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Effect of various rice-based cropping systems on system productivity, uptake, utilization and use efficiency of N, P and K

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ABSTRACT

A field experiment was conducted in Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar during wet, dry and summer seasons of 2006-07 and 2007-08 with an objective to study the effect of various rice-based cropping systems on system productivity, uptake, utilization and use efficiency of N, P and K. Rice-maize-okra system showed the highest system productivity of 25.91 t ha^{-1} yr. *The lowest system productivity (12.12 t ha^{-1} yr^{-1}) was with rice-groundnut-fallow system. Rice-maize-okra system removed the highest amount of N (293.5 kg ha^{-1}), P (62.1 kg ha^{-1}) and K (287.0 kg ha^{-1}) where as the lowest N, P and K uptake of 177.1, 41.0 and 201.3 kg ha^{-1} was in rice-radish-sesame, rice-groundnut-cucumber and rice-groundnut-fallow systems, respectively. The highest N harvest index was obtained in rice-french bean-sesame system (90.17 %) where as rice-french bean-bitter gourd system had the highest P and K harvest index of 95.45 and 92.52 per cent, respectively. The highest P uptake efficiency (1.49 kg uptake kg^{-1} added) was observed in rice-french bean-sesame system. Rice-tomato-cowpea had the highest N, P and K utilization efficiency with corresponding values of 105.64, 485.73 and 83.25 kg REY kg^{-1} uptake. This system was also best in respect of P and K use efficiency with 414.96 and 217.45 kg REY kg^{-1} added, respectively.*

Key words: *system productivity, rice equivalent yield, uptake, utilization and use efficiency*

The burgeoning population of India will demand 260 to 264 million tonnes of food grains by 2030 (Paroda, 2002), which have to be produced under shrinking natural resources. Future augmentation in food grain production has to be harnessed vertically through efficient cropping systems. Selection and sequencing of component crops in a cropping system is of paramount importance as it is influenced by several factors like soil, climate, available technologies, socio-economic constraints and available infrastructural facilities. Biological complexities and interactions in cropping systems can integrate the efficiencies resulting in increased productivity when appropriate crops are chosen (Francis, 1989). Crop sequencing can also accentuate synergistic interaction among the crops (Tanaka *et al*., 2005). Diversification of existing cropping patterns is needed to enhance the agricultural production with an ultimate aim of poverty alleviation, environment preservation and moreover, to meet the ever increasing demand for cereals, pulses, oil seeds, fibre, fodder and fuel (Newaj and Yadav, 1994). Thus promising cropping systems with respect to productivity and income have to be identified for varied farming situations of the country.

Eastern India comprising Odisha, West Bengal, Bihar and Assam accounts for 45 per cent of country's rice area and 37 per cent of total production. Hence, there is always scope for the rice-based cropping systems which are more productive as well as profitable in addition to the normal performance of rice. Hence, it is more judicious to study rice-based cropping systems suitable for this part of the country.

Inclusion of vegetables like okra, tomato and radish as well as leguminous vegetables like frenchbean and cowpea will increase the economic return from any cropping system. Legumes are known to increase the soil fertility through their capacity to fix atmospheric nitrogen and to improve nitrogen mineralization potential of soil. Other advantages due to inclusion of legumes in crop rotation are improvement in biological, physical and chemical properties of soil, soil conservation, increased soil mineral activity, organic matter restoration and pest and disease control (Parihar *et al*., 2003). Acreage and production of vegetables can be increased suitably through their inclusion in different cropping systems. Application of fertilizers to supply essential nutrients is another important component that has helped to increase the cropping intensity and to boost productivity.

Keeping these compounded problems in view, the present investigation was designed to identify the promising rice-based cropping systems with higher productivity and nutrient uptake pattern of each system.

