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Research Papers

Productivity and sustainability of rice (*Oryza sativa*) based cropping systems in Kymore plateau and Satpura hills zone of Madhya Pradesh

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ABSTRACT

A field experiment was conducted during 2007–08 and 2008–09 on a sandy clay loam soil, to indentify sustainable rice (*Oryza sativa* L.) based cropping systems with higher productivity, economics and efficient use of water in Kymore Plateau and Satpura hills zone of Madhya Pradesh. In these 12 cropping systems, rice was sequenced with feasible *rabi* viz., wheat [*Triticum aestivum* (L.) emend. Paol & Fiori], chickpea *(Cicer arietinum* L.*)*, onion (*Allium sepa* L.), berseem (*Trifolium alexandrinum* L.), potato (*Solanum tuberosum* L.), *gobhi sarson* (*Brassica napus var. napus*), vegetable pea, (*Pisum sativum* L.), garlic (*Allium sativum* L.), marigold (*Tagetes erecta* L.) and summer crops viz., maize (*Zea mays* L.), green gram (*Vigna radiata* L. Wilczek), sunflower (*Helianthus annuus* L.), groundnut (*Arachis hypogaea* L.), okra (*Abelmoschus esculentus* L. Moench) and cowpea (*Vigna unguiculata* (L.) Walp.). Hybrid rice 'JRH-5'–garlic–maize+cowpea cropping system recorded the highest productivity (27.35t/ha/year) in terms of rice equivalent yields (REY) with net monetary returns of ₹ 1,75,980/ha/year, 4.47 benefit:cost ratio and water productivity of 137.9kg/ha/cm. Both the existing cropping systems viz., rice–wheat and rice–chickpea recorded the least productivity, net monetary returns, benefit:cost ratio and water productivity. The highest total uptake of N, P and K nutrients was under rice–*gobhi sarson*–okra cropping system. After completion of 2 crop cycles, there was a slight improvement in organic carbon and total N content of soil due to inclusion of legumes.

Key words : Economics, Productivity, Rice based cropping system, Water use efficiency

Rice–wheat and rice–chickpea cropping systems are predominant under irrigated as well as rainfed production systems in almost all districts of Kymore Plateau and Satpura hills agro-climatic zone of Madhya Pradesh. Rice was grown in about 1.7 million ha area in Madhya Pradesh (Commissioner of land record, 2005-06). Mostly long duration traditional varieties of rice are grown under rainfed conditions. In some pockets of these areas where rainfall is less or irrigation water is not adequate, rice–chickpea cropping system is prevalent. Both rice and wheat crops are fertility exhaustive and also require more irrigation water, labour, energy and investment for their cultivation than other pulses and oilseeds. Though the market value of chickpea is considerably good with low cost of production, its productivity is lower than other crops (Sharma and Jain, 1997). Hence, there is an urgent need to diversify the rice based cropping systems aimed with higher productivity, efficient use of water and need based higher profit and competitiveness in both domestic and international markets, improving soil health, protecting environment and facilitating better cropping system. Therefore twelve rice based cropping systems involving pulses, oilseeds, ornamental, spice, vegetable and fodder crops were composed for their productivity, returns, water use efficiency and better soil health.

MATERIALS AND METHODS

A field experiment was conducted during 2007–08 and 2008–09 at Krishi Nagar, Research farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh) lies in $23^0$30' N latitude and $80^0$00' E longitudes with an average altitude of 411.78 meters above the mean sea level. The soil was a sandy–clay loam, with a pH 7.7, low OC content (6.8g/kg), medium in available N (266 kg/ha) and available K (300 kg/ha) but low in available P (9.2 kg/ha). The experiment comprised of 12 crop sequences *viz.,* rice–wheat (RW), rice–chickpea (RC), hybrid rice–onion–green gram (ROG), 'Pusa Basmati-1' rice–berseem (fodder+seed) (RB), hybrid rice–potato–maize (cob+fodder) (RPM), hybrid rice–*gobh isarson*–maize (cob+fodder) (RSM), hybrid rice–vegetable pea–sunflower (RVSf), hybrid rice–potato–groundnut (RPGn), hy-

