RESEARCH ARTICLE Legume Research- An International Journal, Volume 46 Issue 1: 75-79 (January 2023)

On-farm Evaluation of Balanced Fertilization in Rice-groundnut Cropping System for Productivity, Nutrient Use Efficiency and Profitability

T.R. Mohanty[1], R.K. Paikray[1], A.K. Patra[1], S.K. Swain[1], K.C. Sahoo[1], P.K. Samant[2]

10.18805/LR-4789

ABSTRACT

Background: Increasing cost of fertilizers warrants the necessity of finding methods for increasing the use efficiency of nitrogen in a cropping system. Data from on-farm research on evaluation of use efficiency of applied nutrients using check plot or omission plot technique has been lacking.

Methods: A researcher designed and farmer managed experiment was conducted in Angul district under Mid Central Table Land Zone of Odisha to study the on-farm crop response to plant nutrients by involving 12 farmers during 2015-16 and another 12 farmers during 2016-17 in rice (*Oryza sativa* L.)- groundnut (*Arachis hypogaea* L.) cropping system with seven treatments, *viz.* control (no fertilizer application), recommended N alone (N-0-0-0), NP (N-P-0-0), NK (N-0-K-0), NPK (N-P-K-0), NPK+$ZnSO_4$/$CaSO_4$ (N-P-K-$ZnSO_4$ in rice and N-P-K- $CaSO_4$ in groundnut) and farmers' practice (FP).

Result: The highest system rice equivalent yield (REY) (12.63 t/ha) was recorded with the recommended doses of nitrogen, phosphorus and potassium (N-P-K @ 80, 17.5 and 33 kg/ha)+25 kg $ZnSO_4$/ha to rice and recommended doses of nitrogen, phosphorus and potassium (N-P-K @ 40, 17.5 and 33 kg/ha)+250 kg $CaSO_4$/ha to groundnut followed by recommended NPK alone to both the crops without $ZnSO_4$/$CaSO_4$ (12.18 t/ha). Partial factor productivity (PFP) of N in rice-groundnut system can be increased to 42% over sole N application through application of recommended quantity of NPK. The agronomic efficiency (AE) of N increased by 122, 87 and 186% in rice groundnut cropping system by applying recommended doses of N with P, K and PK over N alone, respectively. Application of recommended quantity of NPK+$ZnSO_4$ to rice and NPK+$CaSO_4$ to succeeding groundnut crop recorded highest system net return of Rs. 92690/ha followed by application of recommended NPK only to both the crops (Rs. 89950/ha). Application of balanced fertilizer improved the status of organic carbon and available N, P and K at the end of the cropping season in both the years compared to control.

Key words: Agronomic efficiency, Balanced fertilization, Partial factor productivity, Rice-groundnut system.

INTRODUICTION

Rice-groundnut is the predominant cropping system in Mid Central Table Land Zone of Odisha covering about 10,830 ha (Govt. of Odisha, 2015). However, the productivity of both rice and groundnut in Odisha are lower than national productivity and it might be due to low and imbalanced applications of nutrients.

Cereal production in the country increased by five fold, while fertilizer consumption increased 322 times during the period from 1950-51 to 2007-08, implying a very low fertilizer use efficiency (Rajendra Prasad, 2009). Nitrogen, phosphorus and potassium are the macro-nutrients required by the cereal-based systems for balanced nutrition. Among the micronutrients, Zn significantly influences crop growth and yield (Panwar *et al*., 2019). Generally, most of the Indian soils are deficient in S and Zn (Singh *et al*., 2008). Sufficient on-farm data regarding use efficiency of applied nutrients using check plot or omission plot technique has been lacking.

Considering the above facts, a participatory research was carried out in farmers' fields to evaluate the production potential, profitability and nutrient use efficiency of applied nutrients under balanced fertilization in rice-groundnut cropping system.

[1]Department of Agronomy, Directorate of Research, Odisha University of Agriculture and Technology, Bhubaneswar-751 003, Odisha, India.

[2]Department of Soil Science, Directorate of Research, Odisha University of Agriculture and Technology, Bhubaneswar-751 003, Odisha, India.

