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Production Potential, Economic Viability and Soil Properties as Influenced by Rice (*Oryza sativa* L.) and Maize (*Zea mays*) based Cropping Systems in Central Plain Zone of Uttar Pradesh, India

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Abstract: A field experiment was conducted with ten crop sequences consecutive for four years to identify most productive, profitable and sustainable cropping system and their impact on soil health. Crop sequence consisting of maize+black gram–potato-onion was found most efficient with respect to production (33.54 t ha^{-1}year^{-1} rice equivalent yield) system profitability Rs. 793.3 ha^{-1}day^{-1}, Net monetary return Rs. 234062 ha^{-1}year^{-1} followed by Maize – Garlic – Green gram (Grain+Recycling) and Maize + Green gram – Potato – Wheat cropping sequence. While most economical crop sequence was hybrid rice–wheat which fetched 2.84 time more benefits over the investment of Rs. 1.0 followed by Maize + Black gram –Potato– Onion crop sequence with 1:2.81 benefit – cost ratio. The sequence included legumes / pulse crops in system improved the physico-chemical properties of the soil besides availability of nutrients to the crops.

Key words: *Cropping system, economic viability, land use efficiency, production efficiency, profitability, system productivity*

Introduction

Rice – wheat cropping system is the predominant cropping system in central plain zone of Uttar Pradesh of India. The wide adoption of rice – wheat cropping system is mainly due to its high productivity, stability and less risk. Though, the system has sustained over the years, yields gradually stagnate (Nambiar and Abrol 1992). This stagnation in productivity can be attributed mainly to monotony of the system as well as exhaustive nature of the cereal-to-cereal crop sequence. Besides, continuously following the same system has shown adverse effect on soil condition, ultimately reducing the productivity of the system (Kumar and Yadav 1993). Therefore, it is needed to be reversed either by crop intensification and diversification during the seasons. Inclusion of oilseeds and pulses with vegetables are receiving more attention owing to high prices and demand and being a part of these crops in sequence was found more beneficial than cereals alone (Kumar *et al.* 2008). An intensive cropping system, which not only highly productive and profitable but also stable over time and maintains soil fertility, is of great importance in present conditions. In view of these facts, the present investigation was carried out to identify most productive, profitable and sustainable cropping system and their impact on soil health.

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Materials and Methods

An experiment was conducted at student's Instructional Farm, C.S. Azad University of Agriculture and Technology, Kanpur during 2010-11 to 2013-14 to identify biologically most efficient and profitable cropping system for Central Plain Zone of Uttar Pradesh. The experiment was comprised with10 crop sequences *viz.*, (i) Rice-Wheat (ii) Hybrid Rice-Wheat (iii) Hybrid Rice-Wheat-Green gram (Grain+Recycling) (iv) Maize-Wheat (v) Maize-Mustard-Onion (vi) Maize-Mustard-Green gram (vii) Maize+Green gram-Potato-Wheat (viii) Maize+Black gram-Potato-Onion (ix) Maize-Garlic-Green gram (Grain+Recycling) (x) Rice (Scented)-Wheat-Okra. These crop sequences were raised with recommended agronomic practices tested in Randomized Block Design with four replications. The Variety taken in *Kharif* in hybrid rice - Pant-12, Hybrid rice PHB-71, Scented rice - Sugandha, Maize - Azad Uttam, Black Gram – Shekhar - 1, Green gram - K-851. In *Rabi* wheat PBW-343, Late Wheat - K-7903, Mustard Kanti, Potato - Type 379, Garlic- Local and in *Zaid* Onion - Nasik Lal Gol. Green gram- Samrat and Okra - Azad Bhindi -1.

