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Review/Overview

Crop architecture effects on elephant foot yam (*Amorphophallus paeoniifolius*) productivity and economics under rainfed conditions

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ABSTRACT

A field experiment was conducted during 2008–09 and 2009–10 under rainfed conditions in *Alfisols*, to investigate the effect of broad bed and furrow, crop geometry and spacing on elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]. The experiment was conducted in a randomized block design with 5 replications. The treatment consisted of 90 cm × 90 cm, 75 cm × 75 cm and 60 cm × 60 cm spacing in square and triangle planting on broad bed and furrow (BBF) along with 90 cm × 90 cm square planting on pits followed by mounds (normal). The broad bed and furrow method of planting performed better than pits followed by mound. Triangle planting under all spacings gave higher yield owing to better growth, leaf-area index (LAI) and dry-matter production. Decreasing the plant spacing significantly increased the corm yield. The highest corm yield (28.4 t/ha) was observed at the closest spacing of 60 cm × 60 cm, though per plant yield was lesser. The corm yield at 60 cm × 60 cm spacing was statistically on a par with 75 cm × 75 cm spacing both under square and triangle planting. Higher net returns of ₹1,18,800/ha were noticed with 75 cm × 75 cm spacing in broad bed and furrow (BBF) triangle planting. But higher benefit: cost ratio (1.96) was noticed in 90 cm × 90 cm spacing BBF triangle planting.

Key words : Broad bed and furrow, Elephant foot yam, Square planting, Triangle planting, Tuber crop production

Elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] is a popular tropical tuber crop having high production potential and popularity as a vegetable in various delicious cuisines. Many indigenous ayurvedic and unani medicinal preparations are also made from its corms. The corms are believed to have blood purifying characteristics and are used in medicines for the treatment of piles, asthma, dysentery and other abdominal disorders (Mondal *et al*., 2012). It is distributed predominantly in tropical Asian and African countries (Chandra, 1984; Sugiyama and Santosa, 2008) and it is speculated that human activity has played an important role in its distribution (Hetterscheid and Ittenbach, 1996; Jansen *et al*., 1996).

Elephant foot yam grows well on medium to light soils rich in organic matter because they prefer well-aerated soils (Sugiyama and Santosa, 2008). In high rainfall areas like Odisha, temporary flooding during cropping season is common. Temporary flooding restricts plant growth and causes corm rot (Sugiyama and Santosa, 2008). The most common method of planting is pit of various dimensions depending on the soil type (Sugiyama and Santosa, 2008). Harvesting is cumbersome in pit planting and difficult to get cut/bruise free corms. Raised bed planting have been found effective in saving water in crop production. Higher grain and biological yields and harvest index were obtained under raised bed method of sowing of wheat (*Triticum aestivum* L.) in clay loam soils (Idnani and Ashok Kumar, 2012). Ram *et al*. (2012) reported that in vertisol, soybean [*Glycine max* (L.) Merrill] produced higher yield, water productivity and net returns in raised bed sowing compared to flat sowing. Rhizomatous crops like ginger (*Zingiber officinale* Roscoe) and turmeric (*Curcuma longa* L.) are normally recommended for growing on raised broad beds in *Alfisols* for getting higher yield and lesser incidence of rhizome rot disease (Paramaguru *et al*., 2012). More returns are realized when vegetables are raised on broad beds in *Alfisols* of Odisha (Behera and Mohanty, 2008). However, no effect of raised bed system was found in onion (*Allium cepa* L.) in loamy sand soil (Saini and Walia, 2012).

