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EVALUATION OF CONVENTIONAL AND ZERO TILLAGE FOR POTATO CULTIVATION IN RICE – POTATO SEQUENCE

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ABSTRACT: A field study was conducted at the research farm of ICAR-Central Potato Research Institute RS, Gwalior (M.P.) during *Rabi* 2020-21 with three levels of rice cuttings *viz*. ground level, at 30 cm height and 60 cm height; and three tillage practices *viz*. tuber zone tillage, tuber row zone tillage and normal tillage, replicated thrice. Highest tuber emergence count (98.3%) was recorded with ground level rice harvest + tuber row zone tillage. Rice harvest at 60 cm height + tuber row zone tillage recorded highest plant height (41.3 cm). Highest fresh haulm weight/plant was recorded with rice harvest at 30 cm height + normal tillage (173.7 g). Highest tuber yield/plant was recorded with rice harvest at 30 cm height + normal tillage (144.9 g). Highest total number of tuber was recorded with ground level rice harvest + tuber row zone tillage (575.7 thousand/ha). Highest total yield of tuber was recorded with rice harvest at 30 cm height + normal tillage (16.5 t/ha) which was significantly higher than T_3 but statistically same with all other treatments. Highest net return was recorded with rice harvest at 30 cm height + normal tillage (27.3 thousand/ha). Highest number (31.3%) and yield (28.9%) of green tuber was recorded with rice harvest at 30 cm height + tuber zone tillage. Overall, integrated management of soil including conservation tillage is essential to enhance the crop productivity, economic profitability, and environmental quality.

KEYWORDS: Tuber zone tillage, tuber row zone tillage, normal tillage, Potato

INTRODUCTION

Potato (*Solanum tuberosum* L.) is worldwide grown and is very sensitive to soil and water conditions as it grows and produces better on deep and well-drained soils (Djaman *et al*., 2021). Potato is the 4th largest crop produced worldwide after rice, wheat, and maize (FAOSTAT, 2021). Tillage at different planting and growth stages of potatoes is a requirement and necessary for preparing a seedbed and for weed control. Potato production is associated with different practices such as planting, diking, cultivation, hilling, and harvest that significantly disturb the soil environment with heavy machinery. Soil and water management in potatoes are therefore critical to assure optimal crop growth and development. Tillage practices are adopted to create the proper environment for potato growth and yield potential. Commercial potato production under traditional management practices involves heavy to very heavy machinery and equipment during seedbed preparation and during the growing season for different operations such as cultivation, herbicide and pesticides application and harvest, exposing the soil to compaction (Paul *et al.,* 2016; Choudhary *et al.,* 2010, 2021). Compaction before and during planting can restrict root growth (Rajpoot *et al*., 2021). Huntenburg *et al.* (2021) also found that potato shoot growth was restricted by adverse compacted soil conditions. Soil compaction in combination with drought can decrease plant water availability and limit biomass production and potato tuber dry weight (Huntenburg

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et al., 2021). Larney *et al*. (2016) reported that integration of conservation management practices led to yield and disease control benefits without negatively impacting tuber quality. Conservation tillage practices increase soil organic matter of the topsoil and can improve soil structure and soil biological properties during the potato growing season within the rotation cropping systems (Carter and Sanderson, 2001; Kumar *et al.,* 2021). Deep soil tillage such as ploughing and ridging promote plant growth and macronutrient (N, P, K, Ca, and Mg) uptake by potato plant and translocation in potato tubers (Nunes *et al*., 2006). While potato growers usually opt for deep ploughing before seedbed preparation and ridging to ensure an adequate volume of loose-structured soil which is required for optimal tuber formation and quality, this intense soil preparation may be detrimental to soil structure, soil quality, and promote soil erosion (Drakopoulos *et al*., 2016). Potato (*Solanum tuberosum* L.) is an intensively managed crop with yields often limited by subsoil compaction and tillage pans and the mechanical loosening of compacted soil via subsoiling is often believed to be a useful method to enhance root elongation and improve a crop's ability to access deeper soil water (Ghosh and Daigh, 2020). Drakopoulos *et al*. (2018) investigated the effect of reduced tillage and standard tillage practices on soil quality indicators in organic potato production system and found that soil temperature and soil moisture content were not found to be greatly affected by tillage practices; soil mineral N (NO_3 and NH_{4+}) concentrations showed similar decreasing patterns over time across both tillage systems during the potato production period, however, soil mineral N was overall higher in the upper 15 cm soil layer under reduced tillage and in the 15–30 cm soil layer under standard tillage.