The recommended doses of NPK were applied through urea, DAP and muriate of potash, respectively. For comparison between crop sequences, the yield of all crops was converted into rice equivalent yield on price basis (Yadav and Nevas 1990). The soil of the experimental field was sandy loam in texture, slightly alkaline in nature having pH 8.1, EC 0.18 dS m^{-1}, low in organic carbon (0.45%), available phosphorus (11.5 kg ha^{-1}) and available potassium (205 kg ha^{-1}). The economics was computed at prevailing market rate of different commodities during 2013-14. The benefit-cost ratio was calculated as gross return divided by cost of cultivation. Production efficiency valued in term of kg $ha\text{-}day^{-1}$ was worked out by dividing total production in crop rotation by total duration of crops in that rotation. Land use efficiency was obtained by taking total duration of crops in individual crop rotation divided by 365 days. Apparent nutrient productivity was calculated by dividing the equivalent yield of the system with the total quantity of nutrient applied (Yadav 2003). The soil samples (0-15 cm) were collected from each treatment after harvesting the *Zaid* crops. The soil sample were processed and analyzed for pH, EC, organic carbon, available P and K by standard methods. The organic carbon was determined by Walkely and Black rapid titration method (Jackson 1973), available phosphorus was determined as per Olsen *et al.* (1954) and available potassium was determined by flame photometer (Jackson 1973). The pH of the soil was determined by 1:2.5 soil water suspension using pH meter as described by Jackson (1973). Electrical conductivity in the soil was determined in 1:2.5 soil water suspensions with the help of Systronics digital electrical conductivity meter.

Results and Discussion

Rice-Wheat and Maize-Wheat cropping system are exhaustive feeders of plant nutrients and continuous adoption of cereal-cereal system results in removal of nutrients in substantial amounts that often exceed replenishments through fertilizer and manure, leading deterioration in soil fertility and reducing productivity. There is a growing need to meet the food grain requirement of the ever-increasing human population and to sustain reasonably higher productivity level. The crop diversification and/or intensification show lot of opportunities in alleviating these problems. Inclusion of legumes oilseeds and other crops using intensification and interceptive approaches depending on availability of resources led to significant improvement in productivity and profitability on one hand and soil fertility on the other hand.

System productivity

The total production of a sequence in terms of rice equivalent yield (Table 1), the means of four-year experimentation revealed that highest system productivity 33.543 t ha^{-1} was obtained with Maize + Black gram–Potato–Onion crop sequence in comparison to other maize as well as rice based cropping sequences. It was closely followed by Maize – Garlic – Green gram (Grain+Recycling) crop sequence (25.10 t ha^{-1}). The highest rice equivalent yield in these

Table 1. Yield and economics of rice and maize based cropping system mean of four years (2010-11 to 2013-14)

Crop rotations	Yield (Kg ha^{-1})						Rice equivalent yield (kgha^{-1})	Cost of Cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C Ratio
	Kharif		Rabi		Zaid						
	Grain	Straw	Grain	Straw	Grain	Straw					
T_1 Rice-Wheat	4874	5841	4318	6082	-	-	12289	78427	112861	76005	2.32
T_2 Hybrid Rice-Wheat	7948	9116	4545	5559	-	-	15900	92847	141100	112119	2.84
T_3 Hybrid Rice-Wheat-Green gram (Grain+Recycling)	8167	9524	4664	5290	763	-	18174	106239	170034	124905	2.51
T_4 Maize-Wheat	2905	9121	4730	6432	-	-	10322	68053	94616	62055	2.18
T_5 Maize-Mustard-Onion	2964	9293	1727	6180	12339	-	18667	124408	165965	117444	2.25
T_6 Maize-Mustard-Green gram (Grain+Recycling)	2930	9302	2050	6012	866	-	11402	81879	105339	61029	1.97
T_7 Maize+ Green gram-Potato-Wheat	2897	8194	20626	-	-	-	24456	157608	225345	149190	2.16
T_8 Maize-Black gram-Potato-Onion	2964	9295	22659	-	12762	-	33543	194777	300443	234062	2.80
T_9 Maize-Garlic-Green gram (Grain+Recycling)	3084	10140	7730	-	967	-	25098	160810	223415	162135	2.46
T_{10} Rice-Wheat-Okra	4655	6141	4443	5181	3450	-	16691	113602	107124	99009	2.18

cropping systems was owing to replacement of wheat in rice – wheat cropping system with high volume or high-priced vegetable crops like potato onion and garlic. Lowest rice equivalent yield (10.32 t ha^{-1}) was recorded in maize – wheat sequence which was 19.06 per cent lower than the yield of pre-dominant rice – wheat cropping sequence.

Production efficiency

Production efficiency refers to productivity of a particular crop sequence / day from a unit area of land. The highest production efficiency 113.70 kg $ha^{-1}day^{-1}$ was recorded through maize + black gram – potato – onion crop sequence followed by maize + green gram – potato – wheat and maize – garlic – green gram (Grain+Recycling) cropping sequence while the lowest production efficiency 46.50 kg $ha^{-1}day^{-1}$ was noted with maize – wheat crop-sequence (Table 2).