MATERIALS AND METHODS

A field experiment was conducted in Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar during wet season, dry season and summer seasons of 2006-07 and 2007-08. The soil of the experimental site was sandy loam in texture with pH 6.34, organic carbon 0.53 %, EC 0.259 dS m^{-1} with available N, P_2O_5 and K_2O of 212 , 31.37 and 122.4 kg ha^{-1}, respectively. The experiment was laid out in RBD with three replications comprising of ten treatments viz., rice-maize-cowpea, rice-maize-okra, rice-mustard-okra, rice-mustard-cowpea, rice-frenchbean-bittergourd, rice-groundnut-cucumber, rice-groundnut-fallow, rice-tomato-cowpea, rice-radish-sesame and rice-french bean-sesame. The crop varieties used in the experiment were RGL 2538 (rice), Navjyoti (maize), Parbati (mustard), Selection 9 (French bean), Smruti (groundnut), BT 10 (tomato), Chetki long (radish), Utkala Manika (cowpea), BO 2 (okra), Nakhara improved (bitter gourd), Summer Queen (cucumber) and Uma (sesame). The net plot size was 6.5 m X 3.0 m. The crops were grown following the normal package of practices. Full dose of N was applied as basal to French bean, groundnut and cowpea. Two equal splits of N were applied as basal and top dressing to tomato, radish, bitter gourd, cucumber and sesame. Rest of the crops were applied with three splits of N. the sources of NPK were urea, SSP and MOP, respectively. Schedule of irrigation was given as per the requirement of the crops. Crops' saving against insect pest and diseases during the entire period of investigation through need based plant protection measures was attended to. Composite soil samples from 0 to 15 cm soil depth were collected from each treatment after harvest of each crop in both the years of the experimentation. Soil pH, EC, organic carbon and available N, P and K were determined

The observations for yield of component crops at harvest were recorded from the harvest area earmarked in each plot at the centre leaving the sampling area and border. The sun dried bundles of grain crops from the respective net plot were threshed using pedal operated thresher. The grains were cleaned, sun dried and weighed. The yield was reported in tonne per hectare. In case of maize, the number of cobs were counted and reported on per hectare basis. In case of french bean and cowpea, the fresh weight of pods were recorded and reported in kg $hectare^{-1}$. Similarly the fresh weight of bitter gourd, cucumber and okra was recorded and expressed in tonnes $hectare^{-1}$. The weight of the crop residue from each net plot was recorded after harvesting of maize, French bean, cowpea, okra, bitter gourd and cucumber and the threshing of rest of the crops. The weight of crop residue was recorded in kg $hectare^{-1}$. The value of the produce $hectare^{-1}$ of each crop was calculated as per the prevailing market price. It was divided by the value of rice $tonne^{-1}$ to get the rice equivalent yield in kg $hectare^{-1}$.

System productivity of different rice-based cropping systems was obtained by addition of rice-equivalent yields of component crops. Uptake of a particular nutrient by any crop was calculated by adding the uptake in its economic yield and crop residue, which were obtained by multiplying their content with corresponding yields. Uptake by a system was the addition of uptake by the component crops.

Nutrient harvest index is the uptake of a particular nutrient by economic part expressed as percentage of that by total biomass (Moll *et al*., 1982).

Nutrient harvest index (%) =

$$\frac{\text{Nutrient uptake in economic part (kg ha}^{-1}\text{)}}{\text{Total uptake (kg ha}^{-1}\text{)}} \times 100$$

Nutrient uptake efficiency was calculated as per the formula given by Moll *et al.* (1982).

Nutrient uptake efficiency (kg uptake kg^{-1} nutrient added through fertilizer) =

$$\frac{\text{Total uptake of a nutrient by a system (kg ha}^{-1}\text{)}}{\text{The fertilizer nutrient added to the system (kg ha}^{-1}\text{)}}$$

Nutrient utilization efficiency was calculated as per the formula given by Moll *et al*. (1982).

Nutrient utilization efficiency (kg REY/ kg nutrient uptake) =

$$\frac{\text{System productivity (kg REY ha}^{-1}\text{)}}{\text{Total uptake of a nutrient the system (kg ha}^{-1}\text{)}}$$

Nutrient use efficiency (NUE) was calculated as per the formula given by Moll *et al*. (1982).