Corresponding Author: T.R. Mohanty, Department of Agronomy, Directorate of Research, Odisha University of Agriculture and Technology, Bhubaneswar-751 003, Odisha, India.
Email: tusharranjan70@gmail.com

How to cite this article: Mohanty, T.R., Paikray, R.K., Patra, A.K., Swain, S.K., Sahoo, K.C. and Samant, P.K. (2023). On-farm Evaluation of Balanced Fertilization in Rice-groundnut Cropping System for Productivity, Nutrient Use Efficiency and Profitability. Legume Research. 46(1): 75-79. doi: 10.18805/LR-4789.

Submitted: 11-09-2021 **Accepted:** 29-12-2021 **Online:** 19-02-2022

MATERIALS AND METHODS

Field experiments were conducted in 24 nos. of farmers' fields at three locations (Koshala, Machakutta and Handiguda villages) of Chhendipada block in Angul district of Odisha during 2015-16 and 2016-17. The villages were adopted by All India Coordinated Research Project on

Integrated Farming Systems, Odisha University of Agriculture and Technology, Bhubaneswar. Four farmers were selected from each village to conduct the experiment during each year. A set of seven fertilizer treatments were allotted to seven fixed plots (100 m^2 each) in a single block in each of the farmers' field both in rice and groundnut. The seven treatments were control (no fertilizer application), recommended N alone (N-0-0-0), NP (N-P-0-0), NK (N-0-K-0), NPK (N-P-K-0), NPK+$ZnSO_4$/$CaSO_4$(N-P-K- $ZnSO_4$ in rice and N-P-K- $CaSO_4$ in groundnut) and farmers' practice (FP). The recommended doses of N, P and K (elemental form) were 80, 17.5 and 33 kg/ha for rice and 20, 17.5 and 33 kg/ha for groundnut, respectively. The recommended quantity of $ZnSO_4$ and $CaSO_4$ were 25 kg/ha and 250 kg/ha for rice and groundnut, respectively. In FP, rice crop received 61, 13.3 and 26 kg of N, P and K/ha, respectively, whereas groundnut crop received 14, 14.9 and 24.8 kg of N, P and K/ha, respectively. Nitrogen, P, K, Zn and S were applied through urea [$CO(NH_2)_2$] containing 46% N, Single superphosphate [$Ca(H_2PO_4)_2$] containing 16% P_2O_5, potassium chloride [KCL] containing 60% K_2O, zinc sulphate [$ZnSO_4 . 7H_2O$] containing 21% Zn and calcium sulphate [$CaSO_4 . 2H_2O$] containing 18.5% S, respectively. In rice, the total quantity of recommended P, K and $ZnSO_4$ were applied as basal while N was applied in three splits *i.e.* 25% as basal, 50% at the time of tillering and rest 25% at P.I. stage. Moreover, in groundnut, the total quantity of recommended N, P, K and $CaSO_4$ were applied as basal. The treatments were applied to rice and groundnut crops in sequence. Rice cultivar 'Naveen' and groundnut cultivar 'Kadiri 6' was taken for the experiment. In 2015-16, rice crop received 791.7 mm rainfall in 47 rainy days and groundnut received 94.1 mm rainfall in six rainy days. Similarly, in 2016-17, rice crop received 914.6 mm rainfall in 45 rainy days and groundnut received 52 mm rainfall in five rainy days.

The experiment was conducted in randomized block design taking each farmer as a replication.Soil samples were collected from each of the 24 locations at the start and end of cropping cycle for both the years from a depth of 0-15 cm and analysed for organic carbon, N, P and K using standard procedures (Jackson, 1973). The details of initial physico-chemical properties of soil are given in Table 1. Plant samples were also analyzed for N, P and K concentration in grain and straw.