Land use efficiency

Highest land use efficiency (87.67%) was achieved with maize – garlic – green gram followed by rice – wheat – okra crop sequence. The lowest land use efficiency (60.82) was recorded with maize – wheat as the land in this sequence was occupied for a short period in comparison to other crop sequences. It is also obvious from the data (Table 2) that crop intensification utilized land properly throughout the year which will not only enhance the profitability but also generates more employment to the farmers during lean period in the year. Cropping system analysis not only illustrates the current land use but also reflects how the land pattern has changed over the time (Gangwar and Ram 2005).

Table 2. Efficiency of rice and maize based cropping system mean of four years (2010-11 to 2013-14)

Cropping Sequence	Production efficiency (Kg $ha^{-1}day^{-1}$)	Profitability (Rs $ha^{-1}day^{-1}$)	Land use efficiency (%)
T_1 Rice-Wheat	51.42	319.35	65.21
T_2 Hybrid Rice-Wheat	66.81	471.09	65.21
T_3 Hybrid Rice-Wheat-Green gram (Grain+Recycling)	76.36	524.81	81.64
T_4 Maize-Wheat	46.50	279.53	60.82
T_5 Maize-Mustard-Onion	63.28	398.12	80.82
T_6 Maize-Mustard-Green gram (Grain+Recycling)	50.68	271.24	82.13
T_7 Maize+Green gram -Potato-Wheat	95.90	585.06	69.86
T_8 Maize+Black gram-Potato-Onion	113.70	793.43	80.82
T_9 Maize-Garlic-Green gram (Grain+Recycling)	78.43	506.67	87.67
T_{10} Rice-Wheat-Okra	55.09	326.76	83.01

Profitability

Maximum profitability Rs.793.43 ha^{-1} day^{-1} was recorded with maize + black gram – potato – onion crop sequence followed by Rs. 585.06 $ha^{-1}day^{-1}$ with maize + green gram – potato – wheat crop sequence (Table 2). Crop diversification through intensification not only enhance the productivity and profitability of the farmers but also generates the employment to the farming community for the longer periods which help in the minimizing the problem of the migration during lean period.

Economic viability

The pooled analysis results of successive four years (Table 1) revealed that highest cost of cultivation (Rs. 194777) incurred on maize + black gram – potato – onion crop sequence followed by maize – garlic – green gram crop sequence and minimum (Rs. 68053) in maize – wheat and Rs. 78427 in rice – wheat cropping sequence. Increase in cost of cultivation in maize + black gram – potato – onion and maize – garlic – green gram crop sequence is merely because of higher cost of cultivation of potato, onion and garlic as they required heavy fertilization and labours. Maximum gross return (Rs. 300443 ha^{-1}) was also obtained with maize + black gram – onion crop sequence followed by maize – garlic – green gram (Grain+Recycling) crop sequence. Minimum gross return Rs. 94616 ha^{-1} was recorded with traditional crop sequence *i.e.* maize – wheat and rice – wheat crop sequence. Among all ten crop sequences maize + black gram – potato – onion crop sequence was found most profitable crop sequence providing maximum net return of Rs. 234062 ha^{-1} followed by maize – garlic – green gram (Grain+Recycling) crop sequence (Rs. 223415 ha^{-1}). Hybrid rice – wheat crop sequence was found most economical crop sequence by fetching 2.84 times more benefit over the investment of Rs. 1.0 followed by maize + black gram – potato – onion crop sequence with 1: 2.80 benefit cost ratio. It showed that these are input responsive crop sequence resulting higher return ha^{-1}. Yadav *et al.* (2008) and Shekhar *et al.* (2009) reported higher economic viability with the inclusion of high yielding crops under existing cropping system from different agroclimatic condition.

