Integrated Nutrient Management for Groundnut and Redgram on Acid Soils in Odisha

By Sushanta Kumar Pattanayak, U.K. Misra, A.K. Sarkar, and K. Majumdar

On-farm experiments for 3 years in 130 farmers' fields showed that soil test-based fertiliser application, integrated with inorganic and organic ameliorants, significantly improved productivity, crop quality parameters, and economic return in groundnut and redgram in acid upland soils of Odisha. Post harvest soil analysis showed improved status of organic C, N, and P in treated plots, but available K status declined—emphasising the need for close monitoring and appropriate K application in such soils.

About 100 million hectares (M ha) of land in India is designated as acidic, half of which is under cultivation. Soil acidity and poverty are synonymous in the state of Odisha where 80% of soils are acidic. Low water holding capacity, high bulk density, and soil crusting along with chemical constraints like low pH, low CEC, low base saturation (16 to 67%), high Al, Fe and Mn saturation, and high P fixing capacity (80 to 91%) are major reasons for low crop productivity in such soils (Misra et al., 1989). Acid soils are generally deficient in Ca, Mg, P, Mo, B, and Si. The availability of Fe, Mn, Cu and Zn is high, sometimes reaching toxic levels. These problems can be managed by inorganic and organic ameliorants. Lime application (inorganic) increases pH, base saturation, and CEC; and reduces Al, Fe, and Mn availability, acidity and P fixation (Panda and Koshy, 1982; Misra et al., 1989; Sahu and Patnaik, 1990; Mishra and Pattanayak, 2002). Organic ameliorants (FYM/compost) reduce exchangeable Al in soil through precipitation with OH-ions (Hue, 1992; Iyamuremye et al., 1995). The organic acids released from organic ameliorants complex with Al and Fe, reducing their availability and harmful effects. Combined use of organic and inorganic ameliorants simultaneously controls soil acidity, reduces Al and Fe toxicity, and increases nutrient availability (Misra and Das, 2000; Mohanty and Pattanayak, 2000) leading to better crop growing conditions in these soils.

The present study was conducted in Dhenkanal, Balasore, and Mayurbhanj districts of Odisha covering 16 villages and 130 farmers over three consecutive years (2006, 2007, and 2008). The soils of the study area are classified as Alfisols, Inceptisols and Entisols. These coarse-textured soils are generally low in basic cations due to crop removal and leaching. The soils of the study area were acidic (pH 4.6 to 5.3), with low status of organic C (2.5 to 4.2 g/kg soil), N (105 to 128 kg/ha), P_2O_5 (3.8 to 5.8 kg/ha), and K_2O (28 to 97 kg/ha). Six different fertilisation strategies including: (i) Farmers' Practice or Control, (ii) 100% NPK based on soil test, (iii) 50% of soil test-based NPK + Lime, (iv) 100% of soil test-based NPK + Lime, (v) 50% of soil test-based NPK + Lime + FYM at 2 t/ha, and (vi) 100% soil test-based NPK + Lime + FYM at 2 t/ha were studied in the common groundnut-redgram intercropping system comprised of six rows of groundnut sown alternatively with two rows of redgram. The soil test-based 100% NPK fertiliser rates for both crops was determined by matching soil N, P, and K fertility levels (low, medium, and high) with the corresponding fertility level-based recommendations from the State. Thus the 100% NPK recommendation was 20-40-40 kg N-P_2O_5-K_2O/ha for both the crops. The primary nutrients were applied through urea, single superphosphate, and potassium chloride. Farmers only use FYM at 2 t/ha. The lime requirement (LR) of these soils ranged from 3.3 to 4.0 t/ha. Lime was applied at 0.2 LR in the form of paper mill sludge (PMS), a locally available liming material (60% $CaCO_3$ equivalent),

Common abbreviations and notes: Al = aluminium; B = boron; C = carbon; Ca = calcium; CEC = cation exchange capacity; Cu = copper; Fe = iron; FYM = farmyard manure; K = potassium; Mg = magnesium; Mn = manganese; Mo = molybdenum; N = nitrogen; NH_4OAcK = ammonium acetate extractable K; P = phosphorus; S = sulphur; OH = hydroxide; OM = organic matter; Si = silicon; Zn = zinc.

