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Soil Properties under Rainfed Rice (*Oryza sativa*) Crop as Affected by Integrated Supply of Nutrients

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***Abstract* – Effect of integrated supply of nutrients on soil properties and yield of rainfed rice crop was studied at Regional Agricultural Research Station, Assam Agricultural University, Gossaigaon, Assam (India) during *kharif* season of 2012. In the experiment, application of 50% recommended dose of fertilizers (RDF) + 50% N supplied through FYM showed the lowest bulk density and the highest water holding capacity, mean weight diameter, water stable aggregates, organic carbon, CEC and base saturation of soil after harvest of the crop. Nutrient integrations with organic and inorganic sources had a non significant effect on pH and electrical conductivity of soil. Available N, P and K of soil were significantly affected by integrated nutrient treatments which showed up to 65.29, 81.03 and 21.46% increase of these nutrients over control, respectively. Significantly highest exchangeable Ca and Mg and available S as compared to control and RDF were observed from the treatment of 50% RDF (inorganic) + 50% N FYM i.e. T_4 treatment, followed by 50% N (inorganic) + 50% N (FYM) + PK (adjusted) i.e. T_6 treatment. The detail soil physico-chemical properties and grain yield of rainfed rice as affected by integrated supply of nutrients in an Inceptisol of Assam of north-east region of India are explained in this article.**

***Keywords* – INM, Physico-Chemical Properties, Crop Yield, Rainfed Rice.**

I. Introduction

The growth rate of world agricultural production and crop yields have slowed, raising fears that the world may not be able to grow enough food to meet the needs of future population. Use of faulty agricultural practices and higher depends on synthetic fertilizers may be the root cause of constant decline in factor productivity and law yield of crops. Declining trend in productivity due to continuous use of chemical fertilizers alone has been observed in several long term experiments all over India [1]. It is however, difficult to meet the crop nutrient requirements with bulky organic manure alone and there is a need for integrated application of different sources of nutrients including biofertilizers for sustaining the desired crop productivity [2]. The combined use of organic and inorganic sources of nutrients helps in maintaining yield stability through correction of nutrient deficiencies, enhancing their efficiency and by providing favourable soil physical condition [3].

Several studies emphasized the role of Integrated Nutrient Management (INM) in increasing yield of crops and in sustaining soil health under long run [2]-[4]-[5]. Although, very sporadic studies regarding the effect of integrated nutrient management on soil properties has been conducted in Assam, the literatures on post harvest physico-chemical properties as well as primary and secondary nutrient status in rainfed *kharif* rice are not adequate. Therefore, the present investigation was carried out to study the effect of integrated supply of nutrients on physico-chemical properties and nutrient status of soil under rainfed rice (*Oryza sativa* L.) crop in an Inceptisol of Assam of north-east region of India.

II. Materials and Methods

The present investigation was carried out during *kharif* season of 2012 in case of rainfed rice (*Oryza sativa* L.) crop at Regional Agricultural Research Station, Assam Agricultural University (AAU), Gossaigaon, Assam (located in latitude 26.48′N, longitude 89°90′E and altitude 48.12m). Previously, the crop field was under rice -rice cropping sequence since 2006-2007. The details of initial soil characteristics of the experimental site are presented in Table 1. The experiment was established in randomized block design. Seven treatments combinations (Table 2) were tested replicating thrice in 21 plots with individual sizes of 4 × 4 sq. m.

Table 1. Initial soil characteristics of the site

Soil parameters	Value
Mechanical composition	
Sand (%)	48.35
Silt (%)	19.45
Clay (%)	32.20
Textural class	Sandy clay
Physical properties	
Bulk density (Mg m^{-3})	1.28
Water holding capacity (%)	35.00
Mean weight diameter (mm)	0.59
Water stable aggregates (%)	40.00
Chemical properties	
pH (1: 2.5)	5.00
Organic carbon (%)	0.41
Cation exchange capacity [c mol(p+)kg^{-1}]	5.10
Base saturation (%)	35.00
Electrical conductivity (dS m^{-1})	0.13
Macronutrients	
Available N (kg ha^{-1})	250.00
Available P (kg ha^{-1})	7.00
Available K (kg ha^{-1})	126.65
Exchangeable Ca [c mol(p+) kg^{-1}]	1.10
Exchangeable Mg [c mol(p+) kg^{-1}]	0.50
Available sulphur (kg ha^{-1})	8.27