Soil fertility and apparent nutrient productivity

Change in soil properties over four years cropping sequence (Table 3) showed slight decrease in soil pH in all the treatment over the its initial value. Maximum decrease in soil pH value was recorded with hybrid rice-wheat- green gram (Grain+Recycling) and maize-garlic-green gram (Grain+Recycling) crop sequence followed by maize-mustard-green gram (Grain+Recycling) crop sequence. This is obviously due to release of organic acid during decomposition of green manuring in the soil. Unlike pH, EC values differed in all the treatment over its initial value. Green manuring treatment and inclusion of legumes in cropping sequence showed slight increase in EC value while application of inorganic fertilizer treatment showed slight decrease in EC value over its initial value. Increase in EC value in green manuring and inclusion of legumes is may be due to release of organic acid during decomposition of green manure which increases soluble salt concentration in soil. Decreases in EC value is may be due to the use of inorganic fertilizers. The organic carbon content percent in soil increased in all the treatments over its initial value. Maximum increase in organic carbon content was noted in green manuring treatments and where legumes were included in the sequence. This increase in organic carbon content is attributed due to the higher contribution of biomass to the soil in the form of crop stables and residue. The subsequent decomposition of these materials might have resulted the enhancement of the organic carbon content in the soil. These results are in conformity with the findings of Sharma and Sharma (2002). The status of available nitrogen increased in all the cropping sequences in comparison to its initial value. Maximum increase in available nitrogen was recorded in green manuring treatments and inclusion of legume in the cropping sequence treatment than other inorganic nutrient treatments. The increase in available nitrogen in the soil may be due to the use of recommended dose of fertilizer in all crop sequence and incorporation of green manures and inclusion of legumes crops in cropping

Table 3. Change in soil fertility status after four years of crop cycle and apparent nutrient productivity (kg ha^{-1}) under rice and maize based cropping system.

Cropping Sequence	pH	EC (ds m^{-1})	OC (%)	Available Nutrient (kg ha^{-1})			Apparent nutrient productivity (kg ha^{-1})
				N	P	K	
T_1 Rice-Wheat	8.0	0.17	0.50	225	13.0	210	25.60
T_2 HybridRice-Wheat	7.9	0.16	0.51	229	13.6	213	30.23
T_3 HybridRice-Wheat-Green gram (Grain+Recycling)	7.7	0.22	0.58	261	13.9	217	34.62
T_4 Maize-Wheat	8.0	0.16	0.52	234	13.3	209	21.50
T_5 Maize-Mustard-Onion	7.9	0.17	0.50	225	13.1	211	38.90
T_6 Maize-Mustard-Green gram (Grain+Recycling)	7.8	0.21	0.56	252	13.5	215	23.79
T_7 Maize-Green gram-Potato-Wheat	7.9	0.20	0.53	239	13.4	212	38.21
T_8 Maize-Black gram-Potato- Onion	7.9	0.20	0.55	248	13.6	214	52.41
T_9 Maize-Garlic-Green gram (Grain+Recycling)	7.7	0.22	0.57	257	13.8	216	52.28
T_{10} Rice-Wheat-Okra	7.9	0.17	0.51	229	13.1	211	34.77
Initial Status	8.1	0.18	0.45	203	11.5	205	-

sequence. Sharma *et al.* (2004) also observed that sequence including leguminous crop improve the soil fertility. The status of available phosphorus was also increased in all the treatments over its initial value. Maximum increase in available phosphorus was recorded in green manuring and legumes included cropping sequence. The increase in available phosphorus in the soil may be due to the use of recommended dose of fertilizer in all crop sequence and incorporation of green manure and inclusion of legumes crop on cropping sequence. These finding are supported by the findings of Tolanur and Badanur (2003). The available potassium increased in all the treatments over its initial value. Maximum increase in available potassium was recorded with Hybrid rice-wheat-green gram followed by maize- garlic-green gram, crop sequence and minimum in rice-wheat cropping sequence. Increase in available potassium might be due to the *in situ* incorporation of green gram in cropping sequence. These findings are related to the findings of Singh *et al.* (2004) and Kumar *et al.* (2001). Maximum apparent productivity 52.41 kg ha^{-1} was recorded with maize-black gram-potato- onion crop sequence followed by 52.28 kg ha^{-1} in maize-garlic-green gram crop sequence and minimum 21.50 kg ha^{-1} in maize-wheat crop sequence. Increase in apparent productivity

appears to be due to the improvement in physico-chemical properties of soil with the green manuring and inclusion of legumes in cropping sequence.

Conclusion

Thus, it can be concluded that maize + black gram-potato-onion cropping sequence identified as the most productive and profitable cropping sequence while Hybrid rice-wheat cropping sequence was identified as most economical crop sequence in central plain zone of Uttar Pradesh.

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