Resource poor farmers growing groundnut and redgram were able to improve their income with an integration of 50% of the recommended NPK dose with lime plus FYM.

Table 1. Influence of nutrient management and soil amelioration on yield of redgram and groundnut.

Treatments	Redgram seed yield	Groundnut pod yield	Dry biomass
	- - - - - - - - - - - - - kg/ha		- - - - - - - - - - - - -
Farmers' practice	470 (-48)	1,080 (-36)	7,400 (-33)
100% NPK	900	1,690	11,100
50% NPK + PMS	920 (2)	1,770 (5)	10,950 (-2)
100% NPK + PMS	1,040 (16)	1,810 (7)	11,900 (7)
50% NPK + PMS + FYM	1,100 (22)	2,000 (18)	12,230 (10)
100% NPK + PMS + FYM	1,200 (33)	2,080 (23)	13,000 (17.0)
CD (p = 0.05)	142	103	900

Data in the parenthesis indicate percent increase/decrease compared to 100% NPK.

Table 2. Crop quality as influenced by nutrient management and soil amelioration.

Treatments	------- Groundnut ------- Shelling, %	Oil, %	-- Redgram -- Seed Protein, %
Farmers' practice	63.0	43.1	26.3
100% NPK	65.0	44.9	30.0
50% NPK + PMS	65.0	44.6	29.5
100% NPK + PMS	65.3	45.1	30.8
50% NPK + PMS + FYM	67.0	45.9	30.9
100% NPK + PMS + FYM	67.9	45.8	31.4
CD (p = 0.05)	1.3	0.8	1.6

Table 3. Effect of nutrient management and soil amelioration on combined uptake of nutrients (kg/ha) by the intercrop system.

Treatments	N	P	K	Ca	Mg	S
Farmers' practice	180.0	11.7	97.3	59.0	17.6	9.0
100% NPK	310.8	20.3	132.3	105.5	32.5	18.6
50% NPK + PMS	312.2	18.0	118.8	109.9	40.9	17.3
100% NPK + PMS	318.0	22.0	134.1	111.3	42.1	19.3
50% NPK + PMS + FYM	376.2	23.0	124.2	134.0	54.4	19.9
100% NPK + PMS + FYM	379.1	23.3	135.4	138.3	56.3	20.3
CD (p = 0.05)	20.0	1.8	10.0	6.0	2.9	1.2

Table 4. Treatment effects on extra gain of N over farmers' practice and apparent recovery (%) of nutrients in the intercrop system.

Treatments	Extra N gain, kg/ha	APR	AKR	ASR
		----------	%	----------
100% NPK	130.8	48	105	32
50% NPK + PMS	132.2	70	124	55
100% NPK + PMS	138.0	54	110	34
50% NPK + PMS + FYM	196.2	62	158	68
100 % NPK + PMS + FYM	199.1	61	124	35
CD (p = 0.05)	6.2	-	-	-

APR, AKR, and ASR denote apparent P, K, and S recovery.

below the seed zone at the time of sowing.

Results

The seed yield of redgram (**Table 1**) varied between 470 and 1,200 kg/ha and that of groundnut pod between 1,080 and 2,080 kg/ha. Application of soil test-based nutrient rates, with or without soil ameliorants, increased redgram seed and groundnut pod yield compared to the farmers' practice. Combining FYM and lime with 100% NPK increased redgram seed and groundnut pod yields significantly by 33 and 23%, respectively, compared to yields due to 100% NPK alone (**Table 1**). Combined application of FYM and lime with 50% of recommended NPK increased redgram seed and groundnut pod yields by 22 and 18.4% compared to 100% NPK alone. No significant yield difference was observed between 100% and 50% of soil test-based nutrient application when applied in combination with lime or lime + FYM. This might be related to the issue of balanced nutrition of crops that goes beyond the context of N, P, and K. Addition of high rates of N, P, and K as part of the treatment may stimulate deficiencies of secondary or micronutrients, which probably was adequate for the 50% NPK rates (Johnston et al., 2009). Acid soils are often deficient in S, B, and Mo and utilization and efficiency of applied N, P, and K can be severely restricted by the deficiencies of such nutrients.

