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Performance of greater yam (*Dioscorea alata*) and maize (*Zea mays*) intercropping as influenced by mulching and levels of N-P-K fertilization

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ABSTRACT

A field experiment was conducted for consecutive 3 years (from 2003-04 to 2005-06) at Dumuduma, Bhubaneshwar under rainfed conditions to find out the influence of mulching along with different levels of NPK fertilization on total productivity, energy use efficiency and economics of greater yam (*Dioscorea alata* L.) and maize (*Zea mays* L.) intercropping system. Higher total productivity (23.0 tonne/ha), productivity efficiency (109.5 kg/ha/day) and net return (Rs 55,700/) were obtained with the application of 120-39.3-100 kg N-P-K/ha along with mulching. However, higher energy use efficiency (5.07) was found with the application of 100-32.7-83.3 kg N-P-K/ha along with mulching. Mulching along with 120-39.3-100 kg N-P-K/ha registered the highest N, P and K uptake and post-harvest soil nutrients status followed by mulching along with 100-32.7-83.3 kg N-P-K/ha.

Keywords: Cost Benefit analysis, *Dioscorea alata,* Energy value, Greater Yam, Maize, Productivity

Greater yam (*Dioscorea alata* L.) serves as a staple food in Africa, Asia and South as well as Latin America (Etissa, 1998). In India, it is a subsistence food crop in tribal and hilly areas and vegetable cash crop in rest of the area (Nedunchezhiyan *et al*., 2002). It is grown commercially in Andhra Pradesh, Gujarat, Kerala, Tamil Nadu, Orissa, Tripura and Meghalaya. Greater yam being a trailing herb requires staking. Higher yield of yams (Ikeorgu and Igwilo, 2002) was reported with the traditional wooden stakes. The cost of staking was 25 to 35% of total cost of cultivation of yam. Availability of staking material is a big constraint for its large-scale cultivation. Under Indian conditions, maize (*Zea mays* L.) was found best live staking in greater yam cultivation (one row of maize sown between greater yam rows), which reduces 60.0% anthracnose incidence and increases yield by 26.3% (Nedunchezhiyan *et al*., 2006). Maize haulms which remain in the field after harvest of the cobs at physiological maturity serve as mulch (Nedunchezhiyan *et al*., 2008).

Greater yam + maize system is getting popular in sandy loam soils of Orissa. Greater yam and maize are having different growth habits and maturity. As greater yam is long duration crop, under rainfed conditions it is planted immediately after first monsoon showers. One-row of maize as intercrop is also simultaneously sown between greater yam rows, accommodating 37,037 maize plants/ha (two-thirds recommended population). Usually, greater yam is planted with 200 g cut tuber pieces. The establishment of the cut tubers depend on soil moisture conditions. Unfavourable soil moisture condition causes rotting of the cut tubers fast and may produce weak plants. Maize establishment and growth also affected by early moisture stress. Mulching is considered essential in rainfed conditions owing to the many benefits they impart on soil rhizosphere. It moderates the soil temperature besides conserving soil moisture. Mulching is essential for high value cash crop like greater yam in regions like Orissa where dry spells are common in the beginning of the monsoon in spite of high total rainfall. Fertilizer is the other major and scarce input, which influence the crop growth and yield tremendously. In view of this, present investigation was carried out to assess the influence of mulching along with different levels of N, P and K fertilizer on total productivity, energetics and economics of greater yam and maize intercropping system.

MATERIALS AND METHODS

A field experiment was conducted for consecutive three years (from 2003-04 to 2005-06) at the Regional Centre of Central Tuber Crops Research Institute, Dumuduma, Bhubaneswar in Alfisols under rainfed conditions. The experiment was conducted in split plot design with 4 replications. Main plot treatments consisted of no mulching (M_0) and mulching (M_1) and sub plot treatment consisted of 4 levels of N-P-K (kg/ha) fertilization i.e. F_1: 60-19.7-50, F_2: 80-26.2-66.7, F_3: 100-32.7-83.3 and F_4: 120-39.3-

