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Assessment of the Productivity and Profitability of Alternate Cropping System for Diversification of Rice – Wheat Cropping System

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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

A field study was conducted from 2022-23 to 2023-24 through on-farm trials in Panipat district, Haryana, India, to evaluate alternative cropping systems to the traditional rice–wheat system in terms of productivity and profitability. The experiment compared three cropping systems: rice–wheat, rice – wheat with muskmelon (*Cucumis melo* L.) in a relay system, and rice – mustard – muskmelon. Results indicated that the system productivity of the rice-mustard-muskmelon and rice-wheat+muskmelon relay cropping systems surpassed the traditional rice-wheat system by 68.3%

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and 49.7%, respectively. Furthermore, rice-mustard-muskmelon provided significantly higher gross (Rs. 4,66,104) and net returns (Rs. 3,32,084) compared to the other cropping systems. The findings suggest that the rice – mustard – muskmelon cropping system reduces the buildup of pests and diseases common to rice-wheat cropping system, increased land productivity, and broaden a farmer's sources of income and food. Thus, it is a viable and more remunerative alternative to the conventional rice – wheat system and holds promise for enhancing sustainability and income generation in the Indo - Gangetic Plains.

Keywords: Cropping system; net returns; system productivity; yield; benefit; cost ratio.

1. INTRODUCTION

Indian agriculture is largely dependent on rice based cropping systems. Elevating the productivity of these systems has proven to be a crucial strategy for attaining livelihood security, increased income, poverty alleviation and the generation of employment opportunities. The rice-based cropping system plays a pivotal role in securing the livelihoods of over half a billion farm families (Panda et al*.,* 2018).

Rice (*Oryza sativa* L.), a member of the Poaceae family, serves as the staple food for more than half of the global population. As the most important and widely cultivated cereal crop grown across tropical and subtropical regions. Despite its dominance, significant challenges emerge during the Rabi season when establishing a second crop following rice. These include difficulties in timely field preparation, suboptimal crop establishment methods, limited moisture availability, particularly in the upper soil layers and poor germination rates. As a result, the area under second crop cultivation remains limited to approximately 38%, which is relatively low considering the region's favourable agro-climatic conditions, especially in terms of rainfall. During the Rabi season, among pulses chickpea, lathyrus and pea while among oilseeds mustard and linseed can be grown (Puhup et al*.,* 2021).

The primary winter cereal crop in Haryana and North-West India is wheat. With a distinct wet rainy season (kharif) from July to September and a dry winter season (rabi) from October to April, the climate is semi-arid and sub-tropical. Wheat is seeded after the harvest of the kharif crop and generally sown in the last week of October-November. In North-East Haryana, wheat is mostly planted in an annual cycle with rice, but in South West Haryana, it is grown in succession with cotton, pearl millet, and clusterbean in an irrigated double-cropping pattern (Coventry et al., 2011).

In India, the rice-wheat cropping system (RWCS) makes a significant contribution to ensuring food security. However, the ongoing cultivation of the rice-wheat cropping system over the past three decades has led to a number of second-generation issues such as a drop in the water table, the emergence of multinutrient deficiencies, the formation of hard pan, and the accumulation of various weeds in the rice and wheat crops. In addition, recent years have seen a stagnation in the productivity and profitability of the system. (Ladha et al*.,* 2003; Busari et al*.,* 2015). Despite substantial input applications, wheat yields are declining to a critical level, primarily due to the overall decline in system productivity. In addition to the above mentioned challenges associated with the rice–wheat cropping system, maintaining previous yield levels now requires increased input use, which in turn is contributing to a decline in farm income. Thus, sustainability of rice-wheat system is now being threatened (Nawaz et al., 2019) and requires corrective measures.

Diversification of the existing cropping system may be the viable option to alleviate the problems of the RWCS. Diversified cropping methods reduce unforeseen risks like the accumulation of pests and diseases typical of rice monoculture, boost land productivity, and expand a farmer's food and revenue sources (Saha et al*.,* 2020). By diversifying the rice-wheat system, India can reduce the gap between current and potential yields of currently employed cultivars and protect long-term soil fertility, crop productivity, and profitability (Shahane and Shivay, 2019; Saha et al*.,* 2020).