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The recommended level of nitrogen, phosphorus and potassium (60, 20 and 40 kg ha^{-1}, respectively) for rice were applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. The amount of FYM needed for a particular treatment was calculated on the basis of nitrogen content and applied as per the treatments, except in biofertilizer based INM package. In T_6 and T_7, recommended dose of P and K was adjusted after subtracting their contribution through FYM. Biofertilizer culture *i.e. Azospirillium* + phosphate solubilizing bacteria (PSB) dual culture (count at 10^8 cfu g^{-1} of carrier for both *Azospirillium* and PSB, separately) developed by Biofertilizer Section of AAU, Jorhat was applied @ 3 kg ha^{-1} before transplanting of *kharif* rice following root dip treatment. The treatment of biofertilizer based INM package was also added with FYM @ 3 ton ha^{-1}, rock phosphate (RP) @ 50 per cent of recommended dose of P and MOP @ 100 per cent of recommended dose of K. Half of urea, whole of SSP, RP and MOP were broadcasted at the time of transplanting of *kharif* rice. The remaining urea was splited as top dressing at the time of maximum tillering stage and panicle initiation stage of the crop. The rice (cv. Ranjit) was transplanted on July and harvested on November. All other crop management practices were practiced as per the standard recommendation of the region.

After harvest of the *kharif* rice, three replications of soil samples were collected randomly (from each plot) from effective root-zone depth of the crops (0-30 cm). The samples from within a plot were mixed, air dried, processed to pass through a 2 mm sieve and stored in polythene bags for analysis. Bulk density was determined in undisturbed soil core, and water holding capacity was determined by Keen-Rackzowski Box method [6]. Mean weight diameter and water stable aggregate were determined by modified Yoder's wet sieving method [7]. Processed samples were analyzed for pH and EC in 1:2.5 soil-water suspensions by using glass electrode pH meter and Systronics Digital Electrical Conductivity Meter, respectively [8]. Organic carbon was estimated by wet digestion method of *Walkley* and *Black* [9]. CEC of the soil was determined by leaching the soil with neutral normal ammonium acetate solution using the distillation method or ammonium saturation method [10]. The leachate ammonium acetate thus obtained from the soil was taken for determining the exchangeable cations. The EDTA method [8] was used for determination of Ca and Mg, while for available sulphur determination mono-calcium phosphate extractable S method was used [11]. The per cent base saturation of the soil was estimated with the help of the following formula:

$$B.S. (\%) = (\text{Total exchangeable bases} / \text{CEC}) \times 100$$

Available nitrogen, phosphorus and potassium content in soil were determined respectively by alkaline potassium permanganate method [12], Bray and Kurtz No.1 method and flame photometrically [8]. All data were subjected to statistical analysis as per the procedure outlined by *Gomez* and *Gomez* [13].

III. Results and Discussion

3.1. Physical properties of soil

The data as affected by integrated application of organic and inorganic sources of nutrients on physical properties of post harvest status of rice growing soil are presented in Table 2. The results revealed that- integrated nutrient management (INM) had a non significant effect on bulk density of soil after *kharif* rice. The lowest bulk density was recorded from the treatment of 50% recommended dose of fertilizers (RDF) plus 50% N through FYM. The bulk density was highest in the plot receiving no FYM or chemical fertilizers. Nutrients integration showed a significant effect on soil's water holding capacity and data varied between 33.50 and 40.00%. All the treatments showed an increase in water holding capacity of soil except in control treatment. There was an 14.29% increase in water holding capacity of soil over control when 50% RDF was substituted through 50% N in organic form (FYM), followed by Bio-fertilized based INM package (i.e. T_3) treatment.

The INM treatments significantly increase the mean weight diameter and water stable aggregates of soil (Table 2). Mean weight diameter measurements varied from 0.58-0.70mm after harvest of the *kharif* rice. The highest mean weight diameter of soil was recorded in case of 50% RDF (inorganic) + 50% N (YFM) i.e. T_4 treatment, followed by Bio-fertilized based INM package (T_3) and 50% N (inorganic) + 50% N (FYM) + PK (adjusted) i.e. T_6 treatment, respectively. Data revealed that substitution of 50% of recommended dose of fertilizers through 50% N FYM (i.e. T_4 treatment) showed 25.93% and 29.64% increase in water stable aggregates of soil over RDF and control, respectively.

