Yield and economic viability of alternate cropping system as a diversification strategy for the rice-wheat cropping pattern

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ABSTRACT

The enduring sustainability challenges of the predominant rice-wheat cropping system (RWCS) in the Indo-Gangetic plains, encompassing yield stagnation, resource inefficiencies and environmental degradation, necessitated the evaluation of alternative, diversified cropping systems. A field experiment was conducted during 2022-2024 in Panipat, Haryana, where three cropping systems were investigated: the traditional rice-wheat, rice-cole crop-late sown wheat and rice-potato-late sown wheat. System productivity was assessed using wheat equivalent yield (WEY), while economic viability was evaluated through cultivation cost, net return and benefit-cost ratio (BCR). The rice-potato-late sown wheat system was found to achieve the highest productivity at 264.64 q per ha, followed by rice-cole crop-late sown wheat at 243.27 q per ha, significantly outperforming the traditional rice-wheat system (149.10 q/ha). These diversified systems demonstrated 77.49 per cent and 63.16 per cent higher productivity, respectively. Although the diversified systems incurred higher cultivation costs (Rs 221,513/ha for rice-potato-late sown wheat and Rs 212,928/ha for rice-cole crop-late sown wheat) compared to the traditional RWCS (Rs 82,083/ha), they generated substantially higher net return (Rs 380,549/ha and Rs 340,509/ha respectively, versus Rs 257,124/ha). While the RWCS exhibited the highest BCR (4.13), net return was considered a more accurate indicator of overall profitability. These findings underscore that diversified rice-based cropping systems offer a more productive and profitable alternative, contributing to enhanced food security and farm income, despite higher initial investment costs.

Keywords: Rice; wheat; cropping system; crop diversification; system productivity; wheat equivalent yield

INTRODUCTION

Rice and wheat crops have been cultivated in south Asia (India, Nepal, Pakistan, Bangladesh and Bhutan) and China for over 1,000 years. More than 85 per cent of the rice-wheat cropping system (RWCS) practiced in south Asia is located in the Indo-Gangetic plains.

In India, Indo-Gangetic plains cover about 20 per cent of the total geographical area (329 Mha) and about 27 per cent of the utilized agricultural area, but produce almost 50 per cent of the total food consumed in the country; providing food for more than 400 million people of south Asia (Kumar et al 2018). Rice (*Oryza sativa* L) is the most important and widely cultivated cereal crop; it is extensively grown across tropical and subtropical regions. RWCS is the backbone of food security in southeast Asia (Baghel et al 2018). The RWCS is contributing immensely towards meeting the food security in India.

Despite its dominance, significant challenges emerge during the rabi season when establishing a second crop following rice and has consequently led to many sustainability issues viz yield stagnation (Banjara et al 2021), poor water and nutrients use efficiency (Jat et al 2019), depletion of soil organic carbon (SOC) (Sapkota et al 2017), soil (Jat et al 2019) and environment degradation (Bhatt et al 2016), multi-nutrient deficiencies (Ladha et al 2003), reduction in factor productivity (Banjara et al 2021), the resurgence of diseases, insects and weeds, increase in cultivation costs and reduction in profit margins (Chauhan et al 2012) and reduction in biodiversity (Singh et al 2019).

Wheat (*Triticum aestivum* L) is the primary winter cereal crop grown in northwest India, particularly in Haryana. The region experiences a semi-arid, sub-tropical climate, with a clear distinction between seasons – a wet monsoon (kharif) season from July to September and a dry winter (rabi) season from October to April. In the Indo-Gangetic plains (IGPs) spread over India, Pakistan, Nepal and Bangladesh in south Asia, wheat is cultivated in rotation with rice. Wheat is grown sequentially in an irrigated double-cropping pattern; in southwest Haryana it is mostly grown in rotation with cotton, pearl millet and cluster bean, whereas, in northeast Haryana, wheat is mainly grown in an annual rotation with rice (Coventry et al 2011).

RWCS is contributing immensely towards meeting the food security in India. But the continuous cultivation of rice-wheat cropping system during last three decades has resulted in many second generation problems like decline in water table, emergence of multi-nutrient deficiencies, formation of hard pan and build up of several weeds in rice and wheat crops. Besides that, the stagnation in system productivity and profitability is being experienced in recent years (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 aforementioned challenges associated with the RWCS, maintaining previous yield levels now require increased input use, which in turn is contributing to a decline in farm income. Thus sustainability of this cropping system is threatened (Nawaz et al 2019) and requires remedial measures.

