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Research Paper

Balanced fertilization in rice (*Oryza sativa*)–groundnut (*Arachis hypogaea*) cropping system

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ABSTRACT

A field experiment was conducted in farmers' field of Angul district under mid-central table land zone of Odisha by involving 48 farmers during 2013–15, to study the response of rice (*Oryza sativa* L.)–groundnut (*Arachis hypogaea* L.) cropping system to balanced nutrient application. The highest system rice-equivalent yield (REY) (10.78 t/ha) was recorded with the recommended doses of nitrogen, phosphorus and potassium (N, P and K @ 80, 17.5 and 33 kg) + 25 kg $ZnSO_4$/ha to rice and recommended doses of N, P and K @ (40, 17.5 and 33 kg/ha) + 250 kg $CaSO_4$/ha to groundnut followed by recommended NPK alone without $ZnSO_4$/$CaSO_4$ (10.36 t/ha). The average increase in system REY of these 2 treatments was 73 and 66% over the control (6.23 t/ha) and 25 and 20% over the farmers' practice (8.63 t/ha). Agronomic efficiency (AE) of N, P and K was 19.8, 29.0 and 17.2 kg REY/kg applied nutrient for rice–groundnut system. The agronomic efficiency of N increased by 49, 55 and 108% in rice–groundnut system by applying the recommended quantity of N with recommended quantity of P, K and PK, respectively, instead of N alone. The AE of P and K increased by 40 and 34% in rice–groundnut system when the recommended quantity of P or K was applied with recommended quantity of NK or NP instead of with N alone. Application of NPK + $ZnSO_4$ to rice and NPK + $CaSO_4$ to succeeding groundnut recorded the highest system net returns (₹63,123/ha) followed by application of recommended NPK to both the crops (₹60,509/ha). These 2 treatments also recorded higher nutrient uptake due to the high biomass production with application of balanced nutrients.

Key words: Agronomic efficiency, Balanced fertilization, Nutrient uptake, Rice–groundnut system

Cereal production in the country increased 5 fold, while fertilizer consumption increased 322 times during the 1950–51 to 2007–08 period, implying a very low fertilizer-use efficiency (Rajendra Prasad, 2009). Large scale applications of fertilizer nitrogen have also shown deleterious effects on groundwater quality, especially its nitrate content, which is harmful to health. Furthermore, gaseous losses of N as NH_3 and NO_2 resulting from N fertilization have adverse effects on the environment (Ravisankar *et al*., 2014). In addition to nitrogen, phosphorus and potassium are 2 other macro-nutrients required by the cereal-based systems. Phosphorus and potassium deficiencies are becoming widespread in areas not previously considered to be deficient. These deficiencies are mainly due to the increase in cropping intensity coupled with emphasis on nitrogen rather than a balanced application of all macronutrients required for sustaining soil fertility. The result of unbalanced application of fertilizers leads decline in the efficiency of fertilizers.

Rice–groundnut is the predominant cropping system in mid-central table 1 and zone of Odisha, covering about 10,830 ha area with an average rice-equivalent system yield of 8.1 t/ha (Government of Odisha, 2015). Rice crop is popular in Odisha owing to its versatile characteristics of suitability and adaptability. Groundnut is preferred after harvesting of rice, as the crop meets the demand for vegetable oil and fortifies soil through biological nitrogen fixation which is economically sound and environmentally acceptable, thereby sustaining the productivity of the cropping system. However, the productivity of both rice and groundnut of Odisha are lower than national productivity, and it might be due to low and imbalanced applications of nutrients. The success of any cropping system depends upon the appropriate management of resources including

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balanced use of manures and fertilizers. It is often reported that, even the best performing farms of the farmers cannot match the yields the researchers get at on-stations. With this background, the present investigation was carried out rice–groundnut cropping system to identify the production potential, profitability and agronomic efficiency of applied nutrients from balanced fertilization in farmers' field.