Mustard (*Brassica juncea* L.) have a deep taproot system which reduces reduce the need of irrigation water and is grown throughout the dry winter season It can help save water and improve water-use efficiency because it takes less irrigation water (about 150–200 mm) than wheat (400–500 mm). The guaranteed minimum support price (MSP) for mustard is subject to annual revisions by the Indian government (GOI, 2018–19). Both rainfed and irrigated agro-ecologies can benefit from mustard as a crop substitute. Mustard is extensively found in the rainfed agro-ecosystems of eastern, central, and peninsular India as well as the northeastern hill region. The Government of India (GOI) recently announced a policy to encourage mustard in rice fallow regions (NAAS, 2013). During the Rabi season, replacing wheat with Indian mustard can help sustain both crop and soil productivity. Additionally, this shift supports the growing need for increased oilseed production, thereby contributing to the reduction of vegetable oil imports in India.

A sustainable method that maximizes system productivity, compensates for the yield of two crops at once, and resolves time constraints between crop sowings is relay cropping. It can reduce the need for chemical pest control by controlling weeds and pest infestations, improving soil quality, and increasing net return and land equivalent ratio (Jabbar et al*.,* 2011; Bandyopadhyay et al*.,* 2016). Using Furrow Irrigated Raised Bed (FIRB) technology and relay cropping cucurbits with wheat can increase spatial and temporal productivity because small and marginal farmers in the northeastern plain zone (NEPZ) primarily use broadcasting for wheat seeding, which reduces wheat yield. Among vegetables, cucurbits represent one of the largest and most adaptable groups, thriving across a wide range of climates—from arid regions to humid tropics. Muskmelon (*Cucumis melo* L.), a warm-season cucurbit from the family Cucurbitaceae, is an ancient crop valued not only for its fruit but also for its medicinal properties—its leaves and seeds have been traditionally used to treat hematoma, while the stems are known to help reduce hypertension. Given these benefits, incorporating cucurbits like muskmelon into relay cropping systems, particularly by utilizing furrows in wheat fields under a furrow-irrigated raised bed (FIRB) planting system, presents a promising strategy for enhancing profitability (Tripathi et al*.,* 2021).

Farmers hesitate to adopt the more sustainable cropping methods, due to the lack of sufficient procurement, assured minimum support prices (MSP), subsidized irrigation, and electricity, along with limited awareness (Chikkalaki et al*.,* 2024). A field experiment was therefore carried out to determine the more profitable and productive farming systems that could take the place of the current rice-wheat cropping system.

2. MATERIALS AND METHODS

2.1 Site and Soil Characteristics

The field experiment was conducted in the Panipat at the farmer’s field level, Haryana, India, during 2022-23 and 2023-24. It is located at 28.4° N and 77.1° E at an elevation of 228.6 m above mean sea level (Arabian Sea). The region is characterized by a semi-arid climate, with the majority of annual precipitation occurring during the southwest monsoon season (July to September). The average annual rainfall is approximately 680 mm, indicating a significant seasonal concentration of precipitation.

Table 1. Initial soil properties of the experimental field

Soil Properties	Values	Interpretation
Mechanical composition		
Sand (%)	52.06	Sandy clay loam
Silt (%)	22.54	
Clay (%)	25.40	
Chemical properties		
pH	7.6	Normal
OC (%)	0.55	Medium
N (kg/ha)	248	Low
P (kg/ha)	14	Low
K (kg/ha)	285	High
Zn (mg/kg)	0.78	Medium

2.2 Treatment Details and Experimental Design

On farm trails were laid out at different location in Panipat district of Haryana. Treatments consisted of 3 cropping systems, namely rice-wheat, rice – wheat and muskmelon in relay system and rice-mustard-muskmelon. Variety of rice, wheat and mustard sown was PB 1509, HD 2967 and P45S46 respectively. The field experiment conducted over two consecutive cropping years, with distinct sowing periods for each crop in accordance with their respective seasons. During the Kharif season of 2022, rice was sown between 26 June and 8 July 2022. In the subsequent Rabi season, wheat was sown from 27 October to 5 November 2022. In an alternative treatment, muskmelon was relay-cropped, with sowing carried out between 22 February and 27 February 2023. Additionally in third treatment mustard was sown earlier in the Rabi season from 6 October to 13 October 2022, while muskmelon in this treatment was sown between 3 March and 8 March 2023.

