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# Effect of leguminous and non-leguminous crops as staking on productivity of greater yam (*Dioscorea alata*)

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**Abstract**
Root and tuber crops are important food crops that are climate resilient. *Dioscorea* species (yams) are most valuable food security crops that sustain many livelihoods in the tropics and subtropics. The high cost of producing yam discourages farmers from increasing areas cropped with yam. The high production cost arises mainly from the cost of planting material (seed yam), the cost of stakes and a high labour requirement. The main objective of the study was to assess the effect of staking and intercropping on productivity and net economic return of greater yam in yam based cropping system. The greater yam was raised as sole crop (with and without staking) and intercropped with maize, cumbu and pigeon pea at 1:3 Ratio. The greater yam recorded maximum yield in sole crop with staking individual plants (38.25 t/ha) eventually tap more light to give a higher yield than sole, unstaked yam (29.49 t/ha). Based on the highest Land Equivalent Ratio (1.68), Income Equivalent Ration (1.79), Yam Equivalent Yield (38.59 t/ha) and Bnefit cost ratio (3.36), intercropping unstaked greater yam with maize in 1:3 Ratio was recorded as the best cropping system which reduces the cost of staking and labour requirement.

**Keywords**: Greater yam, legume, non-legume, inter cropping, staking, LER-IER-BCR yield

## Introduction

Yam is the common name for some plant species in the genus *Dioscorea* (family *Dioscorea*ceae) that form edible tubers. These are perennial herbaceous vines cultivated for the consumption of their starchy tubers. Consumer demand for yam is generally very high in the tropical region and yam cultivation is very profitable despite high production costs. The greater yam, *Dioscorea alata*, also known as water yam, winged yam and purple yam was first cultivated in south East Asia and has the largest distribution world wide of any cultivated yam being grown in Asia, the Pacific Islands, Africa and West Indies. Yam (*Dioscorea* spp.) is a tropical crop grown on about 5 million hectares of land in about 47 countries in tropical and sub-tropical regions (Acquaah, 2005; IITA, 2009) [1, 9].

In India, greater yam is cultivated in the states of Andhra Pradesh, Kerala, West Bengal, Bihar, Odisha, North Eastern states, Uttar Pradesh, Tamil Nadu, Gujarat and Maharashtra (Chadha, 2002) [5]. The yam tubers are rich source of carbohydrates, proteins and amino acids. Normally tubers are consumed as boiled, baked or fried vegetables. It is also useful for making chips, flakes and flour. Greater yam is a climber and responds well to artificial support or staking. Staking is a costly practice next to seed material in commercial yam cultivation. If yams are planted without staking, the crop will be devastated by anthracnose (*Colletotrichum gloeosporioides* Penz.) disease (Chadha, 2002) [5]. Staking exposes the leaves to sunlight resulting in greater photosynthesis. Yams are also staked on different supports such as casuarina and bamboo poles. Non-staking led to 32.5% reduction in yield as compared to vertical staking option. The search for stakes is laborious and forms about 20% of the labour requirement and major cost of yam production (Asante, 1996; Koli, 1973; Wholey and Haynes, 1971) [2, 11, 18]. The objective of the present study was to find out suitable alternative for live staking as well as to reduce the cost of cultivation.

## Materials and Methods

### Description of Experimental Sites

The study was conducted in the Department of Vegetable Crops, Horticultural College and Research Institute, Coimbatore, Tamil Nadu during 2015 and 2016 cropping seasons. The experimental site is characterized with clay loamy soil texture rich in organic matter content. Coimbatore receives on an average 650-700 mm rainfall annually and is situated at an elevation of 426 M (longitude: 77°E and latitude: 11oN). The average annual temperature ranges from 25-38 °C. The preplant and post-harvest soil nutrient status was presented in Table 1.

**Table 1:** Soil nutrient status

| Pre plant | | | | | Post-harvest | | | | |
|---|---|---|---|---|---|---|---|---|---|
| N (kg/ha) | P (kg/ha) | K (kg/ha) | OC (%) | pH | N (kg/ha) | P (kg/ha) | K (kg/ha) | OC (%) | pH |
| 365 | 33 | 907 | 0.75 | 8.38 | 204 | 23 | 773 | 0.73 | 8.44 |