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100. A uniform dose of FYM @ 10 tonne/ha along with full dose of P was applied during the last ploughing. N and K were applied in 2 equal splits at 30 and 60 days after planting (DAP). Urea, single superphosphate and muriate of potash were the source of N, P and K. The main crop greater yam 'Orissa Elite' tubers of 200 g was planted in 30 cm × 30 cm × 30 cm size pits followed by mound at 90 cm × 90 cm spacing. One row of maize 'Navjot' was sown as intercrop in between 2 rows of greater yam with intra-row spacing of 30 cm (37,037 plants/ha) immediately after greater yam planting. Greater yam and maize were planted on 16 June, 2003, 15 June, 2004 and 20 June, 2005 in each year respectively immediately after onset of monsoon. In mulching treatments, dried weeds and leaves @ 2 tonne/ha was applied as mulch around the mounds immediately after planting of greater yam. Mulch was applied around the mounds to conserve soil moisture around the tubers for early sprouting and vigour. The mulch materials mostly consisted of dried weed plants (*Tephrosia* sp., grasses etc.), dried leaves of *Glyricidia*, *Pongamia*, *Simarubha* and *Hevea brasilence*. Greater yam was trailed on maize 1-month after planting. Two hand weedings were carried out 25 to 30 and 55 to 60 DAP. Maize cobs were harvested at physiological maturity stage (90 DAS) and the haulms were left in the field as such. Greater yam was harvested at 210 DAP by careful digging of the tubers.

The climate of the region is characterized by hot and humid summer and cold and dry winter. The total rainfall received during crop growth period is 1,825.3 mm (85 rainy days), 949.2 mm (54 rainy days) and 1,389.0 mm (64 rainy days) in 2003-04, 2004-05 and 2005-06, respectively. Maximum rains received between July and August months. The average maximum temperature ranged between 29.0^0 and 38.9ºC, whereas the average minimum temperature ranged between 14.9^0 and 26.7ºC.

The soil was having pH 5.2, organic carbon 0.36%, available nitrogen 262 kg/ha, available phosphorus 18.2 kg/ha and available potassium 132 kg/ha before start of the experiment. The water holding capacity of the soil was 12.4%. The FYM and dried weeds and leaves contained 0.49-0.51% N, 0.18-0.22% P and 0.48-0.52% K and 0.98-1.04% N, 0.16-0.20% P and 0.90-0.96% K, respectively.

The prevailing market prices of greater yam tuber and maize grain were used for calculating tuber equivalent yield (TEY). Productivity efficiency was calculated by dividing TEY by 210 days (greater yam duration). Energy input and output was calculated using energy equivalents as suggested by Devasenapathy *et al*. (2009) and Nedunchezhiyan (2007). Energy use efficiency was calculated by dividing output energy by total input energy. Benefit: cost ratio was calculated by dividing net returns by cost of cultivation. Nutrient uptake was calculated by considering nutrient content and yield of greater yam tuber and maize grain. Greater yam tuber and maize grain were the economic parts actually removed from the field and other things were returned back into the field.

RESULTS AND DISCUSSION

Effect of mulching

Appreciable variation in greater yam tuber yield was observed with the application of mulch (Table 1). Mulching increased greater yam tuber yield by 21.0% over no mulching. The increase of tuber yield was higher during relatively dry year 2004-05 (29.6%) than wet years 2003-04 (14.4%) and 2005-06 (17.9%). This higher yield was due to higher tuber diameter (Table 1). The provision of

Table 1. Greater yam, maize yield (tonne/ha) and nutrient uptake (kg/ha) as influenced by mulching and nutrient levels