MATERIALS AND METHODS

A field study was conducted at the research farm of ICAR-Central Potato Research Institute RS, Gwalior (MP) during the *Rabi* season of 2020- 21. Geographically, Gwalior is located at 26.22° North latitude and 78.18° East longitude and 197 meter above mean sea level which lies in the north tract of M.P. The climate of experimental site was semi-arid with extremely hot summers and cold winters. The soil was silty clay loam with pH 7.3. Potato cv. 'Kufri Chandramukhi' was grown with 9 treatment combinations. Treatments consisted of conservation tillage for potato cultivation *viz* T1: Ground level rice harvest + tuber zone tillage, T2: Ground level rice harvest + tuber row zone tillage, T3: Ground level rice harvest + normal tillage, T4: Rice harvest at 30 cm height + tuber zone tillage, T5: Rice harvest at 30 cm height + tuber row zone tillage, T6: Rice harvest at 30 cm height + normal tillage, T7: Rice harvest at 60 cm height + tuber zone tillage, T8: Rice harvest at 60 cm height + tuber row zone tillage, T9: Rice harvest at 60 cm height + normal tillage. Treatments were replicated thrice. Direct seeded rice was sown on raised beds of 120 cm width. Crop was fertilized with 120 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha. Potato tubers were planted just after harvest of rice as per treatment. Recommended dose of nutrients, *i.e.* 180:80:120 kg/ha of N:P_2O_5:K_2O, respectively were applied as per schedule during crop raising. Half N and full quantity of P_2O_5 and K_2O were applied before planting and remaining half N dose was applied at earthing up. Gross plot size was 3.6 m × 4.0 m. Well sprouted potato tubers were planted on 25.11.2020. Four irrigations were applied as per requirement in addition to winter rains on 4.12.2020, 29.12.2020, 14.1.2021 and 15.2.2021. Crop was sprayed with herbicide metribuzin @ 0.5 kg a.i./ha on 26.11.2020 for control of weeds. For control of

insect's insecticide imidacloprid was sprayed @ 4 ml/10 liter water on 14.12.2020. Haulm killing of potato was done at 90 days after planting (physiological maturity) on 25.2.2021 to facilitate timely harvesting. Crop was harvested after haulm killing on 5.3.2021 to estimate fresh tuber yield. To assess economic viability of different treatments for potato production, both fixed and operating costs were taken into consideration. Economics of potato production under variable treatments were calculated (Rana *et al*., 2014). Net returns were estimated as difference between gross income and total production cost. Gross returns were product of yield and wholesale market price of potato. The experiment was laid out in completely randomized block design (CRBD). The data were analyzed statistically by standard analysis of variance (ANOVA). Least significant difference (LSD) test was used to determine whether differences exist between certain comparisons. The probability level for determination of significance was 0.05.

RESULTS AND DISCUSSION

Emergence count

Highest emergence count was recorded with T2: Ground level rice harvest + tuber row zone tillage (98.3%) which was significantly higher than T5, T6 and T8 but statistically same with T1, T3, T4, T7 and T9. Number of compound leaves and number of stems/plant were statistically not influenced by different treatments. T8: Rice harvest at 60 cm height + tuber row zone tillage recorded highest plant height (41.3 cm) which was significantly higher than all other treatments except T1. Highest fresh haulm weight/ plant was recorded with T6: Rice harvest at 30 cm height + normal tillage (173.7 g) which was significantly higher than all other treatments except T5, T8 and T9.Yaroson *et al.* (2019) investigated potato response to ridges tillage, zero-tillage, mound tillage, and flat tillage in Nigeria and found that soil management practices had a significant effect on plant height, the number of leaves, leaf area, canopy cover, and tuber yield. Highest tuber number/plant was recorded with T5: Rice harvest at 30 cm height + tuber row zone tillage which was significantly higher than all other treatments except T2. Highest tuber yield/plant was recorded with T6: Rice harvest at 30 cm height + normal tillage (144.9 g) which was significantly higher than all other treatments except T1 and T2. Nelson and Giles (2017) found that multiple cultivations provided better weed control in potatoes than the herbicide pendimethalin alone but not as good as pendimethalin and cultivation combined. Highest fresh haulm yield/ha was recorded with T9: Rice harvest at 60 cm height + normal tillage (6.4 t) which was significantly higher than all other treatments except T6 and T8. Dry haulm yield/ha was statistically same under all the treatments.