Nutrient use efficiency (kg REY/ kg nutrient added through fertilizer)=

$$\frac{\text{System productivity (kg REY ha}^{-1}\text{)}}{\text{Total addition of a fertilizer nutrient to the system (kg ha}^{-1}\text{)}}$$

RESULTS AND DISCUSSION

Maximum grain yield of rice was recorded to the tune of 4.45 t ha^{-1} under rice-tomato-cowpea system (Table 1). It was closely followed by rice-frenchbean-sesame system (4.39 t ha^{-1}). However, the grain yield of rice produced under different rice-based cropping systems ranged between 4.25 to 4.45 t ha^{-1}. In rice-tomato-cowpea system, cowpea is a legume as summer crop preceding to wet season rice. Legumes are known as soil replenishing crops and that could be the reason for high grain yield of succeeding rice crop. Quayyam and Maniruzzaman (1996) have also reported favourable impact of legumes on yield and yield attributes of succeeding rice crop. As regards to straw yield, rice-mustard-cowpea cropping system produced maximum straw yield of rice (6.53 t ha^{-1}) followed by rice-tomato-cowpea (6.50 t ha^{-1}) and rice-groundnut-cucumber (6.43 t ha^{-1}). However, rice-maize-cowpea system registered the lowest straw yield of rice (6.25 t ha^{-1}). Similar observations were recorded by Quayyam and Maniruzzaman (1996). As regards to REY of dry season crops, tomato produced the maximum REY (10.18 t ha^{-1}) in rice-tomato-cowpea system closely followed by maize with REY of 10.01 and 10.08 t ha^{-1} in rice-maize-cowpea and rice-maize-okra systems, respectively. On the other hand mustard produced the lowest REY of 3.44 and 3.50 t ha^{-1} in rice-mustard-okra and rice-mustard-cowpea systems, respectively.

In summer season, maximum REY was registered by okra with a value of 11.21 t ha^{-1} in rice-mustard-okra followed by the same crop in rice-maize-okra (10.91 t ha^{-1}) system. Sesame produced the minimum REY of 2.80 and 2.96 t ha^{-1} in rice-radish-sesame and rice-french bean-sesame cropping systems, respectively. Total productivity of any cropping system depends upon the productivity and market price of component crops. Yield of component crops under the present investigation varied with the system. In dry season crops, maize yield (REY) was higher in rice-maize-okra than in rice-maize-cowpea system (Table1). Mustard yield was more in rice-mustard-cowpea than rice-mustard-okra system. REY of French bean was higher in rice-french bean-bitter gourd than rice-french bean-sesame system.

Among the summer season crops, the REY of cowpea was more in rice-mustard-cowpea than rice-tomato-cowpea and rice-maize-cowpea systems. Again sesame REY was higher in rice-french bean-sesame in comparison to rice-radish-sesame system. This type of variation in yield of crops can only be explained by the fact that the biological and environmental complexities and interactions in cropping systems could have modified the plant capacities to express itself in the systems (Francis, 1989).

Differences in system productivity due to various rice-based cropping systems were found significant in pooled data. Rice-maize-okra system recorded the highest system productivity of 25.91 t ha^{-1} yr^{-1} which was significantly superior to other rice-based cropping systems. Rice-tomato-cowpea was the second best system with productivity of 19.93 t ha^{-1} yr^{-1} followed by rice-mustard-okra (19.64 t ha yr^{-1}). The other systems in order were rice-maize-cowpea (19.41 t/ha/yr) and rice-groundnut-cucumber (19.27 t ha^{-1}yr^{-1}). The contribution of winter crops to REY of rice-maize-okra, rice-tomato-cowpea, and rice-maize-cowpea was 38.9, 51.1 and 51.6 per cent, respectively (Table 1). Similarly the contribution of summer crops to REY of rice-groundnut-cucumber, rice-mustard-cowpea, rice-maize-okra and rice-mustard-okra was 37.0, 37.1, 42.1 and 57.1 per cent, respectively. Other crops remaining same, inclusion of cowpea and okra as vegetable crops increased the productivity of the systems. Lowest system productivity of 12.12 t ha^{-1} yr^{-1} was observed in rice-groundnut-fallow system.

Data on N, P and K uptake in economic yield and crop residue rice, dry season and summer crops alone and in system are depicted in Fig 1. Differences in N, P and K uptake by economic yield and crop residue due to various rice-based cropping systems were found significant in pooled data. As a system rice-maize-okra registered the highest N uptake of 293.5 kg ha^{-1} in pooled data which established significant superiority over the cropping systems studied. This can be explained through the highest system productivity resulting greater N uptake in the same system.