Treatment	Greater yam tuber diameter (cm)*	Maize number of grains/ cob*	Greater yam tuber yield			Maize yield			Nutrient uptake		
			2003-04	2004-05	2005-06	2003-04	2004-05	2005-06	N	P	K
Mulching											
M_0: No mulch	9.2	241.5	14.6	14.2	15.6	1.9	2.1	2.2	87.4	12.2	110.8
M_1: Mulch	9.8	263.2	16.7	18.4	18.4	2.1	2.3	2.3	105.5	14.8	133.3
SEm±	0.07	3.9	0.3	0.2	0.3	0.02	0.02	0.02	2.5	0.3	3.2
CD (P=0.05)	0.20	11.0	0.8	0.6	0.9	0.10	0.1	0.10	7.2	0.8	9.2
Nutrient level (kg N-P-K/ha)											
F_1: 60-19.7-50	8.9	225.8	10.9	11.3	13.1	1.8	1.9	2.0	70.3	9.6	90.4
F_2: 80-26.2-66.7	9.4	251.7	14.7	15.2	16.5	2.0	2.2	2.3	92.4	11.9	117.2
F_3: 100-32.7-83.3	9.7	263.8	18.0	18.9	19.2	2.1	2.3	2.4	109.5	16.0	137.7
F_4: 120-39.3-100	9.9	268.2	19.0	19.9	19.7	2.2	2.4	2.4	113.7	16.5	142.7
SEm±	0.11	5.6	0.4	0.4	0.9	0.03	0.03	0.03	3.7	0.4	4.7
CD (P=0.05)	0.30	16.0	1.2	1.0	1.4	0.10	0.10	0.10	10.5	1.2	13.4

*Pooled data of 3 years.

mulch might have resulted in conservation of more soil moisture and made the soil rhizosphere more favourable for early sprouting and producing healthy and vigourous plants from cut tuber pieces. Ikeorgu and Igwilo (2002) also reported similar findings. Significant influence of mulch was noticed on maize yield too (Table 1). Though mulching was primarily carried out on the mounds (greater yam planting), the beneficial effect was also found in maize as some of the mulch materials spread in other areas due to wind during crop growing period. A 10.3% increase in maize yield was noticed with mulching. The grain yield of maize during high rainfall year (2003 - 04) was lower than other years. This may be due to more number of cloudy days during crop growth period. The increase in yield under mulching was due to increase in yield attributes like number of grains/cob (Table 1).

Marked variation in total productivity (tuber equivalent yield) was noticed with mulching and nutrient levels (Table 3). Mulching increased total productivity and productivity efficiency by 19.7% each over control. Though mulching increased cost of cultivation nominally, the net return increase was Rs 16,000/-. The benefit: cost ratio accrued due to mulching was 0.73 when compared with 0.46 in control. The energy use efficiency with mulching was 46.1% higher than no mulching. This was due to higher productivity (Table 3).

Effect of nutrient levels

Graded dose of fertilizer significantly influenced greater yam tuber yield (Table 1). Application of 120-39.3-100 kg N-P-K/ha recorded significantly higher yield compared to other treatments (Table 1). However, it was comparable with 100-32.7-83.3 kg N-P-K/ha. Application of 120-39.3-100 kg N-P-K/ha registered 65.3%, 25.8% and 4.3% higher yield over 60-19.7-50, 80-26.2-66.7 and 100-32.7-83.3 kg N-P-K/ha, respectively (Table 1). Longer tubers, higher tuber diameter and tuber yield/plant might be responsible for higher yield in higher levels of fertilizer application. The incremental increase of tuber yield was higher at lower fertility level than higher fertility level. The increase of tuber yield was 34.9, 34.5 and 30.0% in 2003-04, 2004-05 and 2005-06, respectively when the fertility level increased from 60-19.7-50 to 80-26.2-66.7 kg N-P-K/ha. Similarly an increase of 22.4, 24.3 and 16.4% tuber yield in 2003-04, 2004-05 and 2005-06, respectively was found when the nutrient level increased from 80-26.2-66.7 to 100-32.7-83.3 kg N-P-K/ha. However, crop did not significantly respond beyond 100-32.7-83.3 kg N-P-K/ha, the increase of yield was meager 4.3% by application of 120-39.3-100 kg N-P-K/ha indicating the non-responsiveness for higher doses. This indicated that crop was unable to utilize the applied fertilizer at higher doses under rainfed conditions. The lowest greater yam yield was noticed with 60-19.7-50 kg N-P-K/ha probably due to lesser diameter and smaller size tubers (Table 1).