Number and yield of tubers

Number of <25g tubers ('000/ha) were statistically same under all the treatments. Highest number of 25-50 g tuber was recorded with T3: Ground level rice harvest + normal tillage (158.7 thousand/ha) which was significantly higher than T4,T7 and T8 but statistically same with all other treatments.Number of 50-75g tubers ('000/ ha) were highest in T6: Rice harvest at 30 cm height + normal tillage which were statistically same under all the treatments. Highest number of >75 g tuber was recorded with T9: Rice harvest at 60 cm height + normal tillage (46.0 thousand/ha) which was significantly higher than T7 but statistically same with all other treatments. Highest total number of tuber was recorded with T2: Ground level rice harvest + tuber row zone tillage (575.7 thousand/ha) which was

significantly higher than T7, T8 and T0 but statistically same with all other treatments (Table 1).

Yield of <25g tubers (3.8 t/ha) was highest withT4: Rice harvest at 30 cm height + tuber zone tillage which was significantly higher than T9 but statistically same under all other treatments. Highest yield of 25-50 g tuber was recorded with T3: Ground level rice harvest + normal tillage (5.5 t/ha) which was significantly higher than T6 and T9 but statistically same with all other treatments. Yield of 50-75g tubers (5.5 t/ha) was recorded with T6: Rice harvest at 30 cm height + normal tillage which was significantly higher than T4,T5,T7,T8,T9 but statistically same under all other treatments. Highest yield of >75 g tuber was recorded with T9: Rice harvest at 60 cm height + normal tillage (3.6 t/ha) which was significantly higher than all other treatments but statistically same with T6. Drakopoulos *et al.* (2016) compared reduced tillage to standard tillage and found a decrease in tuber yield by 13.4 % under reduced tillage compared to standard tillage due to lower average tuber size which was related to higher soil bulk density and increased vulnerability to drought stress during tuber bulking. Highest total yield of tuber was recorded with T6: Rice harvest at 30 cm height + normal tillage (16.5 t/ha) which was significantly higher than T3 but statistically same with all other treatments. Reduced tillage showed the highest yield followed by mound tillage, flat tillage, and zero tillage with the lowest tuber yield (Yaroson *et al.*, 2019).

Highest dry yield of tuber was recorded with T6: Rice harvest at 30 cm height + normal tillage (3.8 t/ha) which was significantly higher than all other treatments except T3 (Table 2). Ghosh and Daigh (2020) concluded that potato yield and quality benefits from subsoiling are rare, temporary, and highly inconsistent and pointed that the only exception is when moisture is known to be the major limiting factor in a field.

Table 1. Effect of minimum tillage on growth and yield attributes of potato in rice - potato sequence.

