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Prajapati J
Department of soil science & Ag. Chemistry, OUAT, BBSR, Odisha, India

Pattanayak SK
Department of soil science & Ag. Chemistry, OUAT, BBSR, Odisha, India

Mohapatra AK
Department of Agronomy, OUAT, BBSR, Odisha, India

Sharma S
Department of Ag. Meterology, OUAT, BBSR, Odisha, India

Correspondence
Prajapati J
Department of soil science & Ag. Chemistry, OUAT, BBSR, Odisha, India

Effect of site specific nutrient management with nutrient omission technique on chemical properties and nutrients status of soil in rice-maize-green gram cropping system

Prajapati J, Pattanayak SK, Mohapatra AK and Sharma S

Abstract
The experiment was conducted at the farmer field, Delang block of Puri, Odisha, India, for three consecutive years (2013-14 to 2015-16) to study the effect of SSNM with nutrients omission technique on chemical properties and nutrient status of soil in rice-maize-green gram cropping system. The experiment was comprised of 10 treatments (SSNM, SSNM-N, SSNM-P, SSNM-K, SSNM-S, SSNM-Ca, SSNM-B, SSNM-Zn, farmer practice and absolute control) with application of FYM @ 3 t/ha to all treatment except absolute control. The finding revealed that SSNM based nutrient application increase the soil pH, soil OC, cation exchange capacity, base saturation, available N, P, K, and S respectively over initial values and other nutrient omission SSNM treatments. Among the micronutrient, availability of Mn and B were decreased over initial values in all the treatment except Zn omitted treatment. The availability of Zn was maximum in phosphorous omitted SSNM treatment. Thus SSNM based nutrient management was best approach for improving chemical properties and nutrients availability to plants.

Keywords: absolute control, cropping sequence, site specific nutrient management, farmer practice

Introduction
In Odisha, rice is grown under highly diverse ecosystems and a wide range of climatic conditions. Rice (*Oryza sativa* L.) is the major crop of all the agro-climatic zones and is the staple food of the entire population of Odisha. Area of rice in Odisha, is 3941 thousand hectares with a production of 8902 thousand tonnes of which only the *kharif* season rice accounts for over 80 per cent of total production (DES, 2016) [7]. Cropping intensity of Odisha is quite lower (167 per cent) than other states of India (Odisha Agriculture Statistics, 2013-14). Rice-rice cropping system is common practices by farmers in irrigated areas which causes deterioration of physical condition of soil and creates problems of multinutrient deficiencies such as phosphorus, potassium, calcium, sulfur, magnesium, iron, boron, zinc and copper thus causing a decline in partial factor productivity Das (2012) [6]. Crop diversification is a viable option to improve physical, chemical and biological properties of soil with balance application of nutrients. Rice based cropping sequences in different ecosystems such as rice-pop corn-green gram and rice-sweet corn-green gram in uplands will not only increase productivity of crops but also improve the physical condition of soil. Nutrient management for the rice-rice and rice-wheat systems have been widely available in India. However, not much is known about soil condition and fertilizer management practices for the emerging rice-maize-green gram cropping system, particularly involving high yielding hybrid maize. This system is complicated because the component crops are grown in sharply contrasting physical, chemical and biological environments as that for rice-wheat systems Timsina and Connor (2001) [25]. The suitable match of plant needs and balance between applied nutrients by using site-specific nutrient management for higher productivity, profitability and nutrient use efficiencies of crops in cropping systems Xu *et al*. (2009) [27]. Keeping the importance of above facts in mind, the present study was designed to determine the effect of SSNM with nutrients omission technique on chemical properties of soil and nutrient status in rice-maize-green gram cropping system.

Materials and Methods
A field experiment was carried out at the farmer field of village Tailasahi under Delang block of Puri, Odisha, India during 2013-14, 2014-15 and 2015-16.