Nutrient use efficiencies (NUE) were estimated in terms of partial factor productivity (PFP) and agronomic efficiency (AE). Partial factor productivity, calculated as the ratio of the grain yield to applied nutrient, can be increased by increasing the amount, uptake and utilization of indigenous nutrients and by increasing the uptake and utilization efficiency of applied nutrients for grain production (Cassman *et al.* 1996). The agronomic efficiency (AE) is the ratio of incremental increase in grain yield per unit of nutrient applied over control. It quantifies the direct impact of an added nutrient on economic yield enhancement. The PFP (kg grain/kg of native + applied nutrient) and AE (kg grain/kg nutrient applied) for applied N, P and K were calculated using the following equations:

$$PFPn = Yn/Fn, Ynp/Fn, Ynk/Fn \text{ and } Ynpk/Fn \quad (1)$$

$$PFPp = Ynp/Fp \text{ and } Ynpk/Fp \quad (2)$$

$$PFPk = Ynk/Fk \text{ and } Ynpk/Fk \quad (3)$$

$$AEn = (Yn-Y_0)/Fn, (Ynp-Y_0)/Fn, (Ynk-Y_0)/Fn \text{ and } (Ynpk-Y_0)/Fn \quad (4)$$

$$AEp = (Ynp-Y_0)/Fp \text{ and } (Ynpk-Y_0)/Fp \quad (5)$$

$$AEk = (Ynk-Y_0)/Fk \text{ and } (Ynpk-Y_0)/Fk \quad (6)$$

Where

PFPn, PFPp and PFPk are the partial factor productivity of N, P and K, respectively, Y_0, Yn, Ynp, Ynk and Ynpk are the yield of respective treatments (control, N alone, N with P, N with K and N with PK) and Fn, Fp and Fk are the amounts of applied N, P and K, respectively. The quantity of nutrient inputs and economic outputs are expressed in kg/ha. Uptake of N, P and K were computed by multiplying the respective nutrient concentrations with yield.

Gross returns, net returns, B:C ratio (gross return per rupee invested) and rice-groundnut system productivity was evaluated using the minimum support price for economic products declared by Government of India and prevailing market prices for by-products during the year. Statistical analyses were done using standard methodology for randomized block design.

RESULTS AND DISCUSSION

Crop and system yields

Fertilizer application significantly influenced the yield of rice, groundnut and of the system (Table 2). The mean yield advantages in rice grain due to application of recommended quantity of N, NP, NK and NPK over control were to the tune of 35, 60, 58 and 82%, respectively. Similarly, the increases in pod yield of groundnut due to application of N, NP, NK and NPK were 21, 68, 48 and 84% over control, respectively. However, the highest grain yield of rice (5.06 t/ha) and pod

Table 1: Initial Physico-chemical properties of soil (data collected from 12 sites each year).

Treatment	2015-16			2016-17		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
pH	6.6	5.3	6.1	6.7	5.4	6.1
Organic C (%)	0.74	0.54	0.66	0.70	0.58	0.65
Available N (kg/ha)	270	212	244	270	228	252
Available P (kg/ha)	20.6	7.2	13.0	17.8	12.4	14.4
Available K (kg/ha)	220	100	134	180	115	138

yield of groundnut (2.44 t/ha) were obtained with balanced fertilisation of NPK to both the crops along with $ZnSO_4$ to rice and $CaSO_4$ to groundnut, respectively. This treatment (NPK + $ZnSO_4$) produced 90, 41 19, 21, 4 and 11% higher yield over the control, N, NP, NK, NPK and FP, respectively in rice and the treatment NPK + $CaSO_4$ in groundnut increased the pod yield to the tune of 94, 59, 15, 30, 5 and 16% over control, N, NP, NK, NPK and FP, respectively.

The rice-groundnut system productivity was evaluated in terms of rice equivalent yield (REY). Application of recommended quantity of N, NP, NK and NPK to both rice and groundnut in sequence increased the system REY by 29, 64, 54 and 83% over control, respectively. However, the highest system REY (12.63 t/ha) was recorded by application of recommended quantity of NPK with $ZnSO_4$ to rice and $CaSO_4$ to groundnut and the increases were 89, 47, 15, 24, 4 and 14% over the control, N, NP, NK, NPK and FP, respectively. The better yield performance under balanced application of NPK may be attributed to existence of synergistic interaction among these macronutrients. Phosphorus is involved in essential metabolic processes of plants including respiration and photosynthesis, helps in better root development, nitrogen fixation along with efficient use of N by plants. Potassium increases root growth, improves translocation of nutrients and is involved in N metabolism. The combined application of N and P increased the sorghum yield up to 85bu/ac (1 bushel/ac = 62.77 kg/ha), while N alone recorded a yield of 66 bu/ac (Schlegel and Bond 2020). Similarly, combined application of both P and K together enhanced the yield of cornto64 bu/ac as compared to 38-41 bu/ac with P alone (Usherwood and Segars 2001). Ravisankar *et al*. (2014), Hiremath *et al*. (2016) and Panwar *et al*. (2019) have also reported better yield performance under balanced NPK fertilization than application of N alone.

