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Diversification of Potato-based Cropping Systems in Red and Lateritic Soils of West Bengal for Enhanced Productivity, Profitability and Resource Use Efficiency

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ABSTRACT

The present study was conducted at Agricultural farm of the Institute during 2020–21 and 2021–22 to assess the productivity and profitability of various potato-based cropping sequences in red and lateritic soil of West Bengal. Seven cropping sequences, *viz*., potato-sesame; potato-greengram; potato–babycorn; potato-okra; potato-groundnut; potato-blackgram and potato-vegetable cowpea was evaluated in randomized block design with three replications. Potato-vegetable cowpea sequence recorded significantly higher system productivity (47.47 t ha^{-1}) and system production efficiency (130.05 kg ha^{-1} day^{-1}) than all other cropping sequences. The system productivity and production efficiency of potato-babycorn sequence were comparable with potato–groundnut sequence but were significantly higher than potato-okra, potato-greengram, potato-sesame and potato-blackgram sequences. The potato-greengram sequence registered the highest employment generation (142-man days ha^{-1}) whereas the potato-vegetable cowpea sequence and potato-okra sequence recorded the highest land use efficiency (59.86%). The gross return (493×10^3 ₹ ha^{-1}) and net return (365×10^3 ₹ ha^{-1}) was found to be highest in potato-vegetable cowpea sequence over other potato-based cropping sequences. The highest return per rupee invested (3.86) and system economic efficiency (1017×10^3 ₹ ha^{-1}) was achieved in potato-vegetable cowpea which was followed by potato-groundnut sequence. Thus, among the seven potato-based cropping sequences, it was revealed that potato-vegetable cowpea sequence had the highest system productivity, production efficiency, gross return, net return, return per rupee invested and land use efficiency in red and lateritic soil of West Bengal.

KEYWORDS: Potato, cropping-system, productivity, profitability

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1. INTRODUCTION

The continuous adoption of RWCS, particularly in Indo-Gangetic Plains, has been responsible for the declining soil fertility, emergence of multiple micronutrients deficiencies, excess emission of greenhouse gases and decline in water table, etc. (Mal et al., 2018, Shahane and Shivay, 2019). Thus, sustainability of this cropping system is threatened (Nawaz et al., 2019) and requires remedial measures. One such measure could be adoption of altogether an alternative cropping system that overcomes these problems (Lama et al., 2018). Crop diversification has been recognized as an effective strategy for achieving the multiple objectives of food security, nutritional security, income growth, poverty alleviation, employment generation and judicious use of land and water resources, sustainable agricultural development and environmental improvement (Ray et al., 2016). Inclusion of vegetables in a cereal-based cropping system is remunerative and this changes the economics of the crop sequences (Kachroo et al., 2014; Patra et al., 2017). Crop diversification helps farmers by creating the better conditions for food security and by enabling them to grow surplus and diverse agricultural produce to be sold in the market to earn income (Ijaz et al., 2019). Crop diversification also helps the farmers to target the international and national markets with new agricultural products (Cereals, legumes, oilseeds, sugar crops, fiber crops, medicinal plants). It reduces the risk of total crop failure and also provides alternative means of generating income, as different crops will respond to climate scenarios in different ways (Khanam et al., 2018). Diversification and intensification by inclusion of winter and/or summer legumes and vegetables in the cropping sequence enhanced the productivity and profitability, improved land use efficiency and generated more employment as compared to the rice-wheat-fallow sequence (Banjara et al., 2022; Saha et al., 2022; Tetarwal et al., 2023). In small-holder production systems today, horizontal or vertical diversification is vital and has the ability to boost output and economics as a result of increased cropping intensity via addition of high-value, low-volume crops relative to the existing cropping systems (Saha et al., 2022). Most of the lower gangetic plain is located in the state of West Bengal, India, which is primarily a traditional rice-growing area. On medium lands, farmers used to grow pulses such as grass pea, lentil, or Bengal gram in winter, on residual moisture after harvest of long duration, photosensitive local rice. Productivity and return of those crops were low. However, due to introduction of high-yielding short duration rice in the 1970s and increasing irrigated area, dry season rice replaced most pulses in this area. Crop intensification and/or diversification has now further increased with inclusion of short duration rapeseed and potato in between wet season rice or jute and dry season rice, resulting in higher production per unit area per unit time, higher nutrient removal, and varying changes in soil fertility as compared with rice–rice (R–R) and rice–wheat (R–W) systems, the two predominant cropping systems of the IGP (Saha et al., 2021). Most of the previous work has focused on specific aspects of R–W systems with a strong emphasis on agronomic issues (Timsina et al., 2001; Bhandari et al., 2002; Ladha et al., 2003). In the scientific literature, studies offering an integrated assessment of more varied, intensive double and triple cropping systems are still rare, but they are essential to comprehending the IGP's intensification and diversification choices.