Maize responded to incremental increase of fertilizer (Table 1). However, at higher level of fertilizer application the yield increase was very less. The maize yield with 120-39.3-100 and 100-32.7-83.3 kg N-P-K/ha were on par. Significantly lower yield was noticed with 60-19.7-50 kg

Table 2. Interaction effect of mulching and nutrient levels on greater yam and maize yield and nutrient uptake

Mulching	Nutrient level				SEm±	CD
	F_1	F_2	F_3	F_4		(P=0.05)
*Greater yam tuber diameter (cm)**						
M_0	8.6	9.2	9.3	9.6	0.14	0.4
M_1	9.2	9.6	10.1	10.2		
*Maize number of grains/ cob**						
M_0	213.7	239.1	254.5	258.6	7.0	20.0
M_1	237.8	264.2	273.1	277.8		
Greater yam tuber yield (tonne/ha)						
2003-04						
M_0	9.7	13.3	16.8	18.6	0.60	1.7
M_1	12.1	16.1	19.2	19.4		
2004-05						
M_0	9.3	12.8	16.5	18.1	0.54	1.5
M_1	13.2	17.6	21.2	21.6		
2005-06						
M_0	11.3	14.9	17.7	18.6	0.67	1.9
M_1	15.0	18.1	20.7	20.7		
Maize yield (tonne/ha)						
2003-04						
M_0	1.7	1.9	2.0	2.1	0.04	0.1
M_1	1.9	2.2	2.2	2.3		
2004-05						
M_0	1.8	2.1	2.2	2.3	0.04	0.1
M_1	2.1	2.3	2.4	2.5		
2005-06						
M_0	1.9	2.2	2.3	2.3	0.04	0.1
M_1	2.1	2.3	2.4	2.5		
*N uptake (kg/ha)**						
M_0	60.9	81.8	99.7	107.4	5.19	14.8
M_1	79.7	102.9	119.3	120.0		
*P uptake (kg/ha)**						
M_0	7.8	11.6	14.3	15.2	0.56	1.6
M_1	11.5	12.3	17.7	17.8		
*K uptake (kg/ha)**						
M_0	78.8	104.2	125.6	134.5	6.63	18.9
M_1	102.0	130.2	149.9	150.9		

*Pooled data of 3 years

N-P-K/ha.

Successive increase of fertilizer levels increased the total productivity (Table 3). The lowest total productivity was noticed with lowest level of fertilizer application 60-19.7-50 kg N-P-K/ha. The highest total productivity was observed with the application of 120-39.3-100 kg N-P-K/ha. It was just 3.8% higher total productivity than the application of 100-32.7-83.3 kg N-P-K/ha, which was statistically on par. Nnoke *et al*. (1987) reported maize grain yield, cassava root and greater yam tuber yield increased significantly with increasing fertilizer rates in greater yam, maize and cassava intercropping under Nigerian conditions.

Productivity efficiency, net return and benefit : cost ratio were found increase with increase of nutrient levels (Table 3). Maximum Productivity efficiency (104.0 kg/ha/day), net return (Rs 50,200) and benefit : cost ratio (0.85) were noticed with the application of 120-39.3-100 kg N-P-K/ha and minimum was found at 60-19.7-50 kg N-P-K/ha. However, the energy use efficiency was found to increase with increase of nutrient level up to 100-32.7-83.3 kg N-P-K/ha. Beyond that it started declining.

Interaction effect

The interaction effect of mulching and fertilizer application was found significant. Significantly higher greater yam tuber yield, maize grain yield and total productivity were obtained with application of 120-39.3-100 kg N-P-K/ha along with mulching when compared with other treatments (Tables 2 and 4). However, it was comparable with 100-32.7-83.3 kg N-P-K/ha along with mulching.

Total productivity with the application of 100-32.7-83.3 kg N-P-K/ha along with mulching was significantly higher (10.0%) than 120-39.3-100 kg N-P-K/ha alone. Similarly total productivity with 100-32.7-83.3 kg N-P-K/ha without mulching was comparable with application of 80-26.2-66.7 kg N-P-K/ha along with mulching. Greater yam tuber yield with 80-26.2-66.7 kg N-P-K/ha without mulching was on par with 60-19.7-50 kg N-P-K/ha with mulching. This also indicated the possibility of nutrient release to the rhizosphere apart from other beneficial effects viz. soil moisture conservation etc. (Kundu *et al*., 2006).

