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Effect of Zero Tillage Practices on the Economic Performance of Potato

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Potato is an important winter rotation and vegetable crop which provides a stable income for small holders in order to increase the knowledge and profits of farmers through the adoption of zero-tillage potato with rice straw mulch will promote climate-smart agriculture in addition to reduce environmental pollution caused by straw burning. More importantly, the use of rice straw for mulching puts nutrients back in the soil and reduces the emissions of greenhouse gases

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associated with the conventional practice of straw burning. Mulch provides an important habitat for natural enemies, which are vital for pest population regulation. An experiment was conducted during the rabi seasons of 2021-22 and 2022-23 at the Research Farm, ICAR-Central Potato Research Station RS, Gwalior (M.P.). The experiment consisted of 7 treatments viz.; Farmer's practice (T1), CIP Technique (T2), Regional AICRIP/INSTITUTE recommendation/hoeing (T3), Flat-bed planting (T4), Flat-bed planting & mulching (T5), Flat-bed planting & ridging (T6) and Flat-bed planting, ridging and mulching (T7) with 3 replications. The soil of experimental field was a sandy clay loam with uniform topography. The result showed that CIP Technique (T2) followed by Flat-bed planting, ridging and mulching (T7) were registered superior values of growth parameters (number of stems per plant and root length), yield attributes (number of tubers grade-wise and grade-wise tuber yield) as well as economics (gross monetary return) of potato in both years as well as pooled over rest of the treatments. In case of B:C ratio; Flat-bed planting, ridging and mulching (T7) followed by CIP Technique (T2) observed significantly economical (1.65 and 1.50; respectively) over rest of the treatments in pooled analysis.

Keywords: Economics; growth parameters; potato; tillage practices; yield attributes.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is an annual, herbaceous, tuber crop of Solanaceae family that contains all the essential food ingredients required for maintaining proper health (Gupta et al., 2014). Potato contains water (74.7-75%), sugar and starch (22.9%), fat (0.1%), minerals & vitamins (0.6%) and protein (1.21-2%) (Nandekar et al., 2009). Potato is used for variety of purposes *viz.* potato food product (potato flour, chips, French fries etc.) and food ingredients, feed to cattle, pigs and chickens and processed into starch for industry and typically used as a vegetable as a result regarded as "King of vegetable".

The global production of potato is around 375 million tonnes, India ranks 2nd in area and production of potato in the world after China (Anonymous, 2022-23b). In India, it is grown on an area of 2.35 million hectares with the production of 56 million tonnes and the productivity is 23829 kgha^{-1} (Anonymous, 2022-23a). Madhya Pradesh covers 158.14 thousand hectares with production of 3582 thousand tonnes and the productivity is 22651 kgha^{-1} (Anonymous, 2022-23).

The presence of crop residue mulch at the soil atmosphere interface has a direct effect on infiltration of rainwater into the soil and evaporation from the soil leading to improved soil water supply for crops. The rice straw is an important source of organic material that also benefits the subsequent crops. Zero tillage systems such as no-tillage (NT) or direct drill, which plant directly through the mulch with minimal soil disturbance and diverse crop rotations are the practices that could maintain and improve soil quality. The mixing of residues/surface retention into the soil increases SOM mineralization due to greater exposure to microbial decomposers and optimal moisture and temperature. For long-term sustainability, zero tillage practices are needed that are based on strategies that circumvent problems with nutrient limitations and weed infestations.

With the initiatives taken under international potato centre (CIP), zero tillage potato cultivation has been fabulously adopted in various regions of the states. Farmers today can adopt the ZT potato cultivation practice as this system can give higher yield with limited labour and water use thus making the whole production system a lot more economic. More importantly, the use of rice straw for mulching puts nutrients back in the soil and reduces the emissions of greenhouse gases associated with the conventional practice of straw burning.

2. MATERIALS AND METHODS

An experiment was conducted during the *rabi* seasons of 2021-22 and 2022-23 at the Research Farm, ICAR-Central Potato Research Station RS, Gwalior (M.P.). The experiment consisted of 7 treatments *viz*.; Farmer's practice: Removing/Burning of straw from field, tillage, planting and irrigation afterwards (T_1), CIP Technique: Flat planting of seed tubers after FYM & fertilizer application + covering with paddy straw mulch (T_2), Regional AICRIP/INSTITUTE recommendation/hoeing (T_3), Flat-bed planting: Direct planting of potato by opening slit and covering it with soil (Root

zone tillage in 10 cm width and 15 cm depth) and no mulching or earthing (T_4), Flat-bed planting & mulching: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) + mulching by chopped straw and no earthing (T_5), Flat-bed planting & ridging: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) + earthing after 20-25 days by tilling soil between rows and no mulching (T_6) and Flat-bed planting, ridging and mulching: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and15 cm depth) and earthing after 20-25 days by tilling soil between rows + mulching of chopped straw after earthing (T_7) with 3 replications. The soil of experimental field was a sandy clay loam with uniform topography. The potato variety "KCM" was sown as 60 cm row to row spacing and 20 cm plant to plant spacing with 3.5 Tha^{-1} seed rate.

