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Research Paper

Diversification of rice (*Oryza sativa*)-based cropping systems for higher production efficiency, water productivity and economic viability in Madhya Pradesh

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ABSTRACT

A field experiment was conducted during 2006–07 to 2010–11 on diversification of rice (*Oryza sativa* L.)-based cropping systems under irrigated situations involving different crops, to study production efficiency and water productivity. The soil was clay loam in texture, slightly alkaline in reaction (pH 7.5 kg/ha), medium in organic carbon (0.66%) and available N (312 kg/ha) and low in available phosphorous (9.4 kg/ha) and high in available in potassium. The treatments consisted with 12-crop sequences which were evaluated in randomized block design with 4 replications. Hybrid rice 'JRH 5'–*gobhi sarson* (*Brassica napus* L.)–okra (*Abelmoschus esculentus* L.) system recorded maximum production efficiency (53.81 kg/ha/day), rice-equivalent yield (18.83 t/ha/year) and water productivity (410.74 kg/ha/cm) followed by scented rice–berseem (*Trifolium alexandrinum* L.) fodder + seed system (47.42 kg/ha/day, 14.56 t/ha/year, 140.11 kg/ha/cm), and the pre-dominant cropping systems of the region, i.e. rice–wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] and rice–chickpea (*Cicer arietinum* L.) (45.50 kg/ha/day, 11.69 t/ha/year and 15.57 kg/ha/cm; and 45.54 kg/ha/day, 11.15 t/ha/year) and (213.51 kg/ha/cm respectively). The lowest production efficiency, rice-equivalent yield and water productivity were recorded by hybrid rice 'JRH 5'–garlic (*Zingiber officinali Ros.*)–sorghum [*Sorghum* bicolor (L.) Moench.] + cowpea [*Vigna unguiculata* (L.) Walp.] 4:2 (28.66 kg/ha/day, 9.23 t/ha/year and 125.92 kg/ha/cm). The highest net returns of (₹1,24,238/ha/year) were realized from hybrid rice 'JRH 5'–*gobhi sarson*–okra and followed by hybrid rice–potato (*Solanum tuberosum* L.)–groundnut (*Arachis hypogaea* L.) (₹87,854/ha/year) system. Intervension of improved varieties and hybrids in rice-based cropping systems such as hybrid rice in rice based cropping system 'JRH 5'–*gobhi sarson*–okra, 'JRH 5'–potato–groundnut, hybrid rice 'JRH 5'–*gobhi sarson*–groundnut 'Jyoti' + maize 'JM 12' 4:2 row, rice 'Kranti'–chickpea 'JG 322', rice 'Pro Agro 6444'–onion 'Pusa Red'–green gram 'Pusa Vishal', rice 'Pro Agro 6444'–marigold 'African Giant'–maize 'JM 12' cob + fodder or rice 'Sugandha 5'–berseem 'JB 5' fodder + seed resulted in higher rice-equivalent yield, gross returns, net returns, production efficiency and benefit: cost ratio over pre-dominant systems of region.

Key words : Diversification, Economic viability, Intensification, Production efficiency, Rice-based cropping systems, Water productivity

Rice–wheat is one of the main cropping systems and occupies nearly 10.5 million ha area in India (Sharma *et al*., 2004). Both rice–wheat and rice–chickpea cropping systems are predominately practiced under irrigated as well as rainfed production systems in all the districts of Kymore Plateau and Satpura hills agro-climatic zone of Madhya Pradesh respectively. As a whole, cultivation of both rice and wheat crop is costly, time-consuming, energy-exhaustive and tedious. Hence there is an urgent need for diversification and intensification of cropping system in rice-based cropping system by improving the productivity and profitability per unit area per unit time without jeopardizing the soil health. In addition, the legumes have favourable impact on improving the soil fertility and help in increasing the yield of succeeding rice crop (Kharub *et al.,* 2003). Irrigation water is becoming scarce and costly wealth of the nation, which is not efficiently utilized under existing rice-based cropping systems. The resource-use efficiency, viz. land-use efficiency, water productivity and employment opportunity, can be increased through proper diversification and intensification of rice-based cropping systems with minimization of agricultural risks. In view of

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these facts, the present investigation was carried out to find out the suitability of different need-based pulse or oilseed or vegetable or fodder for substituting in existing rice-based cropping system as crop diversification and introducing need-based short-duration crop as intensification under Jabalpur conditions.