Improvement in physical properties of soil may be due to increased in organic matter content of soil, improvement in overall soil structural condition and beneficial effect of certain polysaccharides formed during decomposition of organic residues by microbial activity in soil [14]. It is explicit from the data (Table 2) that- soil bulk density increases and water holding capacity, mean weight diameter and water stable aggregates of soil decreases without addition of external sources of organic and inorganic forms of nutrients in soil.

3.2. Chemical properties of soil

Effects of nutrient integrations on various chemical properties of soil after rice crop are presented in Table 2. Data showed clearly that the effect on soil pH and electrical conductivity (EC) was non-significant due to INM treatments. In the present investigation, T_4 treatment, i.e. 50% RDF (inorganic) + 50% N (FYM) recorded the height pH and EC of soil, followed by 50% N (inorganic) + 50% N (FYM) + PK (adjusted) i.e. T_6 treatment, whereas lowest values were recorded in case of control plot. Higher pH in the soil with INM treatments may be defined as the deactivation of Al^{3+} and concomitant release of basic cations due to addition of organic matter. Such rise in pH value is in conformity with earlier finding [15]. Nutrient integrations (both with organic and inorganic sources) showed an increase in EC of soil and data ranged

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Table 2: Effect of integrated nutrient management on physico-chemical properties of soil after rainfed *kharif* rice

Treatments	BD (Mg m^{-3})	WHC (%)	MWD (mm)	WSA (%)	pH	EC (dS m^{-1})	OC (%)	CEC [c mol(P$^+$)kg^{-1}]	BS (%)
T_1	1.36	33.50	0.58	39.34	4.90	0.12	0.34	5.00	34.32
T_2	1.33	36.50	0.61	40.50	5.15	0.13	0.42	5.12	35.77
T_3	1.27	38.25	0.68	42.75	5.10	0.14	0.51	5.15	36.00
T_4	1.25	40.00	0.70	51.00	5.20	0.19	0.57	5.38	37.00
T_5	1.31	37.50	0.66	46.20	5.07	0.14	0.52	5.12	35.85
T_6	1.30	37.00	0.67	49.85	5.17	0.16	0.54	5.30	35.50
T_7	1.34	36.20	0.63	42.00	5.04	0.13	0.48	5.08	35.20
S.Ed(±)	0.004	0.811	0.010	0.613	0.072	0.024	0.043	0.043	0.874
CD (p=0.005)	NS	1.77	0.021	1.34	NS	NS	0.09	0.09	NS

Note, T_1 : Control, T_2 : Recommended Dose Fertilizers (RDF), T_3 : Biofertilizer based INM package, T_4 : 50% RDF (inorganic) + 50% N (FYM), T_5 : 75% RDF (inorganic) + 25% N (FYM), T_6 : 50% N (inorganic) + 50% N (FYM) + PK (adjusted), T_7 : 75% N (inorganic) + 25% N (FYM) + PK (adjusted); **BD**, bulk density, **WHC**, water holding capacity, **MWD**, mean weight diameter, **WSA**, water stable aggregates, **OC**, organic carbon, **BS**, base saturation, **CD**, critical difference, **NS**, non significant

between 0.12 and 0.19 dS m^{-1}. More availability of soluble forms of K, Ca, Mg and Na those lead to formation of some salts due to addition of organics, which might be responsible for the higher EC of the soil after harvest of the rice crop [16].

Results revealed that- integrated application of both organic and inorganic sources of nutrients significantly increased the soil organic carbon content over RDF and control treatment. In the present investigation, there was 41.18- 67.65% increase in organic carbon content in soil due to INM treatments over absolute control plot. Maximum (67.65%) increase in organic carbon content of soil was recorded from the plot receiving 50% RDF (inorganic) + 50% N (FYM) i.e. T_4 treatment. Such increase in organic carbon might be due to supply of organic sources to the soil. The effect was further enhanced by addition of NPK fertilizers resulting in higher root and shoot growth and thus increased in production of biomass might have raised the organic carbon content in soil. Such results also correlated the findings of *Banswasi* and *Bajpai* [17].