Bastia *et al*. (2008) have also reported maximum N uptake in rice-based cropping systems with maize and cowpea as component crops in Odisha. This was closely followed by rice-maize-cowpea system having registered N uptake of 284.1 kg ha^{-1} (pooled data). However, it was clearly indicated from the pooled data that the lowest N uptake of 177.1 kg ha^{-1} was observed in rice-radish-sesame system (Fig 1a).

As regards to P uptake it was clearly indicated from the pooled data that rice-maize-okra system registered the highest P uptake of 62.1 kg ha^{-1} which established significant superiority over the cropping systems investigated. This could be attributed to higher P uptake by rice, maize and okra crops combinedly. However, the lowest P uptake of 35.5 kg ha^{-1} was obtained in rice-groundnut-fallow system (Fig.1b).

Rice-maize-okra system recorded the highest total K uptake as indicated from pooled data (287.0 kg ha^{-1}) which was significantly superior over rest of cropping systems studied. Similar findings have been observed by Rossiter (1947). He was of the opinion that cereals and grasses having low root exchange capacity utilize more K from exchange complex than other crops. Deka and Singh (1984) also observed higher K uptake by maize crop. This was followed by rice-maize-cowpea and rice-mustard-okra system. However, the lowest total K uptake was obtained in rice-radish-sesame during 2006-07 (201.3 kg ha^{-1}) while rice-groundnut-fallow recorded the lowest total K uptake of 197.1 and 201.3 kg ha^{-1} in 2007-08 and pooled data, respectively (Fig.1c).

Pooled data with respect to N harvest index, uptake, utilization and use efficiency indicated that maximum N harvest index was obtained in rice-french bean-sesame system (90.17 %) followed by rice-french bean-bitter gourd system (90.13%). This can be attributed to the wider differences in N uptake between economic yield and crop residue of both french bean and sesame crops. The values were 52.4 to 54.0 kg ha^{-1} in green pod and 4.7 to 5.9 kg ha^{-1} in crop residue of frenchbean and 35.4 to 37.4 kg ha^{-1} in grain and 11.4 kg ha^{-1} in crop residue of sesame. Similarly, those of bitter gourd were in the range of 53.6 to 64.3 kg ha^{-1} in fruits and 4.4 to 5.0 kg ha^{-1} in by-product, respectively (Table 4). As regards to N uptake efficiency six out of ten cropping systems removed more N than the N added. However, maximum N uptake efficiency was expressed in rice-groundnut-fallow system (1.88 kg N uptake kg^{-1} N added) followed by rice-maize-cowpea (1.24 kg N uptake kg^{-1} N added). Both the systems

Table 1. Rice equivalent yield, system productivity and production efficiency of various rice-based cropping systems

Treatments	Rice yield (t ha^{-1})		REY (t ha^{-1})		System productivity	Production efficiency
	Grain	Straw	Dry season	Summer	(t ha^{-1} yr^{-1})	(kg^{-1} ha^{-1} day^{-1})
Rice-Maize-Cowpea	4.32	6.25	10.01	4.41	19.41	69.85
Rice-Maize-Okra	4.25	6.27	10.08	10.92	25.91	85.65
Rice-Mustard-Okra	4.32	6.35	3.44	11.20	19.64	65.26
Rice-Mustard-Cowpea	4.36	6.53	3.50	5.14	13.66	49.42
Rice-Frenchbean-Bitter gourd	4.36	6.22	6.50	4.13	15.69	57.17
Rice-Groundnut-Cucumber	4.35	6.43	7.15	7.13	19.27	57.70
Rice-Groundnut-Fallow	4.37	6.30	7.04	0.00	12.12	47.64
Rice-Tomato-Cowpea	4.45	6.50	10.18	4.60	19.93	66.11
Rice-Radish-Sesame	4.30	6.39	6.20	2.80	13.99	51.44
Rice-Frenchbean-Sesame	4.39	6.35	5.87	2.96	13.90	50.09
SEm(±)					0.09	0.32
CD(P=0.05)					0.25	0.90

