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Growth and Yield of Sweet Potato (*Ipomoea batatas* L.) in Rice Fallows: Effect of Tillage and Varieties

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Abstract

A field experiment was conducted for two years (2005-2007) under rice-fish farming system in deep water ecology (>50 cm water depth) at the Experimental Farm of the Central Rice Research Institute, Cuttack, India, to study the performance of different varieties of sweet potato (*Ipomoea batatas* L.) under different methods of tillage in lowland rice fallow. Conventional tillage resulted in higher yield and yield attributes over minimum tillage due to compressed storage root growth under the latter condition. Minimum tillage decreased the bulk density and increased the penetration resistance. The variety Sourin produced higher tuber yield under minimum tillage, while Kishan responded better to conventional tillage. Minimum tillage resulted in70% of the root yield and 90% of vine yield. However it could reduce the crop duration by 20 days and water requirement by 12 cm. The study indicated that for higher cropping intensity and utilization of residual excess moisture, sweet potato crop can be grown in lowland rice fallow with irrigation and also in rice-fish system in deep water situation with the variety Kishan under conventional tillage and Sourin under minimum tillage conditions.

Key words: Tillage, sweet potato, yield attributes, root yield

Introduction

Rice (*Oryza sativa* L.), a staple food crop in Asian countries, is grown throughout the year in different ecologies (Nedunchezhiyan et al., 2011). In lowlands and deep water conditions, excess moisture after rice crop usually creates problem for growing pulses and oil seed crops and the productivity of these crops is mostly low. Under such conditions, sweet potato (*Ipomoea batatas* L.), a crop popular for its starchy roots, can be an alternate crop in wet and marshy rice fallows (Nedunchezhiyan et al., 2011). This dicotyledonous plant serves as secondary staple crop in many of the developing countries in Asia, Africa and Latin America (Ray and Tomlins, 2010). The carbohydrate rich roots are consumed after boiling or baking. The green tops are used as fodder for animals. Tillage is difficult/not possible in marshy/wet soils immediately after harvest of rice. Sweet potato establishes well in excess moisture/ marshy conditions and there is no need for seed bed preparation (tillage) (Nedunchezhiyan et al., 2012). However, for subsequent irrigations of the crop, water resource is necessary and a specialized system like rice-fish farming is suitable for growing this crop because of in-built micro-watershed in the field (Sinhababu et al., 2012).

Wheat (*Triticum aestivum*) yield under zero tillage or minimum tillage was found to be on par with conventional tillage system in most of the locations (Tripathi et al., 2007). Zero tillage sowing of wheat in rice-wheat system is recommended for higher water and nutrient use efficiency (Bhattacharya et al., 2008). Root

and tuber crops may respond differently to zero or minimum tillage. Cassava, a root crop, produced lower yield under zero tillage due to compactness and experienced difficulty in weeding and harvesting (Howeler, 2001). However, in well drained coastal alfisols of Uyo, Nigeria, no significant difference was observed in sprouting, growth, yield attributes and yield of *Colocasia* and *Xanthosoma* between zero and other tillage practices (Ndaeyo et al., 2003). In the rainforest zone of South-West Nigeria, reduced tillage techniques were as effective as conventional tillage for cocoyam (*Xanthosoma sagittifolium* (L.) Schott) cultivation (Agbede, 2008).

Soils of lowland puddled rice ecosystem are quite different from upland ecosystem. Puddling, which is done to reduce percolation rate causes soil compaction (Peeyush Sharma et al., 2005). Sweet potato being a root crop may respond differently in puddled and tilled lowland rice fields. Variation in storage root length, diameter and shape in sweet potato is well documented. Response of sweet potato varieties to tillage regime may vary under puddled rice ecosystem. There is not much information on the effect of tillage on sweet potato varieties grown after rice in rainfed lowland and deep water ecologies. The objectives of the present study were to find out a suitable sweet potato variety and method of tillage and stand establishment in rice fallow under deep water rice-fish system.

Materials and Methods

A field experiment was conducted during 2005-2006 and 2006-2007 under rice-fish farming system in deepwater ecology in the Experimental Farm of the Central Rice Research Institute, Cuttack, India.