Elephant foot yam canopy area is more or less round and it is considered that roots are distributed radially

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around plants. Therefore, triangular plantings use space more efficiently than square plantings. Triangular planting at a distance of 40 cm × 40 cm × 40 cm, 50 cm × 50 cm × 50 cm, 60 cm × 60 cm × 60 cm, 70 cm × 70 cm × 70 cm and 80 cm × 80 cm × 80 cm were recommended when 100–500 g of corms were used as seed corms in Indonesia (Sugiyama and Santosa, 2008). Higher plant population under closer crop geometry (90 cm × 45 cm) gives higher seed cotton (*Gossypium hirsutum* L.) yield even though less yield per plant was obtained (90 cm × 60 cm; 90 cm × 90 cm) (Bhalerao and Gaikwad, 2010). However, wider spacing promotes higher growth characters and yield attributes. But, Mohankumar and Ravi (2001) reported highest elephant foot yam corm yield under 75 cm × 75 cm spacing compared to closer spacing of 60 cm × 60 cm and 60 cm × 45 cm spacing. Keeping in view of the above, the present experiment was carried out to investigate the effects of broad bed and furrow, crop geometry and population on elephant foot yam.

MATERIALS AND METHODS

A field experiment was conducted during 2008–09 and 2009–10 under rainfed conditions in *Alfisols*. The experiment was conducted in randomized block design with 5 replications. The experiment consisted of 7 treatments, i.e. T_1, 90 cm × 90 cm square planting in pits followed by mounds (normal), T_2, 90 cm × 90 cm square planting on broad bed and furrow (BBF), T_3, 90 cm × 90 cm triangle planting on BBF, T_4, 75 cm × 75 cm square planting on BBF, T_5, 75 cm × 75 cm triangle planting on BBF, T_6, 60 cm × 60 cm square planting on BBF and T_7, 60 cm × 60 cm square planting on BBF. For planting 90 cm × 90 cm, broad bed of 120 cm and furrow of 60 cm was formed (Fig. 1). Leaving 15 cm on both the sides of the broad bed, 2 rows of elephant foot yam was planted on 120 cm broad beds. For planting 75 cm × 75 cm, broad bed of 105 cm and furrow of 45 cm was formed. Leaving 15 cm on both the sides of the broad bed, two rows of elephant foot yam was planted on 105 cm broad beds. For planting 60 × 60 cm, broad bed of 90 cm and furrow of 30 cm was formed. Leaving 15 cm on both the sides of the broad bed 2 rows of elephant foot yam was planted on 90 cm broad beds. The height of the broad bed was 20 cm. The plot size was 9 × 9 m. The crop was planted in the second fortnight of June during both the years of study. The variety 'Gajendra' was used for the study. Whole corms weighing 400 g was planted/hill. The recommended dose of fertilizer N-P-K @ 80-25.8-66.4 kg/ha was applied. Full dose of phosphorus along with farmyard manure 10 t/ha was incorporated at the last ploughing. Half dose of nitrogen and potassium was applied at 1 month after planting (MAP) immediately after first hand weeding. The second half dose of nitrogen and potassium was applied at 2 MAP immediately after second hand-weeding. Third hand weeding was carried out at 3 months after planting (MAP).

The climate of this region is characterized by hot and humid summer and cold and dry winter. The average annual rainfall was 1,400 mm in 55 rainy days. The average maximum temperature ranged between 29.0 and 38.9°C, whereas the average minimum temperature ranged between 14.9 and 26.7°C. July and August were the highest rain receiving months. The soil was sandy silt loam, having pH 5.5, available N 264 kg/ha, available P 20.3 kg/ha and available K 158 kg/ha before the start of the experiment. The water-holding capacity of the soil was 12.8%. Elephant foot yam is a robust herbaceous plant with tripartite leaf divided into a number of segments (leaflets) outspreading crown like foliage which is borne on a fairly thick, single, upright pseudostem (petiole). It produces an average 2 pseudostem per plant or hill when whole corm is planted. Usually second pseudostem emerges at 3 methods after planting (MAP). Growth observations, plant height and canopy spread were measured from the first pseudostem at 1 MAP and the second pseudostem at 5 MAP. However, observations on number of leaflets, leaf-area index (LAI) and dry-matter partitioning were taken from the whole plant/hill at 3, 5 and 8 MAP (harvest). LAI of the plant was calculated dividing leaf area by ground area. Yield was recorded at harvest (8 MAP). Cost of cultivation and returns were calculated from prevailing rates of inputs and output during the cropping period. Benefit: cost ratio was calculated by dividing gross returns by cost of cultivation.

