Madras Agric. J., 99 (10-12): 747-750, December 2012

Influence of NPK Fertilization on Nutrient Uptake, Growth and Yield of Elephant Foot Yam in Laterite Soils of Arunachal Pradesh

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An experiment was conducted with different NPK fertilizer combinations to explore the possibility of improving growth and productivity of popular elephant foot yam (EFY) varieties of Arunachal Pradesh. Two varieties, Gajendra and TRCB-1 were planted in main plot and fertilizer combinations viz., F_0: $N_0P_0K_0$; F_1: $N_{75}P_{25}K_{75}$; F_2: $N_{100}P_{37.5}K_{100}$; F_3:$N_{125}P_{50}K_{125}$; F_4:$N_{150}P_{62.5}K_{150}$ and F_5:$N_{175}P_{75}K_{175}$ (kg ha^{-1}) were applied in sub plots. The growth and yield attributes were the highest with Gajendra variety of elephant foot yam with the application of $N_{175}P_{75}K_{175}$ kg ha^{-1} Similarly, higher yield was recorded by Gajendra (29.02 t ha^{-1}) followed by TRCB-1 (22.73 t ha^{-1}). Among the fertilizer combinations $N_{175}P_{75}K_{175}$ recorded 33.28 t ha^{-1} followed by $N_{100}P_{37.5}K_{100}$ (30.26 t ha^{-1}).

Key words: Elephant foot yam, fertilizers, nutrient uptake, yield, Arunachal Pradesh

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.), Nicolson var. *campanulatus* (Decne) Sivad., is a herbaceous, perennial C_3 crop. It has long been used as a local staple food in many countries such as Philippines, Java, Indonesia, Sumatra, Malaysia, Bangladesh, India, China and South Eastern Asian countries. It serves as a source of starch as well as protein. It is an important tropical tuber crop grown for edible corms as well as for its use in the treatment of digestive disorders. The tubers are used for making vegetable curry, pickle and also as supplementary food. In addition, it is used in pharmaceutical preparations in Ayurvedic medicines (Patel *et al*. 2011). The corms are rich in starch (36-114 mg g^{-1}) calcium, (50 mg g^{-1}), phosphorus (34 mg g^{-1}), sucrose (2.3 mg g^{-1}) and vitamin A (260 IU g^{-1}). The leaves are used as a vegetable by local tribes in India as they contain high concentration of vitamin A (Ravi *et al*. 2009).

Greater care and crop maintenance is required to achieve the potential productivity of elephant foot yam which is very high about 50-80 t ha^{-1}. But, conversely, the crop is being grown in marginal and poor soil condition. Nutrient management imparts greater effects on the balance of competition between crops and increases the overall production potential (Ravindran and Sreedharan, 2001). The crop is traditionally grown as companion crop in the *jhum* land along with rice in Arunachal Pradesh. The farmers are however interested to grow elephant foot yam as mono crop due to its high net realization. There is a need to develop a technique and fertilization schedule to achieve the full potential of crop. The information on the effect of fertilizers on the crop when growing under laterite soil condition is scanty. Keeping the above in mind, the present study was conceived to find out the effect of NPK fertilization on the growth and yield attributes of elephant foot yam under mid hill condition of Arunachal Pradesh.

Materials and Methods

The field experiment was carried out in laterite soil at the experimental farm of ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, during 2009 and 2010. The experiment was laid out on split plot design and replicated thrice. Two varieties namely Gajendra and TRCB-1 were planted in main plot and sub plots were subjected to fertilizer combinations of six levels of NPK (kg ha^{-1}) viz., F_0: $N_0P_0K_0$; F_1: $N_{75}P_{25}K_{75}$; F_2: $N_{100}P_{37.5}K_{100}$; F_3:$N_{125}P_{50}K_{125}$; F_4:$N_{150}P_{62.5}K_{150}$ and F_5:$N_{175}P_{75}K_{175}$.