Mulching increased the total productivity by 30.1%, 24.4%, 18.5% and 11.1% over no mulching with N-P-K @ 60-19.7-50 kg/ha, 80-26.2-66.7 kg/ha, 100-32.7-83.3 kg/ha and 120-39.3-100 kg/ha, respectively. It indicated that mulching was effective under lower levels of fertilizer application. Its efficiency decreased with the incremental levels of fertilizer. Greater yam, a long duration crop gets nutrients from the mulches and maize haulms through slow decomposition and mineralisation at later stages (Nedunchezhiyan *et al*., 2008).

The productivity efficiency (PE) revealed that the highest was observed with 120-39.3-100 kg N-P-K/ha along with mulching (Table 4). The next best treatment was 100-32.7-83.3 kg N-P-K/ha along with mulching, which was

Table 3. Tuber equivalent yield, productivity efficiency, economics and total energy input and output (× 10^3 MJ/ha) of greater yam + maize intercropping system as influenced by mulching and nutrient levels (Pooled data of 3 years)

Treatment	Tuber equivalent yield (tonne/ha)	Productivity efficiency (kg/ha/day)	Cost of cultivation (× 10^3 Rs/ha)	Net returns (× 10^3 Rs/ha)	B:C ratio	Input energy: Manures and fertilizers (A)	Input energy: Total energy input (†)	Energy output from yields	Energy use efficiency
Mulching									
M_0	16.9	80.4	57.6	26.7	0.46	10.62	23.24	98.54	3.21
M_1	20.2	96.2	58.2	42.7	0.73	10.62	24.63	115.96	4.69
SEm±	0.3								
CD (P=0.05)	0.8								
Nutrient levels									
F_1	13.7	65.2	56.8	11.6	0.20	8.35	21.66	82.31	3.79
F_2	17.6	84.0	57.7	30.6	0.53	9.86	23.18	103.05	4.44
F_3	21.0	99.9	58.3	46.6	0.80	11.37	24.69	119.63	4.84
F_4	21.8	104.0	59.0	50.2	0.85	12.88	26.40	124.00	4.73
SEm±	0.3								
CD (P=0.05)	1.3								

Sale price of greater yam and maize: Rs 5/kg

† = A + Field operations: 1.01, Seed: 11.61, Mulch: 1.39

Table 4. Interaction effect of mulching and nutrient levels on tuber equivalent yield, productivity efficiency, economics and total energy input and output (× 10^3 MJ/ha) of greater yam + maize intercropping system (Pooled data of 3 years)

Mulching	Nutrient level				SEm±	CD
	F_1	F_2	F_3	F_4		(P=0.05)
Tuber equivalent yield (tonne/ha)						
M_0	11.9	15.7	19.2	20.7	0.63	1.8
M_1	15.5	19.6	22.8	23.0		
Productivity efficiency (kg/ha/day)						
M_0	56.6	74.9	91.4	98.5		
M_1	73.7	93.1	108.3	109.5		
Cost of cultivation (× 10^3 Rs/ha)						
M_0	56.5	57.4	58.0	58.7		
M_1	57.1	58.0	58.6	59.3		
Net returns (× 10^3 Rs/ha)						
M_0	3.0	21.3	38.0	44.7		
M_1	20.3	39.8	55.1	55.7		
B:C ratio						
M_0	0.05	0.37	0.66	0.76		
M_1	0.36	0.67	0.94	0.94		
Manures and fertilizers energy input						
M_0	8.35	9.86	11.37	12.88		
M_1	8.35	9.86	11.37	12.88		
Total energy input (†)						
M_0	20.97	22.48	23.99	25.51		
M_1	22.36	23.87	25.38	26.90		
Energy output from yields						
M_0	72.86	93.04	110.50	117.75		
M_1	91.76	113.05	128.76	130.26		
Energy use efficiency						
M_0	3.47	4.14	4.61	4.62		
M_1	4.10	4.73	5.07	4.84		

Sale price of greater yam and maize: Rs 5/kg

higher than 120-39.3-100 kg N-P-K/ha application alone. The lowest PE was noticed with 60-19.7-50 kg N-P-K/ha with or without mulching.

