyidin, D. H., Hernanda, M. A., Badruzsaufari, B. (2022): Genetic Diversity of Elephant Foot Yam (*Amorphophallus paeoniifolius*) and Two Other Relatives from the Meratus Mountains of South Kalimantan, Indonesia. – Journal of Tropical Biodiversity and Biotechnology 7(1): 66231. http://dx.doi.org/10.22146/jtbb.66231.
[18] Nedunchezhiyan, M., Laxminarayana, K., Chauhan, V. B. (2018): Soil microbial activities and yield of elephant foot yam as influenced by weed management practices in alfisols. – International Journal of Vegetable Science 24(6): 583-596. https://doi.org/10.1080/19315260.2018.1454567.
[19] Ofori, F., Stern, W. R. (1987): Cereal-legume intercropping systems. – Advances in agronomy 41: 41-90.
[20] Rai, C. L., Tiwari, R. K., Sirothia, P., Pandey, S. (2016): Intercropping and weed management effects on weed dynamics, productivity, and economics of pigeonpea. – Indian Journal of Weed Science 48(1): 44-47. http://dx.doi.org/10.5958/0974-8164.2016.00010.1.
[21] Ravi, V., George, J., Ravindran, C. S., Suja, G., Nedunchezhiyan, M., Byju, G., Naskar, S. K. (2010): Method for leaf area determination in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]. – Journal of Root Crops 36(1): 78-82.
[22] Raza, M. A., Gul, H., Hasnain, A., Khalid, M. H. B., Hussain, S., Abbas, G., Ahmed, W., Babar, M. J., Ahmed, Z., Saeed, A., Riaz, M. U. (2022): Leaf Area Regulates the Growth Rates and Seed Yield of Soybean (*Glycine max* L. Merr.) in Intercropping System. – International Journal of Plant Production. https://dx.doi.org/10.7717/peerj.7262.
[23] Salama, H. S., Abdel-Moneim, M. H. (2021): Maximizing land use efficiency and productivity of soybean and fodder maize intercrops through manipulating sowing schedule and maize harvest regime. – Agronomy 11(5): 863. https://doi.org/10.3390/agronomy11050863.
[24] Singh, A., Chaurasiya, A., Mitra, S. (2016): Assessment of nutritional composition in elephant foot yam (*Amorphophallus paeoniifolius* Dennst-Nicolson) cultivars. – International Journal of Food Studies 5(2): 1-17. https://doi.org/10.7455/ijfs/5.2.2016.a3.
[25] Singh, R., Kumar, S., Kumar, S. (2021): Integrated weed management in elephant foot yam. – Himachal Journal of Agricultural Research 46(2): 151-155.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018

[26] Suja, G., Sundaresan, S., John, K. S., Sreekumar, J., Misra, R. S. (2012): Higher yield, profit, and soil quality from organic farming of elephant foot yam. – Agronomy for sustainable development 32(3): 755-764. https://doi.org/10.1007/s13593-011-0058-5.
[27] Watson, D. J. (1947): Comparative physiological studies on the growth of field crops: I. Variation in net assimilation rate and leaf area between species and varieties, and within and between years. – Annals of Botany 11(41): 41-76.
[28] Williams, R. F. (1946): The physiology of plant growth with special reference to the concept of net assimilation rate. – Annals of Botany 10(37): 41-72.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2105_40054018