Four prediction equations have been developed for rice grain, straw; groundnut pod and haulm yield (Table 3). Adj. R^2 values indicate that the models are best fit to the equations.

Partial factor productivity (PFP)

Application of balanced fertilizer improved the partial factor productivity (PFP) of applied N compared to application of N alone or NP and NK in both the crops and of the system (Table 4). Combined application of NP increased the PFPn by 19, 34 and 27% in rice, groundnut and rice-groundnut system, respectively, compared to that under sole N application. Similarly, combined application of NK increased the PFPn by 19, 21 and 20% in rice, groundnut and rice-groundnut system, respectively, over that under sole N application. However, the maximum increment in PFPn to the tune of 36, 46 and 42% in rice, groundnut and rice-groundnut system, respectively, were observed under balanced fertilization of NPK over sole N application. Similar to N, the improvement for PFP of P when combined with NK over application with N alone were 14, 10 and 11% in rice, groundnut and rice-groundnut system, respectively and the improvement for PFP of K when combined with NP over

Table 2: Productivity and economics of rice-groundnut system as influenced by nutrient application (mean of two years).

Treatment	Productivity (t/ha)					Economics (×10³ `/ha)		
	Rice		Groundnut		System	Cost of	Net	Cost: benefit
	Grain	Straw	Pod	Haulm	REY	cultivation	return	ratio
Control	2.66	3.75	1.26	2.19	6.67	83.98	15.97	1.19
N	3.58	4.82	1.53	2.62	8.60	85.23	43.50	1.51
NP	4.25	5.53	2.12	3.35	10.94	89.01	74.24	1.83
NK	4.19	5.41	1.87	3.13	10.27	87.47	65.98	1.75
NPK	4.85	5.77	2.32	3.53	12.18	91.34	89.95	1.99
NPK+$ZnSO_4$/$CaSO_4$	5.06	5.88	2.44	3.55	12.63	95.24	92.69	1.97
Farmers' practice	4.54	5.63	2.10	3.35	11.07	89.58	75.68	1.84
SEm (±)	0.05	0.07	0.04	0.05	0.11		1.68	
CD (P=0.05)	0.14	0.19	0.10	0.13	0.32		4.75	

REY, rice equivalent yield; Recommended dose of nutrients (N-P-K kg/ha): rice, 80-17.5-33; groundnut, 20-17.5-33; Farmers' practice (N-P-K kg/ha): rice, 61-13.3-26; groundnut, 14-14.9-24.8*$ZnSO_4$ @ 25 kg/ha to rice and $CaSO_4$ @ 250 kg/ha to groundnut.
Sale price (`/t): paddy grain, 14,100 in 2015-16 and 14,700 in 2016-17; paddy straw, 1,000; groundnut pod, 50,000 in 2015-16 and 46,000 in 2016-17.

Table 3: Prediction equation of grain and straw yield (mean of two years).

Particulars	Prediction equation	Adj R^2	Significance of the model
Rice grain	2.69 + 0.010824N + 0.40787P + 0.01992K	0.98	0.01217
Rice straw	3.79 + 0.013509N + 0.034352P + 0.014728K	0.93	0.03947
Groundnut pod	1.26 + 0.01559N + 0.029377P + 0.008038K	0.98	0.00953
Groundnut haulm	2.20 + 0.024545N + 0.03336P + 0.010911K	0.94	0.03288

application with N alone were 16, 21 and 19% in rice, groundnut and rice-groundnut system, respectively.