MATERIALS AND METHODS

A field experiment was conducted on crop diversification under irrigated situation in order to evaluate different promising cropping system over existing rice–wheat and rice–chickpea during 2006–07 to 2010–11 in clay loam soils. This study was initiated from *kharif* season of 2006–07 and in fixed plots at the same site without changing the layout plan and treatments. Cultural practices followed in crops are given in Table 1. The treatments consisted with 12 crop sequences, viz. T_1, rice 'Kranti'–wheat 'GW 273' (existing cropping system); T_2, rice 'Kranti'–chickpea 'JG 322' (existing cropping system); T_3, hybrid rice 'Pro Agro 6444'–onion 'Pusa Red'–greengram 'Pusa Vishal' grain + residue; T_4, rice 'Sugandha 5'–berseem 'JB 5' fodder + seed; T_5, hybrid rice 'JRH 5'–potato 'Kufri Sinduri'–maize 'JM 12' Cob + fodder; T_6, hybrid rice 'JRH 5'–*gobhi sarson* 'Terri Uttam'–maize 'JM 12'; T_7, hybrid rice 'JRH 5'–vegetable pea 'Arkel'–hybrid. sesame 'TKG 55'; T_8, hybrid rice 'JRH 5'–potato 'Kufri Sinduri'–groundnut 'Jyoti'; T_9, hybrid rice 'JRH 5'–*gobhi sarson* 'Terri Uttam'–groundnut 'Jyoti' + maize 'JM 12' 4:2 rows; T_{10}, hybrid rice 'JRH 5'–*gobhi sarson* 'Terri Uttam'–okra 'Parbhani Kranti'; T_{11}, hybrid rice 'JRH 5'–garlic 'G 41'–sorghum 'MP–chari' fodder + cowpea (Local) 4:2 rows; T_{12}, hybrid rice 'Pro Agro 6444'–marigold 'African Giant'–maize 'JM 12' cob + fodder. The rice variety 'Kranti' was used in T_1 and T_2 as predominant variety of this region. The rice variety 'Pro Agro 6444' was used in T_3 and T_{12} treatments, which is high yielding rice. In rest of the treatment early maturity hybrid rice 'JRH 5' was taken for intensifying the predominant cropping systems. These treatments were tested in randomized block design with 4 replications. The total rainfall received during the crop period was 1,031.2, 1,436.1, 1,361.2, 1,514.6 and 1,669.4 mm in 2006–07, 2007–08, 2008–09, 2009–10, and 2010–11 respectively. The yield of winter (*rabi*) and summer crops were converted into rice-equivalent yield by converting the yield into economic value based on the prevailing prices at the local regulated market in a year as per Yadav and Nevaj (1990). Gross returns, net returns, benefit: cost ratio and production efficiency were worked out for all cropping sequences.

Water-use efficiency was calculated dividing REY with total consumptive use of water (cm.) by all crop components in cropping systems (Dastane, 1972). The production efficiency (system productivity) of each crop sequence was worked out treatment-wise with the help of following formula:

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Rice-equivalent yield (kg/ha) of a particular crop sequences}}{\text{Total duration of all crop components of the same crop sequence (days)}}$$