Treatments	Tuber emergence (%)	Compound leaves/ plant	Stem/ plant	Plant height (cm)	Fresh haulm weight/ plant (g)	Tuber number /plant	Tuber yield/ plant (g)	Fresh haulm yield (t/ha)	Dry haulm yield (t/ha)	Number of tuber ('000/ha)				
										<25 g	25-50 g	50-75 g	>75g	Total
T1	97.5	50.6	3.9	39.8	122.7	7.7	138.8	4.0	0.7	329.2	105.9	85.9	38.2	559.2
T2	98.3	44.1	3.7	33.5	105.4	10.9	125.3	5.0	0.7	294.2	151.8	88.8	40.9	575.7
T3	96.4	41.1	2.9	33.9	115.0	7.1	111.2	4.0	0.6	288.4	158.7	86.4	39.9	573.3
T4	96.7	42.6	3.6	30.8	94.2	9.4	93.3	5.2	0.8	304.2	102.4	81.5	31.6	519.8
T5	94.4	44.4	3.1	35.4	151.6	11.6	120.4	5.3	0.7	312.4	128.2	76.4	45.0	562.1
T6	94.2	48.1	3.6	33.1	173.7	8.1	144.9	6.1	0.7	256.2	113.2	95.6	41.4	506.4
T7	95.6	40.1	3.1	37.0	127.3	7.9	105.8	4.5	0.6	303.2	86.1	38.4	20.9	448.7
T8	93.1	37.3	3.3	41.3	163.1	9.4	98.4	5.4	0.6	224.8	65.0	46.5	28.2	364.5
T9	97.2	38.7	2.7	31.7	142.4	9.1	116.3	6.4	0.8	203.4	117.5	54.0	46.0	421.0
SEm±	1.0	2.8	0.4	1.3	11.8	0.5	7.7	0.4	0.1	31.1	16.3	19.3	5.1	36.2
CD (*P*=0.05)	3.0	NS	NS	3.9	35.7	1.6	23.2	1.1	NS	NS	49.3	NS	15.3	109.3

T1: Ground level rice harvest + tuber zone tillage, T2: Ground level rice harvest + tuber row zone tillage, T3: Ground level rice harvest + normal tillage, T4: Rice harvest at 30 cm height + tuber zone tillage, T5: Rice harvest at 30 cm height + tuber row zone tillage, T6: Rice harvest at 30 cm height + normal tillage, T7: Rice harvest at 60 cm height + tuber zone tillage, T8: Rice harvest at 60 cm height + tuber row zone tillage, T9: Rice harvest at 60 cm height + normal tillage

Table 2. Effect of minimum tillage on yield and economics of potato in rice-potato sequence.

Treatments	Yield of tubers (t/ha)						Economics of potato cultivation ('×000 ₹/ha)				Haulm dry matter (%)	Tuber dry matter (%)
	<25	25-50	50-75	>75g	Total	Dry tuber	Cost of cultivation	Gross Return	Net Return	B : C		
T1	3.2	3.8	4.8	2.2	14.0	3.1	125.4	139.6	14.2	1.1	17.3	23.5
T2	3.6	3.6	4.7	2.5	14.3	3.3	125.9	143.4	17.5	1.1	13.7	23.3
T3	3.3	5.5	5.2	2.3	16.2	3.7	137.4	161.8	24.4	1.2	15.1	22.7
T4	3.8	3.6	4.6	2.0	14.1	3.2	125.4	141.3	15.9	1.1	14.5	22.9
T5	3.5	3.7	3.8	2.5	13.6	3.1	125.9	135.5	9.6	1.1	13.3	24.4
T6	3.0	4.8	5.5	3.2	16.5	3.8	137.4	164.7	27.3	1.2	12.1	23.1
T7	3.5	2.7	2.4	1.1	9.6	2.0	125.4	95.8	-29.6	0.8	14.0	20.9
T8	1.9	1.7	2.3	1.0	6.9	1.5	125.9	69.0	-57.0	0.5	11.1	23.4
T9	2.5	4.4	3.2	3.6	13.7	2.8	137.4	136.9	-0.5	1.0	12.5	20.6
SEm±	0.4	0.4	0.3	0.4	0.5	0.2	0	5.1	5.1	0.0	1.3	1.0
CD (*P*=0.05)	1.1	1.1	0.9	1.1	1.6	0.5	0	15.5	15.5	0.1	NS	NS

Economic parameters

T3: Ground level rice harvest + normal tillage recorded highest cost of cultivation 137.4 thousand/ha which was same with T6 and T9 but higher than all other treatments. Highest gross return was recorded with T6 (164.7 thousand/ha) which was significantly higher than all other treatments except T3. Highest net return was recorded with T6 (27.3 thousand/ha) which was significantly higher than T5, T7, T8 and T9 but statistically on par with all other treatments. Highest benefit cost ratio was recorded with T6 (1.2) which was significantly higher than all other treatments except T3. Larney *et al*. (2016) in a 12-year study compared conservation and conventional management for potato in 3- to 6-year rotations which also included dry bean, sugar beet, and soft wheat, oat and timothy, and showed that the conservation management resulted in 18% higher marketable tuber yield and reduced early dying than conventional management under a short term rotation. Haulm dry matter content ranged from 11.1 to 17.3% but values were statistically same under different treatments. Tuber dry matter % ranged from 20.6 to 24.4 but values were statistically same under different treatments (Table 2).

