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Effect of soil amendments and irrigation regimes on minimum tillage planted sweet potato (*Ipomoea batatas*) in rice (*Oryza sativa*) fallows under lowland conditions

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ABSTRACT

A field experiment was conducted during the year 2008-09 and 2009-10 at Central Rice Research Institute, Cuttack, India to study the effects of soil amendments and frequency of irrigation on minimum tillage planted sweet potato (*Ipomoea batatas* L.) in rice (*Oryza sativa* L.) fallows under lowland conditions. The experiment was conducted in split plot design with soil amendments (rice straw, farmyard manure (FYM) and no amendment) in main plot and frequency of irrigation (no irrigation, 2, 3 and 4 irrigations) in sub plots. In minimum tillage planted sweet potato, application of rice straw and FYM increased sweet potato growth and root yield. Increasing number of irrigations also increased minimum tillage planted sweet potato growth and root yield. When rice straw was applied, three irrigations were found optimum, whereas in the case of FYM, four irrigations were required for higher root yield.

Key words: Irrigation, Minimum tillage, Root yield, Soil amendment, Sweet potato

In Asia, rice (*Oryza sativa* L.) is a staple food crop grown in different rice ecologies. In rainfed lowlands and deepwater situations, short duration pulse and oil seed crops are usually grown as second crop after rice depending on the available residual moisture . However, sowing of these crops is delayed if the soil moisture is high or the soil is in swampy condition. The delay may still be more in the case of low temperature, which can lead to moisture stress for succeeding crop. In such conditions, sweet potato (*Ipomoea batatas* L.) was found to be a suitable crop for planting under zero tillage for higher cropping intensity. Sweet potato establishes in marshy conditions and temperature 18°C and above (Nedunchezhiyan *et al*. 2011, Nedunchezhiyan *et al*. 2012). Sweet potato serves as secondary staple food 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 also used as fodder for animals (Nedunchezhiyan 2011). Sweet potato planted in rice fallows by zero/minimum tillage method produced 70-80% root and vine yield of conventional tillage systems irrespective of soil compactness (Nedunchezhiyan *et al*. 2011, Nedunchezhiyan *et al*. 2012).

Soil compactness can be reduced with suitable amendments. Dried leaves and farmyard manures application as mulch or incorporation can reduce soil compactness. Incorporation of mulching materials creates micro and macro pore space and reduces soil compaction. Farmyard manure and rice straw are commonly used for soil amendments. Compost and mulches (amendments) also improve vigour in various crops through providing essential plant nutrients (Nedunchezhiyan and Srinivasulu Reddy 2004, Awodun *et al*. 2007, Nedunchezhiyan *et al*. 2010) as well as increase soil moisture available to plants (Ossom *et al*. 2001). Irrigation also acts as soil lubricant (Miller and Donahue 1992). Increasing the frequency of irrigation reduces soil compactness correspondingly (Roy Chowdhury *et al*. 2002). Keeping these in view, this study was taken up to find out the effect of soil amendments and irrigation regimes on minimum tillage planted sweet potato in rice fallow under lowland condtions.

MATERIALS AND METHODS

A field experiment was conducted during the years 2008-09 and 2009-10 under rice-fish-horticulture system in deepwater ecology in the experimental farm of the Central Rice Research Institute, Cuttack, India. A deepwater (more than 50 cm water depth during wet season) rice field of 0.8 ha area was prepared by land shaping into a multitier based rice-fish-horticulture system, containing areas for growing lowland rice (up to 50 cm water depth) and deepwater 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 rice, fresh water fish (Indian major carps, catla, rohu, mrigal) and horticultural

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crops (mango, guava, banana, papaya, elephant foot yam, greater yam, bhendi, vegetable cowpea etc) were grown in the system. Horticultural crops were grown in uplands.

The present experiment was conducted in the lowland area of the field (up to 50 cm water depth). A high yielding intermediate tall (120-125cm) rice variety (Gayatri) was grown during wet season (*kharif*) as a preceding crop of sweet potato under rainfed conditions. The rice seed was sown (on 20 June 2008 and 24 June 2009) 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 of stand establishment. The crop was grown with the application of recommended N-P_2O_5-K_2O @ 50-25-25 kg/ha. The rice crop was harvested 160 days after sowing (on 26 November 2008 and 30 November 2009).