Description of field layout

A deep water (more than 50 cm water depth during wet season) rice field of 0.8 ha area was prepared by shaping the land into a multi-tier based rice-fish system, containing areas for growing rainfed lowland rice (up to 50 cm water depth) and deep water rice (more than 50 cm water depth), in-built micro-water shed–cum-fish refuge connected to rice field, an upland and wide elevated dykes (bunds) all around. The crops like high yielding rice, fresh water fish (Indian major carps, catla, rohu, mrigal) and horticultural crops (papaya, guava, mango, banana and pineapple) were grown in the system.

Site characteristics

The soil of the experimental site is silty-clay loam (49.5% silt, 32.3% clay and 18.2% sand) of the Mahanadi delta (Typic Endoaquepts) with pH of 5.5-6.5. The available N (275 kg ha ^{1}), P (17.5 kg ha^{-1}) and K (150 kg ha^{-1}) contents of the soil was medium. The bulk density of the experimental site was 1.41 g cm^{-3}. The infiltration rate of the dry soil was 1.6 cm day^{-1} and wet tillage/ puddle soil was 1.3 cm day^{-1}. Penetration resistance of dry soil was 1.5 kg cm^{-2}, whereas wet soil was 1.2 kg cm^{-2}. The rainfall of the region was1200-1300 mm in 65-70 rainy days. The average maximum temperature was 29.0-37.0ºC, whereas the average minimum temperature was 14.5-26.5ºC. July and August were the highest rain receiving months. The mean relative humidity was 60-90%. In general the climate of the region is warm and humid in summer and cool and dry in winter.

Rice cultivation

A high yielding, intermediate tall (120-125 cm) rice variety of Odisha, Gayatri was grown in the rainfed lowland area of the field during wet season (*kharif*) as a preceding crop to sweet potato. The rice was sown (22 June, 2005 and 24 June, 2006) in furrows of 5 cm depth in dry soil before the onset of South-West monsoon following dibbled-row seeding (spacing 20 cm between rows and 15 cm between plants) method. The crop was grown with FYM @ 5 t ha^{-1} and NPK @ 50:25:25 kg ha^{-1}. The rice crop was harvested at 160 days after sowing (on 28 November, 2005 and 30 November, 2006).

Sweet potato culture

Sweet potato was grown during winter/dry season after the harvest of rice crop. The experiment was laid out in split plot design with method of tillage (minimum tillage and conventional tillage) in main plots and varieties in sub plots. The treatments were replicated thrice. In minimum tillage system, sweet potato was planted by pegging the cuttings immediately after the harvest of rice crop in the marshy conditions on flat beds, which were later converted into ridges and furrows at 15-20 days after planting (DAP). In conventional system (one pass of disc plough, three passes of cultivator followed by forming ridges and furrows, and earthing up between 15 to 20 DAP and 60 DAP) planting was carried out on ridges after preparing seed bed. The ridges were made 60 cm apart and plants were spaced at 20 cm on the

ridges. Sweet potato was planted under minimum tillage on 29 November 2005 and 1 December 2006. Under conventional system, it was planted on 18 December 2005 and 20 December 2006. Sweet potato varieties of different storage root shape and neck size (Table 1) were selected for this experiment. Chemical fertilizers to supply NPK @ 75:50:75 kg ha^{-1} was applied to the crop. Half of the N and K and the full P were applied as basal immediately after planting. The remaining quantities of N and K were applied one month after the basal application. Weeding and earthing up was carried out at 15-20 and 60 (days after planting) DAP in minimum tillage treatment and 30 and 60 DAP under conventional tillage. Three irrigations at 30, 60 and 90 DAP in minimum tillage condition and six irrigations at 1, 10, 20, 30, 60 and 90 DAP in conventional tillage were provided from the harvested rain water in micro-water shed-cum-fish refuge. In each irrigation, 4 cm of water was applied. Monocrotophos 0.05% was sprayed at 60 and 90 DAP for the control of sweet potato weevil (*Cylas formicarius* L.). The crop was harvested at 105 DAP.

Penetration resistance of soil was measured using hand held penetrometer as described by Black (1965). The data were subjected to analysis of variance (ANOVA) using Genstat. The significant differences between treatments were determined using critical difference (CD).