RESULTS AND DISSUCTION

Production efficiency of crop-sequences

Production efficiency refers to productivity of a particular crop sequence per day from a unit area of land. Almost all the diversified and intensive crop-sequences significantly led to record more production efficiency (28.66 kg/ha/day to 53.81 kg/ha/day) compared to both the existing cropping sequences, viz. rice–wheat and rice–chickpea (Table 2). Hybrid rice 'JRH 5'–*gobhi sarson*–okra system recorded maximum production efficiency. The next best crop-sequence was scented rice 'Sugandha 5'–berseem fodder + seed, closely followed by hybrid rice 'JRH 5'–potato–groundnut. The combined yields of all crop components under different diversified crop-sequences in terms of rice equivalent-yields (REY) were higher than both the existing crop-sequences, which contributed to greater production efficiencies. Hybrid rice 'JRH 5'–*gobhi sarson*–okra recorded the maximum REY among all crop sequences; hence it had maximum production efficiency. The crop-sequences having potato during the winter (*rabi*) season, viz. hybrid rice 'JRH 5'–potato–groundnut and hybrid rice 'JRH 5'–potato–maize for cob and fodder ranked next to the other cropping sequences tested. Remaining diversified intensive crop sequences showed production efficiency ranging from 28.66 to 46.24 kg/ha/day, being higher than existing cropping systems, viz. rice–wheat and rice–chickpea systems (Table 3). Potato being a high yielding crop during *rabi* season resulted in handsome production efficiency of 40.93 kg/ha/day under hybrid rice 'JRH 5'–potato–maize, although rice 'Sugandha 5' was scented and low yielder, its market value is higher than the other rice varieties, therefore its rice-equivalent yield is also higher. Higher production efficiencies with the inclusion of high-yielding crops under existing cropping systems was also reported by several other workers from different agro–climatic conditions, (Yadav *et al.,* 2000; Chouhan *et al.* 2001; Kharub *et al.,* 2003; Samui *et al.,* 2004; Singh *et al.,* 2004 and Kumar *et al.,* 2005,).

Water-use efficiency of crop sequences

The Water-use efficiency (WUE) was the maximum under hybrid rice 'JRH 5'-*gobhi sarson*–okra with 174.94 cm/ha consumptive use of water among all crop-sequences tested (Table 3). Inclusion of potato in succession to rice

Tabal 1. Details of sowing, spacing cm. (planting geometry), fertilizers application (kg/ha.), no of irrigation (at days), and harvesting
Days after transplanting; DAS, days after sowing