The cation exchange capacity (CEC) measurements of soil varied from 5.00- 5.38 cmol (P$^+$) kg^{-1} (Table 2). Highest CEC was recorded in case of 50% RDF (inorganic) + 50% N (FYM) i.e. T_4 treatment, followed by 50% N (inorganic) + 50% N (FYM) + PK (adjusted) i.e. T_6 treatment. In this investigation, different integrated nutrient treatments showed an increase in per cent base saturation of soil over initial and control treatment (Table 2). However, the effect was non-significant and data ranged between 34.32 and 37.00%. Application of 50% RDF (inorganic) along with 50% nitrogen in organic (FYM) form *i.e.* T_4 treatment exhibited the highest per cent base saturation after harvest of the rainfed rice. As the decomposition products of FYM contain various organic acids; these might have aided in release of different proportion of non-exchangeable K, Ca, Mg and Na to the water soluble form, which contributed to higher base saturation in soil [18].

3.3. Primary nutrients status of the soil

Results from this investigation (Table 3) showed clearly that all the available primary nutrients in soil were considerably affected by INM treatments. The available N in soil was varied from 206.00 to 340.00 kg ha^{-1}. The maximum 36.20% increase in available N was recorded in case of T_4 treatment *i.e.* when 50% RDF was substituted with 50% N in organic (FYM) form over initial. Increase in available nitrogen might be due to interaction of nutrients with FYM which exerted beneficial effects in the release of ammonical and nitrate-nitrogen. Addition of nitrogenous fertilizer along with FYM helps in narrowing down of C:N ratio and thus, increased mineralization resulted in rapid conversion of organically bound N to inorganic forms [19].

Integrated applications of organic and inorganic forms of nutrients significantly affect the available P status of soil after harvest of the *kharif* crop and data ranged between 5.80 and 10.50 kg ha^{-1}. The highest available P in soil was recorded in case of 50% RDF (inorganic) + 50% N (FYM) which showed 50.00 and 81.03% increase over initial and control plot. Favourable effect of combined application of inorganic and organic source of nutrients in enhancing the P availability may be defined as the reduction in fixation of water soluble P and increase in mineralization of P due to microbial action that enhanced the availability of P. The organic anions and hydroxyl acids liberated during the decomposition of organic matter may complex or chelate Fe, Al, Mg and Ca and prevent them from reacting with phosphate [20].

The available K of soil measurements also showed remarkable variation ranging from 102.50 to 124.50 kg ha^{-1} (Table 3). There was maximum 21.46% increase in available K over control treatment (no FYM or fertilizers) after harvest of the rice crop when 50% RDF was applied with 50% N FYM (T_4 treatment). Significantly lowest value was observed under control. However, in the present investigation there was a decline in available K content of soil over the initial value in all treatments. This might be due to a gap between the removal and supplementation of K into the soil. Insufficient addition of K through fertilizers and FYM, and consequently higher removal by crops might be the possible reason of decrease in K availability in soil. Such negative balance of K in soil in rice-rice and rice-niger sequences in Jorhat district of Assam was also reported by earlier workers [2]-[21]. The findings of *Sharma* and *Bali* also supported such result of decline availability of K in soil [22].

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Table 3: Effect of INM on primary and secondary nutrients status of soil after rainfed *kharif* rice

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available S (kg ha^{-1})	Exchangeable Ca [c mol (P$^+$)kg^{-1}]	Exchangeable Mg [c mol (P$^+$)kg^{-1}]
T_1	206.00	5.80	102.50	5.29	0.80	0.42
T_2	270.00	6.10	112.20	8.70	0.90	0.45
T_3	268.75	7.00	122.00	9.00	0.95	0.47
T_4	340.50	10.50	124.50	14.35	1.10	0.52
T_5	310.70	8.50	115.00	11.50	1.07	0.48
T_6	325.20	9.00	116.00	11.75	1.08	0.49
T_7	315.00	6.46	113.65	8.55	1.00	0.46
S.Ed(±)	14.552	1.0	3.3	1.658	0.060	0.035
CD (p=0.005)	31.71	2.3	7.3	3.61	0.13	0.08
CV at %	5.85	5.04	6.76	-	-	-

Note, T_1 : Control, T_2 : Recommended Dose Fertilizers (RDF), T_3 : Biofertilizer based INM package, T_4 : 50% RDF (inorganic) + 50% N (FYM), T_5 : 75% RDF (inorganic) + 25% N (FYM), T_6 : 50% N (inorganic) + 50% N (FYM) + PK (adjusted), T_7 : 75% N (inorganic) + 25% N (FYM) + PK (adjusted).

