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Performance of Rice in Different Crop Sequences under Irrigated Ecosystem of Varanasi

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Abstract

A long term experiment was initiated during 2000-2001 on sandy clay loam soil to study performance of rice (*Oryza sativa* L.) in different rice based crop sequence under irrigated condition and the data in this paper refer to 2002-03 and 2003-04. The performance of rice was evaluated in 10 crop sequences, viz. rice-wheat, rice-chickpea, rice-wheat-green gram, rice-wheat-*Sesbania* (green manure), rice-mustard-green gram, rice-lentil-cowpea fodder, rice-pea, rice-lentil + mustard (3 : 1)-cowpea fodder, rice-maize (green cob) + veg pea (1 : 1)-cowpea fodder and rice-potato green gram. Compared to rice-wheat sequence, sequences involving summer grain/fodder legume or *Sesbania* for green manuring resulted in better growth attributes, yield contributes and higher yield and nutrient uptake of the rice. However, the significant differences were obtained only during 2003-04, except for N and K uptake which proved significant during both the years of experiment. As compared to rice-wheat sequence, the significantly better growth attributes viz. plant height, number of tiller/hill, number of green leaf/hill and dry matter production (g/hill); yield contributes, viz. number of effective tiller (per m^2), number of panicle (per hill), number of grain (per panicle) and grain production (g/hill) and yield viz. grain and straw yield (q/ha) of rice as well as nutrient uptake by rice were recorded in rice-wheat-*Sesbania* (green manure) sequence. However, test weight of 1000 grains diid not differ significantly due to different crop sequences during both the years. The next best performance of rice was recorded in rice-potato-green gram sequence.
Key words : Rice based crop sequences, Growth, Yield, Nutrient uptake.

Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) is the leading cropping system in irrigated ecosystem of Indo Gangetic plain of northern India. This system generally offers more stability, productivity and profitability. However, continuous growing of same nature of crops for prolonged period has brought many problems that were not faced earlier when rice and wheat were grown either as mono crop or in different crop sequences and thus there is consequent declining trend in the productivity of rice-wheat system particularly in high productivity zone of north India (1). Such declining trend in productivity indicated decline in factor productivity owing to emergence of multi-nutrient deficiency and build up of soil pathogens and weed flora. The depletion of soil fertility by the intensive cereal-cereal production system is considered to be a major cause of yield decline. Evolution of a large number of high yielding, short duration crop varieties coupled with advent of efficient tools and implements for tillage has paved the path to diversify the rice-wheat system. However, looking into the agroclimatic and topographic conditions of Varanasi particularly under irrigated eco-system, it is rather difficult to replace rice by any other crop. Therefore, for diversification of this system, the options are either to replace wheat during *rabi* or to intensify the rice-wheat system by including summer grain/fodder legume or green manure crop. Inclusion of pulses, oilseeds and vegetables in the system has been found more beneficial than cereal after cereal (2, 3). Moreover, the legumes are reported to have favorable impact on the soil fertility and help in increasing the yield of succeeding rice crop (4). Therefore, the present experiment was conducted to study the effect of different component crops on the performance of rice in different rice-based crop sequences.

Methods

A long term field experiment on diversification of

Table 1. Effect of different crop sequences on growth attributing characters of rice at harvest.

Crop sequence	Plant height (cm)		Number of tiller (per hill)		Number of green leaf (per hill)		Dry matter production (g/hill)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
S_1 Rice-wheat	81.19	84.44	13.31	14.44	28.25	29.25	25.86	26.66
S_2 Rice-chickpea	84.00	90.19	13.75	14.63	29.00	30.13	26.79	29.60
S_3 Rice-wheat-green gram	87.31	92.50	14.56	15.94	29.88	30.81	28.64	32.68
S_4 Rice-wheat-*Sesbania*	93.38	99.19	15.25	16.38	35.00	35.06	31.02	35.33
S_5 Rice-mustard-greengram	86.25	91.81	14.50	15.69	29.88	32.44	28.52	30.57
S_6 Rice-lentil-cowpea fodder	86.69	90.00	14.25	15.38	29.63	32.63	28.12	30.12
S_7 Rice-pea	84.13	90.00	14.06	15.25	29.38	32.56	26.74	29.40
S_8 Rice-lentil+mustard (3:1)-cowpea fodder	91.19	97.50	14.63	16.00	31.81	35.31	28.83	32.89
S_9 Rice-maize (cob)+veg pea (1:1)-cowpea fodder	90.13	97.38	14.63	16.06	31.50	34.25	28.68	32.46
S_{10} Rice-potato-green gram	93.25	98.94	15.00	16.31	34.44	35.94	30.60	33.97
SE ±	2.78	3.15	0.66	0.43	1.11	1.35	1.10	1.35
CD (P = 0.05)	NS	9.15	NS	1.26	3.21	3.92	NS	3.90