The studied for selected growth and yield attributes by using five plants in randomized manner in each plot. All other agronomic practices were adopted as per recommended package of practices. The data were statistically analysed using the F-test procedure given by Gomez and Gomez (1984). The difference between treatment means were compared with the critical differences (CD) at 5% level of probability (P=0.05).

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

The growth parameters *viz*.; number of stems per plant and root length were significantly varied among different treatments (Table 1). CIP Technique: Flat planting of seed tubers after FYM & fertilizer application + covering with paddy straw mulch (T_2) followed by Flat-bed planting, ridging and mulching: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) and earthing after 20-25 days by tilling soil between rows + mulching of chopped straw after earthing (T_7) registered significantly higher value of growth parameters over rest of the treatments; while lowest values were observed under Flat-bed planting: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) and no mulching or earthing (T_4) during both the years as well as pooled. This may be due to zero tillage systems such as no-tillage (NT) or direct drill, which plant directly through the mulch with minimal soil disturbance and diverse crop rotations are the practices that could maintain and improve soil quality. Therefore; better crop growth resulted higher value of growth parameters. Corroboratory findings in potato crop also reported by Sarangi et al. (2018), Ali et al. (2019) and Ritti et al. (2023).

3.2 Yield Attributes

Different tillage practices significantly affect yield attributes *viz*.; number of tubers grade-wise and grade-wise tuber yield during both the years as well as pooled (Tables 2 & 3). Significantly superior values of yield attributes were observed under CIP Technique: Flat planting of seed tubers after FYM & fertilizer application + covering with paddy straw mulch (T_2) followed by Flat-bed planting, ridging and mulching: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) and earthing after 20-25 days by tilling soil between rows + mulching of chopped straw after earthing (T_7) over rest of the treatments; white lower values were noted by Flat-bed planting: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) and no mulching or earthing (T_4). This may be due to the presence of crop residue mulch at the soil atmosphere interface has a direct effect on infiltration of rainwater into the soil and evaporation from the soil leading to improved soil water supply for crops. The rice straw is an important source of organic material that also benefits the subsequent crops. The increase in yield attributes under these treatments may be attributed to concomitant reduction in weed dry matter that accounted for reductions in crop-weed competition, which provided congenial environment to proper utilization of growth factors *viz*., space, light, moisture and nutrient by the crop and henceforth attained superior values of yield attributes of potato. Results were also confined by findings of Sarangi et al. (2018), Msheik et al. (2019) and Ritti et al. (2023).

3.3 Economics

Gross monetary return and benefit: cost ratio was significantly affected by various tillage practices (Table 4). CIP Technique: Flat planting of seed tubers after FYM & fertilizer application + covering with paddy straw mulch (T_2) followed by Flat-bed planting, ridging and mulching: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) and earthing after 20-25 days by tilling

Table 1. Effect of tillage practices on growth parameters of potato

Treatment	Sy.	Number of stems per plant			Root length (cm)		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Farmer's practice	T_1	3.08	3.14	3.11	11.97	12.00	11.98
CIP Technique	T_2	3.98	4.05	4.02	14.21	14.25	14.23
Regional AICRIP/INSTITUTE recommendation/hoeing	T_3	3.76	3.84	3.80	13.93	13.97	13.95
Flat-bed planting	T_4	2.83	2.91	2.87	11.77	11.80	11.78
Flat-bed planting & mulching	T_5	3.54	3.61	3.57	13.07	13.13	13.10
Flat-bed planting & ridging	T_6	3.41	3.47	3.44	13.13	13.20	13.17
Flat-bed planting, ridging and mulching	T_7	3.89	3.96	3.92	14.03	14.10	14.07
SEm±		0.09	0.10	0.05	0.22	0.24	0.11
CD (5%)		0.27	0.30	0.14	0.67	0.73	0.33

Table 2. Effect of tillage practices on number of tubers grade-wise of potato

Treatment	Sy.	Number of tubers grade-wise (g)											
		<25			25-50			50-75			>75		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Farmer's practice	T_1	224.33	242.43	233.38	122.17	123.33	122.75	86.33	87.87	87.10	38.10	42.43	40.27
CIP Technique	T_2	272.00	273.17	272.58	147.50	153.03	150.27	104.83	105.43	105.13	51.47	52.33	51.90
Regional AICRIP/ INSTITUTE recommendation /hoeing	T_3	258.40	270.80	264.60	144.83	146.87	145.85	102.67	103.87	103.27	49.93	50.17	50.05
Flat-bed planting	T_4	224.90	226.40	225.65	117.53	118.93	118.23	81.70	84.80	83.25	37.87	39.97	38.92
Flat-bed planting & mulching	T_5	246.17	260.47	253.32	134.60	135.70	135.15	94.40	95.63	95.02	45.90	46.20	46.05
Flat-bed planting & ridging	T_6	242.20	248.40	245.30	126.77	133.97	130.37	92.00	93.47	92.73	44.70	44.87	44.78
Flat-bed planting, ridging and mulching	T_7	266.67	272.20	269.43	147.20	148.36	147.78	106.37	108.93	107.65	50.60	50.80	50.70
SEm±		6.19	5.62	2.96	3.90	3.77	1.92	2.86	2.98	1.46	1.75	1.48	0.81
CD (5%)		19.07	17.32	8.63	12.01	11.61	5.59	8.83	9.19	4.27	5.40	4.56	2.37