Crops sequence	Crop	Date of sowing (cm×cm)	Spacing applied (kg/ha) N, P, K,	Fertilizers (DAT and DAS)	No. of irrigation at days	Date of harvesting
T_1, Rice 'Kranti'–wheat 'GW 273'	Rice Wheat	9,3,1,7,5 July(2006–10) 13,16,12,15 Nov.(2006–10)	20×15 20×(5–8)	120-60-40 120-60-40	3, 10, 51 and 81 at. 21, 41, 63, 83, 97 and 117 at.	3,8,4,2,8 Nov. (2006-10) 8,12,6,16,13 Apl.(2007-11)
T_2, Rice 'Kranti'–chickpea 'JG 322'	Rice Chickpea	9,3,1,7,5 July (2006–10) 13,16,12,15 Nov.(2006–10)	20×15 20×8	120-60-40 20-60-20	3, 10, 51 and 81 at. 2, 28 and 63 at.	3,8,4,2,8 Nov. (2006-10) 8,12,6,16,13 Apl. (2007-11)
T_3, Rice 'Pro Agro 6444'–onion 'Pusa red'–greengram 'Pusa Vishal' G+R	Rice Onion Greengram	9,3,1,7,5 July (2006–10) 19,17,16,20,18 Nov.(2006–10) 4,3,6,3,3 Apl.(2007–11)	25×25 30×10 30×10	175-75-50 100-75-50 20-50-20	3, 10, 51 and 81 at. 8,15,26,62,85,117 and 139 at. 3,20,40 and 63 at	5,9,6,5,11 Nov. (2006-10) 3,1,5,3,2 Apl. (2007-11) 7,10,12,4,2 Jun. (2007-11)
T_4, Rice 'Sugandha 5'–berseem 'JB 5' fodder + seed	Rice Berseem	9,3,1,7,5 July (2006–10) 13,16,12,15 Nov.(2006–10)	25×25 Broadcast	120-60-40 20-60-20	3, 10, 51 and 81 at. 2,11,31,42,61,77,87,117,127, 137, 147,157 and 168 at.	3,8,4,2,8 Nov. (2006-10) 9,7,13,3,11May (2007-11)
T_5, Rice 'JRH 5'–potato 'Kufri Sinduri'–maize 'JM 12' cob + fodder	Rice Potato Maize	9,3,1,7,5 July (2006–10) 14, 17, 13, 10, 17 Nov.(2006–10) 23, 27, 23 Feb.4,5 Mar. (2007–11	25×25 60×15 60×15	180-90-60 120-100-100 100-50-30	2,10 and 51 at 3,8,17,36,51,4,81,01 and 106. 4, 16, 36, 51 and 66 at.	3,8,4,2,8 Nov. (2006-10) 22,27,21Feb.2,4Mar. (2007-11 4,10,9,4,5 Jun. (2007-11)
T_6, Rice 'JRH 5–*gobhi sarson* 'Terri Uttam'–maize 'JM-12'	Rice Gobhi sarson Maize	9,3,1,7,5 July (2006–10) 13,16,12,15 Nov. (2006–10) 12,15,7,18,11 Mar.(2007–11)	25×25 30×(5-8) 60×15	180-90-60 60-30-201 00-50-50	2,10 and 51 at 3, 21, 45 and 62 at. 4, 16, 36, 51 and 66 at.	3,8,4,2,8 Nov. (2006-10) 10,13,5,16,9 Mar. (2007-11) 11,15,13,9,10 Jun. (2007-11)
T_7, Rice 'JRH 5'–vegatable pea 'Arkel'–sesame 'TKG 55'	Rice (Veg.) pea Sesame	9,3,1,7,5 July (2006–10) 13,16,12,15 Nov.(2006–10) 18,12,14,17.16 Feb.(2007–11)	25×25 30×10 30×10	180-90-60 20-60-20 60-30-20	2,10 and 51 at 3, 20, 40 and 63 at. 2,8,15,26,35,45,55,65,74, 82,93,105 and 117 at.	3,8,4,2,8 Nov. (2006-10) 16,19,10,15.14 Feb. (2007-11) 1,4,13,9,9 Jun. (2007-11)
T_8, Rice 'JRH 5'–Potato 'Kufri Sinduri'–groundnut 'Jyoti'	Rice Potato Groundnut	9,3,1,7,5 July (2006–10) 14,17,13,10,17 Nov.(2006–10) 26,27,25 Feb. 6,8 Mar.(2007–11	25×25 60×15 30×10	180-90-60 120-100-100 20-60-20	2,10 and 51 at 3,8,17,36,51,4,81,01,106at 7,11,27,42,58,73,88 and 98 at	3,8,4,2,8 Nov. (2006-10) 22,27, 21 Feb.2,4 Mar. (2007-11 9,14,13,8,5 Jun. (2007-11)
T_9, Rice 'JRH 5'–*g*obhi *sarson* 'Terri Uttam'–groundnut 'Jyoti' + maize 'JM 12' 4:2 row	Rice Gobhi sarson Maize	9,3,1,7,5 July (2006–10) 13,16,12,15 Nov.(2006–10) 12,15,7,18,11 Mar.(2007–11)	25×25 30×8 60×15	180-90-60 60-30-20 100-50-30	2,10 and 51 at 3, 21, 45 and 62 at. 6,10,26,41,51,73 and 98 at.	3,8,4,2,8 Nov. (2006-10) 10,13,5,16,9 Mar. (2007-11) 11,15,13,9,10 Jun. (2007-11)
T_{10}, Rice 'JRH 5'–*gobhi sarson* 'Terri Uttam'–Okra 'Parbhani Kranti'	Rice Gobhi sarson Okra	9,3,1,7,5 July (2006–10) 13,16,12,15 Nov.(2006–10) 12,14,7,17,11 Mar.(2007–11)	25×25 30×8 30×20	180-90-60 60-30-20 100-60-40	2,10 and 51 at 3, 21, 45 and 62 at. 6,10,26,36,51,73 and 89 at.	3,8,4,2,8 Nov. (2006-10) 10,13,5,16,9 Mar. (2007-11) 11,5,9,13,11 June (2007-11)
T_{11}, Rice 'JRH 5'–garlic 'G 41'–sorghum 'MP Chari' + cowpea 'Local' 4:2 row	Rice Garlic Cowpea	9,3,1,7,5 July (2006–10) 13,16,12,15 Nov. (2006–10) 26,28,25Feb.6,8 Mar. (2007–11)	25×25 30×10 20×(5-8)	180-90-60 100-75-50 80-30-20	2,10 and 51 at 8,15,25,42,65,86,98,28,44 4, 15, 37, 51 and 61 at.	3,8,4,2,8 Nov. (2006-10) 24,28,21 Feb.2,3 Mar. (2007-11 10,5,9,11,11 June (2007-11)
T_{12}, Rice 'Pro Agro 6444'–marigold 'African Giant'–maize 'JM 12' cob + fodder	Rice Marigold Maize	9,3,1,7,5 July (2006–10) 9,13,16,12,15 Nov.(2006–10) 18,21,19,18.16 Feb.(2007–11)	25×25 30×10 60×15	150-75-50 90-75-60 80-30-20	3, 10, 51 and 81 at. 6,15,40,64,83,98 and 127 at. 4,16,36,51 and 66 at.	5,9,6,5,11 Nov. (2006-10) 16,19,17,15.16 Feb. (2007-11) 12,12,13,8,14 Jun. (2007-11)