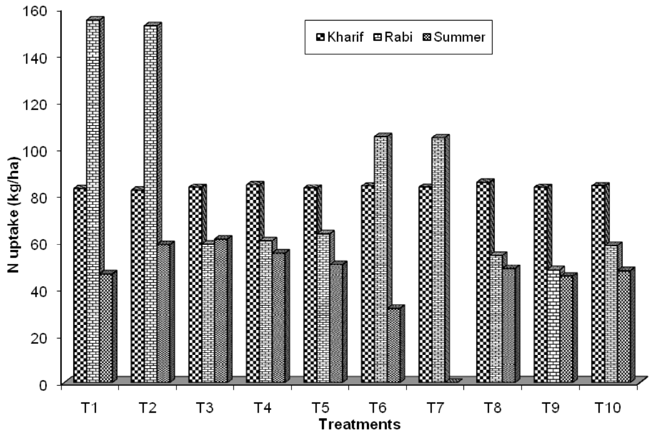

Fig. 1(a)

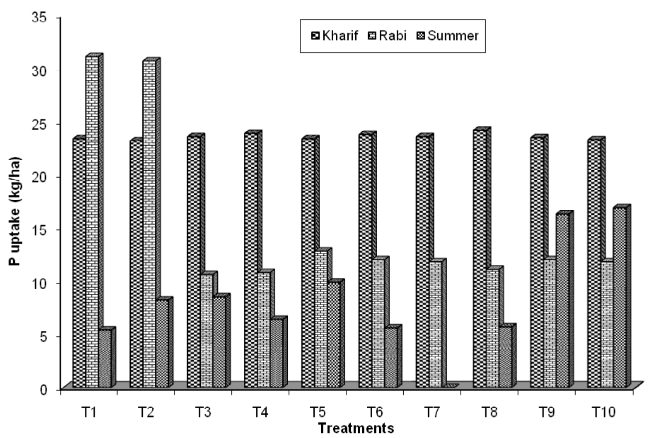

Fig. 1(b)

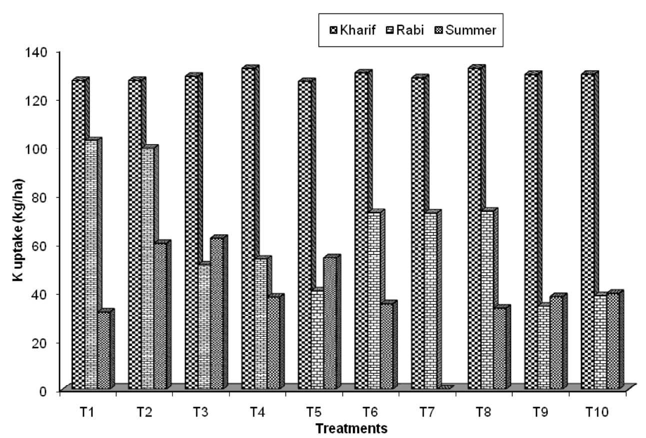

Fig. 1(c)

Fig 1. Effect of rice-based cropping systems on uptake of N, P and K by economic yield and crop residue of component crops and cropping systems

T_1: rice-maize-cowpea, T_2 : rice-maize-okra, T_3 : rice-mustard-okra, T_4:rice-mustard-cowpea, T_5: rice-frenchbean-bittergourd, T_6 : rice-groundnut-cucumber, T_7 : rice-groundnut-fallow, T_8 : rice-tomato-cowpea, T_9 : rice-radish-sesame, T_{10}: rice-french bean-sesame

had legume crops which required less added N fertilizer owing to their N-fixing ability. That might be the possible reason for higher N uptake as well as use efficiency of the system. Rice-tomato-cowpea system expressed maximum N utilization efficiency of 105.64 kg REY kg^{-1} N uptake followed by rice-groundnut-cucumber system. But rice-groundnut-fallow system registered maximum N use efficiency of 121.24 kg REY kg^{-1} N added followed by rice-groundnut-cucumber system (107.07 kg REY kg^{-1} N added). However, the lowest N utilization efficiency was recorded in rice-groundnut-fallow system (64.38 kg REY kg^{-1} N uptake).

