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Research Article

Performance of Cropping System Modules for Productivity, Profitability and Land Use Efficiency in Varanasi Region

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Abstract

A field experiment was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during 2022-23. The experiment was laid out in randomized block design with 3 replications. The treatments comprised 10 cropping system modules (CSM), viz. rice – wheat - fallow (CSM_1), rice –mustard - fallow (CSM_2), sesbania (G.M.) *rice – lentil - black gram (CSM_3), sesbania (G.M.) *rice - vegetable pea - black gram (CSM_4), sesbania (G.M.) * rice – mustard - black gram (CSM5), sesbania (G.M.) * rice – mustard - green gram (CSM_6), sudan fodder – berseem - cowpea fodder (CSM_7), cowpea fodder – berseem - maize fodder (CSM_8), high value rice – potato - lady's finger (CSM9), high value rice – capsicum - cowpea (green pods) (CSM_{10}). The system productivity reached higher in the high value rice-potato-lady's finger cropping system module (CSM_9) followed by high value rice-capsicum-vegetable cowpea (CSM_{10}), significantly surpassing all other cropping system modules. Moreover, it was evident that cropping system modules with a 300% cropping intensity outperformed CSM_1 and CSM_2 with a 200% cropping intensity. High value rice-capsicum-vegetable cowpea cropping system module (CSM10) emerged as the most profitable crop cropping system module among all, although it was comparable to CSM_9. Sesbania*rice-mustard-green gram cropping system module registered the maximum Benefit-Cost (B:C) ratio of 2.27, followed by CSM_{10} with a B:C ratio of 2.25.

Keywords: Cropping System Modules; Treatment; Sesbania; Outperformed; Benefit-Cost Ratio; Profitable

Introduction

Concept of cropping system is as old as agriculture in India. However, one of the biggest agricultural production systems in the world is the rice [*Oryza sativa* (L.)] -wheat [*Triticum astivum* (L.)] cropping system (RWCS). More than 85% of the RWCS practiced in South Asia is located in the IGP. In India, IGP cover about 20% of the total geographical area (329 M ha) and about 27% of the utilized agricultural area, but produce almost 50% of the total food consumed in the country; providing food for more than 400 million people of South Asia [3,5]. RWCS is the backbone of food security in South-east Asia [1]. Due to the consistency of the crop's output, the majority of Indian farmers in the IGP Zone have been cultivating rice and wheat for many years on an area of about 10.5 million hectares [9].

The RWCS has become monotonous over time and also uses chemical fertilizers indiscriminately and irrationally to boost yield, and as a result, soil fertility and health are declining, which ultimately has an impact on the production of sustainable food grains. From the perspective of soil fertility, agricultural diversification with green manure crops is particularly significant. Therefore, incorporating green manure into a cropping system is an excellent way to address this issue. According to [8], the rice-wheat sequence eliminates more than 500 kg of $N+P_2O_5 + K_2O$ ha^{-1} $year^{-1}$ in addition to a sizable quantity of secondary and micronutrients. Legumes that fix atmospheric nitrogen are used as green manure crops, which also help to enhance soil structure, helping to restore soil fertility in the process.

Inclusion of oilseeds and pulses in rice-based cropping was found to be more advantageous than cereal alone in meeting the need for cereal, pulses, and oilseeds of an ever-increasing population [2]. The legume crop is better suited for a cropping system because of its capacity to fix atmospheric nitrogen. By replacing at least one crop with a legume or include a legume in the cropping system, nutrient mining in the traditional rice-wheat and rice-mustard cropping systems can be reduced. In the rice-wheat cropping system, fields are left fallow for roughly 70 to 80 days between the harvest of the wheat crop and the planting of the succeeding rice crop. During that time, short-duration legume crops grow, which can provide farmers with an additional source of income in addition to assisting in the restoration of soil fertility.

The revenue from one-season field crops is insufficient to support marginal and small farm holdings. Hence, for ensuring sustainability and stability, it is important to diversify the traditional rice-wheat and rice-mustard cropping systems with appropriate crops using an integrated farming system approach. As a way to upliftment of overall rural farming community, development of suitable cropping system module is need of the hour for enhancing productivity, profitability, soil health and safer environment. Hence, considering the importance an experiment entitled ''Evaluation of Cropping System Modules for Different Farming System'' is being carried out at agricultural research farm, Institute of Agricultural Science, Banaras Hindu University since 2019.