MATERIALS AND METHODS

The field experiment was conducted on 24 farmers' field of Chhendipada (Koshala, Machakutta and Handiguda villages) and Kishorenagar (Jamunali, Gulasar and Madhupur villages) blocks of Angul district of Odisha adopted by All India Coordinated Research Project on Integrated Farming Systems, Odisha University of Agriculture and Technology, Bhubaneswar during 2013–14. The same experiment was repeated in another 24 farmers' field in the same villages during 2014–15. Four farmers were selected from each village during both the years. All the households selected were either marginal or small farmers. Angul and neighbouring Dhenkanal districts come under mid-central table land zone. The soils were characterized as sandy loam with average *p*H 6.0, electrical conductivity 0.29 dS/m, organic carbon 0.59%, available N 274 kg/ha, P 15 kg/ha, available K 153 kg/ha. The details of soil characteristics before planting of rainy season (*kharif*) crop are furnished in Table 1. The annual rainfall of 1,493 and 1,381 cm was received during 2013–14 and 2014–15, respectively.

The experiment comprised of 7 treatments, viz. control (no fertilizer), recommended N, NP, NK, NPK, NPK + $ZnSO_4$/$CaSO_4$ ($ZnSO_4$ @ 25 kg/ha to rice and $CaSO_4$ @250 kg/ha to groundnut) applied to rice and groundnut in sequence and farmers' practice. The recommended dose of N, P and K were 80, 17.5 and 33 kg/ha for rice and 20, 17.5 and 33 kg/ha for groundnut respectively. In farmers' practice 50, 8.8 and 16.5 kg N, P and K were applied to rice whereas groundnut received only N and P @ 10 and 11 kg/ha respectively. Recommended doses of N, P and K were applied to the crops through urea, single superphosphate and muriate of potash respectively. Zinc (Zn) and calcium (Ca) content in $ZnSO_4$ and $CaSO_4$ were 24 and 21% respectively. The recommended packages of practices were applied in each crop. Rice was grown rainfed and groundnut was raised as an irrigated crop. Farmers' preferred varieties, i.e. 'Naveen' for rice and 'Kadiri 6' for groundnut were taken. All the 7 treatments were allotted in a single block in each of the farmers' field. The area of each treatment at every farmer's plot was 100 m^2. The experiment was laid out in a randomized block design taking each farmer as a replication.

Agronomic efficiency (AE) of N, P and K in rice and groundnut was calculated by using the following formula: Formula:

$$[AE_N = (Y_N - Y_0)/N;\ AE_P = (Y_{NPK} - Y_{NK} + Y_{NP} - Y_N)/2P \text{ and } AE_K = (Y_{NPK} - Y_{NP} + Y_{NK} - Y_N)/2K]$$

where, AE_N, AE_P and AE_K are agronomic efficiency of N, P and K (kg grain or pod/kg N, P or K applied) respectively; Y_0, Y_N, Y_{NP}, Y_{NK} and Y_{NPK} are rice grain or groundnut pod yield under control, N, NP, NK and NPK-treated plots respectively (kg/ha); and N, P and K are the amount of nutrient N, P and K applied (kg/ha) respectively.

The economics (cost of cultivation and gross return) and the rice-equivalent yield of the system for all treatments were computed by using the minimum support price for economic products and prevailing market price for by-products during the year. Benefit: cost ratio of a system was expressed as gross returns per rupee invested. Soil samples were drawn at initial and at the end of cropping cycle for both the years from a depth of 0–15 cm from each treatment and soil organic carbon, N, P and K contents were analysed using standard procedures (Jackson, 1973). Statistical analyses were done using standard methodology of randomized block design.

RESULTS AND DISCUSSION

Crop and system yields

Application of the recommended dose of NPK along with $ZnSO_4$ to rice and gypsum ($CaSO_4$) to groundnut recorded significantly higher grain yield of rice and pod yield of groundnut than the recommended dose of NPK or any other combination of N, P and K during both the years (Table 2). The mean increase in grain yield of rice owing to application of the recommended doses of NPK along with $ZnSO_4$ was 80, 27, 19, 14, 3 and 20% higher over the control, N, NP, NK, NPK and farmers' practice respectively. Similarly in succeeding groundnut, the increase in pod yield with NPK along with $CaSO_4$ was to the tune of 69, 34, 16, 17, 5 and 29% over the control, N, NP, NK, NPK and farmers' practice, respectively. Similar trends were also observed in rice straw and groundnut haulm yields.