### Experimental Design and Cultural Practices

The experiment was established in early June of 2015 and 2016 and harvested in late January of 2016 and 2017, respectively, to assess the effect of staking and intercropping systems on growth atributes, yield and economics of greater yam. A total of eight treatments including three intercrop systems viz., $T_1$- Greater yam sole crop (90cm x 90 cm) non-staking; $T_2$-Pigeon pea sole crop (60 cm x 30 cm) non-staking; $T_3$- Maize sole crop (60 cm x 30 cm) non-staking; $T_4$- Jowar sole crop (60 cm x 30 cm) non-staking; ; $T_5$- Greater yam + Pigeon pea (1:2) additive; $T_6$-Greater yam + Maize (1:2) additive; $T_7$-Greater yam + Jowar (1:2) additive; $T_7$- Greater yam sole (90cm x 90 cm) staking individual plantswere used. In intercropping, pigeon pea, Maize and Jowar to be grown in intra rows of greater yam. Thus the intercrops spacing will be 90 cmx 30 cm and trailing can be done on the respective intercrop. Each plot measured 9 x 5.4 m (48.6 m2) and contained 60 plants. Setts each weighing 250 g were used as planting materials. The setts were planted into holes 15 cm deep spaced 90cm x 90cm in a complete randomized block design. Staking was done prior to sprouting of planted setts by inserting pointed stake supports into the soil about 20 cm away from planted holes or spots.

### Data Collection

A total of fourteen characters of various growth and yield traits were recorded. Data were subjected to analysis of variance (ANOVA) using the AGRES statistical programme.

### Land equivalent ratio (LER)

LER is used, as the criterion for mixed stand advantage. In particular, LER indicates the efficiency of intercropping for using the resources of the environment compared with monocropping (Mead and Willey, 1980) [12]. When the LER is greater than one, the intercropping favors the growth and yield of the species. The LER was calculated as (Willey and Osiru, 1972) [17].

$$LER = (Y_{AB}/Y_{AA}) + (Y_{BA}/Y_{BB})$$

Where; $Y_{AB}$= Yield of crop A when intercropped with crop B

$Y_{BA}$= Yield of crop B when intercropped with crop A

$Y_{AA}$= Yield from sole planted crop A

$Y_{BB}$= Yield from sole planted crop B

### Income equivalent ratio (IER)

IER is similar in concept to LER, except that yield is measured in terms of net income, rather than plant product productivity. To calculate the IER market price or gross income (GI) obtained from intercropping a hectare of land were used. It was calculated by the formula developed by (Ghaffarzadeh, 1997) [7]

$$IER = \frac{\text{GI/ha of intercropped crop A}}{\text{GI/ha of sole cropped crop A}} + \frac{\text{GI/ha of intercropped crop B}}{\text{GI/ha of sole cropped crop B}}$$

### Equivalent yield (EY)

Yields of both the crops were taken from whole plot. Greater yam equivalent yield was computed by converting yield of intercrops on the basis of prevailing market price of individual crop following the formula of Bandyopadhyay (1984) [4] as given below:

$$GYeq = Yigy + \frac{Yim \times Pi}{Pgy}$$

Where,

GYeq = Greater yam equivalent yield

Yigy = Yield of maincrop greater yam in the intercrop plot,

Yim =Yield of intercrop maize

Pgy = Price of gy, Pi = Price of intercrop (maize)

## Results and Discussion

Staking contributes to increase growth and development of greater yam (Table 2). Yam produced under staked system out-grows and out-yields those in non-staked system (Norman *et al.*, 2015) [13]. Ennin *et al.*, (2014) [19] reported that vertical staking option had highest fresh leaf, dry leaf and vine weight which translated into highest fresh and shoot weights, tuber yields and numbers.

### Productivity of intercropping system

Intercropping greater yam with different crop showed variable amount of yield difference (Table-6). Fresh tuber yield of greater yam was significantly higher in stake plots (38.25 ton/ha) than the non-stake plots (29.49 t/ha). The highest greater yam mean tuber yield was obtained at 1 greater yam: 2 maize intercropping system (36.79 t/ha).

Yam produced under staked system out-grows and out-yields those in non-staked system (Tsado, 2012 [15] and Norman *et al.*, 2015) [13]. Similar results were observed by Islam *et al.*, (2014) in maize: sweet potato intercropping system. A yield increase of 50 to 60% was observed in stake plots compared to non-stake plots in Cameroon. Norman *et al.*, (2015) [13] observed 37-45% more yield in stake plots compared to non-stake plots. Another study on staking options using a promising non-staked yam line TDR95/19177 showed that non-staked yam resulted in a high (32.5%) yield reduction (Ennin *et al.*, 2014) [19].

### Land equivalent ratio (LER)

Total LER were influenced by different intercropping systems (Table 6) which varied form1.68 in 1 greater yam: 2 maize, 1.63 in1 greater yam: 2 jowarand1.53 in1 greater yam: 2 pigeon pea intercropping arrangements, which shows an advantage from those intercropping systems over pure stands in terms of the use of environmental resources for plant growth (Mead and Willey, 1980) [12]. Emuh *et al.* (2012) [20] reported that, Within the 3 crops association studied, tall staked yam had higher LER than medium or short staked yam. The highest IER was also recorded (Table 6) in 1 greater yam: 2 maize intercropping arrangement (1.79), which shows an advantage from other intercropping arrangements and pure stands.