Number of tubers under different categories

Number of normal tubers (486.8 thousand/ha) were recorded with T3 which was significantly higher than all other treatments except T2 and T6. Highest number of green tuber was recorded with T4 (162.5 thousand/ha) which was significantly higher than T3, T6 and T9 but statistically same with all other treatments. Highest number of cut tuber was recorded with T3 (27.8 thousand/ha) which was statistically same with all other treatments. Highest number of green tuber was recorded with T4 (31.3%) which was significantly higher than T3 and T6 but statistically same with all other treatments. Highest number of cut tuber was recorded with T8 (7.9%) which was statistically same with all other treatments (Table 3).

Yield of tubers under different categories

Highest yield of normal tubers (14.2 t/ha) was recorded with T6 which was significantly higher than T3 but statistically same with all

Table 3. Effect of minimum tillage on production of different categories of potato tubers in rice-potato sequence.

Treatments	Number of tuber (×000/ha)						Yield of tuber (t/ha)					
	Normal	Green	Cut	Total	Green (%)	Cut (%)	Normal	Green	Cut	Total	Green (%)	Cut (%)
T1	393.8	141.3	24.9	559.9	25.7	4.5	9.6	3.5	0.9	14.0	25.3	6.8
T2	416.9	136.5	23.1	576.5	23.6	4.0	10.7	2.9	0.7	14.4	20.3	4.8
T3	486.8	59.5	27.8	574.1	10.1	4.9	13.8	1.5	1.0	16.2	9.2	5.8
T4	336.0	162.5	21.9	520.5	31.3	4.3	9.2	4.1	0.9	14.1	28.9	6.5
T5	382.6	158.6	21.7	562.9	28.1	3.9	9.6	3.3	0.7	13.6	24.0	5.0
T6	424.5	64.3	18.3	507.1	12.4	3.5	14.2	1.7	0.6	16.5	10.0	3.9
T7	309.2	123.8	16.3	449.3	27.5	3.6	6.6	2.4	0.5	9.6	25.0	5.4
T8	234.9	105.0	25.1	365.0	28.0	7.9	4.5	1.7	0.7	6.9	24.8	10.5
T9	315.5	84.6	21.4	421.5	20.2	5.1	11.1	1.7	0.9	13.7	12.4	6.5
SEm±	30.1	23.3	3.8	36.2	3.8	1.2	0.8	0.5	0.1	1.0	3.3	1.1
CD (*P*=0.05)	91.0	70.3	NS	109.5	11.6	NS	2.5	1.5	NS	3.0	9.9	3.4

other treatments. Eddis *et al.* (2020) found a significant positive correlation between high compaction and the high proportion of small size potato tubers in Saudi Arabia and a significant negative correlation between high compaction and the high proportion of large size tubers. Highest yield of green tuber was recorded with T4 (4.1 t/ha) which was significantly higher than T3, T6, T8 and T9 but statistically same with all other treatments. Highest yield of cut tuber was recorded with T3 (1.0 t/ha) which was statistically same with all other treatments. Highest yield of green tuber was recorded with T4 (28.9%) which was significantly higher than T3, T6 and T9 but statistically same with all other treatments. Highest yield of cut tuber was recorded with T8 (10.5%) which was statistically same with all other treatments (Table 3). Potato tuber quality in terms of crude protein, fat, crude fiber, and carbohydrate was better under zero tillage planting with paddy straw mulching compared to ridge planting (Sangari *et al.*, 2021; Larkin *et al.*, 2021).

CONCLUSION

Commercial potato growers are more favorable to intensive tillage practices but the machinery traffic across the field may result in deep soil compaction incompatible with potato root growth, maximum tuber yield and grade. Therefore, potato producers should be aware of the contrasting results however, they should adopt integrated management of soil and potato crop contributing to the improvement of soil health including cover cropping, crop rotations, soil amendments, and conservation tillage that may enhance crop productivity, system sustainability, system vitality, economic profitability, and environmental quality.

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