Results and Discussion

The rice yields obtained were 4.0 t ha^{-1} of grain and 7.5 t ha^{-1}of straw during 2005 and 3.8 t ha^{-1}of grain and 8.3 t ha^{-1}of straw during 2006 (Table 2). Higher grain yield during 2005 was due to more number of panicles m^{-2} and 1000 grain weight. Higher straw yield during 2006 was due to taller plants. However, there was not much difference in the grain and straw yield between the years (5.0% and 10.6%, respectively). There are no variants during the first or second year as far as rice is concerned. Moreover, difference in performance between years can also be due to climatic variations.

The method of tillage showed distinct effect on yield attributes of sweet potato (Table 3). The yield attributes (number of storage roots per plant, storage root length, storage root diameter and storage root yield per plant) were significantly higher in conventional method of tillage. The diameter of the storage root was uniform in this condition. While in minimum tillage method of crop establishment, the storage root size and shape were

Table 1. Description of sweet potato varieties

Variety	Pedigree	Originating institution	Storage root shape	Storage root length (cm)	Average yield (t ha^{-1})
Sourin	Poly cross, the female parent is accession No. 1162	Regional Centre of CTCRI, Bhubaneswar, Orissa	Round to elliptic; short neck	10-15	16.2
Kalinga	Selection from open pollinated seeds	Regional Centre of CTCRI, Bhubaneswar, Orissa	Round to elliptic; short neck	10-15	17.2
Kishan	Poly cross, the female parent is accession No. 1016	Regional Centre of CTCRI, Bhubaneswar, Orissa	Elliptic to cylindrical; long neck	15-25	17.0
Samrat	Clonal selection from germplasm	Acharya N.G. Ranga Agricultural University, Hyderabad, Andhra Pradesh	Globular; long neck	15-20	15.0

Table 2. Yield attributes and yield of rainfed lowland rice preceding sweet potato (mean of 5 replicates)

Year	Plant height (cm)	No. of panicles m^{-2}	No. of grains panicle^{-1}	1000 grain weight (g)	Sterility (%)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
2005	126±11	224±7	110±12	20.2±4.3	27.1±1.6	4.0±0.3	7.5±0.3
2006	128±9	220±12	115±15	19.8±2.8	29.3±2.1	3.8±0.2	8.3±0.4

± Standard deviation

Table 3. Effect of tillage on yield attributes of sweet potato varieties (Mean of 2 years)

Treatments	No. of storage roots plant^{-1}	Storage root length (cm)	Storage root diameter (cm) N-S	E-W	Storage root yield (g plant^{-1})
Method of tillage					
Minimum tillage	2.8	11.3	3.0	6.1	177.3
Conventional tillage	3.1	14.2	6.9	6.8	237.4
CD (0.05)	0.1	1.2	0.1	0.3	20.3
Variety					
Sourin	2.7	9.9	6.3	8.0	209.5
Kalinga	3.0	9.3	5.6	7.5	192.0
Kishan	3.3	16.9	3.7	5.3	245.0
Samrat	3.0	13.5	4.2	5.1	230.0
CD (0.05)	0.1	1.6	0.1	0.5	28.5
Interaction					
MT x Sourin	2.6	8.8	3.9	7.6	191.5
MT x Kalinga	2.9	8.5	3.4	7.2	171.0
MT x Kishan	3.0	15.5	1.7	4.9	166.5
MT x Samrat	2.8	12.2	2.8	4.7	180.0
CT x Sourin	2.8	11.0	8.7	8.4	227.5
CT x Kalinga	3.0	10.0	7.8	7.8	117.5
CT x Kishan	3.5	20.1	5.7	5.7	324.0
CT x Samrat	3.1	15.7	5.5	5.4	280.5
CD (0.05)	0.2	2.3	0.2	0.6	32.6

MT: Minimum tillage; CT: Conventional tillage

affected. Shorter length and compressed storage roots were observed and the diameter of N-S direction of storage root was very less compared to E-W direction. In minimum tillage system, significant reduction in yield attributes might be due to compactness/resistance of the soil (Table 3, Table 6). Considerable variation in yield attributes was observed among the sweet potato varieties (Table 3). Higher number of storage roots per plant, storage root length and storage root yield per plant were observed in variety Kishan, whereas higher storage root diameter was noticed in Sourin. The variety Sourin produced lower number of storage roots per plant, while Kalinga and Kishan had shorter storage root length and storage root diameter, respectively.