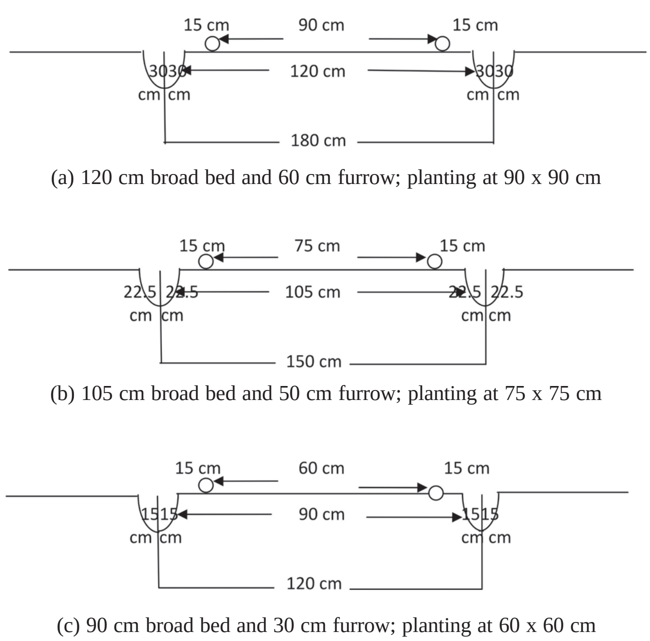
The data were subjected to the analysis of variance (ANOVA) appropriate to the design using GENSTAT programme. The significant differences between the treatments were compared with the critical difference (CD) at a 5% level of probability.

RESULTS AND DISCUSSION

Growth dynamics

In elephant foot yam, second pseudostem is taller than first pseudostem. Taller plants were observed under closer planting than wider spacing (Table 1). At 3 and 5 MAP, significantly taller plants were observed under closer spacing (60 cm × 60 cm). Plant tends to grow taller under closer spacing due to etiolation under shade competition for light. The BBF 90 cm × 90 cm planting produced taller plants than normal 90 cm × 90 cm planting. Each broad bed and furrow (BBF) acted as a micro water harvesting structure; the water harvested from broad bed during rainy days was stored in furrow which was subsequently available to the crop. Further, the excess moisture in the root zone was drained into the furrow; thereby improving the aeration in the root zone which helped to augment the crop growth. Crop geometry did not much influence plant height (Table 1). Marked variation in canopy spread was observed (Table 1). Canopy spread was lower in closer spacing than wider spacing at 3 and 5 MAP. BBF planting produced greater canopy spread than normal (pit followed by mound) method of planting. Among crop geometry, triangular planting resulted in more canopy spread than square planting. Significantly widest canopy spread was observed under 90 cm × 90 cm triangular planting on BBF. Crown like foliage of elephant foot yam plants utilized the space efficiently in the triangular planting, where competition between plant to plant was minimum compared to square planting.

At 3 MAP, number of leaflets/plant/hill was significantly higher in 90 cm × 90 cm BBF planting compared to 75 cm × 75 cm and 60 cm × 60 cm spacing BBF as well as 90 cm × 90 cm normal planting (Table 1). Significantly lower number of leaflets/plant/hill was observed in 60 cm × 60 cm spacing BBF. However, it was statistically comparable with 90 cm × 90 cm normal planting and 75 cm × 75 cm spacing BBF. At 5 MAP, significantly higher number of leaflets/plant/hill was noticed in 90 cm × 90 cm BBF planting. Significantly lower number of leaflets/plant/hill were observed in 60 cm × 60 cm spacing BBF. Among crop geometry, more leaflets/plant/hill was observed in triangle planting compared to square planting at 3 and 5 MAP, though not statistically significant. Maximum LAI was noticed with closer planting at 60 cm × 60 cm spacing than wider planting at 75 cm × 75 cm and 90 cm × 90 cm both at 3 and 5 MAP. This might be due to