Results and Discussion

It is apparent from the data presented in Table 1 that all vegetative parameters were markedly influenced by different varieties and fertilizer levels. However, it was observed that through-out the cropping period during 2010 more rainfall was received than 2009 which ultimately influenced the growth attributes of elephant foot yam positively irrespective of fertilizer treatments and varieties. Growth attributes like maximum plant height, basal girth and canopy spread was exhibited higher 73.81, 15.12 and 68.06 cm, respectively in Gajendra over TRCB-1. Plant height was highest (80.73 cm) in the

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Table 1. Influence of varieties and fertilizer levels on vegetative growth of elephant foot yam at 200 DAP

Treatment	Plant height (cm)			Basal girth (cm)			Canopy spread (cm)		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
Varieties									
Gajendra	72.87^{a}	74.74^{a}	73.81	14.63^{a}	15.12^{a}	14.88	66.98^{a}	69.13^{a}	68.06
TRCB-1	61.14^{b}	63.21^{b}	62.18	12.41^{b}	13.07^{b}	12.74	62.30^{b}	64.01^{b}	63.16
LSD (*P*=0.05)	2.57	2.23		0.41	0.46		2.07	1.75	
Fertilizer levels									
F_0	51.65^{e}	53.18^{e}	52.42	10.20^{e}	10.80^{e}	10.50	48.97^{e}	51.68^{e}	50.33
F_1	59.45^{de}	61.37^{de}	60.41	12.23^{d}	12.52^{d}	12.38	62.97^{d}	65.05^{d}	64.01
F_2	65.03^{cd}	67.25^{cd}	66.14	13.27^{cd}	13.72^{cd}	13.50	64.45^{cd}	66.47^{cd}	65.46
F_3	69.98^{bc}	71.92^{bc}	70.95	14.17^{bc}	14.90^{bc}	14.54	68.00^{bc}	69.85^{bc}	68.93
F_4	76.18^{ab}	78.40^{ab}	77.29	15.25^{ab}	15.80^{ab}	15.53	70.22^{ab}	71.85^{ab}	71.04
F_5	79.73^{a}	81.73^{a}	80.73	16.02^{a}	16.83^{a}	16.43	73.23^{a}	74.50^{a}	73.87
LSD (*P*=0.05)	8.97	8.45		1.61	1.57		4.25	4.35	

F_0: $N_0P_0K_0$; F_1: $N_{75}P_{25}K_{75}$; F_2: $N_{100}P_{37.5}K_{100}$; F_3:$N_{125}P_{50}K_{125}$; F_4:$N_{150}P_{62.5}K_{150}$; F_5:$N_{175}P_{75}K_{175}$

treatment receiving the highest level of NPK (175:75:175 kg ha^{-1}) followed by NPK (150:62.5:150 kg ha^{-1}). Fertilizer application positively influenced other biometric parameters of the plant. Highest level of fertilizer recorded the maximum basal girth (16.43 cm) followed by NPK@ 150:62.5:150 kg ha^{-1} (15.80 cm). The lowest growth parameters were recorded on control, without fertilizer application. Similar findings were reported by Ravindran and Sreedharan (2001) and Sen and Mukerjee (2002); Dutta *et al*. (2003) in various regions and in different cropping systems.

Yield attributes and yield

All yield attributes were markedly influenced by varieties and fertilizer levels (Table 2). Var. Gajendra recorded 24.07, 19.96, 28.83 and 28.00% higher corm diameter, corm breadth, corm weight and yield $plant^{-1}$ over TRCB-1. Among the different fertilizer combinations the highest corm diameter, corm breadth, weight of corm and yield $plant^{-1}$ were recorded by the highest level of NPK (175:75:175 kg ha^{-1}) followed by NPK (150:62.5:150 kg ha^{-1}). Similar finding was also recorded by Chattopadhyay *et al*. (2006) and Suja *et al*. (2010). Elephant foot yam

Table 2. Influence of varieties and fertilizer levels on yield and yield attributes of elephant foot yam at 200DAP