Table 2. Rice equivalent yield, cumulative cropping days, production efficiency and Economic analysis under different crop - sequences (2006-07 to 2010-11).

Crops sequence	Rice-equivalent yield (t/ha/year)				Crop duration (days)	Production efficiency (kg/ha/day)	Cost of cultivation (×10³₹ /ha/year)	Gross monetary returns (×10³₹ /ha/yr)	Net monetary returns (×10³₹ /ha/yr)	Benefit: cost ratio
	Kharif	Rabi	Smmer	Total						
T_1, Rice 'Kranti'–wheat 'GW 273'	5.72	5.97	-	11.69		45.50	36.9	105.1	68.2	2.85
T_2, Rice 'Kranti'–chickpea 'JG 322'	5.88	5.28	-	11.16		45.54	33.4	100.4	67.0	3.01
T_3, Rice 'Pro Agro 6444'–onion 'Pusa red'–greengram 'Pusa Vishal' G+R	7.44	2.82	3.77	14.02		42.37	51.3	126.2	74.9	2.46
T_4, Rice 'Sugandha 5'–berseem 'JB 5' fodder + seed	7.00	7.56	-	14.56		47.42	44.1	131.0	86.9	2.97
T_5, Rice 'JRH 5'–potato 'Kufri Sinduri'–maize 'JM 12' cob + fodder	5.77	5.48	2.14	13.39		40.93	55.8	120.5	64.6	2.16
T_6, Rice 'JRH 5–*gobhi sarson* 'Terri Uttam'–maize 'JM-12'	5.86	3.47	1.87	11.20		34.46	42.8	100.8	58.0	2.36
T_7, Rice 'JRH 5'–vegatable pea 'Arkel'–sesame 'TKG 55'	5.93	2.92	2.52	11.37		35.20	45.1	102.4	57.3	2.27
T_8, Rice 'JRH 5'–Potato 'Kufri Sinduri'–groundnut 'Jyoti'	6.04	5.03	4.88	15.95		46.24	55.8	143.6	87.8	2.58
T_9, Rice 'JRH 5'–gobhi *sarson* 'Terri Uttam'–groundnut 'Jyoti' + maize 'JM 12' 4:2 row	5.85	3.61	2.56	12.02		34.85	43.2	108.2	65.0	2.51
T_{10}, Rice 'JRH 5'–*gobhi sarson* 'Terri Uttam'–Okra 'Parbhani Kranti'	6.00	3.65	9.18	18.84		53.81	45.3	169.5	12.4	3.75
T_{11}, Rice 'JRH 5'–garlic 'G 41'–sorghum 'MP Chari' + cowpea 'Local' 4:2 row	6.02	1.16	2.05	9.23		28.66	54.1	830.6	28.9	1.54
T_{12}, Rice 'Pro Agro 6444'–marigold 'African Giant'–maize 'JM 12' cob + fodder	7.27	2.91	1.84	12.01		37.77	49.1	108.1	58.9	2.20
SEm±	0.83	0.59	0.33	0.50	–	-	0.01	0.33	0.45	0.25
CD (P=0.05)	2.47	1.74	0.99	1.48	–	-	0.03	0.99	1.35	0.76