The geographical location of the site is located at latitude 20°7.036' N and longitude 85°44.862' E. The experimental site falls under a tropical climate with very hot summers and mild winters. Soil samples (0-15 cm depth) were collected from experimental fields using a core sampler before commencement of the experiment in 2013-14 and after completion of three cropping system cycles (i.e. post greengram season 2016). The soil of the experimental field belongs to Order *Inceptisols*, having loamy sand texture (sand 83%, silt 7% and clay 10%) with the pH of 4.9, low organic matter content (4.1 g/kg), low cation-exchange capacity 11 cmol/kg and 145, 25 and 125 kg/ha N, P, and K respectively analyzed by following Walkley and Black (1934)[26] for organic carbon, alkaline $KMNO_4$ method Subbiah and Asija (1956) [24] for available nitrogen, Bray-1 by Bray and Kurtz No.1 (1945) [2] for available phosphorus, 1M NH_4OAc, pH 7.0 extraction for available potassium and available sulphur by extracting the soil with 0.15 per cent $CaCl_2$ solution and determined colorimetrically by turbidimetric method using $BaCl_2$ Chesin and Yien (1951) [4]. Micronutrients content were low in case of Zn (0.41ppm) and adequate Mn (8.2 ppm) in soil analyzed by DTPA extraction and low B content (0.45 ppm) determined by Hot water method in the top 15 cm of soil. The experiment consisted of 10 treatments i.e SSNM, SSNM-N, SSNM-P, SSNM-K, SSNM-S, SSNM-B, SSNM-Zn, SSNM-Ca, absolute control (no nutrient applied) and farmers practice to both rice and maize crop in cropping system (Table 1). The FYM was applied @ 3 t/ha common to all treatment except for absolute control. During the three years green gram was taken as residual crop after maize (no fertilizers applied only seeds were inoculated with *Rhizobium*).

Table 1: Total nutrients applied to rice and maize crops during three years

Inorganic nutrient applied (kg/ha)								
S.No.	**Treatments**	**N**	**P**	**K**	**S**	**B**	**Zn**	**Ca**
1	SSNM	750	132	300	195	6	30	300
2	SSNM-N	-	132	300	195	6	30	300
3	SSNM-P	750	-	300	195	6	30	300
4	SSNM-K	750	132	-	195	6	30	300
5	SSNM-S	750	132	300	-	6	30	300
6	SSNM-B	750	132	300	195	-	30	300
7	SSNM-Zn	750	132	300	195	6	-	300
8	SSNM-Ca	750	132	300	195	6	30	-
9	A.C.	-	-	-	-	-	-	-
10	F.P.	480	105	201	-	-	-	-
Organic nutrient applied (kg/ha)								
i	FYM@3 t/ha	72	45	60	29	-	-	-
Total applied nutrient (Inorganic+organic) kg/ha								
ii	Complete SSNM	822	177	360	224	6	30	300
iii	F.P.	552	150	261	29	-	-	-

F.P. (Farmer practice), A.C. (Absolute control)

Results and Discussion

Soil Reaction: The initial soil pH was strongly acidic (4.9) in nature. The average value of three years cropping sequence, the highest soil pH (5.60) was recorded due to complete SSNM practice compared to other nutrient omitted SSNM practices over three years of cropping sequence (Table 2). It registered an increase of 7.14, 8.92, 10.71 and 12.50 per cent respectively over farmer practice, SSNM-B, absolute control and initial soil. Balance supplied of nutrient through organic (FYM) and inorganic fertilizers as well as addition of liming material PMS (paper mill sludge) every year to soil which help to increased soil pH by neutralizing the soil acidity and by buffering action of FYM Pattanayak *et al*. (2011) [18]. Omission of Ca from treatment (SSNM-Ca) accelerated to decrease in soil pH (4.1) compared to other nutrient omitted SSNM practices. Acidity in soil increased where no ameliorant was applied. These results corroborate with the findings of Kalaivanan *et al.* (2012) [11] who reported that loss of basic cations from soil either by crop removal or leaching led to soil acidity.

Organic Carbon: At the beginning of experiment, the organic carbon in soil was very low 4.1 g/kg. Average three years of cropping, organic carbon in soil was increased due to all the treatment except absolute control (3.7 g/kg), N and Ca omitted SSNM practices (3.9 and 4.0 g/kg) as well as farmer practice (4.0 g/kg) (Table 2). The higher organic carbon content was found in complete SSNM (4.8 g/kg) followed by SSNM-S=SSNM-Zn (4.7 g/kg) > SSNM-P (4.4 g/kg) > SSNM-B (4.3 g/kg) > SSNM-K (4.2 g/kg). This SSNM practice led to 18.75, 8.33, 12.5 and 10.42 per cent increase in organic carbon over SSNM-N, SSNM-P, SSNM-K and SSNM-B respectively. It might be due combined application of organic and inorganic nutrients as well as soil ameliorant viz., paper mill sludge and lime under SSNM practice which increases organic carbon status in soil Sharma and subehia (2014)[19]. Another reason due to diversification with legume crops contributed more fibrous root biomass in soil which enhanced soil organic pool Li *et al*. (2011) [13].