The rice–groundnut system responded positively with the application of recommended quantity of N, P and K (Table 2). Application of recommended quantity of macronutrients to rice–groundnut system along with $ZnSO_4$ to rice and $CaSO_4$ to groundnut recorded the highest rice-equivalent system yield (10.78 t/ha), the increases being 73, 25 and 4% over the control, farmers' practice and NPK respectively. The next best treatment was NPK and the rice-equivalent system yield was 66 and 20% higher over the control and farmers' practice respectively. The increase in system yield owing to application of NP or NK was found to be 47 and 49%, respectively, over the control. The better yield observed in balanced application of NPK may be attributed to involvement of P in better root development and subsequent absorption of N, while K is involved in N metabolism. Ravisankar *et al*. (2014), Hiremath *et al.* (2016) and Ray *et al.* (2017) also reported balanced NPK fertilization is essential in crops to achieve the targeted yield.

Agronomic efficiency of nutrients

The agronomic efficiency of N, P and K was 12.4, 18.0 and 14.5 kg grain/kg applied nutrient for rice, 15.5, 12.5 and 6.2 kg pod/kg applied nutrient for groundnut and 19.8, 29.0 and 17.2 kg REY/kg applied nutrient for rice–groundnut system respectively (Table 3). Farmers, specially the marginal and small farmers, generally, tend to apply only N. However, the AE_N of applied N can be largely increased by adequate P and K fertilization (Ravisankar *et al*., 2014). Agronomic efficiency of N increased by 25, 41 and 80% in rice by applying the recommended quantity of N with recommended quantity of P, K and PK, respectively, instead of N alone. Similarly, the respective increases were 74, 69 and 108% in case of groundnut and 49, 55 and 108% in case of rice–groundnut system.

Agronomic efficiency of P increased by 45% in rice when the recommended quantity of P was applied with recommended quantity of NK instead of with N only. The respective increase was 36 and 40% in case of groundnut and rice–groundnut system. Similarly, agronomic efficiency of K increased by 28, 40 and 34% in rice, groundnut and rice–groundnut system respectively, when the recommended quantity of K was applied with recommended quantity of NP instead of with N alone. Similar results with cereal-based cropping systems were also reported by Singh *et al*. (2017), Chandrakar *et al*. (2017) and Mahto *et al*. (2017).

Economic analysis

Application of NPK + $ZnSO_4$ to rice and NPK + $CaSO_4$ to succeeding groundnut exhibited the highest system cost of cultivation (Table 2). The highest net returns were also

Table 1. Initial physico-chemical properties of soil (data collected from 24 sites)

Parameter	2013–14			2014–15		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
*p*H	6.2	5.8	6.0	6.7	5.8	6.1
Electrical conductivity (dS/m)	0.36	0.24	0.29	0.32	0.25	0.29
Organic carbon (%)	0.61	0.55	0.58	0.69	0.53	0.61
Available N (kg/ha)	296	232	267	309	242	280
Available P (kg/ha)	17.2	13.0	14.7	18.9	12.8	16.2
Available K (kg/ha)	168	125	144	195	138	162

Table 2. Productivity and economics of rice–groundnut system under researcher designed and farmer managed experiments (mean of 2 years data)

Treatment	Productivity (t/ha)				System	Economics (× 10^3 ₹/ha)		Cost:
	Rice		Groundnut			Cost of	Net	
	Grain	Straw	Pod	Haulm	REY	cultivation	return	benefit ratio
Control	2.40	2.86	1.20	1.93	6.23	65.81	14.81	1.22
N	3.39	3.96	1.51	2.54	8.21	67.10	39.36	1.59
NP	3.64	4.20	1.74	2.82	9.19	71.30	47.65	1.67
NK	3.80	4.39	1.72	2.88	9.31	69.47	51.13	1.74
NPK	4.19	4.71	1.93	3.09	10.36	73.67	60.51	1.82
*NPK+$ZnSO_4$/$CaSO_4$	4.33	4.80	2.02	3.23	10.78	76.42	63.12	1.83
FP	3.60	4.18	1.57	2.67	8.63	69.78	42.15	1.60
SEm±	0.02	0.03	0.02	0.02	0.04		0.51	
CD (P=0.05)	0.04	0.05	0.04	0.04	0.07		1.01	