Materials and Methods

A field experiment was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during 2022-23. The experiment was laid out in randomized block design with 3 replications. The treatments comprised 10 cropping system modules, viz. rice HUR 3022- wheat HUW 234-fallow (CSM_1), rice HUR 3022- mustard RH 749 -fallow (CSM_2), sesbania (G.M.) * rice HUR 3022- lentil local variety black gram Azad 3 (CSM_3), rice HUR 3022-vegetable pea Kashi nandini- black gram Azad 3 (CSM_4), sesbania (G.M.) * rice HUR 3022- mustard RH 749-black gram Azad 3 (CSM_5), sesbania (G.M.) * rice HUR 3022-mustard RH 749- green gram HUM 16 (CSM_6), Sudan fodder MFSH 4- berseem Premier- cowpea fodder Hariyali (CSM_7), cowpea fodder Hariyali- berseem Premier- maize fodder African tall (CSM_8), high value rice Rajendra kasturi- potato Kufri khyati- lady's finger Lucky 267 (CSM_9), high value rice Rajendra kasturi- capsicum F1 hybrid- vegetable cowpea Kashi kanchan (green pods) (CSM_{10}). The soil of the experimental field was sandy loam with slightly alkaline pH (7.6), having medium available nitrogen (206.25 kg/ha), available phosphorus (19.23 kg/ha) and high in available potassium (190.22 kg/ha) content. Fertilizers were applied based on the recommended dose for each crop. For valid comparison between tested crop sequences, the yields (main product and by-product) of all crops were converted into rice-equivalent yield (REY) based on market price. Final crop yields were recorded and gross return (Rs/ha) were calculated on the basis of prevailing market price of the produce. Net return was calculated by subtracting cost of cultivation from gross value of the produce, including by-product value. Benefit: cost ratio (B:C) for different crop sequences was calculated as dividing net returns by cost of cultivation. Land-use efficiency (LUE) was calculated by taking total duration of crops in a sequence and divided by 365 as per [10].

Results and Discussion

System yield and productivity

The main product yield, by-product yield and rice equivalent yield of all the tested cropping sequences are given in Table 1. The system productivity reached higher in the high value rice-potato-lady's finger cropping system module (CSM_9) followed by high value rice-capsicum-vegetable cowpea (CSM_{10}), significantly surpassing all other cropping system modules given in table 2. Further examination of the data revealed that CSM_4 exhibited significantly higher system productivity compared to both conventional treatments (CSM_1 and CSM_2). Moreover, it was evident that cropping system modules with a 300% cropping intensity outperformed CSM_1 and CSM_2 with a 200% cropping intensity. These results are in accordance with the findings of [6], who also noted enhanced productivity with the incorporation of vegetables in rice-based cropping systems.

In terms of system profitability, high value rice-capsicum-vegetable cowpea cropping system module (CSM_{10}) emerged as the most profitable crop cropping system module among all, although it was comparable to CSM_9. However, the Sesbania (G.M.) * rice-mustard-green gram cropping system module (CSM_6) demonstrated significantly higher system profitability compared to cropping system modules CSM_5, CSM_1, and CSM_2 but was on par with CSM_3 and CSM_4 given in Table 2. Additionally, the rice-mustard cropping system module was found to be the least profitable. This trend aligns with the findings reported by [7].

Land-use efficiency

Upon careful examination of the data which is provided in table 2, it is apparent that the high-value rice-potato-lady's finger cropping system module (CSM_9) achieved the highest land use efficiency at 92.72%. This was followed by the high-value rice-capsicum-vegetable cowpea cropping system module with a land use efficiency of 90.81%. Furthermore, it is evident from the data that cropping system modules with three crops per year demonstrated higher land use efficiency compared to the rice-wheat and rice-mustard cropping system modules, which had a 200% cropping intensity.