The maximum amount of energy input of 26.90 x 10^3 MJ/ha was used in 120-39.3-100 kg N-P-K/ha along with mulching (Table 4). This was due to use of higher manure and fertilizer energy (12.88 x 10^3 MJ/ha). The next higher amount of energy input was utilized by 100-32.7-83.3 kg N-P-K/ha along with mulching. The application of 120-39.3-100 kg N-P-K/ha along with mulching had produced higher output energy compared to other treatments. This was due to higher total productivity (Table 4). The application of 100-32.7-83.3 kg N-P-K/ha along with mulching followed it. However, the energy use efficiency of all the treatments revealed that the application of 100-32.7-83.3 kg N-P-K/ha along with mulching recorded maximum energy use efficiency (5.07), which was higher than all other treatments (Table 4). This indicated that this treatment have the best biological efficiency.

The perusal of data on economic analysis revealed that the maximum net return was obtained with the application of 120-39.3-100 kg N-P-K/ha along with mulching. This was due to higher total productivity (Table 4). The application of 100-32.7-83.3 kg N-P-K/ha along with mulching was the next best treatment. The lowest net return was observed with 60-19.7-50 kg N-P-K/ha with or without mulching. This was due to lower yield. However, the benefit : cost ratio of 100-32.7-83.3 kg N-P-K/ha along with mulching (0.94) was same as that of 120-39.3-100 kg N-P-K/ha along with mulching. This was due to lower cost of cultivation and comparable yield as that of 120-39.3-100 kg N-P-K/ha along with mulching.

Table 5. Post harvest soil nutrient status of greater yam + maize intercropping system as influenced by mulching and fertility levels

Treatment	Organic carbon (%)			Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
	2003-04	2004-05	2005-06	2003-04	2004-05	2005-06	2003-04	2004-05	2005-06	2003-04	2004-05	2005-06
Mulching												
M_0	0.36	0.36	0.36	260	258	257	18.0	17.8	17.6	128	127	127
M_1	0.38	0.39	0.40	263	266	266	18.4	18.4	18.2	133	134	134
SEm±	0.01	0.01	0.01	4	4	4	0.1	0.1	0.1	3	3	3
CD (P=0.05)	NS	0.02	0.02	NS	NS	NS	0.3	0.2	0.3	NS	NS	NS
Nutrient level												
F_1	0.36	0.35	0.34	252	247	242	17.5	16.9	16.1	120	115	111
F_2	0.36	0.37	0.36	258	254	251	17.8	17.4	16.9	126	122	117
F_3	0.37	0.38	0.39	264	270	273	18.6	18.9	19.1	136	139	143
F_4	0.38	0.40	0.41	272	277	280	18.9	19.2	19.5	141	146	151
SEm±	0.01	0.01	0.01	6	5	6	0.1	0.1	0.2	4	4	4
CD (P=0.05)	NS	0.03	0.03	16	15	17	0.4	0.3	0.4	11	12	9

Nutrient uptake

Marked variation in N, P and K uptake was noted due to mulching (Table 1). A 20.7, 21.3 and 20.3% higher N, P and K uptake respectively was found in mulch over no mulch treatment. The higher uptake of nutrients was due to higher yield (Table 1). Further mulching enriched the soil nutrient status, which was available to the crop. Nutrient levels significantly influenced N, P and K uptake (Table 1). Significantly the highest N, P and K uptake was registered with the application of 120-39.3-100 kg N-P-K/ha. However, it was comparable with 100-32.7-83.3 kg N-P-K/ha. Higher availability of soil organic C, N, P and K as well as higher yield (Table 1) can be attributable for the higher uptake of nutrients.

Interactive effects of mulching and nutrient levels on N, P and K uptake were found significant (Table 2). Nutrients (N, P and K) uptake at all fertility levels were higher with mulching than no mulching. Significantly higher N, P and K uptake was found with mulching at 60-19.7-50 and 80-26.2-66.7 kg N-P-K/ha when compared with corresponding levels of fertility without mulching. Application of mulch along with 120-39.3-100 kg N-P-K/ha registered the highest N, P and K uptake followed by mulch along with 100-32.7-83.3 kg N-P-K/ha. Higher level of fertilizer nutrients application and mulching resulted in higher soil nutrient status which the crops utilized efficiently and produced higher yield that lead to higher nutrient uptake in these treatments.