**Intercrop efficiency based on equivalent yield and benefit cost**

Total productivity in terms of equivalent yields and economic study of greater yam based intercropping presented in table 8. Among intercropping systems, the highest greater yam equivalent yield (38.59 t ha-1) was recorded in 1 greater yam: 2 maize combination which was much higher than other combinations. This result is in line with the findings of Uddin *et al.* (2006) [16]. The highest benefit cost ratio (3.6) was also recorded in1 greater yam: 2 maize combination indicating profitable combination of maize greater yam intercropping systems. The results are consistent with those obtained by Dorosh (1988) [6] and Norman *et al*., (2015) [13]. Maize in this system not only provided additional yield but also acted as a live stake. Similar results were observed in the study conducted by Antaryami Lenka *et al*., (2013) [3].

**Table 2:** Biometric characters of greater yam/maize/jowar/pigeon pea in different treatments

| Treatments | Vine length (cm) | | | | | No. of leaves/plant | | | | | LAI | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAP | 60 DAP | 90 DAP | 150 DAP | 210 DAP | 30 DAP | 60 DAP | 90 DAP | 150 DAP | 210 DAP | 30 DAP | 60 DAP | 90 DAP | 150 DAP | 210 DAP |
| $T_1$ | 59.25 | - | 106.25 | 148.83 | 200.59 | 15.87 | - | 51.93 | 78.87 | 104.00 | 0.76 | - | 1.95 | 3.44 | 2.63 |
| $T_2$ | 82.85 | - | 166.09 | 250.16 | 257.31 | 526.27 | - | 1201.60 | 1644.80 | 1925.67 | 0.82 | - | 1.58 | 2.06 | 2.04 |
| $T_3$ | 89.18 | 184.90 | 239.48 | - | - | 5.27 | 10.80 | 14.73 | - | - | 2.63 | 5.17 | 3.34 | - | - |
| $T_4$ | 67.66 | 127.30 | 217.83 | - | - | 3.33 | 9.07 | 11.87 | - | - | 1.47 | 2.76 | 1.29 | - | - |
| $T_5$ G. Yam | 69.33 | - | 122.13 | 173.02 | 230.01 | 16.20 | - | 53.20 | 80.60 | 107.33 | 0.88 | - | 2.23 | 3.96 | 3.05 |
| $T_5$ Pigeon pea | 68.81 | - | 140.97 | 232.72 | 244.20 | 497.60 | - | 1136.53 | 1556.40 | 1821.87 | 0.72 | - | 1.33 | 1.75 | 1.80 |
| $T_6$ G. Yam | 84.34 | - | 156.63 | 213.54 | 284.96 | 18.87 | - | 62.87 | 94.73 | 124.60 | 0.91 | - | 2.30 | 4.08 | 3.16 |
| $T_6$ Maize | 72.89 | 161.28 | 207.88 | - | - | 4.67 | 9.53 | 14.07 | - | - | 2.08 | 4.53 | 2.72 | - | - |
| $T_7$ G. Yam | 82.29 | - | 145.66 | 206.00 | 266.93 | 17.40 | - | 60.33 | 89.40 | 116.07 | 0.88 | - | 2.15 | 3.95 | 3.00 |
| $T_7$ Jowar | 59.95 | 115.61 | 221.26 | - | - | 2.47 | 6.93 | 9.67 | - | - | 2.18 | 3.99 | 1.83 | - | - |
| $T_8$ G. Yam | 91.78 | - | 162.24 | 229.34 | 305.68 | 19.73 | - | 66.87 | 99.13 | 132.13 | 0.97 | - | 2.47 | 4.37 | 3.32 |

**Table 3:** Yield attributes & yield of maize

| Treatments | No. of cobs/plant | Grains/cob | Test weight | Yield ($tha^{-1}$) |
|---|---|---|---|---|
| $T_3$ | 2.33 | 643.87 | 38.48 | 6.12 |
| $T_6$ | 1.93 | 511.73 | 37.33 | 4.97 |

**Table 4:** Yield attributes & yield of pigeon pea

| Treatments | No. of pods/plant | Seeds/pod | Test weight | Yield ($tha^{-1}$) |
|---|---|---|---|---|
| $T_2$ | 996.93 | 4.07 | 9.01 | 1.14 |
| $T_5$ | 844.67 | 3.93 | 8.97 | 0.87 |