Sweet potato variety Sourin was planted at the spacing of 60 cm × 20 cm on 27 November 2008 and 1 December 2009 (winter season) after harvest of the rice in the marshy conditions on flat beds. The Sourin is a shallow bulking, short neck and short duration variety. The experiment was conducted in a split plot design with amendments, viz. application of farmyard manure (FYM) and rice straw @ 2 tonnes/ha each, without amendment (control) in main plots and number of irrigation (control, 2, 3 and 4 irrigations) in sub-plots. The treatments were replicated thrice. Soil amendments were applied as per treatment after planting as mulch and later incorporated in the soil at the time of making ridge and furrows at 15-20 days after planting (DAP). Paddy straw was chaffed into pieces of 3-4 cm length before application. Well decomposed FYM was applied as amendment. Irrigation was given as per treatment. Irrigation given at 30 and 90 DAP in two irrigations treatment, at 30, 60 and 90 DAP in three irrigations treatment and at 30, 60, 75 and 90 DAP in four irrigations treatment. A fertilizer dose of 75-50-75 N-P_2O_5-K_2O kg/ha were applied to sweet potato crop. Half the dose of nitrogen and potassium and full amount of phosphorus were applied as first dose while making ridge and furrow (earthing up). The remaining dose of nitrogen and potassium were applied one month after first dose of application during earthing up (50-60 DAP). The crop was harvested 105 DAP (on 11 March 2009 and 15 March 2010). Growth, yield attributes and yield were recorded at harvest. Penetration resistance of soil was measured with handheld penetrometer as described by Black (1965). The data were subjected to analysis of variance (ANOVA) using Genstat.

RESULTS AND DISCUSSIONS

Growth parameters values presented in the Table 1, revealed that soil amendments had significant influence on number of branches/plant (P = 0.003), vine length (P = 0.011), number of leaves/plant (P < 0.001) and leaf area index (LAI) (P = 0.003). Significantly higher number of branches and leaves/plant were observed with the application of rice straw (Table 2). But, it was comparable with FYM application. Amendment substrates contain considerable

Table 1 ANOVA (P value) for effect of soil amendments and frequency of irrigation on growth and yield of zero tillage planted sweet potato

Source	No. of branches	Vine length	No. of leaves	LAI	No. of roots/ plant	Root length (cm)	Root diameter (cm)		Root yield (tonnes/ha)	Vine yield (tonnes/ha)	HI	Penetration resistance (MPa)
							N-S	E-W				
Soil amendments (S)	0.003**	0.011*	<0.001**	0.003**	0.008**	0.004	0.011*	0.005**	0.001**	<0.001**	0.003**	<0.001**
Irrigation frequency (I)	<0.001**	<0.001**	<0.001**	<0.001**	<0.001	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
S × I	<0.001**	0.268	<0.001**	0.296	0.119	0.052	0.009**	0.096	<0.001**	0.005**	0.082	<0.001**

*Significant at 0.05 level, **Significant at 0.01 level

Table 2 Effect of soil amendments and frequency of irrigation on sweet potato growth parameters, yield attributes and yield (Pooled mean of 2 years)

Treatment	No. of branches/ plant	Vine length (cm)	No. of leaves/ plant	LAI	No. of roots/ plant	Root length (cm)	Root diameter (cm)		Root yield (tonnes/ ha)	Vine yield (tonnes/ha)	HI
							N-S	E-W			
Soil amendments (2 tonnes/ha)											
Control	2.7	8.8	14.2	18.8	2.7	8.8	5.8	7.8	14.2	18.8	2.7
FYM	2.8	9.0	16.4	19.8	2.8	9.0	6.0	8.0	16.4	19.8	2.8
Straw	2.9	9.4	17.5	19.7	2.9	9.4	6.3	8.3	17.5	19.7	2.9
CD (P=0.05)	0.07	0.2	0.9	0.3	0.07	0.2	0.3	0.2	0.9	0.3	0.07
No. of irrigations											
0	2.7	8.9	14.6	17.1	2.7	8.9	4.9	7.0	14.6	17.1	2.7
2	2.8	9.0	15.7	18.9	2.8	9.0	5.7	8.0	15.7	18.9	2.8
3	2.8	9.2	16.5	20.2	2.8	9.2	6.5	8.5	16.5	20.2	2.8
4	2.9	9.3	17.3	21.5	2.9	9.3	7.0	8.6	17.3	21.5	2.9
CD (P=0.05)	0.04	0.1	0.2	0.3	0.04	0.1	0.2	0.2	0.2	0.3	0.04

amount of nutrients, which were available to the crop during growing period. These might be the causes for better growth in sweet potato (number of branches/plant, vine length, number of leaves/plant and LAI) under soil amendments. Escalada and Ratilla (1998) also reported that the compost and mulches improved crop health by providing essential plant nutrients. This might be due to retaining more moisture in rhizosphere by straw compared to FYM.