Agronomic efficiency of nutrients

Agronomic efficiency (AE) of applied nutrients can be increased in rice, groundnut and rice-groundnut system by combined application of recommended quantity of N, P and K rather than sole application N or NP and NK (Table 5). Combined application of NP increased the AE of N by 73, 169 and 122% in rice, groundnut and rice-groundnut system, respectively instead of N alone and the AEn further increased to 139, 233 and 186% in rice, groundnut and rice-groundnut system, respectively, by applying recommended quantity of N with P and K rather than N alone. Similar to N, the improvements for AE of P when combined with NK over application with N alone were 38, 24 and 29% in rice, groundnut and rice-groundnut system, respectively and the improvements for AE of K when combined with NP over application with N alone were 43, 61 and 53% in rice, groundnut and rice-groundnut system, respectively. Ravisankar *et al*. (2014) and Panwar *et al*. (2019) have also reported higher agronomic efficiency of applied nutrients in cereal based cropping systems under combined application over their lone application.

Uptake of nutrients

Application of balanced fertilizer along-with $ZnSO_4$/ $CaSO_4$ *i.e*. NPK+$ZnSO_4$ to rice and NPK+$CaSO_4$ to groundnut recorded higher uptake of N, P and K by rice-groundnut system (Table 6). The increases in N uptakes due to application of recommended NPK+$ZnSO_4$ to rice and NPK +$CaSO_4$ to groundnut were found to be 89, 44, 15, 22, 3 and 14% over control, N, NP, NK, NPK and farmers' practice respectively, while the respective increases for P uptakes were 88, 47, 12, 21, 3 and 12% and K uptakes were 82, 45, 18, 14, 2 and 14%. The uptake of N when applied along-with P (213.7 kg/ha) and uptake of N when applied along-with K (201.6 kg/ha) were higher by 25 and 18% respectively, over that under application of N alone. Similarly, the respective increases for P uptakes were 31 and 22% and respective increases for K uptakes were 23 and 28%. However, both the treatments (N with P or N with K) recorded lower N, P and K uptake compared to balanced fertilisation with NPK. Patra *et al*. (2019) also reported higher uptake of nutrients under balanced fertilization in cereal based cropping system.

Economics of rice-groundnut system

Balanced application of NPK+$ZnSO_4$ to rice and NPK+$CaSO_4$ to succeeding groundnut fetched maximum system net return (`92,690/ha) followed by application of recommended NPK to both the crops (`89,950/ha) (Table 2). This treatment also increased the system net return by 480, 113, 25, 40, 3 and 22% over control, N, NP, NK, NPK and FP, respectively, while the increases in respective cost of cultivation were only 13, 12, 7, 9, 4 and 6%. The increases in net return under application of N with P or N with K over N alone were 71 and 52%, respectively. However, both the treatments (N with P or N with K) recorded lower marginal returns compared to balanced fertilisation with NPK. Singh *et al*. (2017) also reported higher net return with balanced

Table 4: Partial factor productivity (PFP) of N, P and K in rice-groundnut system as influenced by nutrient application (mean of 2 years).

Treatment	Rice (kg grain/ kg nutrient)	Groundnut (kg pod/ kg nutrient)	Rice-groundnut (kg REY/ kg nutrient)
PFP (N)			
N alone	44.71	75.27	85.96
With P	53.08	100.60	109.39
With K	52.34	91.29	102.73
With PK	60.60	110.16	121.77
PFP (P)			
With N	242.64	114.98	312.53
With NK	277.05	125.89	347.92
PFP (K)			
With N	126.88	55.33	155.65
With NP	146.92	66.76	184.50

Table 5: Agronomic efficiency (AE) of N, P and K in rice-groundnut system as influenced by nutrient application (mean of 2 years).

Treatment	Rice (kg grain/ nutrient)	Groundnut (kg pod/ kg nutrient)	Rice-groundnut (kg REY/ kg nutrient)
AE (N)			
N alone	11.44	14.98	19.21
With P	19.80	40.31	42.64
With K	19.07	31.00	35.98
With PK	27.33	49.86	55.02
AE (P)			
With N	90.54	46.07	121.82
With NK	124.94	56.99	157.21
AE (K)			
With N	46.22	18.79	54.52
With NP	66.26	30.22	83.37

Table 6: Nutrient uptake in rice-groundnut system as influenced by nutrient application (mean of 2 years data).