Crop quality was significantly influenced by combined application of fertiliser, lime, and FYM (**Table 2**). The shelling percent and oil content of groundnut pod increased from 63 to 67.9% and 43.1 to 45.8% respectively, by applying the 100% NPK dose of fertiliser with lime and FYM. There was no significant difference in the above parameters between the 50% and 100% NPK doses combined with lime and FYM. Seed protein content of redgram increased from 26.3% with farmers' practice to 31.4% with 100% NPK combined with lime and FYM. Combining nutrients and ameliorants again showed no significant difference in protein content of redgram seed between the 50% and 100% NPK doses.

Removal of nutrients by the test crops (**Table 3**) followed the order N (180 to 379.1 kg/ha) > K (97.3 to 135.4 kg/ha) > Ca (59.0 to 138.3 kg/ha) > Mg (17.6 to 56.3 kg/ha) > P (11.7 to 23.3 kg/ha) > S (9.0 to 20.3 kg/ha). Organic and inorganic ameliorants, either alone or together, created better growing conditions in acid soils which favored (doubled) the uptake of essential nutrient elements. This resulted in extra gain of N, ranging from 131 to 200 kg/ha, and recovery of P, K, and S from 48 to 70%, 105 to 158%, and 32 to 68%, respectively (**Table 4**).

The post harvest soil properties (**Table 5**) indicated that the soils had the tendency of turning more acidic where ameliorants were not applied. Lime (PMS) application, either alone or with FYM, maintained higher pH in the soil by neutralizing the acidity and by buffering action of FYM. The organic C status in soil had increased except under farmers' practice. Mostly the leaf shading property of the crops and FYM addition (in specific treatments) increased organic C status in soil. Both the crops were N fixing leguminous crops, which not only benefited the crops, but also improved the residual N balance in the soil in the form of readily available NH_4^+ and NO_3^--N. The available P status in soil declined significantly under farmers' practice and 50% NPK treatments where addition was low, but maintained the P status in 100% NPK treatments. Maintaining available P status through adequate P application is critical for sustainable production in acid soils. Irrespective of K application rates, available K levels declined sharply in all the treatments except in the farmer's practice, where yield levels are half of the maximum yield achieved in both the crops. This is probably due to mismatch between application rates and crop removal as well as leaching loss of K in coarse-textured soils under high rainfall. This suggests that we need to critically assess the K recommendations for pulses and oilseeds in these depleted, coarse-textured acid soils where recommendations often do not consider yield target, crop uptake, and the possibility of nutrient leaching in a way that could a realistically achieve the twin goals of high productivity and sustained soil fertility.

Acidity in soil increased where no ameliorant was applied and a reverse trend was observed in PMS and organic

Table 5. Average post harvest soil properties after groundnut-redgram intercropping.

Treatments	pH	Organic Carbon	NH_4^++NO_3^-	Bray IP	NH_4OAcK	Acidity, cmol+	Exchangeable Ca per kg soil
		----- g/kg -----		----- kg/ha -----			
Farmers' practice	4.56	3.0	57	12.0	206	1.66	1.02
100% NPK	4.60	4.3	168	18.0	102	1.62	0.97
50% NPK + PMS	5.58	4.2	102	13.0	113	0.40	1.62
100% NPK + PMS	5.68	4.3	171	16	98	0.39	1.60
50% NPK + PMS + FYM	5.08	4.4	157	14.4	124	0.68	1.52
100% NPK + PMS + FYM	5.74	4.5	168	15	120	0.57	1.54
Initial	4.66	4.0	46	14.0	220	1.56	1.10
Range	4.6-5.3*	2.5-4.2	41-83	9.0-15.3	107-240	1.42-1.61	1.04-1.23
CD (p = 0.05)	0.04	0.03	7.0	1.1	12.0	0.31	0.40

ameliorated soils (**Table 5**). This is due to the loss of basic cations either by crop removal or leaching. This was reflected in the exchangeable Ca status where lime ameliorated treatments maintained exchangeable Ca status while it decreased in farmers' practice and 100% NPK only treatments.

