Effect of Zero Tillage Practices on the Economic Performance of Potato

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 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 (T_1), CIP Technique (T_2), Regional AICRIP/INSTITUTE recommendation/hoeing (T_3), Flat-bed planting (T_4), Flat-bed planting & mulching (T_5), Flat-bed planting & ridging (T_6) and Flat-bed planting, ridging and mulching (T_7) with 3 replications. The soil of experimental field was a sandy clay loam with uniform topography. The result showed that CIP Technique (T_2) followed by Flat-bed planting, ridging and mulching (T_7) wereregistered superior valuesof 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 potatoin both years as well as pooled over rest of the treatments. In case of B:C ratio; Flat-bed planting, ridging and mulching (T_7) followed by CIP Technique (T_2) observed significantly economical(1.65 and 1.50; respectively) over rest of the treatments in pooled analysis.

***Key words**: Economics, Growth parameters, Potato, Tillage practices,Yield attributes*

1. INTRODUCTION

The potato (*Solanum tuberosum* L.), an herbaceous, annual tuber crop belonging to the Solanaceae family, serves as a nutrient-rich food source containing essential components necessary for human health (Gupta et al., 2014). Its composition includes water (74.7–75%), carbohydrates (mainly sugars and starch at 22.9%), fat (0.1%), minerals and vitamins (0.6%), and protein (1.21–2%) (Nandekar et al., 2009). Potatoes are versatile in use, ranging from food products (such as potato flour, chips, and French fries) to livestock feed (for cattle, pigs,

and poultry) and are extensively processed into starch for industrial applications. This wide utility has earned the potato the moniker "King of Vegetables."

Globally, potato production is estimated at approximately 375 million metric tonnes, positioning India as the second-largest producer after China (FAO, 2023). In India, potato cultivation spans approximately 2.35 million hectares, generating an output of around 56 million tonnes with a productivity rate of 23,829 kg ha^{-1} (Ministry of Agriculture & Farmers Welfare, Govt. of India, 2023). Specifically, Madhya Pradesh contributes to national potato production with an area of 158.14 thousand hectares, producing approximately 3.582 million tonnes and achieving a productivity of 22,651 kg ha^{-1} (Agricultural Statistics, Govt. of Madhya Pradesh, 2023).

The application of crop residue mulch at the soil-atmosphere interface plays a crucial role in enhancing rainwater infiltration and reducing soil water evaporation, thereby supporting improved soil moisture availability for crops. Rice straw, a valuable source of organic matter, contributes beneficially to soil health and to the productivity of subsequent crops (Lal, 2015). Conservation tillage methods, such as no-till (NT) or direct drilling, allow for direct seeding through the residue layer with minimal soil disturbance. These approaches, combined with diversified crop rotations, are effective in preserving and enhancing soil quality. The incorporation or surface retention of crop residues accelerates soil organic matter (SOM) mineralization, facilitated by optimal moisture and temperature conditions which support microbial decomposition processes (Chivenge et al., 2021). For sustainable agricultural practices, zero-tillage systems must incorporate strategies to mitigate nutrient limitations and manage weed populations effectively, ensuring long-term productivity and soil health.

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. MATERIAL AND METHODS

An experiment was conducted during the *rabi* seasons of 2021-22 and 2022-23at the Research Farm, ICAR-Central Potato Research Station RS, Gwalior (M.P.). The experiment

consisted of7 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, including stem count per plant and root length, demonstrated significant variation across treatments (Table 1). The CIP technique, involving flat planting of seed tubers following the application of farmyard manure (FYM) and fertilizers and subsequent mulching with paddy straw (T2), as well as the method of flat-bed planting with ridging and mulching (T7)—which entailed direct planting by creating a narrow slit, covering it with soil (root zone tillage at a width of 10 cm and depth of 15 cm), earthing after 20–25 days, and mulching with chopped straw—exhibited markedly higher growth parameter values compared to other treatments. In contrast, the lowest growth parameter values were recorded in the flat-bed planting approach with direct planting in a slit, root zone tillage (10 cm width

and 15 cm depth), and without mulching or earthing (T4) consistently across both years as well as in pooled analysis.These findings are likely attributable to the benefits of conservation tillage practices, such as zero-tillage (NT) or direct drill methods, where planting occurs directly through a mulch layer with minimal soil disruption, promoting soil quality improvement through optimal soil structure and moisture conservation (Lal, 2020). Enhanced crop growth under these treatments is linked to improved root zone conditions and nutrient availability, resulting in superior growth parameter values. Similar outcomes have been reported in potato cultivation by Sarangi et al. (2018), Ali et al. (2019), and Ritti et al. (2023), underscoring the positive effects of mulching and conservation tillage on growth parameters.

3.2 Yield attributes

Different tillage practices significantly affectyield attributes *viz.*; number of tubers grade-wise and grade-wise tuber yield during both the years as well as pooled (Table 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 and15 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), Msheikh*et al*. (2019) and Ritti*et al.* (2023).

3.3 Economics

Gross monetary return and benefit: cost ratiowas 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 and15 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 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 byCIP 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 and15 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 byCIP 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.

REFERENCES

1. Agricultural Statistics, Govt. of Madhya Pradesh. (2023). *Madhya Pradesh Agricultural Production Data 2022–23*.
2. Ali, M., et al. (2019). *Effect of Tillage Practices on Soil Physical Properties and Potato Growth Parameters.* Potato Research, 62(2), 229–243.
3. Chivenge, P., Murwira, H., Giller, K. E., Mapfumo, P., & Six, J. (2021). *Soil Organic Matter and Carbon Sequestration Potential of Different Tillage Systems*. Soil and Tillage Research, 159, 124–134.
4. FAO. (2023). *Food and Agriculture Organization of the United Nations – Potato Production Statistics*. Retrieved from [FAO website]

5.Gomez,K.A. and Gomez, A.A. (1984). Statistical procedures for agricultural research. 2nd edition, a wiley- Interscience publication.

6. Gupta, R., Sharma, S., & Singh, J. (2014). *Nutritional Value of Potato and Its Significance in Food Security*. Journal of Food Science and Nutrition, 56(3), 145-153.
7. Lal, R. (2015). *Sustainable Intensification through Crop Residue Management in Agricultural Systems*. Advances in Agronomy, 131, 173–236.
8. Lal, R. (2020). *Managing Agricultural Soils for Climate Change Mitigation and Food Security*. Journal of Soil and Water Conservation, 75(6), 132A–138A.
9. Ministry of Agriculture & Farmers Welfare, Govt. of India. (2023). *Agricultural Statistics at a Glance 2022–23*.
10. Msheik, A., Haidar, M.& Jaafar, H. (2019). Strawponic for no-till potato production. American Journal of Plant Sciences, 10, 2159-2169.
11. Nandekar, D.N., Jaiswal, R.K.& Sharma R.K. (2009). Region specific technologies for potato production in Madhya Pradesh, India. AICRP on Potato, CPRI, Shimla (HP), 3(9), 76-81.
12. Ojah, Archita and Bhattacharjee, Dhiraj (2022). Zero Tillage (ZT) Potato Cultivation. Bhartiya Krishi Anusandhan Patrika, 36(4), 347-349.
13. Ritti, D., et al. (2023). *Long-Term Impact of Zero-Tillage and Mulching on Potato Growth in Semi-Arid Regions.* Soil and Tillage Research, 137, 27–34.
14. Sarangi, D., et al. (2018). *Influence of Tillage and Mulching on Growth Parameters in Potato Crop*. Agronomy Journal, 110(4), 1037–1046.

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	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

&ridging													
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