**Table 5:** Yield attributes & yield of jowar

| Treatments | No. of ear head/plant | Seeds/ ear head | Test weight | Yield ($tha^{-1}$) |
|---|---|---|---|---|
| $T_4$ | 2.07 | 1767.40 | 3.11 | 4.09 |
| $T_7$ | 1.93 | 1654.73 | 2.97 | 3.42 |

**Table 6:** Harvest index, yield and land equivalent ratio of greater yam

| Treatments | HI at Senescence | Yield/plant | Yield ($tha^{-1}$) | LER |
|---|---|---|---|---|
| $T_I$ | 0.77 | 2.29 | 29.49 | |
| $T_5$ | 0.72 | 2.51 | 31.39 | 1.50 |
| $T_6$ | 0.75 | 2.90 | 36.79 | 1.68 |
| $T_7$ | 0.74 | 2.61 | 33.50 | 1.63 |
| $T_8$ | 0.79 | 3.32 | 38.25 | |

**Table 7:** Economics

| Treatments | Cost of cultivation | Gross Income | Net Income | B:C ratio | Income Equivalent Ratio (IER) |
|---|---|---|---|---|---|
| $T_1$ | 150500 | 3,96,124 | 2,45,624 | 2.63 | |
| $T_2$ | 55500 | 73,730 | 18,230 | 1.33 | |
| $T_3$ | 52000 | 66,983 | 14,983 | 1.29 | |
| $T_4$ | 36000 | 44,765 | 8,765 | 1.24 | |
| $T_5$ | 159500 | 4,44,347 | 2,84,847 | 2.79 | 1.43 |
| $T_6$ | 154500 | 5,18,360 | 3,63,860 | 3.36 | 1.79 |
| $T_7$ | 153500 | 4,72,958 | 3,19,458 | 3.08 | 1.57 |
| $T_8$ | 158500 | 5,13,793 | 3,55,293 | 3.24 | |

**Table 8:** Effect of cropping system on the yam equivalent yield and benefit cost ratio

| Treatment | Sole crop yield (t/ha) | Inter crop yield (t/ha) | Yam equivalent yield (t/ha) | BCR |
|---|---|---|---|---|
| $T_1$ | 29.49 | | 29.49 | 2.63 |
| $T_2$ | 1.14 | | 2.17 | 1.33 |
| $T_3$ | 6.12 | | 2.32 | 1.29 |
| $T_4$ | 4.09 | | 2.15 | 1.24 |
| $T_5$ | 31.39 | 0.87 (1.69) | 33.08 | 2.79 |
| $T_6$ | 36.79 | 4.97 (1.80) | 38.59 | 3.36 |
| $T_7$ | 33.50 | 3.42 (1.71) | 35.21 | 3.08 |
| $T_8$ | 38.25 | | 38.25 | 3.24 |
| S.Em± | | | 1.21 | 0.04 |
| SED | | | 1.69 | 0.05 |
| CD (0.05) | | | 3.27 | 0.11 |

**Table 9** Pooled analysis of effect of cropping system on the yam equivalent yield

| Treatment | Yam equivalent yield (t/ha) | | | BCR Mean |
|---|---|---|---|---|
| | 2015-16 | 2016-17 | Mean | |
| $T_1$ | 31.71 | 29.49 | 30.60 | 2.81 |
| $T_2$ | 2.31 | 2.17 | 2.24 | 1.38 |
| $T_3$ | 2.32 | 2.32 | 2.32 | 1.32 |
| $T_4$ | 2.15 | 2.15 | 2.15 | 1.28 |
| $T_5$ | 35.49 | 33.08 | 34.29 | 3.07 |
| $T_6$ | 41.45 | 38.59 | 40.02 | 3.63 |
| $T_7$ | 37.82 | 35.21 | 36.52 | 3.27 |
| $T_8$ | 41.43 | 38.25 | 39.84 | 3.48 |
| S.Em± | 1.24 | 1.21 | 1.22 | |
| SED | 1.75 | 1.69 | 1.71 | |
| CD (0.05) | 3.74 | 3.27 | 3.65 | |

## Conclusion

The results revealed that staking is beneficial in yam production contributing an average of 22.9% more fresh tuber yields than non-staking. Leaves of staked yams have greater interception of sunlight and improved aeration, which promote photosynthetic activity leading to bigger and heavier tuber formation. It also reduces the infection and spread of soil-borne diseases from one plant to another. Staking is however expensive, laborious and difficult to mechanize. Greater yam 1 row + 2 rows maize combination could be suitable for increasing productivity and profitability. This implies that intercropping is indeed a sustainable farming practice.

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