rice-wheat system was initiated under All India Coordinated Research Project on Cropping Systems during 2000—2001 at the Agricultural Research Farm, Banaras Hindu University, Varanasi (UP). However, the impact of different rice-based crop sequences on growth, yield and yield contributing characters and nutrient uptake by rice was studied during 2002-03 and 2003-04. The experimental soil was sandy clay loam having pH 7.4 and 0.34% organic carbon with an electrical conductivity (EC) of 0.30 dS/m. It was characterized as low in available nitrogen (190 kg/ha) and medium in available phosphorus (19.3 kg/ha) and potassium (206 kg/ha). The treatment consisting of ten crop sequences viz. rice-wheat (S_1), rice-chickpea (S_2), rice-wheat-green gram (S_3), rice-wheat-*Sesbania* for green manuring (S_4), rice-mustard-green gram (S_5), rice-lentil-cowpea fodder (S_6), rice-pea (S_7), rice-lentil + mustard (3 : 1)-cowpea fodder (S_8), rice-maize (green

Table 2. Effect of different crop sequences on yield contributing characters of rice.

Crop sequence	Number of effective tiller m^2		Number of panicle (per hill)		Number of grain/ panicle		Test weight of 1000 grain (g)		Grain production (g/hill)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
S_1 Rice-wheat	280	316	13.25	13.31	53.00	54.24	21.29	21.54	10.21	11.25
S_2 Rice-chickpea	324	338	13.50	14.38	55.87	58.34	20.75	21.12	10.28	12.12
S_3 Rice-wheat-green gram	344	357	14.13	14.75	59.41	61.38	20.58	20.98	11.27	13.42
S_4 Rice-wheat-*Sesbania*	389	400	15.00	15.69	68.37	69.76	21.28	21.59	12.19	14.46
S_5 Rice-mustard-green-gram	340	357	13.94	14.75	59.28	61.12	21.12	21.68	11.23	12.68
S_6 Rice-lentil-cowpea fodder	334	346	13.94	14.94	58.34	60.86	21.19	21.49	10.99	12.55
S_7 Rice-pea	332	345	13.69	13.88	57.34	59.28	21.01	21.57	10.73	12.12
S_8 Rice-lentil-mustard (3:1)-cowpea fodder	382	395	14.75	15.38	62.34	64.25	20.69	21.41	11.46	13.75
S_9 Rice-maize (cob)+veg pea (1:1)-cowpea fodder	350	360	14.31	15.31	59.44	62.34	21.02	20.99	11.43	13.48
S_{10} Rice-potato-green gram	382	391	14.81	15.44	64.25	66.34	20.78	21.27	11.64	13.85
SE ±	23.07	16.16	0.71	0.49	2.68	2.08	0.32	0.35	0.59	0.58
CD (P = 0.05)	NS	46.91	NS	1.43	7.78	6.03	NS	NS	NS	1.68

Table 3. Effect of different crop sequences on grain and straw yield and harvest index of rice.

Crop sequence	Grain yield (q/ha)		Straw yield (q/ha)		Harvest index	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003.04
S_1 Rice-wheat	36.02	40.11	51.82	53.47	41.00	42.87
S_2 Rice-chickpea	36.37	41.23	53.04	57.55	40.63	41.76
S_3 Rice-wheat-green gram	37.33	44.62	53.99	59.73	40.97	42.79
S_4 Rice-wheat-*Sesbania*	38.37	45.92	54.26	62.07	41.44	42.50
S_5 Rice-mustard-greengram	38.54	42.55	55.38	58.33	41.02	42.21
S_6 Rice-lentil-cowpea fodder	39.24	43.40	56.25	57.12	41.10	43.16
S_7 Rice-pea	37.50	42.71	53.56	55.90	41.25	43.31
S_8 Rice-lentil-mustard (3:1)-cowpea fodder	37.59	45.49	54.86	54.95	40.66	45.29
S_9 Rice-maize (cob) + veg pea (1:1-cowpea fodder	38.28	45.31	54.43	56.34	41.31	44.60
S_{10} Rice-potato-green gram	38.46	45.33	55.30	56.08	41.10	44.68
SE ±	1.19	1.32	1.78	1.85	1.13	0.68
CD (P = 0.05)	NS	3.83	NS	5.38	NS	1.97