Value of rice scented rice, wheat, chickpea, vegetable pea, potato, *gobhi sarson,* sesame, groundnut, onion, garlic, okra, greengram, berseem fodder, berseem seed, maize fodder, marigold, other fodder and haulms and wheat straw was ₹ 800, 1,300, 1,100, 2,200, 800, 400, 2,500, 2,500, 2,500, 500, 1,000, 800, 5,000, 70, 10,000, 70, 800, 50 and 100/q respectively. Value for maize cob was ₹0.50/cob

Table 3. Consumptive use of water and water productivity of different cropping components and crop–sequences (2006–07 to 2010–11).

Crops sequence	Consumptive use of water (cm/ha)				Water-use efficiency (kg/ha/cm)				Soil pH.	Electrical conductivity (dS/m)	Organic carbon (g/kg)
	Rainy season	Winter season	Summer	Total	Rainy season	Winter season	Summer	Total			
T_1, Rice 'Kranti'–wheat 'GW 273'	106.39	58.58	-	164.97	53.80	101.91	-		7.71	0.49	7.00
T_2, Rice 'Kranti'–chickpea 'JG 322'	104.64	33.54	-	138.18	56.21	157.30	-		7.66	0.47	6.74
T_3, Rice 'Pro Agro 6444'–onion 'Pusa red'–greengram 'Pusa Vishal' G+R	109.01	61.58	29.60	200.19	68.22	45.73	127.36		7.72	0.51	7.50
T_4, Rice 'Sugandha 5'–berseem 'JB 5' fodder + seed	104.41	103.44	-	207.85	67.00	73.11	-		7.72	0.52	7.00
T_5, Rice 'JRH 5'–potato 'Kufri Sinduri'–maize 'JM 12' cob + fodder	99.64	47.1	43.35	190.09	57.91	116.28	49.32		7.72	0.50	7.00
T_6, Rice 'JRH 5–*gobhi sarson* 'Terri Uttam'–maize 'JM-12'	100.02	21.61	45.01	16.64	58.60	160.39	41.57		7.65	0.48	6.80
T_7, Rice 'JRH 5'–vegatable pea 'Arkel'–sesame 'TKG 55'	97.44	31.65	48.81	177.90	60.86	92.16	51.69		7.71	0.48	7.00
T_8 , Rice 'JRH 5'–Potato 'Kufri Sinduri'–groundnut 'Jyoti'	99.92	43.5	66.68	210.10	60.48	115.63	73.17		7.72	0.52	7.00
T_9, Rice 'JRH 5'–gobhi *sarson* 'Terri Uttam'–groundnut 'Jyoti' + maize 'JM 12' 4:2 row	100.43	20.42	61.41	182.26	58.29	176.64	41.74		7.71	0.50	7.00
T_{10}, Rice 'JRH 5'–*gobhi sarson* 'Terri Uttam'–Okra 'Parbhani Kranti'	99.41	19.61	55.92	174.94	60.40	186.18	164.16		7.82	0.52	7.00
T_{11}, Rice 'JRH 5'–garlic 'G 41'–sorghum 'MP Chari' + cowpea 'Local' 4:2 row	97.83	60.02	45.48	203.33	61.53	19.34	45.05		7.51	0.46	6.90
T_{12}, Rice 'Pro Agro 6444'–marigold 'African Giant'–maize 'JM 12' cob + fodder	108.92	41.45	43.55	193.92	66.72	70.08	42.20		7.71	0.50	6.40
Initial value	–	–	–	–	–	–	–		7.70	0.48	6.80
SEm±	0.29	0.67	0.19	0.52	0.17	0.18	0.26				
CD (P=0.05)	0.86	1.98	0.56	1.54	0.50	0.52	0.77				