Vegetable crops are known as protective foods as they are a rich source of micronutrients (vitamins, minerals and secondary metabolites). According to the recommended dietary allowances (RDA) of the Indian Council of Medical Research (ICMR), the per capita consumption of vegetables must be 300 g and at present, the per capita availability of vegetables is about 400 g, which is about 25 per cent higher over the RDA. However, they are lacking in balanced nutrition as over 64 per cent of the total production share is contributed by only five crops such as potato (20.4%) followed by cabbage (18.17%), tomato (9.56%), cauliflower (9.28%) and brinjal (6.88%). Therefore, to ensure the nutritional security, it is imperative to promote diversification of diets through promotion of nutritionally superior vegetable crops (Kalia and Singh 2023).

Cole crops comprise the largest group of temperate vegetables that includes cauliflower (*Brassica oleracea* var *botrytis*), cabbage (*B oleracea* var *capitata*), broccoli (*B oleracea* var *italica*), Brussels sprout (*B oleracea* var *gemmifera*), kale (*B oleracea* var *acephala*), knolkhol (*B oleracea* var *gongylodes*) and so on. Globally, cole crops are being cultivated on 3.77 million ha area with annual production of 96.39 million tonnes. However, in India, the average yield from these two prominent vegetable brassica crops (cabbage and cauliflower) is higher than the overall national vegetable productivity in India (15.5 tonnes/ha) (Singh et al 2022).

Potato (*Solanum tuberosum* L) has become a key food crop in India, representing approximately 11.3 per cent of the world's total area under potato cultivation and contributing 12.5 per cent to global potato output. It stands as the fourth most significant food crop worldwide, following rice, wheat and maize. During the 2021-2022 agricultural year, India produced over 56,175 thousand tonnes of potatoes from 2,225.75 thousand hectares, achieving an average yield of 25,239 kg per hectare (Anon 2023). Recognized as a vital commercial crop, the potato plays a crucial role in global food security due to its high productivity per unit area and short growing period. In India's Indo-Gangetic plains alone, potatoes are grown on around 1.5 million hectares, typically following rice in the rice/basmati-potato-summer mungbean or fodder maize cropping sequence (Singh and Sandhu 2023).

In rice-based cropping systems, crop diversification has been acknowledged as a successful approach to achieving the goals of increasing productivity for food security, resource conservation and sustainable agriculture for the marginalised group of farmers (Singh 2010). In India's intricate agro-ecosystem, crop diversification can reduce weather-related problems and boost farm revenue by 13 per cent (Basantaray et al 2024).

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). India's varied agro-ecosystem is ideal for growing a variety of pulses, oilseeds, vegetables, fodder and aromatic and medicinal crops. With the prudent use of resources for marginalized farmers (Singh 2010), crop diversification in rice-based systems, particularly with vegetables (Birthal et al 2015) has been acknowledged as an effective strategy for achieving the goals of improving productivity, food security (Panda 2014) and nutrition (Rajendran et al 2017).

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 while keeping the aforementioned factors in mind.

MATERIAL and METHODS

The field experiment was conducted at Panipat, Haryana in the farmers' fields during 2022-23 and 2023-24. It is located at 28.4° N and 77.1° E at an elevation of 228.6 m amsl (Arabian sea). The region is characterized by a tropical and dry sub-humid 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. Soil in Panipat is mostly tropical arid in nature with variations from sandy loam to alkaline loam.

On-farm trails were laid out on farmers' fields comprising five farmers. Treatments consisted of 3 cropping systems, namely rice-wheat, rice-cole crop-late sown wheat and rice-potato-late sown wheat. Variety of rice and wheat was PB 1509 and HD 2687 respectively. During the kharif season, rice was transplanted between 24 and 27 June 2023. In the subsequent rabi season, late sown wheat was planted from 24 December 2023 to 18 January 2024. As part of an alternative cropping treatment, cole crops such as cabbage and cauliflower were sown between 28 September and 4 October 2023. In a third treatment, potato cultivation was initiated with sowing carried out from 2 to 7 October 2023. The wheat equivalent yield (WEY) of different crops was computed in order to assess and compare their productivity. Using current market prices, this approach converted non-wheat crop yields into their wheat counterparts. The following formula was used to conduct the calculation:

$$WEY = Yx\,(Px/Pr)$$

where Yx = Non-wheat crop's yield (kg/ha), Px = Its market price (Rs/kg), Pr = Its market price (Rs/kg)

All input and output prices were assumed to be constant over the experimental period for the purposes of analysis. The wheat equivalent yields of the various crops in each cropping system were added to determine the system productivity of each cropping system as per the procedure described by Lal et al (2017).