cob) + veg. pea (1:1)-cowpea fodder (S_9) and rice-potato-green gram (S_{10}) were tested in randomized block design with four replications. The gross plot size was 7 m × 6 m with one meter plot border. With a view to avoid the mixing of soil in different treatments, individual plots were thoroughly prepared by power tiller in each season. Cultivation practices were followed based on local recommendation for each crop. *Sesbania aculeata* as green manure and green gram after last picking were cut from the ground level and green biomass so obtained was incorporated *in situ.* The cowpea for green fodder was harvested from the ground level at 60 days stage. The rest of the crop was harvested at maturity. However, harvesting of maize for green cobs and vegetable pea was done at proper stage. The weather condition during the two year trials was congenial for growth and development of crops. During rice growing season of 2002-03, 577.1 mm rain was received but in 2003-04, the rain recorded was 665.5 mm. To find out the effect of component crops in different sequences on rice, growth attributes at harvest, yield contributing characters and yield of rice and nutrient uptake by rice were recorded.

Results and Discussion

Growth Attributes

Rice grown in different crop sequences showed marked variations in growth attributes at maturity (Table 1). However, the significant differences in plant height (cm), number of tiller/hill, and dry matter production (g/hill) were recorded only during 2003-04. The sequences involving *Sesbania* as green manure, dual purpose green gram or cowpea fodder recorded higher plant height (cm), number of tiller/hill, number of green leaf/hill and dry matter production (g/hill).

As compared to rice-wheat sequence, taller plants of rice were recorded in all the other sequences. However, differences were significant only with respect to rice-wheat-*Sesbania* (G.M.), rice-lentil + mustard (3:1)-cowpea fodder, rice-maize (green cob) + veg. pea (1:1)-cowpea fodder and rice-potato-green gram sequences during 2003-04. As regard the number of tiller/hill and dry matter production (g/hill), crop sequences viz. S_3, S_4, S_8, S_9 and S_{10} though remained comparable recorded significantly higher values than rice-wheat sequrence (S_1) during second year of experiment. Similar trend was observed for green leaf/hill during both the years. These data indicate the advantage of summer legume or *Sesbania* for green manuring. The green manure or summer legume crops improved the organic carbon and available nitrogen of soil (data not reported). Nitrogen is a major constituent of protein and vitally associated with the activity of every living cell. Thus under higher nitrogen availability, there was vigorous growth of arial organs due to high rate of synthesis of protoplasmic protein. These results are in conformity with the findings of Sharma et al. (5). Singh and Sharma (6) reported maximum growth attributes of rice in wheat-mung bean (green manure)-rice sequence.

Table 4. Effect of different crop sequences on nutrient uptake (kg/ha) by rice.

Crop sequence	Nitrogen		Phosphorus		Potassium	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
S_1 Rice-wheat	75.99	81.05	12.14	12.94	88.4	91.0
S_2 Rice-chickpea	78.96	87.91	12.67	14.13	92.0	103.7
S_3 Rice-wheat-green gram	81.70	95.06	13.24	15.45	98.3	114.8
S_4 Rice-wheat-*Sesbania*	85.30	100.66	14.29	16.80	111.4	127.8
S_5 Rice-mustard-greengram	84.60	91.77	13.78	14.91	105.9	114.0
S_6 Rice-lentil-cowpea fodder	88.61	94.82	14.71	15.60	116.1	119.3
S_7 Rice-pea	80.66	89.11	12.91	14.08	96.7	102.2
S_8 Rice-lentil+mustard (3:1)-cowpea fodder	83.13	94.43	13.80	15.49	109.5	112.9
S_9 Rice-maize (cob)+veg pea (1:1)-cowpea fodder	84.51	95.10	13.98	15.57	110.3	116.1
S_{10} Rice-potato-green gram	82.27	91.26	13.45	15.02	95.1	100.7
SE ±	2.20	2.45	0.54	0.41	4.85	3.66
CD (P = 0.05)	6.38	7.10	NS	1.19	14.08	10.62

Further, the differences in the growth attributing characters of rice in the sequences involving grain/fodder legume and *Sesbania* for green manuring was more conspicuous in 2003-04 that was actually the fourth year of the field experiment. This shows that it took at least four years to reflect the legume effect on rice by legume components in different rice-based crop sequences.