Treatment	Corm Diameter (cm)			Corm breadth (cm)			Corm weight (g)			Yield (kg $plant^{-1}$)			Projected yield (t ha^{-1})		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
Varieties															
Gajendra	20.41^{a}	21.54^{a}	20.98	10.24^{a}	11.15^{a}	10.70	1.29^{a}	1.56^{a}	1.43	2.04^{a}	2.44^{a}	2.24	27.63^{a}	30.41^{a}	29.02
TRCB-1	16.31^{b}	17.51^{b}	16.91	8.52^{b}	9.31^{b}	8.92	1.01^{b}	1.21^{b}	1.11	1.61^{b}	1.88^{b}	1.75	21.53^{b}	23.92^{b}	22.73
LSD (*P*=0.05)	0.91	0.80		0.81	0.67		0.09	0.13		0.11	0.13		1.48	1.50	
Fertilizer levels															
F_0	14.58^{c}	15.65^{d}	15.12	6.75^{d}	7.65^{d}	7.20	0.67^{d}	0.79^{d}	0.73	0.76^{d}	0.92^{d}	0.84	14.93^{e}	17.58^{c}	16.26
F_1	17.08^{bc}	17.97^{cd}	17.53	8.50^{c}	9.33^{c}	8.92	0.99^{c}	1.11^{c}	1.05	1.68^{c}	1.95^{c}	1.82	21.14^{d}	24.31^{b}	22.73
F_2	17.80^{b}	18.75^{bc}	18.28	9.30^{bc}	10.17^{bc}	9.74	1.11^{bc}	1.32^{bc}	1.22	1.89^{bc}	2.18^{bc}	2.04	23.95^{cd}	26.32^{b}	25.14
F_3	18.78^{b}	19.68^{bc}	19.23	10.00^{abc}	10.83^{abc}	10.42	1.27^{ab}	1.51^{b}	1.39	2.06^{ab}	2.47^{ab}	2.27	26.71^{bc}	29.26^{ab}	27.99
F_4	20.07^{ab}	21.42^{ab}	20.75	10.63^{ab}	11.28^{ab}	11.00	1.36^{a}	1.56^{b}	1.46	2.21^{ab}	2.62^{ab}	2.42	28.99^{ab}	31.52^{a}	30.26
F_5	21.83^{a}	23.67^{a}	22.75	11.10^{a}	12.10^{a}	11.60	1.51^{a}	2.01^{a}	1.76	2.37^{a}	2.84^{a}	2.61	31.76^{a}	34.00^{a}	32.88
LSD (*P*=0.05)	3.04	2.99		1.59	1.56		0.24	0.32		0.33	0.44		4.77	4.98	

receiving NPK (175:75:175 kg ha^{-1}) recorded 50.46% corm diameter, 61.11% corm breadth, 41.10% weight of corm and 210.70% yield $plant^{-1}$ higher over fertilizer received NPK (0:0:0 kg ha^{-1}). However, as fertilizer combination of NPK decreased from higher levels, yield attributes were consequently decreased. Gajendra variety registered 27.72% higher tuber yield, over TRCB-1 (Table 2). This may be due to inherent genetic characteristics and positive response of variety to the applied fertilizers. It is lucid that the entire yield attributes significantly higher in Gajendra than TRCB-1, this in turn helped the plants to register higher yield. Among the fertilizer combination, NPK with 175:75:175 kg ha^{-1} recorded 102.21% higher yield followed by 86.10% higher in NPK (150:62.5:150 kg ha^{-1}) over control. Similar to yield attributes, as fertilizer levels decreased the yield ha^{-1} decreased significantly. The findings of the present study are corroborative to the earlier findings of Chattopadhyay *et al*. (2006) and Saravaiya *et al*. (2010).

Nutrient uptake

Interesting observations are recorded over the nutrient uptake pattern of elephant foot yam with varying fertilizer treatments (Table 3). The nitrogen uptake was recorded 34.39% higher in Gajendra than the TRCB-1. Similarly, phosphorus and potassium uptakes were recorded 43.88 and 43.49% respectively higher than the TRCB-1. The inherent ability of Gajendra to respond linearly to fertilizer application in turn resulted in to uptake of major growth nutrients. This increase in uptake of nutrients positively influenced the different

Table 3. Influence of varieties and fertilizer levels on nutrient uptake pattern of elephant foot yam at 200 DAP