The minimum support prices (MSPs) set by the Indian government for rice, wheat, cole crops and potatoes were taken into account for calculating the WEY and economics. However, vegetables, fodder crops and crop byproducts were not eligible for MSPs and hence the current market prices were taken into account.

According to the economic analysis, WEY was calculated using the price of rice at Rs 2,300 per quintal, potatoes at Rs 850 per quintal, cole crops at Rs 12,000 per quintal and wheat at Rs 2,275 per quintal. For the sake of comparing yield and profitability, these prices were taken to be constant over the course of the experiment. The economic analysis was performed using the procedure given by Lal et al (2017).

RESULTS and DISCUSSION

Wheat equivalent yield and system productivity

The WEY, system productivity and per cent increase are displayed in Table 1. Out of all of them, the rice-potato-late-planted wheat system produced the most, with 264.64 q per ha (54.4+362.5+41.4 q/ha). The rice-cole crop-late sown wheat system was next producing 243.27 q per ha (54.4+206.2+46.2 q/ha). The widely used rice-wheat system, on the other hand, only yielded 149.10 q per ha (54.4+60.2 q/ha).

The rice-cole crop-late sown wheat and rice-potato-late sown wheat systems outperformed the conventional rice-wheat system by 77.49 and 63.16 per cent respectively in terms of productivity. The sum of the WEY of each crop in each system was

Table 1. Wheat equivalent yield and economics of different cropping systems

Treatment	Wheat equivalent yield (q/ha)	Increase (%)	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit-cost ratio
Rice-wheat	149.10 (54.4+60.2)	-	82,083	339,207	257,124	4.13
Rice-cole crop-late sown wheat	243.27 (54.4+206.2+46.2)	63.16	212,928	553,437	340,509	2.60
Rice-potato-late sown wheat	264.64 (54.4+362.5+41.4)	77.49	221,513	602,062	380,549	2.72

used to determine the overall system productivity. Each crop's WEY changed according to its yield and market price in relation to rice's MSP, which caused variations in equivalent yield between systems.

Economics

The data depicted in Table 1 show the cost of cultivation, net return and benefit-cost ratio of different cropping systems.

Among them, the traditional rice-wheat system had the lowest cultivation cost (Rs 82,083/ha). Conversely, the rice-potato-late sown wheat system incurred the highest cost (Rs 221,513/ha) closely followed by the rice-cole crop-late sown wheat system (Rs 212,928/ha). The rice-potato-late sown wheat system also delivered the highest increase in net return over the conventional system, generating Rs 380,549 per ha, while the rice-cole crop-late sown wheat system yielded Rs 340,509 per ha. The lowest net return was from the traditional rice-wheat system (Rs 257,124/ha), underlining its lower profitability compared to the diversified systems. Differences in agricultural yields and market prices were the main causes of these variances in returns.

The benefit-cost ratio (BCR) was highest for the rice-wheat system at 4.13. The rice-potato-late sown wheat and rice-cole crop-late sown wheat systems had lower BCR of 2.72 and 2.60 respectively. While BCR is a measure of the economic efficiency of crop production, reflecting the return on each rupee invested, it does not directly represent total profit. Therefore, net return is considered a more accurate indicator of profitability.

Thus diversified cropping systems, specifically rice-potato-late-planted wheat and rice-cole crop-late sown wheat, significantly outperformed the traditional rice-wheat system in terms of overall productivity and net economic returns, despite incurring higher cultivation costs. While the conventional rice-wheat system showed the highest BCR, indicating greater economic efficiency per rupee invested, the diversified systems delivered substantially higher overall yields and more importantly, much greater total profits (net return), making them more profitable choices for farmers.

CONCLUSION

The findings from this experiment robustly indicate that diversified cropping systems offer a superior alternative to the conventional rice-wheat cropping system, particularly in terms of overall productivity and net economic returns. While higher cultivation costs were incurred by the rice-potato-late-planted wheat and rice-cole crop-late sown wheat systems, these were overwhelmingly compensated by their significantly higher yields and consequently, greater net profits.

It was observed that the traditional rice-wheat system exhibited a higher benefit-cost ratio, suggesting a greater return per rupee invested. However, this metric alone was not deemed a complete representation of overall profitability. Instead, net return was considered a more accurate indicator and in this regard, the diversified systems delivered substantially higher total profits.

Therefore, for the sake of long-term sustainability, improved farm income and enhanced food security in regions reliant on rice-based systems, the adoption of diversified cropping patterns, such as the rice-potato-late-planted wheat and rice-cole crop-late sown wheat systems, is strongly supported by these results. These systems are shown to contribute immensely towards mitigating the long-standing challenges associated with the continuous practice of the conventional rice-wheat monoculture.

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