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Control	130.4	19.0	96.1
N	170.5	24.3	120.6
NP	213.7	31.9	148.0
NK	201.6	29.6	154.1
NPK	237.6	34.8	171.9
NPK + $ZnSO_4$/$CaSO_4$	245.8	35.7	175.2
Farmers' practice	215.5	31.8	153.8
SEm(±)	2.25	0.35	1.59
CD (P=0.05)	6.35	0.99	4.48

fertilization in cereal-based cropping system. The benefit: cost ratio was higher under recommended application of NPK.

CONCLUSION

In conclusion, our study shows that balanced fertilization with recommended doses of nitrogen, phosphorus and potassium to both rice and groundnut along with $ZnSO_4$ to rice and $CaSO_4$ to the succeeding groundnut is required for achieving higher system equivalent yield, increased efficiency of native and applied nutrients and better net returns with better residual soil fertility to rice-groundnut system in Mid Central Table Land Zone of Odisha.

Conflict of interest: None.

REFERENCES

Casman, K.G., Gines, G.C., Dizon, M.A., Samson, M.I., Al-cantara, J.M. (1996). Nitrogen-use efficiency in tropical low land rice systems: Contributions from indigenous and applied nitrogen. Field Crops Research. 47: 1-2.

Govt. of Odisha. (2015). Odisha Agriculture Statistics 2013-14. Directorate of Agriculture and Food Production, Government of Odisha, Bhubaneswar.

Hiremath, S.M., Mohan Kumar, R. and Kumar, G.A. (2016). Influence of balanced nutrition on productivity, economics and nutrient uptake of hybrid maize (*Zea mays*)-chickpea (*Cicer arietinum*) cropping sequence under irrigated ecosystem. Indian Journal of Agronomy. 61(3): 292-96.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd, New Delhi. pp. 183-204.

Panwar, A.S., Shamim, M., Babu, S., Ravishankar, N., Prusty, A.K., Alam, N.M., Singh, D.K., Bindhu, J.S., Kaur, J., Dashora, L.N., Latheef Pasa, M.D., Chaterjee, S., Sanjay, M.T. and Desai, I.J. (2019). Enhancement in productivity, nutrient use efficiency and economics of rice-wheat cropping systems in India through farmer's participatory approach. Sustainability. 11: 122.

Patra, A.K., Garnayak, L.M., Mishra, K.N., Mohanty, T.R., Mohapatra, B.K. and Swain, S.K.(2019). Balanced fertilization in rice (*Oryza sativa* L.)-groundnut [*Arachis hypogaea*] cropping system. Indian Journal of Agronomy. 64(3): 52-56.

Rajendra Prasad. (2009). Efficient fertilizer use: The key to food security and better environment. Journal of Tropical Agriculture. 47(1-2): 1-17.

Ravisankar, N., Gangwar, B. and Prasad, K. (2014). Influence of balanced fertilization on productivity and nutrient use fficiency of cereal based cropping systems. Indian Journal of Agricultural Sciences. 84(2): 248-54.

Schlegel, A. and Bond, H.D. (2020). Long-term nitrogen and phosphorus fertilization of irrigated grain sorghum. Kansas Agricultural Experiment Station Res Rep. 6: 1-6.

Singh, D.K., Singh, G.D., Singh, R., Singh, A.P., Chaturvedi, S. and Singh, M. (2017). Himalayas farmer participatory evaluation of balanced application of nutrients in rice (*Oryza sativa*)- wheat (*Triticum aestivum*) system in Kumaon hills. Indian Journal of Agronomy. 62(4): 401-06.

Singh, V.K., Tiwari, R., Gill, M.S., Sharma, S.K., Tiwari, K.N., Dwivedi, B.S., Shukla, A.K., Mishra, P.P. (2008). Economic viability of site-specific nutrient management in rice-wheat cropping. Better Crops India. 2:16-19.

Usherwood, N.R. and Seagars, W.I. (2001). Nitrogen interactions with phosphorus and potassium for optimum crop yield, nitrogen use effectiveness and environmental stewardship. Science World. 1: 57-60.