REY, rice equivalent yield; FP, farmers' practice

Recommended dose of nutrients (N-P-K kg/ha): rice, 80-17.5-33; groundnut, 40-17.5-33; Farmers' practice (N-P-K kg/ha): rice, 50-8.8-16.5; groundnut, 10-11-0

*$ZnSO_4$ @ 25 kg/ha to rice and $CaSO_4$ @ 250 kg/ha to groundnut

Sale price (₹/t): paddy grain, 12,500; paddy straw, 1,000; groundnut pod, 40,000

Table 3. Agronomic efficiency of nutrients in rice–groundnut system under researcher designed and farmer managed experiments (mean of 2 years data)

Treatment	Rice (kg grain/kg nutrient)	Groundnut (kg pod/kg nutrient)	Rice–groundnut (kg REY/kg nutrient)
AE (N)			
N alone	12.42	15.45	19.84
With P	15.46	26.88	29.59
With K	17.51	26.13	30.75
With PK	22.35	36.60	41.32
AE (P)			
P alone	18.00	12.50	29.00
With N	70.71	30.74	84.55
With NK	102.20	41.86	118.07
AE (K)			
K alone	14.50	6.20	17.20
With N	42.47	15.85	46.59
With NP	54.20	22.20	62.61

AE, Agronomic efficiency; REY, rice-equivalent yield

realized with this treatment, followed by application of recommended NPK to both the crops. However, both the treatments had almost the same benefit: cost ratio. The increase in system net returns under NPK + $ZnSO_4$ to rice and NPK + $CaSO_4$ to groundnut was found to be 326, 60, 32, 23, 4 and 50% over the control, N, NP, NK, NPK and farmers' practice, respectively, while the increase in respective cost of cultivation was only 16, 14, 7, 10, 4 and 10%. Similarly, balanced fertilization with recommended NPK to both the crops resulted in 54, 27, 18 and 44% increase in system net return over N, NP, NK and farmers' practice, while the respective increase in cost of cultivation was only 10, 3, 6 and 6%. Singh *et al*. (2017) also recorded higher net returns with balanced fertilization in cereal-based cropping system.

Post-harvest nutrient status of soil

There was not much variation in soil organic carbon after the harvesting of groundnut due to application of recommended N, P and K in different combinations (Table 4). However, higher available N, P and K were observed with the application of recommended nutrients to rice and succeeding groundnut over the control. Further the inclusion of a legume like groundnut in the cropping system was responsible for nutrient build-up of soil, as it added considerable amount of crop residue to the soil besides symbiotic N fixation. Hiremath *et al.* (2016) and Ray *et al.* (2017) reported significant improvement in post-harvest soil fertility with application of nutrients.

Nutrient uptake

Application of NPK + $ZnSO_4$ to rice and NPK + $CaSO_4$ to groundnut resulted in significantly higher system uptake of N, P and K over rest of the treatments during both the years. The N uptake by rice–groundnut system due to application of NPK + $ZnSO_4$/$CaSO_4$ ($ZnSO_4$ to rice and $CaSO_4$ to groundnut), NPK, NK, NP, N and farmer practice was 83, 76, 58, 53, 38 and 44% higher over the control respectively (Table 5). The respective increase in P

Table 4. Soil-nutrient status as influenced by nutrient combinations in rice–groundnut cropping system (mean data from 24 sites)