(a) 120 cm broad bed and 60 cm furrow; planting at 90 x 90 cm

(b) 105 cm broad bed and 50 cm furrow; planting at 75 x 75 cm

(c) 90 cm broad bed and 30 cm furrow; planting at 60 x 60 cm

Fig. 1. (a), (b) and (c) Broad bed systems lay out

Table 1. Growth dynamics of elephant foot yam as influenced by method of planting, crop geometry and spacing (pooled data of 2 years)

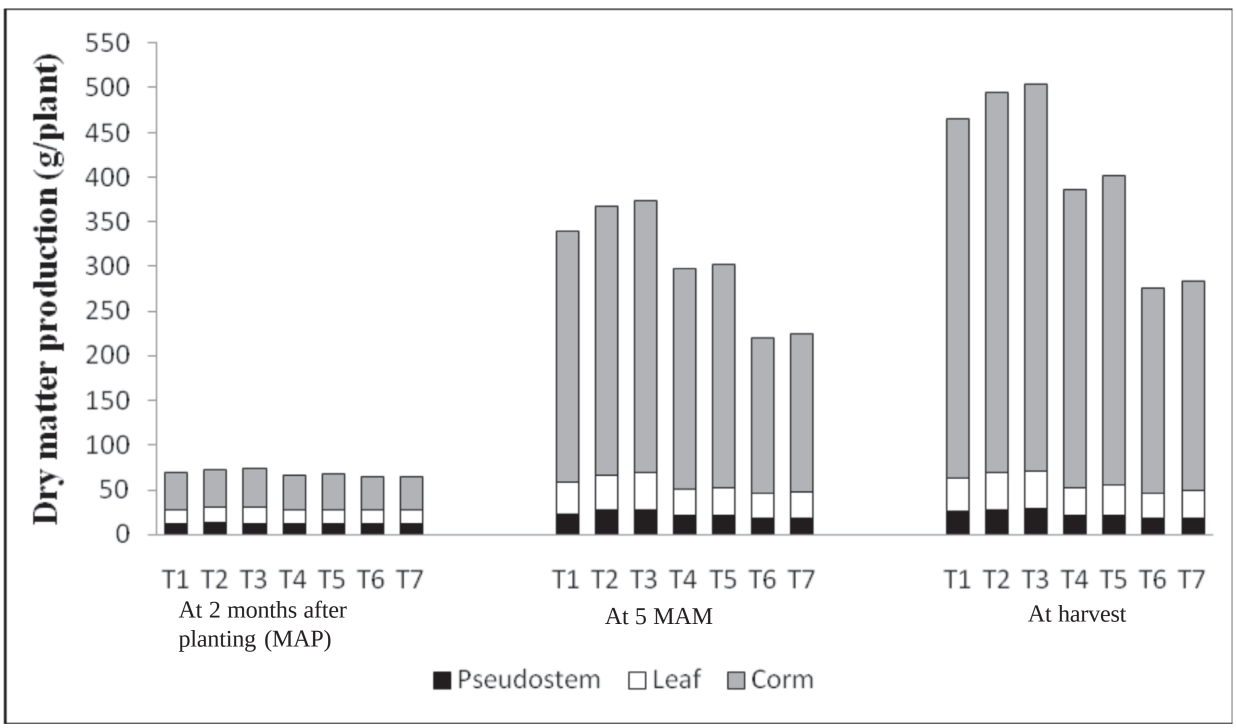
Treatment	Psudostem height (cm)		Canopy spread (cm)		Leaflets/plant		Leaf-area index	
	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP
90 cm × 90 cm square planting on mounds (normal)	56	102	82	115	230	520	0.46	0.83
90 cm × 90 cm square planting on broad bed and furrow (BBF)	62	110	88	122	286	592	0.38	0.95
90 cm × 90 cm triangle planting on broad bed and furrow (BBF)	64	115	90	135	302	628	0.47	1.01
75 cm × 75 cm square planting on broad bed and furrow (BBF)	62	112	82	110	232	484	0.54	1.10
75 cm × 75 cm triangle planting on broad bed and furrow (BBF)	65	118	85	115	236	506	0.55	1.15
60 cm × 60 cm square planting on broad bed and furrow (BBF)	68	120	78	88	216	440	0.76	1.54
60 cm × 60 cm triangle planting on broad bed and furrow (BBF)	70	125	80	92	222	464	0.79	1.62
SEm±	1.4	2.7	1.7	2.7	7.6	14.4	0.02	0.02
CD (P=0.05)	4	8	5	8	22	42	0.05	0.07