Treatment	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
Varieties									
Gajendra	107.12^{a}	117.26^{a}	112.19	17.69^{a}	19.32^{a}	18.51	121.19^{a}	132.67^{a}	126.93
TRCB-1	79.31^{b}	87.64^{b}	83.48	12.27^{b}	13.52^{b}	12.90	84.39^{b}	93.34^{b}	88.865
LSD (*P*=0.05)	6.05	6.02		1.02	1.00		6.59	6.56	
Fertilizer levels									
F_0	38.48^{e}	45.35^{e}	41.92	4.84^{e}	5.71^{e}	5.28	44.48^{e}	52.41^{e}	48.45
F_1	61.95^{d}	71.21^{d}	66.58	8.75^{ed}	10.06^{d}	9.41	17.42^{de}	82.09^{d}	49.76
F_2	81.08^{cd}	89.06^{cd}	85.07	11.59^{d}	12.71^{d}	12.15	91.17^{cd}	100.05^{cd}	95.61
F_3	101.42^{c}	111.10^{c}	106.26	16.07^{c}	17.59^{c}	16.83	108.73^{bc}	119.10^{bc}	113.92
F_4	126.32^{b}	137.33^{b}	131.83	21.78^{b}	23.68^{b}	22.73	135.84^{b}	147.71^{ab}	141.78
F_5	150.06^{a}	160.65^{a}	155.36	26.85^{a}	28.75^{a}	27.80	165.12^{a}	176.66^{a}	170.89
LSD (*P*=0.05)	21.36	22.34		4.07	4.29		27.88	29.22	

morphological, physiological and nutritional aspects of the plants. Sethi *et al*. (2002) recorded the increase in yield with the fertilizer application in the hilly tracks of Odisha. Similar to the varieties, fertilizer treatments also affected the nutrient uptake by plants. It was quite understandable that as fertilizer levels were increased, the uptake of nutrients were registered significantly higher than the lower levels of NPK. Geetha (2001) reported the highest nutrient removal by the plants which are fed with equally good amount of fertilizers and other growth inducing nutrients.

Solar radiation interception

Solar radiation interception was significantly influenced by varieties and different fertilizer combinations and is presented in Table 4. The solar radiation interception was recorded 7.80% higher by Gajendra variety over TRCB-1. This might be due to better growth parameters (plant height, canopy spread) which helped the plant to intercept more solar radiation than the TRCB-1. Similarly, as the fertilizer levels were increased vegetative growth was recorded higher, which directly helped the plant to intercept more solar radiation on their canopy and least radiation was penetrated to ground. Highest solar radiation was intercepted on NPK with 175:75:175 kg ha^{-1}and least with NPK (0:0:0 kg ha^{-1}). Sethi *et al*. (2002) reported the higher utilization of solar energy by the plants with higher crop canopy under optimum nutrients condition. High solar radiation interception enhanced plant photo synthesis by trapping more photosynthetically active radiation which in lieu increases the content of photo assimilates (Choudhary *et al*. 2006).

Weed dynamics

Weed dynamics in elephant foot yam was significantly influenced by varieties and fertilizers (Table 4). The weed species observed during the experimental period were viz., broad leaves

Table 4. Influence of varieties and fertilizer levels on weed dynamics of elephant foot yam at 75DAP

Treatment	Solar radiation interception (%)			Weed density (m^{-2})*			Weed dry weight (g m^{-2})*			Weed control efficiency (%)		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
Varieties												
Gajendra	71.94^{a}	73.49^{a}	72.72	14.47^{b} (211.56)	14.93^{b} (225.50)	14.70	7.60^{b} (57.91)	7.79^{b} (69.71)	7.70	25.32	26.73	26.02
TRCB-1	66.48^{b}	68.43^{b}	67.46	15.17^{a} (233.61)	15.90^{a} (257.17)	15.54	7.96^{a} (63.49)	8.10^{a} (65.70)	8.03	24.31	23.08	23.69
LSD (*P*=0.05)	2.45			0.39	0.38		0.15	0.16				
Fertilizer levels												
F_0	56.73^{e}	58.40^{e}	57.57	12.69^{e} (160.67)	13.07^{e} (170.50)	12.88	6.58^{e} (42.88)	6.72^{f} (44.70)	6.65			
F_1	63.30^{d}	65.12^{d}	64.21	13.14^{e} (172.33)	13.55^{e} (183.17)	13.35	7.21^{d} (51.50)	7.33^{e} (53.27)	7.27	43.95	43.90	43.92
F_2	68.12^{cd}	69.67^{cd}	68.90	13.99^{d} (195.33)	14.46^{d} (209.00)	14.23	7.67^{c} (58.53)	7.82^{d} (60.67)	7.75	32.74	33.23	32.99
F_3	71.57^{bc}	73.32^{bc}	72.45	15.11^{c} (228.50)	15.84^{c} (251.00)	15.48	8.00^{b} (63.63)	8.19^{c} (66.70)	8.10	23.44	23.93	23.69
F_4	75.20^{b}	77.12^{b}	76.16	16.36^{b} (267.50)	17.11^{b} (292.83)	16.71	8.45^{a} (71.07)	8.63^{b} (74.10)	8.54	16.76	16.31	16.53
F_5	80.37^{a}	82.15^{a}	81.26	17.64^{a} (311.17)	18.47^{a} (341.50)	18.06	8.77^{a} (76.58)	8.96^{a} (79.78)	8.87	7.19	7.14	7.16
LSD (*P*=0.05)	5.00	4.60		0.75	0.88		0.32	0.31				