Yield Contributing Characters

The yield contributing characters of rice, viz. number of effective tiller (per m^2), number of panicle/hill, number of grain/panicle, test weight of 1000 grain and grain production (g/hill) are presented in Table 2. Like growth attributing characters, the various yield contributing characters of rice differed significantly during 2003-04 only except for test weight of rice, which remained non-significant during both the years. However, number of grain/panicle differed significantly during both the years of observation. The significant difference observed during second year, was actually the cumulative effect of component crops in different sequences after three years of experimentation. As compared to rice-wheat, sequences having summer green gram/cowpea fodder or *Sesbania* for green manuring viz. rice-wheat-green gram, rice-wheat-*Sesbania*, rice-mustard-green gram, rice-lentil-cowpea fodder, rice-lentil + mustard (3:1)-cowpea fodder, rice-maize (cob) + veg. pea (1:1)-cowpea fodder and rice-potato-green gram sequences resulted in higher number of effective tiller (per m^2), number of panicle/hill, number of grain/panicle, and grain production (g/hill). This might be due to inclusion of legume or intensification of rice-wheat system by summer legumes that might have improved the soil physical properties and nitrogen status of soil and resulted in better growth attributing characters and ultimately improved yield contributing characters of the rice. These results confirm the findings of Singh and Verma (7) and Singh and Sharma (6).

Rice Productivity

Marked variations in grain and straw yield of rice was also observed in different crop sequences (Table 3). Crop sequences involving summer grain/fodder legume or *Sesbania* for green manuring produced higher grain and straw yield than rice-wheat system. However, the differences were significant only during 2003-04. As the experiment was initiated in 2000-01, it took four years to become legume effect significant in terms of rice yield. The crop sequences, viz. rice-wheat-*Sesbania*, rice-lentil + mustard (3:1)-cowpea fodder, rice-potato-green gram, rice-maize (cob) + veg. pea (1:1)-cowpea fodder and rice-wheat-green gram though remained comparable among themselves produced significantly higher grain yield of rice than rice-wheat system. However, as regards the straw yield, only rice-wheat-*Sesbania* (GM) and rice-wheat-green gram sequences could produce significantly higher straw yield of rice during 2003-04. These re-

sults are in close conformity with the finding of Singh and Sharma (6) and Sharma et al. (5).

Effect of crop sequences on harvest index of rice was conspicuous in 2003-04, during which rice-lentil-cowpea fodder, rice-pea, rice-lentil + mustard (3:1)-cow pea fodder, rice-maize (cob) + veg. pea (1:1)-cowpea fodder and rice-potato-green gram recorded higher harvest index of rice than rice-wheat sequence. However, the difference was significant only between rice-lentil + mustard (3:1)-cowpea fodder and rice-wheat. This shows that in rice-lentil + mustard (3:1)-cowpea fodder sequence involving two legume components, the assimilation of nitrogen was more efficient towards grain production of rice than rice-wheat sequence.

N, P and K Uptake by Rice

The N, P and K uptake by rice varied significantly due to rice grown in different crop sequence during both the years except for P uptake in first year (Table 4). The sequences involving summer green gram/cowpea fodder or *Sesbania* for green manuring with greater grain and straw yield resulted in significantly higher N, P and K uptake by rice crop. This could be attributed to the legume component in these sequences improving the nutrient status of the soil (data not reported), which resulted in higher nutrient content and yield of rice and finally more nutrient uptake. These observations are in close agreement with the findings of Singh et al. (8).

Therefore, the results of the experiment indicated that diversification of rice-wheat system through substitution of wheat by other crops and inclusion of summer grain/fodder legume or *Sesbania* for greeen manuring could be one of the possible ways to enhance the productivity of rice on sustainable basis.

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