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brid rice–*gobhi sarson*–groundnut+maize (4:2row) (RSGnM), hybrid rice–*gobhi sarson*–okra (RSOk), hybrid rice–garlic–maize + cowpea (4:2 rows) (RGaMCp), and hybrid rice–marigold–maize (cob+fodder) (RMgM) was conducted in randomized block design with 4 replications. Land preparation and transplanting of rice, onion and marigold seedlings or sowing of different crops under different crop sequences was done as per recommended package of practices for different crops. The recommended dose of N, P and K was supplied through urea, single super phosphate and muriate of potash, respectively. All crops were irrigated immediately after sowing for proper germination and after that irrigation was applied at critical growth stages (Table 1). Weed control was done by hand weeding at critical period of crop weed infestation and plant protection measures were taken as and when required. The total rainfall received during rainy season (July-October) was 1,149 mm in 2007 and 1,358 mm in 2008. The prevailing market price (₹/tonne) was of rice 8,000, 'Pusa Basmati-1' 13,000, wheat 11,000, chickpea 22,000, onion 5,000, berseem fodder 700, berseem seed 1,00,000, potato 4,000, maize fodder 700, *gobhi sarson* 25,000, vegetable pea 8,000, sunflower 22,000, groundnut 25,000, okra 8,000, greengram 250,00, cowpea 700, garlic 25,000 and marigold 10,000. Wheat straw and haulm or straw of other crops were 1,000 and 500/t, where as maize cob were sold at the rate of ₹ 0.50/cob. Soil samples were collected at the end of cropping cycle and analyzed for pH, EC, organic carbon, available N, P and K as per standard procedure.

The yield of crops grown during *rabi* and summer seasons were converted into rice equivalent yields (REY) and REY of all crop components of a particular crop sequence were summed up and economics of different crop sequences was statistically analyzed. Water use efficiency was calculated by dividing REY with total consumptive use of water (cm) by all crop components in cropping systems (Dastane N.G., 1972).

RESULTS AND DISCUSSION

Growth and yield attributes of rice

Hybrid rice 'JRH-5' had significantly tallest plants while 'Pusa Basmati-1' had the shortest plants (Table 2). Numbers of effective tillers/m^2 were highest in 'Pro Agro 6444' and lowest in 'Pusa Basmati-1'. The average number of grains/panicle were 154 in 'Pro Agro 6444', 152 in 'JRH-5', 132 in 'Pusa Basmati-1' and 128 in 'Kranti' varieties, but the difference between 'Pro Agro 6444' and 'JRH-5' was not significant. 'Kranti' had the heaviest grains (28.25 g) closely followed by 'JRH-5' (26.95 g) and the next to follow were 'Pro Agro 6444' (25.6 g) and 'Pusa Basmati-1' (24.6 g).

Grain and biological yields and harvest index

Rice hybrid 'Pro Agro 6444' gave the highest grain yield of 5.72t/ha followed by hybrid 'JRH-5' with the production of (5.53 t/ha). Variety 'Kranti' ranked third for the grain yield (5.33 t/ha). 'Pusa Basmati-1' produced the lowest grain yield (3.64 t/ha). Variety 'Pro Agro 6444' topped in straw yields (14.14 t/ha) closely followed by 'Kranti' (14.08 t/ha). Hybrid 'JRH-5' (13.98 t/ha) and 'Pusa Basmati-1' (9.47 t/ha) were produced the lowest biological yield. The HI value was the highest (39.98%) with hybrid variety 'Pro Agro 6444' closely followed by hybrid 'JRH-5' (39.75%). The next best variety was 'Pusa Basmati-1' (38.43%) which was at par to 'Kranti' (37.89%).

Systems Productivity

The highest productivity of the cropping systems (based on REY) was recorded for 'rice-garlic-maize+cowpea' (RGaMC) and the least with 'rice-chickpea' (RC). Different cropping systems can be arranged in the following 7 significantly different groups in respect of the productions. They were Group 1- Rice-garlic-maize+cowpea (RGaMCp), Group 2- Rice-potato-groundnut (RPGn), Group 3- Rice-potato-maize cob+fodder (RPM), Group 4- Rice-onion-green gram (ROG), Rice-berseem (fodder+seed) (RB), Rice-marigold-maize (RMgM), Rice-*gobhi sarson*-groundnut + maize (RSGnM), Rice-*gobhi sarson*-okra (RSOk), Group 5- Rice-*gobhi sarson*-maize (RSM), Rice-vegetablepea-sunflower (RVSf), Group 6- Rice-wheat (RW) and Group 7- Rice-chickpea (RC). Thus present study bring out that the diversification of the conventional RW and RC cropping systems in the Kymore Plateau and Satpura hills zone of Madhya Pradesh can considerably increase the productions. Diversification of the conventional RW cropping system has also become necessary due to likely unsustainability of this cereal-cereal cropping system (Parasd, 2005). The diversified cropping system rice-potato-onion gave the highest system productivity in terms of rice-equivalent yields followed by the rice-potato-sunflower among rice based cropping systems at Sabour, Bihar (Sharma *et al*., 2004) and the rice-pea-okra was the most remunerative cropping sequence with the highest rice equivalent yields (170.98 q/ha/year) among all the rice based sequences with highest system productivity for irrigated agro-ecosystem at Uttar Pradesh (Singh *et al*., 2007).