The economic analysis of different nutrient management practices (**Table 6**) indicated that there was a sharp increase in net income in the 100% NPK treatment compared to farmers' practice. Net income was further improved when lime and FYM were added to soil test-based nutrient recommendation. Both inorganic (PMS) and organic (FYM) amelioration of the acid soils in the study area had strong economic impact when applied in conjunction with recommended fertiliser rates. Even 50% of the recommended NPK rate, applied in combination with lime and FYM, increased farmer income by about 70% over the current practices, which can have a strong impact on livelihoods. This prioritizes the importance of soil amelioration, along with proper nutrient management, for increasing the productivity and farmer profit from crops grown on acid soils.

Table 6. Effect of improved nutrient management and soil amelioration on economics of production.

Practices	Expenditure, INR/ha	Gross Income, INR/ha	Net Income, INR/ha	Benefit-to-Cost ratio
Farmers' practice	10,360	31,000	20,640	2.99
100% NPK	17,000	51,800	34,800	3.05
50% NPK + PMS	16,000	53,800	37,800	3.36
100% NPK + PMS	17,100	57,000	39,900	3.33
50% NPK + PMS + FYM	17,000	62,000	45,000	3.65
100% NPK + PMS + FYM	18,100	65,600	47,500	3.62

Costs/Prices used are: N = INR 12/kg, P_2O_5 = INR 143/kg, K_2O = INR 16.2/kg, PMS = INR 10/50 kg, FYM = INR 100/100 kg, redgram = INR 20/kg, and groundnut = INR 20/kg.

Summary

This study highlights that unproductive/less productive acid upland soils (Alfisols, Inceptisols, and Entisols) can improve crop yields through application of soil test-based nutrient rates, integrated with organic and inorganic soil ameliorants. The resource poor farmers in the region growing groundnut and redgram can select an integration of 50% of the recommended NPK dose with lime and FYM and can still improve their income substantially. Farmers with higher resource capacity should aim for higher yield targets through soil test and yield target-based nutrient application. Acid soils are often deficient in S, B, and Mo that can limit the expected responses of applied NPK rates. Further studies are required to look into the secondary and micronutrient deficiencies in these soils and their integration in the fertilisation schedule for further improvement in yield and economics of production.

Acknowledgement

Financial assistance from the Indian Council of Agricultural Research, New Delhi, for execution of this project is duly acknowledged. BC-SA

Dr. Pattanayak is Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Odisha University of Agriculture & Technology, Bhubaneswar, Odisha, e-mail: sushanta_1959@yahoo.com; Dr. Misra is Retired Director of Agriculture, Govt. of Odisha; Dr. Sarkar is Dean, College of Agriculture, Birsa Agricultural University, Ranchi, Jharkhand, e-mail: aksarkarranchi@gmail.com; and Dr. Majumdar is Director, IPNI South Asia Program, Gurgaon, e-mail: kmajumdar@ipni.net

References

Johnston, A.M., H.S. Khurana, K. Majumdar, and T. Satyanarayana. 2009. J. Ind. Soc. Soil Sci. 57: 1-10.

Hue N.V. 1992. Com. Soil Sci. 152: 241-264.

Iyomuremye, F., R.P. Dick, and J. Baham. 1995. Soil Sci. 161:426-434.

Mishra, M. and S.K. Pattanayak. 2002. J. Ind. Soc. Soil Sci. 50:14-17.

Misra, U.K and N. Das. 2000. J. Ind. Soc. Soil Sci. 48:298-305.

Misra, U.K., S. Satapathy, and N. Panda. 1989. J. Ind. Soc. Soil Sci. 37:22.

Mohanty, R. and S.K. Pattanayak. 2000. Thesis submitted to OUAT, Bhubaneswar, Orissa, India.

Panda, N. and M.U. Koshy. 1982. *In* Review of Soil Research in India – I XII International Congress of Soil Science 8-16th Feb, New Delhi.

Sahu, G.C. and S. Patnaik. 1990. J. Ind. Soc. Soil Sci. 38:154-157.