under hybrid rice–potato–groundnut and hybrid rice–potato–maize for cob and fodder had WUE of 249.28 and 223.51 kg/ha/cm respectively. The REY from hybrid rice–onion–green gram, hybrid rice–*gobhi sarson*–maize, scented rice 'Sugandha 5'–beseem fodder and seeds, hybrid rice–garlic–sorghum + cowpea and hybrid rice–marigold–maize cob + fodder ranged from 9.22 to 14.55 t/ha/year with the higher consumptive water use of 166.61 to 203.33 cm/ha, which attributed to lesser water productivity. Rice–berseem sequence showed the minimum water productivity (Table 3), because of quite high consumptive water use (207.85 cm/ha). These results confirm the findings of several workers. They reported that total water-use efficiency was higher in rice–lentil–greengram cropping sequences followed by rice–wheat–greengram. However, total water use efficiency was more at optimum level of irrigation during first year, whereas during second and third year, reverse was the case (Singh *et al.,* 2001; Kumar *et al.,* 2005 ; Kumar *et al.,* 2008 ; Singh *et al.,* 2008).

Economic viability

Economic analysis showed that the highest cost of cultivation incurred on hybrid rice 'JRH 5'–potato–maize sequence, followed by Hybrid rice 'JRH 5'–potato–groundnut. Inclusion of potato, maize and groundnut in the system increased the cultivation cost, as they required heavy fertilization and labour. Significantly higher gross returns were recorded with hybrid rice–*gobhi sarson*–okra cropping sequence, followed by hybrid rice–potato–groundnut and scented rice 'Sugandha 5'– berseem (fodder + seed) cropping sequence. The higher gross returns were owing to higher yield of rice, potato, groundnut and berseem in the sequence with rice than other crops (Table 2). The net returns were significantly higher with the hybrid rice–*gobhi sarson*–okra, followed by hybrid rice–potato–groundnut and scented rice 'Sugandha 5'–berseem (Table 2). The traditional system of rice - wheat and rice–chickpea gave net returns of ₹68,200 and ₹67,049 ha/year respectively. These all crop sequences were significantly superior to hybrid rice–garlic–sorghum+cowpea cropping sequence (₹28,986 ha) with regard to net monetary returns. Similarly, benefit: cost ratio was also significantly higher with hybrid rice 'JRH 5'–*gobhi sarson*–okra, followed by both existing cropping systems, viz. rice–chickpea and rice–wheat. The hybrid rice 'JRH 5'–garlic–sorghum+cowpea system gave the lowest benefit: cost ratio, which indicated less benefit from this sequence (Table 2). Yadav *et al.,* (2008) and Shekhar *et al*., (2009) reported higher economic viability with the inclusion of high-yielding crops under existing cropping systems from different agro –climatic conditions.

Soil fertility

Based on data pertaining to change in soil fertility after the end of cropping sequences, all cropping sequences were safe to maintain the soil properties. After harvest of the rainy season, winter season and summer crops, the status of soil slightly varied under different treatments over the initial status. There was no any significant change in pH, organic carbon content; but continuous rice–wheat cropping gave an indication for deplication of organic carbon and N in the soil after completion of 2 cycles of rotation and available NPK status. Slightly rising value recorded for electrical conductivity. Inclusion of legumes in succession to rice tended towards the improvement of organic carbon and N content of soil over their parental status (Table 3).

It was concluded that diversification and intensification significantly result in the higher productivity, over existing rice–wheat and rice–chickpea cropping systems in Madhya Pradesh.

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