*Figures in parenthesis are original values

(*Ageratum conyzoids, Boreria hispida* and *Commelina bengalensis*) and grasses (*Echinochloa crusgalli* and *Panicum repens*). Gajendra recorded comparatively lower weed density and weed dry weight m^{-2} over the TRCB-1. However, between the years, 2010 recorded higher weed density and weed dry weight owing to high rainfall received during the year. Weed control efficiency was recorded higher on var. Gajendra, 15.82% higher than the TRCB-1. The higher canopy spread and crop growth by Gajendra variety inversely affected the weed growth and its spread. As fertilizer levels increased, profuse weed dynamics was recorded. The weed density was recorded highest for NPK

Table 5. Influence of various treatments on cost of cultivation of elephant foot yam

Treatment	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C Ratio
Varieties				
Gajendra	54150	212870	158720	2.93^{a}
TRCB-1	54150	167440	113290	2.09^{b}
LSD (*P*=0.05)				0.42
Fertilizer levels				
F_0	50500	123060	72560	1.44^{e}
F_1	52972	170170	117198	2.21^{d}
F_2	53926	184240	130314	2.42^{d}
F_3	54880	204820	149940	2.73^{c}
F_4	55834	220640	164806	2.95^{bc}
F_5	56788	238000	181212	3.19^{a}
LSD (*P*=0.05)				0.26

with 175:75:175 kg ha^{-1} followed by NPK with 150:62.5:150 kg ha^{-1}. However, the lowest weed density m^{-2} was recorded on NPK (0:0:0 kg ha^{-1}). Weed dry weight followed the similar trend to weed density. Weed control efficiency was recorded highest with NPK (0:0:0 kg ha^{-1}) followed by NPK (75:25:75 kg ha^{-1}). However, the least weed control efficiency was recorded on NPK with 175:75:175 kg ha^{-1}. This might be due to as fertilizer levels increased the availability of nutrients were also more for weeds, which helped the plant to grow and helped in accumulating more dry matter in different plant parts. Sen and Mukherjee (2002) also recorded the higher weed dry weight when fed with more nutrients. Optimum and right use of fertilizers is pre-requisite to avoid the negative effect of increased fertilizer use on elephant foot yam.

Economics

The in-depth analysis on influence of varieties and fertilizers on elephant foot yam revealed that the cost of cultivation was similar for both the varieties but gross and net return was recorded higher for Gajendra variety. Consequently, B: C ratio was recorded significantly (P<0.05) higher for Gajendra (Table 5). Among the fertilizer combinations, cost of cultivation recorded higher as fertilizer levels increased and highest was recorded of NPK with 175:75:175 kg ha^{-1} followed by NPK with 150:62.5:150 kg ha^{-1}. The increase in investment per unit area was due to the additional rupee spent to utilize more fertilizers in order to obtain higher production and productivity. This higher spending was reasonably compensated by the rather exponential increase in yield of elephant foot yam. Saravaiya *et al*. (2010) and Chattopadhay *et al*. (2006) reported the increase in cost of cultivation with higher NPK fertilization. Higher gross and net return was recorded on NPK with 175:75:175 kg ha^{-1} followed by NPK with 150:62.5:150 kg ha^{-1}. Similarly, B: C ratio was recorded the highest on NPK with 175:75:175 kg ha^{-1} followed by NPK with 150:62.5:150 kg ha^{-1}. The findings of this study are in line with the result of earlier findings by Saravaiya *et al*. (2010) and Kundu *et al*. (1998) who reported the positive influence of NPK fertilizers on elephant foot yam.

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Received: April 16, 2012; Accepted: September 4, 2012