Pooled data indicated that rice-frenchbean-bittergourd system registered maximum P harvest index (95.45 %) followed by rice-mustard-cowpea (93.50 %) while the lowest value of 78.51 % was in rice-radish-sesame system (Table 3). Highest P harvest index in rice-frenchbean-bitter gourd system was mainly due to wider difference of P uptake in economic yield and crop residue of frenchbean and bitter gourd. On the contrary, there was very narrow difference of P uptake in the economic yield and crop residue of sesame 54.0 kg ha^{-1} in green pod and 4.7 to 5.9 kg ha^{-1} in crop residue of frenchbean and 35.4 to 37.4 kg ha^{-1} in grain and 11.4 kg ha^{-1} in crop residue of sesame. Similarly, those of bitter gourd were in the range of 53.6 to 64.3 kg ha^{-1} in fruits and 4.4 to 5.0 kg ha^{-1} in by-product, respectively (Table 3). As regards to N uptake efficiency six out of ten cropping systems removed more N than the N added. However, maximum N uptake efficiency was expressed in rice-groundnut-fallow system (1.88 kg N uptake kg^{-1} N added) followed by rice-maize-cowpea. Both the systems had legume crops which required less added N fertilizer owing to their N-fixing ability. Rice-tomato-cowpea system expressed maximum N utilization efficiency of 105.64 kg REY kg^{-1} N uptake followed by rice-groundnut-cucumber system. This was because of its higher REY and total N uptake. But rice-groundnut-fallow system registered maximum N use efficiency added followed by rice-groundnut-cucumber system. However, the lowest N utilization efficiency was recorded in rice-groundnut-fallow system.

Pooled data indicated that rice-frenchbean-bittergourd system registered maximum P harvest index (95.45 %) followed by rice-mustard-cowpea (93.50 %) and rice-mustard-okra (92.35 %) while the lowest value of 78.51 % was in rice-radish-sesame system (Table 3). Highest P harvest index in rice-frenchbean-bitter gourd

Table 2. Effect of different rice-based cropping systems on nitrogen harvest index and its uptake, utilization and use efficiency

Treatments	REY (kg ha^{-1} yr^{-1})	N added (kg ha^{-1} yr^{-1})	Total N uptake (kg ha^{-1} yr^{-1})	N uptake in economic yield (kg ha^{-1} yr^{-1})	N harvest index (%)	N uptake efficiency (kg uptake kg^{-1} added)	N utilization efficiency (kg REY kg^{-1} added)	N use efficiency (kg REY kg^{-1}added)
Rice-Maize-Cowpea	19413	230	284	208.4	73.35	1.24	68.34	84.41
Rice-Maize-Okra	23726	280	294	213.9	72.87	1.05	80.84	84.73
Rice-Mustard-Okra	17413	220	204	171.8	84.36	0.93	85.49	79.15
Rice-Mustard-Cowpea	13657	170	200	173.7	86.66	1.18	68.14	80.33
Rice-Frenchbean-Bitter gourd	14664	200	197	177.7	90.13	0.99	74.40	73.32
Rice-Groundnut-Cucumber	19273	180	221	159.2	72.08	1.23	87.23	107.07
Rice-Groundnut-fallow	12124	100	188	139.5	74.09	1.88	64.38	121.24
Rice-Tomato-Cowpea	19933	190	189	159.3	84.41	0.99	105.64	104.91
Rice-Radish-Sesame	13991	200	177	154.4	87.20	0.89	79.02	69.96
Rice-Frenchbean-Sesame	13476	160	190	171.7	90.17	1.19	70.79	84.23

system was mainly due to wider difference of P uptake in economic yield and crop residue of frenchbean and bitter gourd. On the contrary, very narrow difference of P uptake in the economic yield and crop residue of sesame was resulted in low P harvest index with rice-radish-sesame system.

Pooled data also indicated that five out of ten cropping systems removed more P than what added. However, maximum P uptake efficiency was observed in rice-french bean-sesame system (1.49 kg P uptake kg^{-1} P added) followed by rice-radish-sesame system. This could be due to having one legume crop in all the five cropping systems exhibiting efficient P utilization than other group of crops. Rice-tomato-cowpea registered maximum P utilization and use efficiency. This could be attributed to higher REY of above system. The lowest P use efficiency was obtained in rice-french bean-bitter gourd system.