Discerning differences in number of branches/plant ($P < 0.001$), vine length ($P < 0.001$), number of leaves/plant ($P < 0.001$) and leaf area index (LAI) ($P < 0.001$) was observed due to the effect of irrigation frequency. Increasing number of irrigations had increased the sweet potato growth attributes (Table 2). The number of branches and leaves/ plant, longer vine length and maximum LAI were significantly higher with 4 irrigations. However, number of leaves per plant and LAI were statistically comparable with 3 irrigations level. Creating more water availability in rhizosphere through increasing frequency of irrigations increased sweet potato growth attributes, especially in number of leaves per plant and LAI. Growth parameters like number of branches/plant and vine length was not influenced by application of more number of irrigations, as plant utilizes available water more for producing photosynthetic area. Irrigation is essential for minimum tillage planted sweet potato for growth and development, which was observed in the study in terms of lower growth attributes in no irrigation (control) treatment (Table 2). Moisture stressed conditions reduces photosynthesis rate which in turn decreases growth parameters (Nedunchezhiyan *et al*. 2012).

Soil amendments had significant effect on number of roots ($P = 0.008$), root length ($P = 0.004$), root mean diameter N-S direction ($P = 0.011$) and E-W direction ($P = 0.005$). The highest yield attributes were found in straw incorporation followed by FYM. Lowest yield attributes were observed in control (no amendments). Incorporation of soil amendments increase water holding capacity of soil which might have influenced roots growth. Reduction in root compression and increase in root length were noticed in soil amendments applied treatments (Table 3). Irrigation had marked effect on number of roots ($P < 0.001$), root length ($P < 0.001$), root mean diameter N-S direction ($P < 0.001$) and E-W direction (P= < 0.001). Increasing irrigation frequency increased the yield attributes. Application of 4 irrigations recorded higher yield attributes. The lowest yield attributes were found in control (no irrigation). Increasing frequency of irrigation increases soil moisture, which in turn favoured root growth and development. Soil moisture acts as lubricant (Miller and Donahue 1992) and reduces compactness (Roy Chowdhury *et al*. 2002). The increase in root length and root diameter with increase in frequency of irrigation in the study is in accordance with the earlier observations. Soil moisture stressed conditions restrict the yield forming processes (Nedunchezhiyan *et al*. 2012).

The interaction effect were found significant in the case of root length ($P = 0.052$) and root mean diameter N-S direction ($P = 0.009$), but not in number of roots ($P = 0.119$) and root diameter E-W direction ($P = 0.096$).

Marked difference in root yield was observed due to amendments ($P = 0.001$). The highest root yield was obtained

Table 3 Interaction effect of amendments and frequency of irrigation on sweet potato root and vine yield (Pooled mean of 2 years)

Soil amendments (2 tonnes/ha)	Number of irrigations 0	2	3	4	CD (P=0.05)
Root yield (tonnes/ha)					
Control	13.2	14.1	14.5	15.0	0.9
FYM	14.9	16.1	16.6	18.0	
Straw	15.8	16.9	18.5	18.9	
Vine yield (tonnes/ha)					
Control	16.9	18.4	19.4	20.5	0.5
YM	17.1	19.4	20.6	22.1	
Straw	17.3	18.9	20.6	21.8	

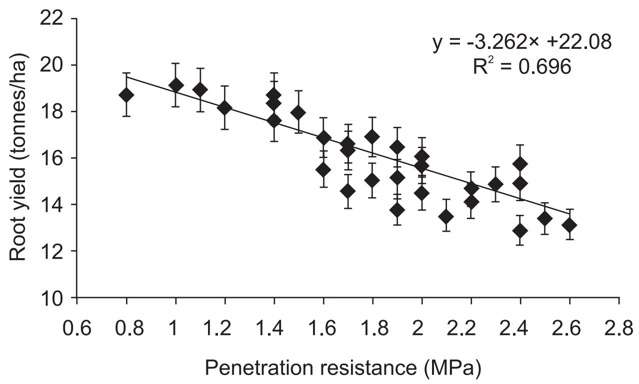

Fig 1 Penetration resistance effect on root yield. (Bars indicate standard error of mean)

in rice straw amendment (Table 2), which was 6.7% and 23.2% higher than FYM and control. FYM application produced 15.5% higher root yield than control. Higher root yield in soil amendments applied treatment was due to higher growth (Table 2) and yield attributes (Table 2) and better partitioning efficiency (Table 2). Soil penetration resistance indicates the soil compactness, which directly influences the root yield of sweet potato (Fig 1). Higher root yield was observed with rice straw treatment where soil resistance was lower.