higher plant population. Das *et al*. (1997) also reported increase in LAI with increase in plant population. LAI of 90 cm × 90 cm BBF planting was higher than 90 cm × 90 cm normal planting. Triangular system of planting produced higher LAI than square planting, but not at statistically significant level.

Dry matter production

Pseudostem and leaf dry-matter production/plant/hill was rapid up to 5 MAP and subsequently the increase was negligible (Fig. 2). Elephant foot yam corm is a modified stem, which initiate along with pseudostem. However, initially the crop growth was slow, then rapid and again slow, but corm growth continued till maturity/senescence of pseudostem. Pseudostem and leaf dry-matter production/plant/hill at 3 MAP was significantly higher in 90 cm × 90 cm BBF planting compared to the other spacings and 90 cm × 90 cm normal planting. Pseudostem and leaf dry-matter/plant/hill in 75 cm × 75 cm and 60 cm × 60 cm BBF as well as 90 cm × 90 cm normal planting were at par. At 5 and 8 MAP, significantly higher pseudostem and leaf dry matter/plant/hill was observed in 90 cm × 90 cm BBF planting and it was followed by 90 cm × 90 cm normal planting. Significantly lowest pseudostem and leaf dry-matter production/plant/hill was noticed in 60 cm × 60 cm planting. No significant effect of crop geometry was noticed, even though triangle planting produced higher pseudostem and leaf dry-matter/plant/hill than square planting. Corm dry matter accumulation/plant/hill was significantly higher in 90 cm × 90 cm BBF planting compared to the other spacings at all stages except at 3 MAP, when it was at par with 90 cm × 90 cm normal planting. Normal planting 90 cm × 90 cm was the next best treatment in case of corm dry-matter accumulation. Significantly lowest corm dry-matter accumulation/plant/hill was noticed in 60 cm × 60 cm planting at all stages (Fig. 2). No significant effect of crop geometry was noticed, though triangle planting recorded higher corm dry matter/plant/hill than square planting.

Rate of total dry matter accumulation/plant/hill was higher in wider spacing (90 cm × 90 cm) (Table 2). The accumulation rate decreased with reduction in spacing (75



	Dry matter production (g/plant) at 3 MAP				Dry matter production (g/plant) at 5 MAP				Dry matter production (g/plant) at 8 MAP (Harvest)			
	Pseudostem	Leaf	Corm	Total	Pseudostem	Leaf	Corm	Total	Pseudostem	Leaf	Corm	Total
SEm±	0.27	0.41	1.17	1.75	0.82	0.96	5.19	6.98	0.86	1.13	7.08	10.38
CD (P=0.05)	0.8	1.2	3.4	5.1	2.4	2.80	15.1	20.3	2.5	3.3	20.6	30.2

Fig. 2. Dry matter production and partitioning of elephant foot yam as influenced by method of planting, crop geometry and spacing (pooled data of 2 years)

Table 2. Dry matter production rate, yield and economics of elephant foot yam as influenced by method of planting, crop geometry and spacing (pooled data of 2 years)