Significant interaction effect was observed between method of tillage and sweet potato varieties (Table 3). The rate of reduction of yield attributes in minimum tillage was found higher in Kishan variety followed by Samrat. In Sourin, the rate of reduction of yield attributes under minimum tillage was lower.

Method of tillage had significant impact on storage root yield (Table 4). The conventional tillage produced significantly higher yield over minimum tillage. Under minimum tillage 30.4% and 36.8% yield reduction was noticed during 2005-2006 and 2006-2007 respectively, compared to conventional tillage. This yield reduction was mainly due to reduction in yield attributes (Table 3) caused by soil compactness. Sarkar et al. (2003) reported that the fine textured soil subjected to formation of compact layer in sub-surface significantly affected the root growth and development. Among the varieties, Kishan produced higher yield compared to the other varieties during both the years of study. The higher yield attributes like number of storage roots per plant and tuber length might have contributed to higher yield in Kishan (Table 3). The variety Samrat was the next best variety. The lowest yield was found in Kalinga. Yield variation among varieties may also be due to genetic character.

A significant interaction effect was noticed between the method of tillage and varieties (Table 4). Under minimum tillage, the variety Sourin responded well with higher yield during both the years. The storage root of Sourin was short and elliptic with short neck (Table 1). The storage roots develop bulking at shallow depth. The practice of earthing up at 15-20 and 60 DAP under minimum tillage treatment helped in shallow bulking in Sourin variety. The variety Kishan produced significantly lower storage root yield. The storage root of Kishan is long and cylindrical with long neck (Table 1). It is a deep bulking variety. Owing to compactness in minimum tillage, the roots were unable to penetrate deep. Irrespective of the variety, lateral compression and shorter roots were observed in minimum tillage. Varietal response to season (Nedunchezhiyan and Byju, 2005), fertility management (Nedunchezhiyan and Srinivasulu Reddy, 2002) and crop growing conditions (Nedunchezhiyan et al., 2004; 2010) are well documented in this crop.

The variety Kishan produced significantly higher yield compared to the other varieties under conventional tillage during both the

Table 4. Effect of tillage on storage root yield of sweet potato varieties

Treatments	Storage root yield (t ha^{-1})			Mean vine yield (t ha^{-1})	Mean harvest index
	2005-2006	2006-2007	Mean		
Method of tillage					
Minimum tillage	14.73	13.16	13.95	16.62	0.46
Conventional tillage	21.16	20.80	20.98	15.78	0.57
CD (0.05)	0.723	0.629	0.624	NS	0.04
Variety					
Sourin	17.85	16.74	17.29	15.65	0.52
Kalinga	15.36	15.27	15.31	15.30	0.50
Kishan	19.92	18.625	19.27	17.03	0.53
Samrat	18.68	17.29	17.98	16.83	0.52
CD (0.05)	1.070	0.944	0.936	NS	NS
Interaction					
MT x Sourin	16.19	14.25	15.22	17.12	0.47
MT x Kalinga	13.70	13.38	13.54	15.77	0.46
MT x Kishan	14.11	12.25	13.18	17.12	0.43
MT x Samrat	14.94	12.75	13.85	16.43	0.46
CT x Sourin	19.51	19.22	19.36	14.17	0.58
CT x Kalinga	17.20	17.16	17.09	14.82	0.54
CT x Kishan	25.73	25.000	25.37	16.91	0.60
CT x Samrat	22.41	21.83	22.12	17.23	0.56
CD (0.05)	1.451	1.258	1.248	NS	NS

MT: Minimum tillage; CT: Conventional tillage; NS: Not significant

years of study (Table 4). Congenial rhizosphere has favoured full development of storage roots. The varieties Samrat and Sourin were the next best in the order. The variety Kalinga produced lower root yield under conventional tillage system. The varieties expressed their genetic potential under conventional tillage.

