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Diversification of rice-wheat cropping system to sustain the productivity and profitability

DINESH KUMAR[1*], WAEL ALI AHMED HAMD-ALLA[2], Y S SHIVAY[1], NAIN SINGH[1], RISHI RAJ[1], VIJAY POONIYA, SEEMA SEPAT[1], VAIBHAV BALIYAN[1] and SHWETA MEHROTRA[1]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

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ABSTRACT

The field experiments were conducted during 2017-19 at the ICAR-Indian Agricultural Research Institute, New Delhi, India. The main aim of the study was to find out a suitable cropping system that can replace the existing rice-wheat cropping system to realize higher productivity and profitability. Four cropping systems, viz. rice (*Oryza sativa* L.) – mustard (*Brassica juncea* L.) – mungbean (*Vigna radiata* L.), maize (*Zea mays* L.) – mustard-mungbean, maize – potato (*Solanum tuberosum* L.) – onion (*Allium cepa* L.) and fodder maize+ cowpea (*Vigna unguiculata* L.) – wheat (*Triticum aestivum* L.) –mungbean, were evaluated in a randomized complete block design with four replications. Results suggested that the highest system productivity was obtained from the maize-potato-onion cropping system, recording almost 150% higher system productivity over the maize-mustard-mungbean and rice-mustard-mungbean cropping systems. The next best cropping system was fodder maize + cowpea -wheat-mungbean, recording significantly higher system productivity than maize-mustard-mungbean and rice-mustard-mungbean cropping systems. The highest gross and net returns was also recorded from the maize-potato-onion cropping system, being significantly higher than all other cropping systems in the first year, and statistically at par with the fodder maize + cowpea – wheat- mungbean cropping system in the second year. Overall, the highest productivity and net returns was recorded from the maize-potato-onion cropping system, and can potentially be an option to replace the existing rice-wheat cropping system of the Indo-Gangetic Plains.

Keywords: Benefit: cost ratio, Cost of cultivation, Gross and net returns, System productivity, Rice equivalent yield, Yield

The rice-wheat cropping system (RWCS) is contributing immensely towards meeting the food security in India. 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). Diversified cropping systems broadens the source of a farmers' food and income, increases their land productivity, and minimizes unpredictable risks such as the build-up of pest and diseases common in rice monoculture (Saha *et al*. 2020). The diversification of rice-wheat system will help safeguard long-term soil fertility, crop productivity and profitability in India and attenuate the gap between current yields and yield potential of currently used cultivars (Shahane and Shivay 2019, Saha *et al*. 2020). For example, introduction of summer legumes, such as mungbean, in the rice-wheat cropping system after the harvest of wheat or mustard and before the transplanting of rice, and sowing maize and fodder maize + cowpea can increase the productivity of these crops (Nawaz *et al*. 2019). Therefore, keeping the above facts in view, a field experiment was conducted to find out the more productive and remunerative cropping systems that can replace the existing rice-wheat cropping system.

Present address: [1]Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi; [2]Crop Intensification Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt. [*]Corresponding author e-mail: dineshctt@yahoo.com.

MATERIALS AND METHODS

The field experiment was conducted in the main block 14-C at the Research Farm of the ICAR-Indian Agricultural Research Institute, New Delhi, India, during 2017-18 and 2018-19. 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 soil of the experimental field was a sandy clay loam (typical Ustochrept) in texture, having 52.06% sand, 22.54% silt and 25.40% clay. Initially, the experimental soil had 0.55% organic carbon, 248 kg/ha alkaline permanganate oxidizable N, 14 kg/ha available P, 286 kg/ha 1 N ammonium acetate exchangeable K and 0.78 mg/kg of DTPA–extractable Zn, and *p*H of 7.6 in 1:2.5 soil: water ratio. Field experiments were laid out in randomized complete block design with four replications. Treatments consisted of 4 cropping systems, namely rice-mustard-mungbean, maize-mustard-mungbean, maize-potato-onion and fodder maize + cowpea -wheat-mungbean.The rice equivalent yields (REY) of different crops were worked out to compare the productivity of different crops as per the procedure described by Lal *et al*. (2017).