Treatment	Organic C (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
Control	0.59	0.59	257	265	13.4	15.8	135	154
	(0.55-0.65)	(0.51-0.62)	(214-280)	(237-294)	(11.9-15.0)	(12.6-17.9)	(115-142)	(135-183)
N	0.59	0.60	266	271	13.9	15.8	138	159
	(0.57-0.61)	(0.53-0.68)	(228-290)	(240-296)	(12.5-15.5)	(12.6-18.2)	(115-150)	(137-194)
NP	0.59	0.60	266	271	14.4	16.2	140	159
	(0.56-0.61)	(0.52-0.68)	(222-292)	(240-296)	(12.8-15.7)	(12.8-18.5)	(122-150)	(138-190)
NK	0.59	0.60	269	271	14.4	16.1	144	164
	(0.57-0.62)	(0.53-0.68)	(226-290)	(241-295)	(13.0-15.5)	(12.7-19.0)	(127-152)	(144-196)
NPK	0.60	0.61	268	278	14.5	16.1	142	164
	(0.57-0.61)	(0.53-0.69)	(230-286)	(239-302)	(13.0-15.4)	(12.7-18.8)	(126-150)	(145-193)
*NPK + $ZnSO_4$/$CaSO_4$	0.59	0.61	269	280	14.4	16.2	143	164
	(0.55-0.62)	(0.54-0.69)	(224-290)	(244-306)	(12.8-16.0)	(12.8-19.1)	(125-152)	(143-192)
FP	0.59	0.60	264	270	13.7	16.0	140	158
	(0.56-0.62)	(0.53-0.68)	(220-284)	(235-295)	(12.2-15.0)	(12.6-18.9)	(120-150)	(136-190)

FP, farmers' practice

Recommended dose of nutrients (N-P-K kg/ha): rice, 80-17.5-33; groundnut, 40-17.5-33; farmers' practice (N-P-K kg/ha): rice, 50-8.8-16.5; groundnut, 10-11-0

*$ZnSO_4$ @ 25 kg/ha to rice and $CaSO_4$ @ 250 kg/ha to groundnut

Figures in parentheses are the range values of 24 sites

Table 5. Nutrient uptake (kg/ha) by rice–groundnut system under researcher designed and farmer managed experiments (mean of 2 years data)

Treatment	Nitrogen	Phosphorus	Potassium
Control	116.3	20.6	80.4
N	160.9	27.9	109.8
NP	178.1	31.9	118.5
NK	184.0	31.6	131.1
NPK	204.7	37.3	146.3
*NPK+$ZnSO_4$/$CaSO_4$	213.1	38.2	150.6
FP	167.6	29.9	119.9
SEm ±	1.82	0.31	0.54
CD (P=0.05)	3.60	0.62	1.06

FP, farmers' practice; recommended dose of nutrients (N-P-K kg/ha): rice, 80-17.5-33; groundnut, 40-17.5-33; farmers' practice (N-P-K kg/ha): rice, 50-8.8-16.5; groundnut, 10-11-0
*$ZnSO_4$ @ 25 kg/ha to rice and $CaSO_4$ @ 250 kg/ha to groundnut

uptake was 85, 81, 53, 54, 35 and 45% over the control and the respective increase in K uptake was 87, 82, 63, 47, 36 and 49% over the control. Application of balanced nutrients (recommended NPK to both the crops) registered 76, 27, 15, 11 and 22% higher N uptake by rice–groundnut system over the control, N, NP, NK and farmers' practice. Similarly application of balanced nutrients to rice–groundnut system recorded 81, 34, 17, 18 and 25% higher system P uptake over control, N, NP, NK and farmers' practice. The respective increase in K uptake was 82, 33, 23, 12 and 22%. The higher uptake of nutrients by the crops was mainly due to the higher biomass production with application of balanced nutrients. Hiremath *et al.* (2016) and Chandrakar *et al.* (2017) also reported similar findings in cereal-based cropping systems.

Thus, it may be concluded that balanced fertilization with N : P : K @ 80 : 17.5 : 33 kg/ha along with 25 kg $ZnSO_4$/ha to rice and N : P : K @ 20 : 17.5 : 33 kg/ha along with 25 kg $CaSO_4$/ha to the succeeding groundnut could be advocated for achieving higher productivity and net returns with better residual soil fertility to rice–groundnut system in mid-central table land zone of Odisha.

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