The root yield was distinctly different due to the effect of frequency of irrigations ($P < 0.001$). The highest root yield was noticed with 4 irrigations and was 4.8%, 10.2% and 18.5% higher than 3 and 2 irrigations, and control, respectively. The control treatment recorded significantly lowest root yield. Nedunchezhiyan *et al*. (2012) reported that improvement in yield under more frequent irrigation was due to higher availability of soil moisture, which might have helped in better nutrient uptake by the crop and assimilation of photosynthates towards sink. Lower root yield was recorded under no irrigation (control) due to less biomass in the crop. Soil compaction and soil moisture are known to influence root growth in sweet potato (Yanfu *et al*. 1989). Soil penetration resistance decreased with increased levels of irrigation. Roy Chowdhury *et al*. (2002) observed higher root volume at higher irrigation levels and it was inversely related to soil penetration resistance.

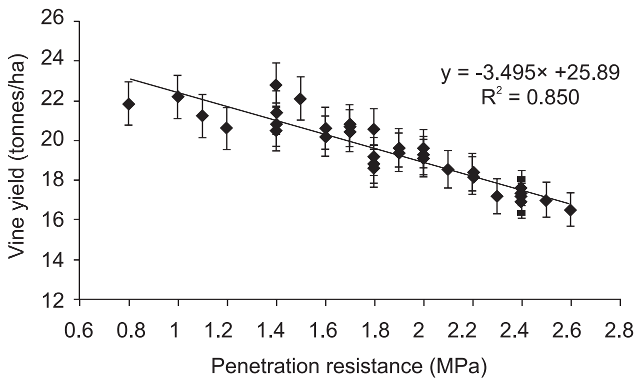

Fig 2 Influence of penetration resistance on vine yield. (Bars indicate standard error of mean)

The interaction effect between amendments and frequency of irrigation was found significant ($P < 0.001$). Across all irrigation levels, higher root yield was noticed with paddy straw amendment and it was statistically on par with FYM application. Both the treatments were significantly superior to no amendment application treatment (control) (Table 3). In the case of no amendment, root yield at 4 irrigations was comparable with 3 and 2 irrigations levels, and was significantly higher than no irrigation (control). Whereas, when FYM was applied as amendment, root yield at 4 irrigations was significantly higher than 3, 2 and no irrigations. The root yield of 3 and 2 irrigations were on par and both were superior to control (no irrigation). Under straw amendment, root yield of 4 irrigations was on par with 3 irrigations and was significantly higher than 2 and no irrigations (control). The highest root yield was observed in straw amendment with four irrigations. The lowest root yield was noticed in no amendment (control) and no irrigation (control). Higher root yield in straw amendment across all irrigation levels indicated that straw amendment provided favourable rhizosphere for root development by retaining more moisture. Thus, when straw amendment was applied, 3 number of irrigations was found optimum, whereas FYM was applied, 4 number of irrigations was essential for higher root yield.

Vine yield was also influenced by soil amendments ($P < 0.001$). The highest vine yield was observed in FYM treatment. However, it was comparable with straw amendments. Higher growth parameters in soil amendments applied treatments led to higher vine yields. The highest vine yield in FYM treatment was due to higher LAI. Soil compaction (penetration resistance) and lower growth parameters decreased vine yield under no amendment treatment (control). Soil penetration resistance significantly influenced the vine yield (P=0.001); higher the resistance lesser the vine yield (Fig 3). The highest vine yield was recorded with four irrigations level, which was 6.4%, 13.8% and 25.7% higher than 3 and 2 irrigations and control, respectively. The control treatment recorded lowest vine yield.

The interaction effect was found significant ($P = 0.005$). At 2, 3 and 4 irrigations levels, higher vine yield was recorded with FYM application and was comparable with straw application. Both the treatments were significantly superior to no amendments treatment (control). The vine yield was not influenced by soil amendments without irrigation. The highest vine yield was observed with FYM application coupled with four irrigations. It was comparable with straw amendment at same level of irrigation. At higher levels of irrigation, more nutrients were available from FYM due to which the vine yield was higher compared to straw amendment and no amendment.

The study indicated that in minimum tillage planted sweet potato, soil amendments through application of rice straw and FYM increase root yield in the crop. Increasing frequency of irrigations further enhance sweet potato root yield under such conditions. Besides, amendment with rice straw is more beneficial compared to FYM with respect to water saving in sweet potato cultivation. Sweet potato root yield at straw with three irrigations was comparable with FYM application coupled with four irrigations. The results bear importance in terms of suitability of minimum tillage established sweet potato cultivation for conservation of farm resources in the specialized rice-fish-horticulture farming system.

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