Cation Exchange Capacity (CEC): The initial soil CEC was 11.0 cmol (p+)/kg soil. Average value of three years cropping sequence, the cation exchange capacity of soil was improved except SSNM-N, SSNM-Ca and absolute control. The highest value of CEC recorded due to complete SSNM [11.8cmol (P^+)/kg] and lowest value of CEC observed under SSNM-Ca [9.9cmol (P^+)/kg] practice (Table 2). It might be due to absence of Ca which directly related with cation exchange capacity and soil pH Misra *et al*. (1982)[15]. This SSNM practice led to 3.39, 16.10, 15.25 and 5.93 per cent enhance CEC over SSNM-Zn, SSNM-Ca, absolute control and farmer practice respectively. Complete SSNM received full ample of nutrient with PMS as lime source and FYM as organic source, which helped to improve CEC of soil Mishra and Pattanayak (2002)[16].

Base saturation per cent: In general, availability of nutrient like Ca, Mg and K in soil increases with the degree of base saturation. At the beginning of experiment, the base saturation of soil was 51 per cent and declined under absolute control by the end of three years cropping sequence (Table 2). The highest base saturation per cent was obtained due to complete SSNM compared to remaining nutrient omitted SSNM practices registering an increase of 5.55 per cent respectively over SSNM-N, SSNM-Ca and absolute control. It might be due to balanced application of nutrient with soil ameliorant (Paper mill sludge) as a Ca source help to increase the base saturation. These results are similar to those of Panda and Koshy (1982) [17], Mishra and Pattanayak (2002) [16] who reported that lime application (inorganic) increases pH, base saturation, and CEC; in acidic soil.

Macronutrients

Available N: During 2013**,** available N of soil was low (145 kg/ha). Average of three years cropping sequence, the highest value of available N of soil was estimated due to complete

SSNM (170.6 kg/ha) and lowest under absolute control (134kg/ha). This SSNM practice led to 19.98, 16.81, 19.39, 14.70, 9.78, 6.50 and 11.54 per cent increase available N over SSNM-N, SSNM-P, SSNM-K, SSNM-S, SSNM-B, SSNM-Zn and SSNM-Ca respectively. These results are similar to those of Dwivedi *et al.* (2003) [8] who reported that imbalance and insufficient application of fertilizers creates deficiency of nutrients in soil and lowers the soil fertility. Omission of different nutrient affect available N in order to SSNM-N<SSNM-K<farmer practice<SSNM-P<SSNM-S<SSNM-Ca<SSNM-B<SSNM-Zn.

Available phosphorus (Bray's-1-P): The initial soil was medium in Bray's-1 P (25kg/ha) while it had increased in all treatment except SSNM-N, SSNM-P and absolute control by the end of three years of cropping system. The highest available phosphorus was estimated in SSNM-Zn followed by SSNM compared to remaining nutrient omitted SSNM practices (Table 2). Relatively lower available P under SSNM might be due to the higher P utilization efficiency by the crops which was result of balanced application of all nutrients through organic and inorganic Singh *et al*. (2014b) [21]. This SSNM-Zn led to 33.33, 53.61, 24.17, 19.44 and 23.05 per cent increase over SSNM-N, SSNM-P, SSNM- K, SSNM-S and SSNM-B respectively. These results corroborate with the findings of Subba Rao and Rupa (2003) [23] who reported that decrease concentration of Zn in soil solution which enhance more accumulation of phosphorus.

Available potassium: The initial soil was medium (125kg/ha) in available K. Average of three years cropping sequence, available K was declined due to omission of nutrients, such as N, P, K, S, B, Zn and Ca compared to initial available K of soil. It might be due to more potassium requirement and uptake in rice-maize system Buresh *et al.* (2010)[3]. Another reason by Joshi *et al.* (2016) [10] who observed that N and K was the most limiting plant nutrient in the maize based production system. The highest available K was found in complete SSNM (129.0 kg/ha) followed by SSNM-Zn (122.3 kg/ha) > SSNM-B (120.7 kg/ha) > SSNM-S (119 kg/ha) > SSNM-P (106.3 kg/ha) > SSNM-N (99.7 kg/ha) > farmer practice (99 kg/ha) > SSNM-K (90.7 kg/ha) > absolute control (83kg/ha). It also increased by 22.71, 17.60, 29.69, 7.75 and 6.43 per cent over omission of nutrients, such as N, P, K, S and B respectively. It might be due to balance supplied of nutrients through organic and inorganic sources which improved availability of soil K Singh *et al*. *(*2015) [22].