Treatments	Yield (kg/ha)						REY(kg/ha)
	Kharif season		*Rabi* season		Summer season		
	Economic yield	Straw yield	Economic yield	Straw yield	Economic yield	Straw yield	
CSM_1	3719	5570	4095	6328	0.00	0.00	7814
CSM_2	3843	5798	1770	5850	0.00	0.00	5613
CSM_3	4010	6027	1283	2826	1007.69	2460.10	6301
CSM_4	3766	5627	4073	4394	1180.11	2666.27	9019
CSM_5	3835	5720	1879	6098	962.91	2195.89	6677
CSM_6	3860	5656	1869	6151	1287.29	3332.28	7016
CSM_7	33336	--	66385	0	28886.43	0.00	128607
CSM_8	33259	--	73184	0	46045.70	0.00	152489
CSM_9	3758	5583	20908	0	8385.79	0.00	33052
CSM_{10}	3749	5700	3215	2489	6453.21	0.00	13417
SEm ±	117	77	1215	118	410.35	57.19	298
CD (P = 0.05)	348	229	3610	350	1670.44	232.81	884

Table 1: Yield of *Kharif*, *Rabi* and summer crops and system REY (2022-23).

CSM: Cropping System Module

Treatments	Land use efficiency (%)	System productivity (kg ha^{-1} day^{-1})	System profitability (Rs ha^{-1} day^{-1})
CSM_1: Rice-wheat-fallow	65.19	19.1	204.47
CSM_2: Rice-mustard-fallow	62.78	18.22	147.01
CSM_3: Sesbania (G.M.) * Rice-lentil-black gram	89.20	42.98	302.15
CSM_4: Sesbania (G.M.) * Rice-veg. pea-black gram	84.18	43.92	301.61
CSM_5: Sesbania (G.M.) * Rice-mustard-black gram	89.20	41.36	273.70
CSM_6: Sesbania (G.M.) * Rice-mustard- green gram	90.30	32.24	354.55
CSM_7: Sudan fodder-berseem -cowpea fodder	88.60	34.86	271.26
CSM_8: Cowpea fodder-berseem -maize fodder	90.30	31.51	260.51
CSM_9: High value rice-potato-lady's finger	92.72	50.48	560.35
CSM_{10}: High value rice-capsicum- vegetable cowpea	90.81	38.97	445.14
SEm±	--	0.58	15.91
CD (P = 0.05)	--	1.76	64.76

Table 2: Effect of diversification in rice-wheat system on land use efficiency, system productivity, system profitability during 2022-23.

(G.M.) *: Green Manure; Rice = HUR3022; High value rice = Rajendra Kasturi

Economic analysis

Upon a comprehensive analysis of the experimental data (Table 3), it was concluded that the high-value rice-capsicum-vegetable cowpea cropping system module (CSM_{10}) generated the highest net return, and this was comparable to CSM_9 (High value rice-potato-lady's finger) but significantly superior to all other cropping system modules. This enhanced financial performance can be attributed to the crops in these cropping system modules having a higher yield potential and commanding higher monetary values.

In contrast, the rice-mustard cropping system module was found to be the least financially rewarding. Although the net return was higher in CSM_{10}, the Sesbania*rice-mustard-green gram crop-

Treatments	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C
CSM_1	93428	97626	1.04
CSM_2	85307	73625	0.86
CSM_3	117164	131929	1.13
CSM_4	119985	121367	1.01
CSM_5	118954	115743	0.97
CSM_6	117613	144398	1.23
CSM_7	115269	114226	0.99
CSM_8	118240	103005	0.87
CSM_9	181623	156898	0.86
CSM_{10}	152904	178712	1.17

Table 3: System gross return, net return and benefit cost ratio under different cropping system modules (2022-23).

ping system module registered the maximum Benefit-Cost (B:C) ratio of 2.27, followed by CSM_{10} with a B:C ratio of 2.25. Both of these cropping system modules proved significantly more profitable than the rest of the cropping system modules, except for CSM_4. The higher B:C in CSM_6 can be attributed to its relatively lower production cost. These findings align with the results reported by [4].

Conclusion

- High value rice-potato-lady's finger had significantly higher rice equivalent yield, followed by high value rice-capsicum-vegetable cowpea. The cropping system modules CSM_6, CSM_7, CSM_3, and CSM_8 were found potential in terms of REY, while the rice-mustard cropping system module was the least productive.
- The high value rice-capsicum-vegetable cowpea cropping system module was the most profitable, with a net income of Rs 1,78,712, followed by high value rice-potato-lady's finger (Rs 1,56,898). In contrast, the rice-mustard cropping system module was the least economically viable (Rs 73,625). However, Sesbania (G.M.) *rice-mustard-green gram had the highest benefit-cost ratio (1.23), closely followed by high value rice-capsicum-vegetable cowpea.

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