Potato is a unique crop that can supplement the food needs of the world, particularly for areas of high human population density like Asia and more particularly in India. Due to its short duration and compatibility of its cultivation with other crops, it has been a useful component in multiple and intercropping systems. Introduction of pulses as a key component in the existing cropping systems can aid in sustaining agricultural production systems (Neelam et al., 2021). In the prevailing period with diminishing land, water, and energy resources, resource efficiency plays a crucial role in determining whether a cropping system is appropriate for increasing total output. (Anderson, 2005, Chitale et al., 2011 and Sharma et al., 2014). Diversification in the IGP can be done by replacing dry season rice with a grain legume, oilseed, forage and tuber crop, while partial diversification is possible by accommodating a short duration legume during summer months when fields generally remain vacant after harvest of mustard or potato crop for about 70–80 days (Saha et al., 2021). Sustainable intensification of rice-based systems with potatoes in the Eastern Indo-gangetic plains of India can lead to improved productivity and increased input use efficiency (Gatto et al., 2020). Hence, a feasible strategy is needed to improve the overall profitability and productivity of the small-holder farmers of the region. Therefore, the present investigation was carried out to evaluate the most productive and profitable potato-based cropping sequence in red and lateritic soil of West Bengal.

2. MATERIALS AND METHODS

The field experiment was conducted during *rabi* and summer seasons of 2020–21 and 2021–22 at Agricultural farm, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal. The geographical coordinates of the experiment area are 23° 39' N latitude, 87° 42' E longitude with an elevation of 58.9 m above mean sea level. The soil of the experimental site was sandy loam in texture, acidic in nature with pH value of 5.12 and low in organic carbon (0.42%). The soil was found to be low in available nitrogen (140.31 kg N ha^{-1}) and phosphorus (20.14 kg P_2O_5 ha^{-1}) and medium in available potassium (192.67 kg K_2O

ha^{-1}) content. The experiment, comprising of seven cropping systems, was laid out in Randomized Block Design and was replicated thrice. The seven treatments were T_1, Potato–sesame; T_2, Potato–greengram; T_3, Potato–babycorn; T_4, Potato–okra; T_5, Potato–groundnut; T_6, Potato–blackgram and T_7, Potato–vegetable cowpea. A recommended dose of fertilizers (200:150:150 kg of N:P_2O_5:K_2O kg ha^{-1}) was applied in potato where half dose of total nitrogen, entire P_2O_5 and K_2O was applied as basal. Top dressing of the remaining nitrogen was done at the time of earthing up at 30 days after planting. Potato (variety Kufri jyoti) was planted on flat beds with a spacing of 50×25 cm^2 on November, 30, during both the years of 2020–21 and 2021–22, respectively and harvested on March 02, during 2020–21 and 2021–22, Summer crops *viz*, sesame (var. Roma), greengram (var. Samrat), Babycorn (hybrid hm-4), okra (Hybrid F-1), groundnut (TAG-24), blackgram (Kalindi) and vegetable cowpea (Pusa sukomal) were sown after harvesting of potato during both the years and harvested during last week of June and first week of July during 2021 and 2022, respectively. The summer crops were raised as per standard recommendations for each crop. The observations for different yield attributes and yield of potato and summer crops were recorded at regular interval. For comparison between crop sequences, economic yield of all the crops were converted into potato equivalent yield (PEY) based on prevailing market price using the formula:

PEY (of a crop)=Yx (Px)/Pp

where, Yx is the yield of crop x (t ha^{-1} of economic harvest), Px is the price of crop x, and Pp is the price of potato. Economics were calculated on the basis of prevailing market price of various produce and by products for both the years. System productivity in potato-based cropping systems was obtained by addition of potato-equivalent yields of component crops in the sequence. System production efficiency (SPE) was calculated by dividing the system productivity by total duration of the system and was expressed in kg ha^{-1} day^{-1}. System economic efficiency (SEE) was calculated by dividing the net returns by total duration of the system and was expressed in ₹ ha^{-1} day^{-1}. Experimental data from two years were pooled and standard statistical methods were followed for analysis using F test at 5% level of probability (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1. *Potato and system productivity*

The analysis of data on yield under various potato-based cropping sequences (Table 1) represented that, the yield of potato in potato-groundnut sequence (23.95 t ha^{-1}) was significantly superior when compared to other sequences, however it was at par with potato–vegetable cowpea (23.67 t ha^{-1}), potato–blackgram (23.64 t ha^{-1}) and potato–greengram (23.51 t ha^{-1}) sequences. The tuber yield of potato in potato–sesame, potato–babycorn and potato–okra sequences were found to be significantly inferior with respect to potato-legume sequences. Similar findings of increased yield of crop with legume sequences such as cowpea, groundnut and greengram have been reported by Ghosh et al. (2007) and Zhang et al. (2022). The potato equivalent yield (PEY) of vegetable cowpea (23.80 t ha^{-1}) was observed to be significantly higher over other summer crops and was followed by babycorn (20.74 t ha^{-1}) and groundnut (18.39 t ha^{-1}) on pooled data basis. This was mainly due to higher yield potential and market price of these crops. The PEY

Table 1: Potato yield, potato equivalent yield, system productivity, employment generation and land use efficiency of different potato-based cropping sequences (pooled data of 2 years)

Treatment details	Potato yield (t ha^{-1})			Potato equivalent yield of summer crops (t ha^{-1})			System productivity (t ha^{-1})		
	Rabi (Nov-Feb) 2020-21	*Rabi* (Nov-Feb) 2021-22	Pooled	Summer (Mar-June) 2021	Summer (Mar-June) 2022	Pooled	2020-2021	2021-2022	Pooled
Potato-sesame	22.06	22.81	22.43	8.45	9.15	8.80	30.50	31.96	31.23
Potato-greengram	23.05	23.97	23.51	7.59	8.48	8.03	30.64	32.45	31.54
Potato-babycorn	22.08	22.71	22.40	20.50	20.98	20.74	42.58	43.69	43.13
Potato-okra	22.20	22.60	22.40	11.63	13.57	12.60	33.83	36.18	35.00
Potato-groundnut	23.22	24.68	23.95	17.54	19.24	18.39	40.77	43.92	42.34
Potato-blackgram	23.16	24.11	23.64	5.70	6.04	5.87	28.86	30.15	29.51
Potato-veg. cowpea	23.02	24.33	23.67	23.18	24.42	23.80	46.19	48.74	47.47
SEm±	0.89	0.37	0.26	0.44	0.67	0.21	1.12	0.81	0.37
CD (p=0.05)	NS	1.14	0.75	1.37	2.06	0.63	3.44	2.49	1.07

Table 1: Continue...