Available sulphur: The available sulphur in initial soil was low (18.4 kg/ha), declined invariably under each treatment except complete SSNM by the end of three year (Table 2). These results are in agreement with earlier work of Mahapatra (1997) [14] and Johnston *et al.* (2009) [9] they reported that intensive cropping system involving 3-4 crops/year can accelerate maximum depletion of S from soil then common crop rotations and can led the problem of secondary nutrients. Sulphur content in soil varied from 9.7 to19 kg/ha during three years of cropping sequence. The highest available sulphur was estimated under SSNM treatment (19 kg/ha) while lowest under absolute control, S omitted treatment followed by SSNM-P (9.7,10.7 and 12.0 kg/ha respectively), registering an increase of 17.37, 36.84, 31.58, 43.68, 24.73 and 48.94 per cent respectively over SSNM-N, SSNM-P, SSNM-K, SSNM-S, SSNM-Ca and absolute control. It might be due to addition of balance organic and inorganic fertilizers in soil which increases sulphur pool in soil solution Kumar *et al*. (2011) [12].

Micronutrients

Manganese (Mn): In general, increases in pH reduce the toxicity of Mn. average value of three years cropping sequence, the maximum Mn was estimated in soil due to SSNM-Zn compared to remaining nutrient omitted practices however it was similar to initial status of soil. It also increased 18.29, 24.39, 28.0,45.12,12.19 and 29.27 per cent respectively over SSNM, SSNM-N, SSNM-P, SSNM-K=S, SSNM-B and SSNM-Ca. It might be due to well known Zn and Mn negative interaction Barben *et al*. (2010c) [1].

Zinc (Zn): In general, availability of zinc highly influence by phosphorus in soil. Availability of Zn in initial soil was highest (0.41 ppm). Average value of three years cropping sequence, the maximum Zn was estimated in soil under SSNM-P followed by SSNM practices compared to other nutrient omitted practices. It also increased by 7.14, 17.86, 39.29, 67.86, 71.42 per cent respectively over SSNM, SSNM-N=SSNM-B SSNM-K, SSNM-S and SSNM-Zn. Availability of Zn increased due to absence of phosphorus whereas PxZn interaction well known for negative Das *et al*. (2005) [5].

Boron (B): B content of initial soil was (0.45 ppm) stated as low. Average value of three years cropping sequence, the maximum availability of B was estimated in soil under SSNM-Zn fallowed by SSNM practices compared to remaining nutrient omitted practices registering an increase of 27.45, 49.01, 31.37, 43.14 and 11.78 per cent respectively over SSNM, SSNM-N, SSNM-P=SSNM-S, farmer practice and initial soil status. Availability of B increased in SSNM-Zn treatment might be due to well known Zn and B negative interaction Singh (2001) [20].

Conclusion

It could be concluded from the three years study on rice-maize–green gram cropping system that SSNM-based nutrient management proved to be the best approach for improving chemical properties of soil such as pH, organic carbon, cation exchange capacity, base saturation and nutrients availability (macro and micronutrients) under acidic soil of Odisha.

Table 2: Effect of nutrient omission SSNM treatments on chemical properties and nutrients status of soil under rice-maize-green gram cropping system (average of 3 years)

Treatment	pH	OC (g/kg)	CEC cmol(p+)/kg	BS %	Macronutrient (kg/ha)				Micronutrient(ppm)		
					N	P	K	S	Mn	Zn	B
SSNM	5.6	4.8	11.8	54	170.7	34.3	129.0	19.0	6.7	2.6	0.37
SSNM-N	5.2	3.9	10.5	51	136.6	24.0	99.7	15.7	6.2	2.3	0.26
SSNM-P	5.3	4.4	11.4	53	142.0	16.7	106.3	12.0	4.5	2.8	0.35
SSNM-K	5.0	4.2	11.5	52	137.6	27.3	90.7	13.0	5.9	1.7	0.31
SSNM-S	5.4	4.7	11.4	52	145.6	29.0	119.0	10.7	5.9	0.9	0.35

SSNM-B	5.1	4.3	11.3	53	154.0	27.7	120.7	17.3	7.2	2.3	0.26
SSNM-Zn	5.3	4.7	11.4	53	159.6	36.0	122.3	13.0	8.2	0.8	0.51
SSNM-Ca	4.1	4.0	9.9	51	151.0	33.6	112.7	14.3	5.8	0.7	0.31
A.C.	5.0	3.7	10.0	50	134.0	14.6	83.0	9.7	7.2	1.0	0.26
F.P.	5.2	4.0	11.1	52	141.3	25.7	99.0	13.7	5.7	0.8	0.29
Initial soil	4.9	4.1	11.0	51	145	25	125	18.5	8.2	0.41	0.45

A.C. (absolute control), F.P. (farmer practice)

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