Soil fertility

After 3 years of experimentation, mulch and nutrient levels significantly influenced the organic C, available N, P and K content in soil (Table 5). The soil organic C was significantly higher with mulching after 3 years. However, in the first year significant difference in organic C content was not noticed due to mulching. Soil available N and K status though increased with the application of mulch with time, it was not statistically significant from no mulch treatment. However, available P status in soil was significantly higher in all the years with mulching when compared with control. After 3 years, soil organic C, available N, P and K status were higher than initial level in mulching, whereas in control it was less than initial status. Continuous application of mulch (2 tonne/ha) has increased soil fertility status (Table 5). Sharma *et al*. (2009) found increased available nutrient contents in soil after 3 years, when residue was incorporated.

Soil analysis data showed a decrease in organic C, available soil N, P and K with time in low fertility levels (Table 5). After 3 years, the soil nutrient status was less than initial status by 5.6, 7.6, 11.5 and 15.9% organic C, available N, P and K respectively with the application of 60-19.7-50 kg N-P-K/ha. Application of 80-26.2-66.7 kg N-P-K/ha, though did not affected soil organic C, but reduced soil N, P and K by 4.2, 7.1 and 11.4% respectively than initial status. The nutrient needs of the crop in these treatments were met from native soil reserves depleting the available soil nutrients. Significantly higher soil organic C, available N, P and K after 3 years were found in 120-39.3-100 kg N-P-K/ha application and followed by 100-32.7-83.3 kg N-P-K/ha. Soil nutrients status of both these treatments was higher than initial status. Higher amount of fer-

Table 6. Interaction effect of mulching and nutrient levels on post harvest soil nutrient status of greater yam + maize intercropping system

Mulching	Nutrient level				SEm±	CD
	F_1	F_2	F_3	F_4		(P=0.05)
			Organic carbon (%)			
			2003-04			
M_0	0.35	0.35	0.36	0.36	0.014	0.04
M_1	0.36	0.37	0.38	0.40		
			2004-05			
M_0	0.34	0.35	0.37	0.38	0.015	0.04
M_1	0.36	0.38	0.39	0.42		
			2005-06			
M_0	0.32	0.34	0.37	0.39	0.015	0.04
M_1	0.36	0.38	0.41	0.43		
			Available N (kg/ha)			
			2003-04			
M_0	250	256	262	271	7.8	NS
M_1	254	260	266	272		
			2004-05			
M_0	241	250	265	276	7.6	20
M_1	252	258	274	278		
			2005-06			
M_0	236	248	266	278	8.7	25
M_1	248	253	280	282		
			Available P (kg/ha)			
			2003-04			
M_0	17.2	17.6	18.5	18.7	0.21	0.6
M_1	17.8	18.0	18.7	19.0		
			2004-05			
M_0	16.6	17.0	18.7	19.0	0.14	0.4
M_1	17.1	17.8	19.1	19.4		
			2005-06			
M_0	15.8	16.4	18.8	19.2	0.24	0.6
M_1	16.4	17.4	19.4	19.7		
			Available K (kg/ha)			
			2003-04			
M_0	116	122	134	140	5.3	15
M_1	123	129	138	142		
			2004-05			
M_0	110	118	138	143	5.8	17
M_1	120	125	140	149		
			2005-06			
M_0	108	111	140	148	5.1	14
M_1	114	123	146	154		

Treatment details in Table 1.

tilizer nutrients application improved the soil nutrients status.

The interaction effect of mulching and nutrient levels on post-harvest residual soil fertility were found significant (Table 6). Mulching maintained higher soil nutrient status at all levels of nutrients than no mulching. Significantly higher soil organic C, available N, P and K were found in application of 120-39.3-100 kg N-P-K/ha along with mulch and followed by 100-32.7-83.3 kg N-P-K/ha application along with mulch. In both these treatments soil nutrients status was higher than initial status. Mulching along with higher amount of fertilizer nutrients application improved the soil nutrients status in these treatments.

Thus, the application of 120-39.3-100 kg N-P-K/ha along with mulching produced higher total productivity, productivity efficiency, net return, N, P and K uptake and post-harvest soil nutrients status. However, higher energy use efficiency was found with the application of 100-32.7-83.3 kg N-P-K/ha along with mulching. The benefit : cost ratio of both the treatments were equal.

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