Vine (green top) serves as green fodder for livestock, which is rich in crude protein (Nedunzhiyan, 2001; Nedunchezhiyan et al., 2010). Method of planting did not influence the vine yield. Minimum tillage advanced the planting date and higher availability of nutrients and moisture might have helped the crop to compete with the conventional tillage. Gupta et al. (2011) reported similar findings in wheat. Soil physico-chemical conditions and moisture after harvest of rice were suitable for vine growth under minimum tillage. Coleman et al. (2006) reported that adequate water was required during the first 21 days after planting of sweet potato for good establishment and growth. Soil compactness did not affect the vine yield. The varietal effect and interaction effect were also not significant. The partitioning efficiency (HI) was found to be higher under conventional system than minimum tillage. Greater absorption of nutrients, synthesis of photosynthates and translocation of photosynthates towards bulking roots might have been favoured by the congenial rhizosphere in conventional tillage than minimum tillage. Among the varieties, Kishan exhibited higher partitioning efficiency (HI) compared to the other varieties. However, it was not significant. No interaction effect was observed between tillage method and varieties.

Gross return, net return and benefit:cost ratio were higher in conventional tillage than minimum tillage in sweet potato (Table 5). This was due to higher storage root yield, even though the cost of production was relatively higher. Among the varieties, Kishan resulted in higher return and benefit:cost ratio and it was followed by Samrat and Sourin.

The varieties did not vary significantly for nutrient uptake. The plant uptake of N, P and K was higher under conventional tillage (Table 5). This might be due to greater dry matter production. Among the varieties, Kishan exported greater N, P and K compared to the other varieties. It was followed by Samrat and Sourin. This trend was similar for total dry matter production.

Table 5. Economics and nutrient uptake of sweet potato varieties under various tillage systems

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	Benefit: cost ratio	Nutrient uptake (kg ha^{-1})		
					N	P	K
Method of tillage							
Minimum tillage	34655	77475	42820	2.24	101.6	12.2	95.7
Conventional tillage	40320	116580	76260	2.89	117.3	14.4	112.2
CD (0.05)	1115	5630	4515	0.14	12.4	1.6	10.3
Variety							
Sourin	37365	96060	58695	2.57	107.7	13.2	101.8
Kalinga	37115	85075	47960	2.29	102.9	12.9	96.1
Kishan	37865	107070	69205	2.83	114.6	14.0	110.8
Samrat	37615	99905	62290	2.66	112.7	13.3	107.1
CD (0.05)	NS	8390	7965	0.21	NS	NS	NS

NS: Not significant

Table 6. Bulk density and penetration resistance under various tillage systems at harvest of sweet potato varieties

Treatment	Bulk density (g cm^{-3})		Penetration resistance (kg cm^{-2})	
	2005-2006	2006-2007	2005-2006	2006-2007
Method of tillage				
Minimum tillage	1.36	1.36	1.46	1.45
Conventional tillage	1.39	1.38	1.43	1.44
CD (0.05)	0.02	NS	0.02	NS
Variety				
Sourin	1.38	1.37	1.45	1.44
Kalinga	1.37	1.36	1.45	1.45
Kishan	1.39	1.38	1.44	1.44
Samrat	1.38	1.37	1.45	1.44
CD (0.05)	NS	NS	NS	NS

NS: Not significant

The effect of treatments on the physical properties of the soil is given in Table 6. The bulk density decreased irrespective of tillage method followed for sweet potato compared to the initial level (Table 6). The decrease in bulk density was higher in minimum tillage than conventional tillage. The varietal effect on bulk density was not significant. Penetration resistance indicates soil compactness. More penetration resistance was noticed in minimum tillage than conventional tillage. The varietal effect on penetration resistance was not observed.

Conclusion

The study indicated that conventional tillage was better for sweet potato in rainfed lowland rice fallow. However, for utilizing the residual excess moisture immediately after the rice harvest in rainfed lowland and also in rice-fish system in deep water areas, minimum tillage method of crop establishment can be followed along with supplementing few irrigations. This practice is beneficial in terms of increasing the cropping intensity, as though it yields 30% less root yield and about 10% less vine yield; it saves 20 days time and 12 cm water compared to conventional tillage. The variety Sourin performed better under minimum tillage, while Kishan did so under conventional system.

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