3.4. Secondary nutrients status of the soil

The tabulated data (Table 3) revealed that- the secondary nutrients of soil were significantly affected by integrated nutrient treatments after harvest of the *kharif* rice. Exchangeable calcium and magnesium in soil were varied from 0.80- 1.10 and 0.42- 0.52 cmol (P$^+$)kg^{-1}, respectively. Application of 50% recommended dose of fertilizers along with 50% N through FYM increased the exchangeable Ca of soil by 37.50 and 22.22% after *kharif* rice over control and RDF, respectively. However, there was a decrease in exchangeable Ca and Mg content in soil over initial (1.10 cmol (P$^+$) kg^{-1} Ca and 0.50 cmol (P$^+$) kg^{-1} Mg, respectively) after the harvest of the crop in case of all the treatments, except in the treatment of 50% RDF (inorganic) + 50% N FYM i.e. T_4. Decrease in exchangeable Ca and Mg content in soil might be attributed to lesser content in FYM and SSP (applied to the crop) and thus, leads to higher removal of these nutrients from the soil after harvest of the crop.

Results on the status of available sulphur (Table 3) revealed that the integrated nutrient management considerably increase the available S content in soil. The maximum S availability (14.35 kg ha^{-1}) was recorded from the treatment of T_4 i.e. 50% RDF (inorganic) + 50% N FYM, followed by T_6 i.e. 50% N (inorganic) + 50% N (FYM) + PK (adjusted) treatment. Build up of available S could be justified as a result of mineralization of organic source that contributed to accumulation of more amount of S in soil [21]. Thus, addition of FYM and SSP in soil might be the possible reason of enhancement of S content in soil. Such results are in line with the observation of earlier workers [20]-[23]-[24].

3.5. Gain and straw yield of crop

A perusal of data (Figure 1) revealed that the yield of rice was significantly affected by different INM treatments. The grain and straw yield of rice were varied from 2.60-4.20 and 4.20-8.00 ton ha^{-1}, respectively. Application of 50% RDF + 50% N FYM (T_4) has produced highest yield of rice as compared to other treatments. Maximum 61.54 and 90.48% increase in grain and straw yield of rice were recorded from T_4 treatment over control plot. Increase in yield may be attributed to a steady decomposition of farmyard manure and release of nutrients throughout the crop growth period couple with better assimilation of nutrients [2]-[25].

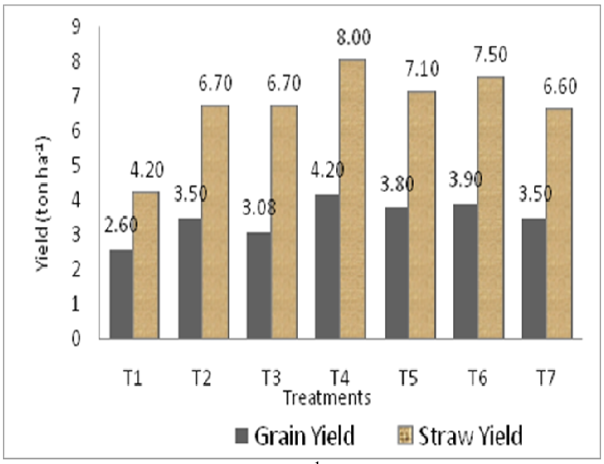

Fig.1. Yield of rice (ton ha^{-1}) as affected by integrated supply of nutrients under rainfed situation

Note, T_1 : Control, T_2 : Recommended Dose Fertilizers (RDF), T_3 : Biofertilizer based INM package, T_4 : 50% RDF (inorganic) + 50% N (FYM), T_5 : 75% RDF (inorganic) + 25% N (FYM), T_6 : 50% N (inorganic) + 50% N (FYM) + PK (adjusted), T_7 : 75% N (inorganic) + 25% N (FYM) + PK (adjusted).

IV. Conclusion

It could be mentioned that judicious and effective integration of chemical fertilizers along with the organic sources of nutrient is mandatory for maintaining the soil productivity in rainfed agriculture. Thus, the foregoing results from this study suggest that we could go in substitution of recommended dose of inorganic sources of NPK to the extent of 50% with organic sources of nutrients using FYM. Application of half of recommended dose of fertilizers along with half of N through organic (FYM) form maintains the sustainability of soil properties in one way, and increases the yield of crops under rainfed situation, in other.

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