Treatment details	System production efficiency (kg ha^{-1} day^{-1})			Total employment generation (Man days ha^{-1})			Land use efficiency (%)		
	2020–2021	2021–2022	Pooled	2020–2021	2021–2022	Mean	2020–2021	2021–2022	Mean
Potato-sesame	83.57	87.55	85.56	125	123	124	53.42	52.05	52.74
Potato-greengram	83.96	88.89	86.42	143	141	142	47.95	47.95	47.95
Potato-babycorn	116.66	119.70	118.18	131	129	130	46.58	47.12	46.85
Potato-okra	92.68	99.12	95.90	136	133	134.5	57.53	62.19	59.86
Potato-groundnut	111.69	120.34	116.01	136	134	135	57.53	61.92	59.73
Potato-blackgram	79.07	82.60	80.84	127	125	126	47.95	47.12	47.54
Potato-veg. cowpea	126.55	133.55	130.05	136	133	134.5	57.53	62.19	59.86
SEm±	3.06	2.22	1.01	-	-	-	-	-	-
CD (p=0.05)	9.42	6.83	2.95	-	-	-	-	-	-

was lower in case of blackgram (5.87 t ha^{-1}) owing to the lower grain yield followed by greengram (8.08 t ha^{-1}) and sesame (8.80 t ha^{-1}). It may be emphasized here that potato equivalent yield of crops is the function of market price along with yield of particular crop in the system.

Potato-vegetable cowpea sequence exhibited significantly higher system productivity (47.47 t ha^{-1}) which might be due to higher quantum in terms of yield and price of vegetable crop and was followed by potato-babycorn sequence (43.13 t ha^{-1}) however, it was statistically at par with potato-groundnut sequence (42.34 t ha^{-1}). The lowest system productivity was obtained from potato-blackgram sequence (29.51 t ha^{-1}). Potato-greengram and potato-sesame sequence were similar to each other with respect to system productivity. Tetarwal et al. (2023) also reported similar findings. Pooled data on system production efficiency as affected by various potato-based sequences revealed that potato-vegetable cowpea sequence (130.05 kg ha^{-1} day^{-1}) recorded significantly higher production efficiency when compared to other potato-based sequences. It was followed by potato-babycorn (118.18 kg ha^{-1} day^{-1}) sequence which was statistically similar to potato-groundnut sequence (116.01 kg ha^{-1} day^{-1}). The lowest production efficiency was obtained in potato-blackgram (80.84 kg ha^{-1} day^{-1}) as compared to other potato-based sequences whereas, potato-greengram and potato-sesame sequences were at par with each other. In view of increasing demand, crops like vegetable cowpea, baby corn, groundnut were introduced in potato-based crop sequence which produced higher yield and fetched higher return in comparison to other conventional crops like blackgram, greengram, sesame, *etc*. Improvement in the productivity was mainly attributed to the higher biological yield and higher market values of these newly introduced crops. Similar views were also expressed by Yadav et al. (2015) in potato-based cropping systems. Banjara et al. (2022) also opined that diversification of the rice-wheat cropping system with green gram or cowpea fodder sequence had better productivity, profitability and energetics of rice in the IGP region.

3.2. *Employment generation and land use efficiency*

Among various potato-based cropping sequences, the highest employment generation (142-man days ha^{-1}) was obtained in potato-greengram sequence when averaged over two years of the study (Table 1) followed by potato-groundnut sequence (135-man days ha^{-1}). This was probably due to higher labour requirement for weeding and harvesting operations. Potato-vegetable cowpea and potato-okra sequence registered similar employment generation of 134.5-man days ha^{-1}. The results were in conformity with the findings of Saha et al. (2022) and Bhargavi et al. (2019). Land use efficiency (59.86%) was found to be highest and similar in potato-vegetable cowpea and potato-okra sequence owing to longer duration of these sequences when compared to other potato-based sequences. This was closely followed by potato-groundnut sequence (59.73%). Higher land use efficiency indicated longer duration of crops in a calendar year as evidenced from the findings of Yadav et al. (2015). Multiple cropping, using short-duration crop cultivars and better management, is a common way of increasing LUE. Similar results have also been reported by Tetarwal et al. (2023).