Treatment	Rate of total dry-matter production/plant (g/g) 3–5 MAP	5–8 MAP	Corm length (cm)	Corm diameter (cm)	Corm yield (g/plant)	Corm yield (t/ha)	Cost of cultivation (×10³₹/ha)	Gross returns (×10³₹/ha)	Net returns (×10³₹/ha)	Benefit: cost ratio
T_1, 90 cm × 90 cm square planting on mounds (normal)	3.88	0.37	18	12	1,750	21.6	111.2	216.3	105.1	1.94
T_2, 90 cm × 90 cm square planting on broad bed and furrow (BBF)	4.08	0.35	19	13	1,850	22.6	118.4	225.8	107.4	1.91
T_3, 90 cm × 90 cm triangle planting on broad bed and furrow (BBF)	4.03	0.35	19	14	1,900	23.3	119.2	233.4	114.2	1.96
T_4, 75 cm × 75 cm square planting on broad bed and furrow (BBF)	3.49	0.30	14	9	1,450	25.8	145.1	257.6	112.5	1.77
T_5, 75 cm × 75 cm triangle planting on broad bed and furrow (BBF)	3.50	0.33	14	10	1,500	26.5	145.8	264.6	118.8	1.81
T_6, 60 cm × 60 cm square planting on broad bed and furrow (BBF)	2.43	0.25	11	8	1,000	28.2	196.1	281.6	85.5	1.44
T_7, 60 cm × 60 cm triangle planting on broad bed and furrow (BBF)	2.46	0.26	10	9	1,000	28.4	196.3	283.7	87.4	1.44
SEm±	0.096	0.01	0.3	0.3	43	1.0	-	-	-	-
CD (P=0.05)	0.28	0.03	1	1	125	3.0	-	-	-	-

MAP, Months after planting; Sale price of elephant foot yam corm ₹10/kg

cm × 75 cm and 60 cm × 60 cm). Slightly higher rate of total dry-matter accumulation/plant/hill was noticed in 90 cm × 90 cm BBF than 90 cm × 90 cm normal planting between 3 and 5 MAP. This was due to favourable hydro-thermal conditions in root zone during the rainy season under BBF. Between 5 and 8 MAP, slightly higher total dry-matter accumulation was noticed in 90 cm × 90 cm normal planting than 90 cm × 90 cm BBF. During post rainy season root zone soils of BBF dries quickly than normal planting because of more exposure of soil. The hydrothermal conditions were better in 90 cm × 90 cm normal planting than 90 cm × 90 cm BBF at this stage. Crop geometry could not exert significant effect. However, triangle planting promoted dry-matter production rate slightly.

Yield and economics

Elephant foot yam corm yield was significantly higher with closer spacing 60 cm × 60 cm BBF and it was on a par with 75 cm × 75 cm spacing BBF (Table 2). Though corm length, diameter and yield/plant were less at closer planting, higher plant population/ha resulted in higher corm yield. Douglas *et al*. (2006) also reported higher corm yield with increase in plant population. Wider spacing 90 cm × 90 cm produced lower corm yield in spite of higher corm length, diameter and yield/plant. This was mainly due to lower plant population. The corm yield in 90 cm × 90 cm BBF planting was higher than 90 cm × 90 cm normal planting, but not statistically significant. The advantage of higher shoot growth was not completely realized in terms of corm yields in BBF. This might be due to drying of raised bed soils more quickly during post rainy season (November–January). Triangle planting at all the spacings gave higher yield. The projection area of the canopy of elephant foot yam is more or less round and it is considered that roots are distributed radially around plants. Therefore, triangular plantings use space more efficiently than square plantings. However at closer spacing (60 cm × 60 cm) the corm yield difference was negligible. In general, square planting and triangle planting were not significantly different. Maximum gross return of was observed in 60 cm × 60 cm BBF triangle planting (Table 2). This was owing to higher corm yield. Higher net return of was noticed in 75 cm × 75 cm BBF triangle planting. This might be due to optimum yield and lesser cost of production. Higher benefit: cost ratio was observed in wider spacing 90 cm × 90 cm. This was due to lower cost of cultivation. The highest benefit: cost ratio was noticed in 90 cm × 90 cm BBF triangle planting.

Thus, planting elephant foot yam whole corm weighing 400 g at 75 cm × 75 cm spacing in BBF system fetches higher net return and optimum corm yield. Though, planting resulted in higher yield at all the spacings than square planting, farmers preferred square planting due to greater convenience in planting.

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