Consumptive use of water (CUW) and water productivity

Consumptive use of water of an individual cropping system as a whole 'rice–berseem' (RB) recorded maxi-

Table 1. Details of seed rate, planting geometry and sowing method in different crop component

Crop	Variety	Seed rate (lg/ha)	Planting geometry	Sowing method	Recommended dose of fertilizer (Kg/ha)			Number of irrigations and their schedule
					N	P_2O_5	K^2O	
Rice	'Kranti'	30	20 cm x 15 cm	Transplanting	120	60	40	3 at 10, 51 and 81 DAT
Hy. Rice	'Pro Agro 6444'	5	20 cm x 15 cm	Transplanting	150	75	50	3 at 10, 51 and 81 DAT
Rice	'Pusa Basmati-1'	30	20 cm x 15 cm	Transplanting	120	60	40	3 at 10, 51 and 81 DAT
Hy. Rice	'JRH-5'	5	20 cm x 15 cm	Transplanting	180	90	60	2 at 10 and 51 DAT
Wheat	'GW-273'	100	20 cm rows apart	Drilling	120	60	40	6 at 21, 41, 63, 83, 97 and 117 DAS
Chickpea	'JG-322'	80	20 cm rows apart	Drilling	20	60	20	2 at 28 and 63 DAS
Green gram	'Pusa Vishal'	20	30 cm rows apart	Drilling	20	50	20	3 at 20, 40 and 63 DAS
Berseem	'JB-5'	20	Broadcast	-	20	60	20	12 AT 11, 31, 42, 61, 77,87,117, 127, 137, 147, 157 and 168 DAS
Gobhi sarson	'Terri Uttam'	4	30 cm rows apart	Drilling	60	30	20	3 at 21, 45 and 72 DAS
Potato	'Kufri Sinduri'	2000	60 cm x 15 cm	Dibbling	120	100	100	8 AT 3,17, 36, 51, 64,81,101 and 106 DAS
Maize	'JM-12'	8	60 cm x 20 cm	Dibbling	100	50	30	4 at 16, 36, 51 and 66 DAS
Vegetable pea	'Arkel'	80	30 cm rows apart	Drilling	20	60	20	3 at 20, 40 and 63 DAS
Sunflower	'PSH-12'	15	60 cm x 20 cm	Dibbling	80	60	40	4 at 11, 26, 42 and 90 DAS
Groundnut	'Jyoti'	80	30 cm rows apart	Drilling	20	60	20	7 at 11, 27, 42, 58, 73, 88 and 98 DAS
Marigold	'African Giant'	1.5	30 cm x 10 cm	Transplanting	90	75	60	6 at 15, 40, 64, 83, 98 and 127 DAT
Garlic	'G-41'	400	30 cm x 10 cm	Dibbling	100	75	50	8 at 15, 25, 42, 65, 86, 98, 128 and 144 DAT
Onion	'Pusa red'	2	30 cm x 10 cm	Transplanting	100	75	50	8 at 15, 26, 38, 65, 82,117, 139 and 155 DAS
Okra	'Parbhni 'Kranti'	20	30 cm rows apart	Dibbling	100	60	40	6 at 10, 26, 36, 51, 73 and 89 DAS
Cowpea	'local'	15	30 cm rows apart	Drilling	100	50	30	4 at 16, 36, 51 and 66 DAS

Note : No. of irrigation in Groundnut + maize 6 at 10, 26, 41, 51, 73, 98 DAS and Maize+cowpea 4 at 15, 37, 51, 61 DAS

mum and lesser in 'rice–chickpea' (RC). All the cropping systems can be arranged in 8 groups and they were significantly differ among themselves. These groups were Group 1- rice–berseem (RB) and Rice-potato-groundnut (RPGn), Group 2- Rice-garlic-maize+cowpea (RGaMCp), Group 3- Rice-onion-green gram (ROG), Group 4- Rice-potato-maize cob+fodder (RPM), Rice-marigold-maize (RMgM), Group 5- Rice-*gobhi sarson*-groundnut+maize (RSGnM), Rice-vegetablepea-sunflower (RVSf), Rice-*gobhi sarson*-okra (RSOk), Group 6- Rice-*gobhi sarson*-maize (RSM), Group 7- Rice-wheat (RW) and Group 8- Rice-chickpea (RC).