3.3. *Economic analysis*

Economic analysis of different cropping sequences (Table 2) revealed that the highest cost of cultivation was incurred in potato-babycorn sequence (136×10^3 ₹ ha^{-1}) and the increased cost was associated to higher cost on babycorn seed and fertilizers. The second highest cost of cultivation was recorded in potato-groundnut sequence (128×10^3 ₹ ha^{-1}) which was closely followed by potato-vegetable cowpea sequence (128×10^3 ₹ ha^{-1}). The lowest cost of cultivation was registered in potato-sesame (114×10^3 ₹ ha^{-1}) sequence

Table 2: System economics as influenced by different potato-based cropping sequences (pooled data of 2 years)

Treatment details	Cost of cultivation (×10³ ₹ ha⁻¹)			Gross return (×10³ ₹ ha⁻¹)			Net return (×10³ ₹ ha⁻¹)			Return per rupee investment (₹)			System economic efficiency (₹ ha⁻¹ day⁻¹)		
	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled
Potato-sesame	112	117	114	305	365	335	193	248	221	2.73	3.12	2.93	529	680	605
Potato-greengram	118	124	121	306	372	339	188	249	218	2.59	3.01	2.80	515	682	598
Potato-babycorn	134	139	136	426	482	454	292	344	318	3.18	3.48	3.33	800	941	871
Potato-okra	120	127	123	338	407	373	219	280	250	2.83	3.22	3.02	599	768	684
Potato-groundnut	126	131	128	408	489	448	282	358	320	3.23	3.73	3.48	772	980	876
Potato-blackgram	114	119	117	289	350	319	174	230	202	2.53	2.93	2.73	478	631	555
Potato-veg. cowpea	125	130	128	462	536	499	337	406	371	3.70	4.11	3.90	923	1111	1017
SEm±	-	-	-	11	9	4	11	9	4	0.09	0.07	0.03	31	23	10
CD (p=0.05)	-	-	-	34	26	11	34	26	11	0.29	0.20	0.09	94	72	30

which was mainly due to lower seed and fertilizer cost in sesame. Significantly higher gross return was exhibited by potato-vegetable cowpea (493×10³ ₹ ha⁻¹) which was mainly due to highest system productivity of this sequence. This was followed by potato-babycorn sequence (448×10³ ₹ ha⁻¹) which was due to higher market price and demand of babycorn, this was however at par with potato-groundnut sequence (441×10³ ₹ ha⁻¹), since the yield of groundnut was considerably higher when compared to rest of the sequences which helped in realising higher gross return.

With respect to the net return of various potato-based sequences, it was found that potato-vegetable cowpea recorded highest net return (365×10³ ₹ ha⁻¹) which was mainly attributed to higher gross return and lesser cost of cultivation when compared to other potato-based sequences. The second highest net return was registered in potato-groundnut sequence which was at par with the potato-babycorn sequence. The potato-blackgram sequence fetched lower net return (196×10³ ₹ ha⁻¹) and return per rupee invested (2.68) on account of lower system productivity which was again due to low potato equivalent yield of blackgram. Return per rupee invested was highest for potato-vegetable cowpea (3.86) due to higher potato equivalent yield of cowpea and lesser cost of cultivation in this sequence. Significantly higher system economic efficiency was recorded in potato-vegetable cowpea (1017 ₹ ha⁻¹ day⁻¹) which signifies that highest net return per day was achieved from this sequence, thus making it as the most profitable sequence that can be adopted in red and lateritic soil of West Bengal. Whereas, potato-blackgram sequence registered lowest economic efficiency on account of lower system productivity which in turn led to lower net return in this sequence. Patra et al. (2019) and Kachroo et al. (2014) also reported similar results on higher system productivity with inclusion of crop such as vegetable cowpea in the system.

4. CONCLUSION

Potato-vegetable cowpea cropping sequence was the most productive and profitable in terms of higher system productivity, production efficiency, gross and net return, return per rupee invested and economic efficiency and could be considered as the most promising cropping sequence for potato-based cropping system in red and lateritic soils of West Bengal.

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