Rice-french bean-bitter gourd system registered maximum K harvest index (92.52 %) and minimum K uptake efficiency (2.22 kg K uptake kg^{-1} K added) and minimum K use efficiency (Table 4). Potassium harvest index was in the range of 71.21 to 92.52 per cent in different rice-based cropping systems (Table 4). Potassium uptake in the economic yield of French bean (28.6 to 34.3 kg ha^{-1}) and bitter gourd

Table 3. Effect of different rice-based cropping systems on phosphorus harvest index and its uptake, utilization and use efficiency

Treatments	REY (kg ha^{-1} yr^{-1})	P added (kg ha^{-1} yr^{-1})	Total P uptake (kg ha^{-1} yr^{-1})	P uptake in economic yield (kg ha^{-1} yr^{-1})	P harvest index (%)	P uptake efficiency (kg uptake kg^{-1} added)	P utilization efficiency (kg REY kg^{-1} added)	P use efficiency (kg REY kg^{-1}added)
Rice-Maize-Cowpea	19413	57	60	47.9	79.88	1.06	324.00	341.97
Rice-Maize-Okra	23726	61	62	49.7	80.14	1.02	382.20	388.08
Rice-Mustard-Okra	17413	48	43	39.3	92.35	0.89	408.71	362.51
Rice-Mustard-Cowpea	13657	44	41	38.5	93.50	0.94	331.63	312.74
Rice-Frenchbean-Bitter gourd	14664	52	46	44.0	95.45	0.88	317.79	279.84
Rice-Groundnut-Cucumber	19273	52	41	36.5	88.47	0.79	466.89	367.78
Rice-Groundnut-fallow	12124	35	35	32.3	90.98	1.01	341.94	347.06
Rice-Tomato-Cowpea	19933	48	41	36.3	88.43	0.85	485.73	414.96
Rice-Radish-Sesame	13991	44	52	40.7	78.51	1.19	269.71	320.40
Rice-Frenchbean-Sesame	13476	44	65	55.1	84.89	1.49	207.68	308.61

Table 4. Effect of different rice-based cropping systems on potassium harvest index and its uptake, utilization and use efficiency

Treatments	REY (kg ha^{-1} yr^{-1})	K added (kg ha^{-1} yr^{-1})	Total K uptake	K uptake in economic yield (kg ha^{-1} yr^{-1})	K harvest index (%)	K uptake efficiency (kg uptake/ kg added)	K utilization efficiency (kg REY/ kg uptake)	K use efficiency (kg REY/ kg added)
Rice-Maize-Cowpea	19413	108	262	186.5	71.21	2.42	74.14	179.20
Rice-Maize-Okra	23726	117	287	206.9	72.09	2.46	82.65	203.36
Rice-Mustard-Okra	17413	92	243	190.3	78.39	2.65	71.73	189.96
Rice-Mustard-Cowpea	13657	83	224	176.6	78.85	2.69	60.98	163.88
Rice-Frenchbean-Bitter gourd	14664	100	222	205.1	92.52	2.22	66.15	146.64
Rice-Groundnut-Cucumber	19273	100	239	186.4	78.06	2.39	80.73	192.73
Rice-Groundnut-fallow	12124	67	201	161.6	80.27	3.02	60.24	181.86
Rice-Tomato-Cowpea	19933	92	239	187.3	78.23	2.61	83.25	217.45
Rice-Radish-Sesame	13991	83	202	161.6	79.89	2.43	69.16	167.89
Rice-Frenchbean-Sesame	13476	83	207	167.0	80.50	2.49	64.96	161.72

(46.3 to 47.0 kg ha^{-1}) was much more than that of crop residue (8.4 to 9.6 kg ha^{-1} in french bean and 7.2 to 8.0 kg ha^{-1} in bitter gourd) exhibiting maximum K harvest index in rice-french bean-bitter gourd (Fig 1 and Table 4). As regards to K uptake efficiency all the ten cropping systems removed more K than what added. Rice-groundnut-fallow expressed maximum K uptake efficiency (3.02 kg K uptake kg^{-1} K added). This was because of more uptake of K by rice and groundnut crops in comparison to addition of K through fertilizer. Rice-tomato-cowpea system registered maximum K utilization and use efficiency.

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