Water productivity was recorded highest in 'Hybrid rice–garlic–maize+cowpea' (RGaMCp) and least in 'rice–chickpea' (RC). Water productivity can also be grouped in 7 significantly differ groups like consumptive use of water. They were Group 1- Rice-garlic-maize+cowpea (RGaMCp), Group 2- Rice-potato-groundnut (RPGn), Group 3- Rice-potato-maize cob+fodder (RPM), Group 4- Rice-*gobhi sarson*-okra (RSOk), Group 5- Rice-*gobhi sarson*-groundnut+maize (RSGnM), Rice-onion-green gram (ROG), Rice-marigold-maize (RMgM), Rice-*gobhi sarson*-maize (RSM), Group 6- Rice-vegetable pea-sunflower (RVSf) and Group 7- Rice-chickpea (RC), Rice-wheat (RW). Rice–lentil–maize+fodder cowpea system gave significantly highest water-use efficiency (83.8 kg grain/ha-cm) among 7 rice–based cropping systems in flood-prone areas at Ghaghraghat, Bahraich (Singh *et al*., 2001). Total water-use efficiency was higher in rice–lentil–greengram (*Vigna radiata* L. Wilczek) among all in rice–based cropping system at Patna (Singh *et al*., 2008)

Economics

Hybrid rice 'JRH-5'–garlic–fodder maize+cowpea (RGaMCp) system fetched higher net monetary returns and lower in 'rice-chickpea' (RC). All the cropping systems were arranged 7 significantly groups (Table 3) and these groups were follow similar trend as in system productivity of cropping systems. *Aman* rice-potato-*boro* rice sequence is more profitable and sustainable compared to the *aman* rice-potato-sesame sequence on the sustainability of potato production in rice based cropping sequences at Hooghly and Burdwan districts of West Bengal under irrigated conditions (Saha *et al*., 2002) and diversification and intensification of rice-wheat cropping system by rice-potato-green gram proved to be highly remunerative and sustainable by generating higher income, employment and protecting the environment in Bihar (Choudhary and Singh, 2007).

Benefit–cost ratio was maximum (4.47) with hybrid rice 'JRH-5'–garlic–fodder maize+cowpea (4:2) system followed by hybrid rice 'JRH-5'–potato–groundnut (3.66), hybrid rice 'JRH-5'–*gobhi sarson*–groundnut+maize (3.56) closely followed by hybrid rice 'JRH-5'–*gobhi sarson*–okra (3.55). Benefit–cost ratio is more or less same in other remaining diversified cropping sequences (3.00 to 3.37), but minimum with rice–chickpea crop sequence (2.59). Rice-cauliflower-frenchbean and rice-vegetable pea-maize cropping systems are sustainable cropping sequences and gave higher benefit-cost ratio with lower energy input than other rice based cropping sequences under subtropical irrigated condition of Jammu (Sharma *et al*., 2007).

Nutrient uptake

The total uptake of N, P and K nutrients were recorded maximum under rice–*gobhi sarson*–okra (358, 51.6, and 441 kg/ha) cropping system (Table 3) followed by rice 'JRH-5'–*gobhi sarson*–groundnut+maize (325, 52.3 and 432 kg/ha) and rice–wheat (332, 43.8 and 394 kg/ha).

Table 2. Yield attributes and yield of rice under different cropping systems (Pooled)

Variety/ Hybrid	Plant Height (cm)	Effective tillers/m^2	Grains/ panicle	1,000–seed weight (g)	Grain yields (t/ha)	Biological Yield (t/ha)	HI (%)
'Kranti'	70.2	301.1	127.5	28.3	5.29	13.97	37.87
'Kranti'	70.6	298.9	129.3	28.2	5.38	14.19	37.91
Rice 'Pro Agro 6444'	60.9	389.8	153.8	25.3	5.72	14.30	40.01
'Pusa Basmati-1'	58.2	271.2	132.0	24.6	3.64	9.47	38.43
'JRH-5'	72.2	316.2	151.4	26.8	5.52	13.90	39.76
'JRH-5'	72.5	315.8	151.8	27.0	5.49	13.83	39.75
'JRH-5'	72.2	316.6	153.2	26.9	5.47	13.86	39.50
'JRH-5'	72.6	315.2	152.9	27.1	5.59	14.03	39.87
'JRH-5'	72.6	317.0	152.0	26.9	5.59	14.13	40.00
'JRH-5'	72.4	315.6	153.0	26.8	5.58	14.11	39.54
'JRH-5'	71.9	315.2	153.1	26.8	5.57	14.08	39.56
'JRH-5'	61.0	391.6	154.1	25.9	5.73	14.33	39.96
SEm±	0.17	0.78	0.96	0.80	0.04	0.08	0.31
CD (P=0.05)	0.50	2.26	2.82	2.31	0.10	0.24	0.89