To compute the REY and economics, the minimum support prices (MSPs) declared by the Government of India for rice, maize, wheat, mustard and mungbean crops were considered. However, MSPs are not available for by-products of crops, vegetables and fodder crops. Therefore, the prevailing market prices were considered for the straw/ stover/ residues. For potato and onion, the wholesale selling price at Azadpur market, Delhi was considered. These prices were further reduced to rationalize the selling prices at farmer's level. On average farmers get 30 – 60% share of the wholesale prices. Therefore, a figure of 46% was considered in both the seasons. The system productivity of each cropping system was computed by adding the rice equivalent yields of different crops in each cropping system. The economic analysis was performed using the procedure given by Lal *et al*. (2017).The data recorded under various treatments were statistically analyzed using one-way analysis of variance Gomez and Gomez (1984). Means separation was done using Duncan's Multiple Range Test (DMRT) at 5% probability level. All statistical analyses were performed using SAS software program (version 9.3).

RESULTS AND DISCUSSION

Rice equivalent yield (REY) and economics of individual crops: Onion grown in maize-potato-onion cropping system gave the highest REY among all crops (Table 1). The next best crops were wheat in fodder maize + cowpea–wheat–mungbean and rice in rice-mustard-mungbean cropping system. Mungbean produced statistically similar REY in three different cropping systems. Similarly, mustard produced at par REY in rice-mustard-mungbean and maize-mustard-mungbean systems. Basically, the REY of an individual crop in the cropping system depends upon its yield achieved and selling price in comparison to selling price (MSP) of rice. Therefore, the rice equivalent yield differed in different cropping systems. The cost of cultivation was highest in onion, closely followed by the potato and the lowest being in mungbean. The highest gross and net returns were obtained by onion crop grown in maize-potato-onion system, being significantly higher than all the other crops grown in different cropping systems (Table 1).The next best crop was rice in rice-mustard-mungbean cropping system, which recorded significantly higher gross and net returns in comparison to all the other crops. In general, mustard and mungbean crops gave lower values of gross and net

Table 1 Rice equivalent yield (t/ha) and economics of individual crops grown under varying cropping systems during 2017-2018 and 2018-2019 growing seasons

Cropping system	Rice equivalent yield (t/ha)		Cost of cultivation (×10^3 ₹/ha)		Gross returns (×10^3 ₹/ha)		Net returns (×10^3 ₹/ha)		B:C ratio	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Rice-mustard-mungbean										
Rice (t/ha)	7.71^{BC}	7.29^{B}	49.3	51.7	119.5^{BC}	127.5^{B}	70.2^{BC}	75.8^{BC}	1.42^{CD}	1.47^{CD}
Mustard (t/ha)	4.51^{F}	4.03^{D}	30.5	32.0	69.9^{F}	70.4^{D}	39.4^{F}	38.4^{FG}	1.29^{CD}	1.20^{D}
Mungbean (t/ha)	3.22^{G}	4.20^{D}	18.9	19.8	49.8^{G}	73.5^{D}	30.9^{F}	53.7^{E}	1.64^{ABC}	2.71^{A}
Maize-mustard-mungbean										
Maize (t/ha)	6.31^{D}	6.37^{C}	37.8	39.6	97.8^{D}	111.4^{C}	60.0^{CDE}	71.8^{BC}	1.59^{BC}	1.82^{BC}
Mustard (t/ha)	4.76^{EF}	4.48^{D}	30.5	32.0	73.7^{EF}	78.3^{D}	43.2^{EF}	46.3^{EFG}	1.42^{CD}	1.45^{CD}
Mungbean (t/ha)	3.96^{FG}	4.37^{D}	18.9	19.8	61.4^{FG}	76.4^{D}	42.5^{EF}	56.63^{DE}	2.25^{A}	2.86^{A}
Maize-potato-onion										
Maize (t/ha)	6.42^{D}	6.16^{C}	37.8	39.6	99.5^{D}	107.8^{C}	61.7^{CD}	68.2^{CD}	1.63^{ABC}	1.72^{BC}
Potato (t/ha)	6.88^{CD}	5.68^{C}	58.8	61.6	106.6^{CD}	99.4^{C}	47.8^{DEF}	37.8^{G}	0.81^{D}	0.61^{E}
Onion (t/ha)	11.43^{A}	9.72^{A}	61.9	64.9	177.2^{A}	170.1^{A}	115.2^{A}	105.2^{A}	1.86^{ABC}	1.62^{BC}
Fodder maize + cowpea-wheat-mungbean										
Maize + cowpea green fodder (t/ha)	5.86^{DE}	5.88^{C}	32.4	34.4	90.7^{DE}	102.8^{C}	58.3^{CDE}	68.4^{CD}	1.80^{ABC}	1.99^{B}
Wheat (t/ha)	8.25^{B}	7.26^{B}	40.9	42.9	127.8^{B}	127.1^{B}	86.9^{B}	84.2^{B}	2.12^{AB}	1.97^{B}
Mungbean (t/ha)	3.77^{FG}	4.06^{D}	18.9	19.8	58.4^{FG}	71.1^{D}	39.5^{F}	51.3^{EF}	2.09^{AB}	2.59^{A}