Table 3. Effect of tillage practices on grade-wise tuber yield of potato

Treatment	Sy.	Grade-wise tuber yield (qha^{-1})											
		<25			25-50			50-75			>75		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Farmer's practice	T_1	22.60	23.63	23.12	35.63	38.20	36.92	61.50	65.50	63.50	83.93	86.67	85.30
CIP Technique	T_2	36.47	38.50	37.48	64.03	66.83	65.43	86.66	88.65	87.66	108.29	109.03	108.66
Regional AICRIP/ INSTITUTE recommendation /hoeing	T_3	30.30	31.80	31.05	58.73	60.40	59.57	79.47	80.63	80.05	100.50	102.50	101.50
Flat-bed planting	T_4	21.77	23.93	22.85	34.53	38.57	36.55	62.13	64.03	63.08	83.90	86.13	85.02
Flat-bed planting & mulching	T_5	25.43	27.13	26.28	45.87	47.00	46.43	71.20	74.53	72.87	97.50	98.00	97.75
Flat-bed planting & ridging	T_6	24.97	26.67	25.82	42.77	45.47	44.12	70.37	73.63	72.00	94.23	96.57	95.40
Flat-bed planting, ridging and mulching	T_7	32.67	34.93	33.80	60.42	62.10	61.26	82.17	83.70	82.93	103.07	105.80	104.43
SEm±		1.64	1.78	0.86	1.35	1.19	0.64	1.55	1.20	0.69	1.43	1.60	0.76
CD (5%)		5.06	5.49	2.50	4.15	3.66	1.85	4.78	3.68	2.02	4.40	4.94	2.22

Table 4. Effect of tillage practices on economics of potato

Treatment	Sy.	Gross monetary return (₹ha^{-1})			Benefit: cost ratio		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Farmer's practice	T_1	203667	214000	208833	1.95	2.07	2.01
CIP Technique	T_2	295456	303010	299233	2.46	2.54	2.50
Regional AICRIP/INSTITUTE recommendation/hoeing	T_3	269000	275333	272167	2.42	2.50	2.46
Flat-bed planting	T_4	202333	212667	207500	1.95	2.07	2.01
Flat-bed planting & mulching	T_5	240000	246667	243333	2.29	2.38	2.33
Flat-bed planting & ridging	T_6	232333	242333	237333	2.19	2.30	2.24
Flat-bed planting, ridging and mulching	T_7	278349	286525	282437	2.59	2.70	2.65
SEm±		9073	9097	4542	0.08	0.08	0.04
CD (5%)		27956	28029	13258	NS	NS	0.12

**NS: Not significant*

soil between rows + mulching of chopped straw after earthing (T_7) registered significantly higher value of gross monetary return (₹299233ha^{-1} and ₹282437ha^{-1}; respectively) over rest of the treatment; while minimum value (₹207500ha^{-1}) was observed under Flat-bed planting: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) and no mulching or earthing (T_4). In case of B:C ratio; Flat-bed planting, ridging and mulching: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) and earthing after 20-25 days by tilling soil between rows + mulching of chopped straw after earthing (T_7) followed by CIP Technique: Flat planting of seed tubers after FYM & fertilizer application + covering with paddy straw mulch (T_2) observed significantly economical (1.65 and 1.50; respectively) over rest of the treatments in pooled analysis. This may be due to efficient utilization of growth factors; which result in better crop growth and development during all stages owing to weed free environment. Mulch provides an important habitat for natural enemies, which are vital for pest population regulation. Reduced tillage could be improving soil quality parameters, minimizing production cost, while also sustaining higher potato yield. Ojah and Bhattacharjee (2021) found that zero tillage technology is done without land preparation after harvesting the paddy; hence the cost of cultivation is less than normal potato cultivation, which in turn helps the farmers to get a better income.

4. CONCLUSION

For obtaining optimum value of growth parameters and yield attributes as well as economics of potato under semi-arid tract and sandy clay loam soils; CIP Technique: Flat planting of seed tubers after FYM & fertilizer application + covering with paddy straw mulch (T_2) followed by Flat-bed planting, ridging and mulching: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) and earthing after 20-25 days by tilling soil between rows + mulching of chopped straw after earthing (T_7) was gave superior performance in both years as well as pooled over rest of the treatments. In case of B:C ratio; Flat-bed planting, ridging and mulching: Direct planting of potato by opening slit and covering it with soil (Root zone tillage in 10 cm width and 15 cm depth) and earthing after 20-25 days by tilling soil between rows + mulching of chopped straw after earthing (T_7) followed by CIP Technique: Flat planting of seed tubers after FYM & fertilizer application + covering with paddy straw mulch (T_2) observed significantly economical (1.65 and 1.50; respectively) over rest of the treatments in pooled analysis.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist

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