Table 3. Rice equivalent yields (REY), water productivity and economics under different cropping systems (pooled)

Crop–sequence	*Rabi* Yield (t/ha)	Summer Yield (t/ha)	REY of system (t/ha/yr)	Cost of cultivation (×10³ ₹/ha)	NMR (×10³₹/ha/yr)	B:C ratio	Consumptive use of water (cm/ha)	Water productivity (kg/ha/cm)	Soil pH	EC (dS/m)	OC (g/kg)	Available nutrient (kg/ha) N	P	K	Total nutrient uptake (kg/ha) N	P	K
Rice–Wheat (RW)	4.67	–	11.73	35.3	70.8	3.00	152.7	76.8	7.64	0.48	6.75	252	9.1	305	332	43.8	394
Rice–Chickpea (RC)	1.55	–	9.64	31.8	50.6	2.59	123.9	77.7	7.65	0.50	7.00	257	9.3	306	265	25.3	386
Rice–Onion–Greengram (ROG)	14.06	1.19	18.22	48.4	106.3	3.19	192.5	94.7	7.70	0.51	7.50	275	9.3	318	266	48.3	437
Rice–Berseem fodder+Seed (RB)	59.96	.49	17.29	42.3	99.9	3.36	204.8	84.4	7.71	0.52	7.00	262	9.1	295	267	20.0	223
Rice–Potato–Maize cob+fodder(RPM)	19.98	48838* 30.59**	21.25	53.8	127.8	3.37	186.5	114.1	7.71	0.52	7.00	262	8.9	295	342	19.8	231
Rice–Gobhi sarson–Maize (RSM)	1.18	48952* 29.14**	14.80	41.0	82.3	3.01	161.2	91.8	7.70	0.52	7.00	268	9.3	310	261	21.1	320
Rice–Vegatable pea–Sunflower(RVSf)	5.66	1.63	15.61	43.3	88.8	3.05	173.5	89.9	7.70	0.49	7.00	268	9.3	302	265	21.6	311
Rice–Potato–Groundnut (RPGn)	20.10	2.62	23.83	55.7	148.6	3.66	202.4	117.7	7.81	0.48	7.00	267	9.1	300	348	49.7	409
Rice–*Gobhi sarson*Groundnut+Maize (RSGnM)	1.27	1.51 27906* 17.22**	17.56	41.4	105.9	3.56	175.7	99.9	7.71	0.50	7.00	268	9.3	294	325	52.3	432
Rice–*Gobhi sarson*–Okra (RSOk)	1.22	8.71	18.11	43.5	111.0	3.55	171.7	105.4	7.71	0.48	6.80	269	9.1	296	358	51.6	441
Rice–Garlic–Maize+Cowpea (RGaMCp)	6.04	4.94*** 28.23**	27.35	56.7	175.9	4.47	198.3	137.9	7.60	0.50	6.40	275	9.0	300	301	49.9	321
Rice–Marigold–Maize (RMgM)	4.71	48547* 30.59**	17.23	46.8	97.4	3.07	186.5	92.4	7.50	0.46	6.90	268	9.0	300	307	49.7	326
Initial value	–	–	–	–	–	–	–	–	7.70	0.48	6.80	266	9.2	300	–	–	–
SEm±	–	–	0.44	0.9	0.5	0.2	1.0	0.2	–	–	–	–	–	–	–	–	–
CD (P=0.05)	–	–	1.32	2.6	1.3	0.6	3.0	2.1	–	–	–	–	–	–	–	–	–

* = number of cob in maize, ** = fodder yield of maize, *** = fodder yield of cowpea, Bold no. = initial soil status

Soil fertility

Based on data pertaining to changes in soil fertility after the end of cropping sequences, all crop sequences were safe to maintain the soil properties. After harvest of *rabi* and summer crops, the status of soil was slightly varied under different treatments over the initial status. There was no any significant change in pH, OC content; but continuous rice–wheat cropping gave an indication for depletion of OC and N in the soil after completion of 2 cycles of the rotation and available NPK status. Slightly rising values recorded for electrical conductivity. Inclusion of legumes in succession to rice tended towards the improvement of OC and N content of soil over their parental status (Table-3). The uptakes of nutrients were higher in intensive rice based cropping at Jabalpur, Madhya Pradesh (Upadhyay *et al.*, 2007).

It was concluded that diversification and intensification significantly gives the higher productivity, economics, water productivity and also soil fertility over existing rice–wheat and rice–chickpea cropping systems in Kymore Plateau and Satpura hills zone of Madhya Pradesh.

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