Means with the same letters in each column are not significantly different at P=0.05 level (Duncan's multiple range test).

returns. The significant variations in gross and net returns of different crops were realized due to their varied yields and selling prices.

The highest benefit: cost ratio (BCR) values were obtained by mungbean crop irrespective of the cropping system. The mean BCR of mungbean in rice-mustard-mungbean, maize-mustard-mungbean and fodder maize+cowpea–wheat-mungbean was 2.17, 2.55 and 2.34, respectively. The BCR of mustard was statistically similar in rice-mustard-mungbean and maize-mustard-mungbean systems. Onion grown in maize-potato-onion system gave a mean BCR value of 1.74. Although the BCR of onion was numerically lower than the mungbean grown in other systems, but it does not confirm that growing of mungbean was more profitable that the onion. The BCR is actually computed in order to examine the economic viability of crop production, showing the relationship between the relative benefits and the costs incurred thereon. In fact, it demonstrates the rate of return per ₹ invested in production of an individual crop. In fact, it is not indicating the volume of profit from the crop production. Thus, net return could be a better indicator of profits. Among different crop components of various cropping systems, the highest net returns were recorded from the onion crop, though the B:C ratio was higher in mungbean.

The correlation and regression analysis was also performed to understand the relationship between different economic variables across all crops (S Table 3 and 4). The values of correlation coefficients were significant (1%) for correlation between any two variables studied, except between cost of cultivation (₹/ha) and net returns (₹/ha). Regression analysis between cost of cultivation (₹/ha) and gross returns (₹/ha) showed that 79.25 and 66.53% of the variability in gross returns could be attributed to the cost of cultivation during 2017-18 and 2018-19, respectively. Similarly, 92.24 and 79.99% variability in net returns could be accounted by the gross returns during 2017-18 and 2018-19, and the remaining variability may be influenced by some unexplained factors.

System productivity: The system productivity is the sum of rice equivalent yields of different crops constituting the cropping system. The highest system productivity was obtained from maize-potato-onion cropping system, which was significantly higher than all other cropping systems (Table 2). The former cropping system recorded almost one and half times higher system productivity over the maize-mustard-mungbean and rice-mustard-mungbean cropping system. The next best was fodder maize + cowpea-wheat-mungbean system that gave significantly higher system productivity than maize-mustard-mungbean and rice-mustard-mungbean systems. The sequence of system productivity is maize-potato-onion> maize + cowpea -wheat-mungbean> rice-mustard-mungbean>maize-mustard-mungbean.

In north-west Indo-Gangetic Plains, inclusion of mungbean in rice-wheat and maize–wheat cropping systems improved system productivity by 18% (Choudhary *et al.* 2018). Sharma and Sharma (2005) compared the five cropping systems and concluded that inclusion of mungbean in the rice–wheat cropping system during summer enhanced the crop productivity and profitability. Replacement of wheat by potato followed by mungbean in summer and rice in the *kharif* (rainy) resulted in the highest productivity (Sharma and Sharma 2005).

Profitability of the crops and cropping systems: The highest cost of cultivation was associated with maize-potato-onion; followed by rice-mustard-mungbean, fodder maize + cowpea- wheat-mungbean (Table 2). The highest gross return was obtained from the maize-potato-onion cropping system, which was significantly higher than all the other cropping systems. Similarly, fodder maize + cowpea-wheat-mungbean recorded significantly higher gross returns than the maize-mustard-mungbean and rice-mustard-mungbean systems. Rice-mustard-mungbean and maize-mustard-mungbean cropping systems recorded statistically similar net returns, which were significantly lower than the other two cropping systems. The highest gross and net returns was recorded from maize-potato-onion cropping system, being significantly higher than all the other cropping systems in the first year, and statistically at par with fodder maize + cowpea–wheat-mungbean cropping system in the second year. Overall, the highest net return in numerical terms was recorded from the maize-potato-onion cropping system in both the years. However, the highest value of the benefit: cost ratio (BCR) was recorded with maize + cowpea–wheat-mungbean (mean 2.05), which was significantly higher than all the other cropping systems. The sequence of mean BCR in decreasing order for different cropping