2.3 Wheat Equivalent Yield and System Productivity

To compare the productivity of various crops, the wheat equivalent yields (WEY) of those crops were calculated. Using the formula REY = Yx (Px/Pr), where Yx is the yield of non-wheat crops (kg ha^{-1}), Px is the price of non-wheat crops (Rs. Kg^{-1}), and Pr is the price of wheat (Rs. kg^{1}), the wheat equivalent yield (WEY) was computed by converting the yield of non-wheat crops into equivalent wheat yield on a price basis. Throughout the experimental period, it was anticipated that the prices of individual inputs and outputs would remain constant. By summing the wheat equivalent yields of various crops in each cropping system, the system productivity of each cropping system was calculated using the methodology outlined by Lal et al*.,* (2017).

2.4 Economic Analysis

To compute the WEY and economics, the minimum support prices (MSPs) declared by the Government of India for rice, wheat and muskmelon crops were considered. However, vegetables, fodder crops, and crop byproducts are not eligible for MSPs. Therefore, the prevailing market prices were considered. The economic analysis was performed using the procedure given by Lal et al*.*, (2017).

3. RESULTS AND DISCUSSION

3.1 Wheat Equivalent Yield and System Productivity

The diversified cropping systems demonstrated significantly higher system productivity compared to the traditional rice–wheat system (Table 2). The highest system productivity of 219.3 q/ha (47.2 + 22.8 + 138.0) was obtained from Rice-mustard-muskmelon cropping system, which was significantly higher than all other cropping systems followed by the rice - wheat + muskmelon cropping system, which recorded 195 q/ha (46.4 + 44.8 + 104.0). In contrast, the predominant rice–wheat system yielded only 130.3 q/ha (46.9 + 53.7). The system productivity of the rice-mustard-muskmelon and rice-wheat+muskmelon relay cropping systems surpassed the traditional rice-wheat system by 68.3% and 49.7%, respectively. The total of the wheat equivalent yields of the many crops that make up the cropping system is the system productivity. In the cropping system, each crop's WEY is determined by its yield and selling price in relation to the rice's selling price (MSP). As a result, different planting techniques produced different wheat equivalent yields.

3.2 Economics

The perusal of data in Table 2 shows the cost of cultivation, net return and benefit-cost ratio of different cropping systems. The rice–wheat system exhibited the lowest cost of cultivation at Rs.79,753/ha. In contrast, the highest cost of cultivation was observed in the rice – wheat + muskmelon cropping system (Rs.1,52,920/ha), followed closely by the rice –mustard–muskmelon system (Rs. 1,34,020/ha).

The greatest increase in net returns over the conventional rice–wheat cropping system was observed in the rice–mustard–muskmelon system (Rs. 3,32,084/ha). This was followed by the rice–wheat + muskmelon system, with a net return of Rs. 2,61,772/ha. The lowest net returns were associated with the traditional rice–wheat system (Rs.1,97,192/ha), highlighting its comparatively lower profitability and reinforcing the economic advantage of diversified cropping systems. Because different crops have different yields and selling prices, there are notable differences in their gross and net returns.

Table 2. Wheat equivalent yield and economics of different cropping systems

Sr No.	Treatment	Wheat Equivalent Yield (q/ha)	Percentage increase	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net Returns (Rs./ha)	B:C
T_1	Rice (PB 1509) – wheat (HD 2967)	130.3 (46.9+53.7)	-	79753	276945	197192	3.47
T_2	Rice (PB 1509)-wheat (HD 2967) + muskmelon in relay system	195.1 (46.4+44.8+ 104.0)	49.7	152920	414692	261772	2.71
T_3	Rice (PB1509) -mustard (P45S46) - Muskmelon	219.3 (47.2+22.8+ 138.0)	68.3	134020	466104	332084	3.48

The highest benefit: cost ratio (3.48) was achieved by the rice–mustard–muskmelon cropping system, primarily due to its superior net returns and overall system yield. This was closely followed by the rice–wheat system, which recorded a benefit: cost ratio of 3.47. In contrast, the rice–wheat + muskmelon cropping system exhibited the lowest benefit: cost ratio (2.71). The BCR is calculated to assess the economic feasibility of crop production by illustrating the correlation between the costs and relative benefits. It shows the rate of return for each rupee spent on the creation of an solitary crop and not on how much money was made from the production of the crop. As a result, net return might be a more accurate measure of earnings.

4. CONCLUSION

After two years of testing, it can be concluded that the rice-mustard-muskmelon cropping system can be suggested for diversifying the rice-wheat system to boost farmers' productivity and profitability. This is because, out of all the crop components of different cropping systems, the rice-mustard-muskmelon crop had the highest system productivity and net returns, along with the B: C ratio *i.e*., 3.48.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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