Table 2 System productivity (t/ha) and economics of different cropping systems during 2017-2018 and 2018-2019 growing seasons

Cropping system	System productivity (t/ha)		Cost of cultivation (×10^3 ₹/ha)		Gross returns (×10^3 ₹/ha)		Net returns (× 10^3 ₹/ha)		B:C ratio	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Rice-mustard-mungbean	15.45^{C}	15.51^{C}	98.7	103.5	239.2^{C}	271.4^{C}	140.5^{C}	167.9^{B}	1.45B	1.62^{C}
Maize-mustard-mungbean	15.00^{C}	15.21^{C}	87.2	91.4	232.9^{C}	266.1^{C}	145.8^{C}	174.7^{B}	1.75A	1.91^{B}
Maize-potato-onion	24.73^{A}	21.55^{A}	158.5	166.1	383.2^{A}	377.2^{A}	224.7^{A}	211.1^{A}	1.43B	1.27^{D}
Fodder maize + cowpea -wheat-mungbean	17.88^{B}	17.20^{B}	92.2	97.1	277.0^{B}	301.0^{B}	184.7^{B}	204.0^{A}	2.01A	2.10^{A}

Means with the same letters in each column are not significantly different at P=0.05 level (Duncan's multiple range test).

system was: maize + cowpea–wheat-mungbean (2.05)> maize-mustard-mungbean (1.83)> rice-mustard-mungbean (1.53) > maize-potato-onion (1.35). In fact, the BCR gives us the idea about the Rupees obtained by investing one Rupee (rate of return) in crop production, but does not tell us the volume of benefits per hectare land. Thus, net return is a better parameter to judge the profitability of crops and cropping systems.

Saha *et al*. (2020) also found better economic returns by diversifying the rice-wheat cropping system. In north-west Indo-Gangetic Plains, inclusion of mungbean in rice-wheat and maize–wheat cropping systems improved net returns by 15% (Choudhary *et al*. 2018). Singh *et al*. (2011) reported that replacement of rice-wheat cropping system with a triple-cropping system, particularly with rice-potato-green gram or rice-maize (cob) + vegetable pea (1:1) - cowpea (fodder) sequences gave higher annual yield, net return, benefit: cost ratio and energy productivity. Singh *et al*. (2018) recommended the rice–chickpea–vegetable cowpea cropping system as an alternative to rice–wheat system to increase the productivity and profitability of farmers in the irrigated situations of Kumaon Himalayas.

Based upon F-test, both linear and quadratic relationships were observed between different economic parameters, e.g. relationship of cost of cultivation & gross returns, and cost of cultivation & net returns for individual crops, cost of cultivation & system productivity, system productivity & gross returns, and gross returns and net returns for cropping systems were linear (S Table 3 & 4). However, the relationship between net returns & B:C ratio (BCR) and gross returns & BCR for cropping systems was found out to be quadratic. The variable on X-axis was considered as independent and on Y-axis as dependent. The coefficient of determination (R^2) was multiplied by one hundred to understand the variation in Y that has been explained by the linear or quadratic function of the variable X. For example, the relationship between cost of cultivation and gross returns across the crops suggest that 79.2% (2017-18) and 66.5% (2018-19) variation in gross returns could be explained by the linear association between the gross returns and cost of cultivation (S Table 3). This implies that about 20.8% (2017-18) and 33.5% (2018-19) of the total variation in gross returns of crops can be explained by factors other than the cost of cultivation. In other words, 20.8% (2017-18) and 33.5% (2018-19) of the total variation in gross returns remained unexplained.For further details, Tables 3 and 4 may be referred.

It is thus concluded that the potential yields of all the crops were obtained in the present field study. Among all the crops under different cropping systems, the economic parameters, viz. cost of cultivation, gross returns and net returns were significantly highest in onion. The benefit: cost ratio was highest for mungbean across all the crops in various cropping systems. Overall, the maize-potato-onion cropping systems proved the best cropping system among the tested cropping systems, particularly with respect to system productivity, gross returns and net returns. Thus, the cropping system maize-potato-onion can potentially replace the existing rice-wheat cropping system that is seen by many as an unsustainable cropping system and cause of concern in many respects.

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