

## Effect of continuous cropping and integrated nutrient management practices on soil properties and yield of rice (*Oryza sativa*)–rice cropping system in acid soil

A. BAISHYA<sup>1</sup>, BHABESH GOGOI<sup>2</sup>, J. HAZARIKA<sup>3</sup>, M. BORAH<sup>4</sup>, A.S. BORA<sup>5</sup>,  
A. RAJBONGSHI<sup>6</sup>, P. DEORI<sup>7</sup>, J.P. HAZARIKA<sup>8</sup> AND P. SUTRADHAR<sup>9</sup>

Assam Agricultural University, Jorhat, Asom 785 013

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### ABSTRACT

The long-term effects of inorganic alone and combine effect of inorganic as well as organic sources of nutrients on soil fertility and crop productivity were investigated in rice (*Oryza sativa* L.)–rice cropping sequence in acid soils of north-east India from 1987 to 2014. The higher average grain (6.50 t/ha) and straw (8.25 t/ha) yields of the rice–rice sequence were recorded in case of 75% recommended nitrogen, phosphorus, and potassium (NPK) through fertilizers along with 25%N through incorporation of crop stubbles in winter rice at the time of puddling and 75% recommended NPK through fertilizers in autumn rice. The higher available N, P and K status of soil were recorded when recommended 50% NPK through chemical fertilizers applied along with 50%N through *Azolla* in winter rice and 100% recommended dose of NPK through chemical fertilizers to autumn rice. However, uptake of NPK by rice–rice sequence was higher when 75% recommended NPK dose was applied through chemical fertilizers to both winter and autumn rice along with 25%N through crop stubbles only in case of winter rice. Thus, integrated nutrient management involving organic and inorganic sources not only increases the availability and uptake of major nutrients but also helps in yield sustainability in rice–rice cropping system under long run in acid soils.

**Key words :** Integrated nutrient management, Long-term cropping system, NPK uptake, Physico-chemical properties of soil, Rice–rice cropping system

Rice is one of the most important food crops and a primary food source for more than one-third of world's population (Prasad *et al.*, 2010). South-East Asia alone will require 275 million tonnes of rice to meet the growing population by 2030 (Subbiah *et al.*, 2001). India has the largest area under rice cultivation (44.3 million ha), amounting for 29.40% of the global rice area. But the productivity of rice in India is lower (2.04 tonnes/ha) as compared to Japan (6.25 tonnes/ha), China (6.24 tonnes/ha) and Indonesia (4.25 tonnes/ha). Limited availability of scarce resources along with declining factor productivity of rice crop is one of the major concern of feeding a population which has been increasing globally by about 80 million people per year (Fischer and Heilig, 1998).

Agricultural sustainability depends to a large extent on

improvements in soil properties those are controlled by many factors, of which the mineral nutrition is by and large most important. The steady decline in soil organic matter levels due to continuous cropping without recycling enough crop or animal residues, coupled with nutrient imbalances due to insufficient application of nutrient has led to negative nutrient balance in agriculture, impaired soil health and declining factor productivity. Declining trend in productivity due to continuous use of chemical fertilizers alone has been observed in several long-term experiments all over India (Nambiar, 1994), while integration of organic sources sustain the productivity. 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 (Gogoi *et al.*, 2010). Since sustainability of the production system depends on the sustainable use of soil resources, it is necessary to develop and adopt soil-management technologies that increase soil organic matter contents and biological activities and improves soil physical conditions to keep lands productive on the sustainable basis (Ali *et al.*, 2012).

<sup>1</sup>Corresponding author Email: baishya.ajit@gmail.com

<sup>1</sup>Chief Agronomist, <sup>2</sup>Junior Soil Scientist, <sup>3</sup>Junior Agronomist (On-station), <sup>4</sup>Junior Economist, <sup>5</sup>Junior Agronomist (On-farm), <sup>6</sup>Senior Research Fallow (Fishery), <sup>7</sup>Senior Research Fallow (Veterinary), <sup>8</sup>Associate Professor (Department of Agricultural Economics and Farm Management), <sup>9</sup>Ph.D. Scholar, Integrated Farming System, Assam Agricultural University, Jorhat, Asom 785 013

Soil productivity is closely linked with soil organic matter (SOM) status. Organic amendments play an important role in the improvement of soil structure and SOM content (Meelu *et al.*, 1994). *Azolla*, Farmyard manure (FYM)/compost and crop stubbles are important sources of organic matter in case of rice crop. The use and management of crop residues, farmyard manures (FYM) and green manure, are an increasingly important aspect of environmentally sound sustainable agriculture (Timsina and Connor, 2001).

Long-term fertility management studies have emphasized that balanced fertilization was must to realize the higher-yields and yield sustainability in rice–rice cropping sequence (Katyal and Gangwar, 2000). Thus, monitoring long-term fertilization effect on crop yield and soil-fertility changes is important for maintaining the system productivity. Because, the long-term experiment plays an important role in understanding the complex interaction of plants, soils, climate and management practices and their effects on crop productivity. Long-term experiments are the primary source of information to determine the effect of cropping systems and thus, site-specific information is needed for evaluation of soil quality. Considering the importance, the details of a study on assessment of the sustainability of rice–rice cropping in terms of soil-fertility and yield stability using data generated from a long-term INM experiment are described here.

## MATERIALS AND METHODS

A long-term integrated nutrient management (INM) trial was established in 1987–88, at the Instructional-Cum-Research Farm (26° 48' N, 95° 50' E and altitude 86.6 m) of Asom Agricultural University (AAU), Jorhat, Assam (India). The aim of the investigation was to study the long-term effect of inorganic alone and combined effect of inorganic as well as organic sources of nutrients on soil fertility and crop productivity and to come out with a suitable nutrient-supply system for the acid soils for rice–rice crop sequence under the climatic condition of north-east India. Being situated in sub-tropics, the climate of the study site is characterized by hot and wet summer and dry and cool winter with 4 distinct seasons such as pre-monsoon season (March–May), monsoon season (June–September), post-monsoon season (October–November) and winter season (December–February). The average annual rainfall in the area was recorded as 1,900 mm, of which the major about 70% of rainfall is received during rainy season and 18–27% in the summer season. Mean maximum and minimum annual temperatures recorded were 27.5° C and 17.2° C, respectively, with lowest temperature in January and highest in June. In a year, average relative humidity prevails maximum during summer (80%) and minimum dur-

ing winter (60%). The average sunshine hours receive during summer and winter are 6 and 4 hours/day respectively.

The soil belongs to Inceptisol. The analysis of initial soil sample of the experimental site revealed that it was of sandy loam (sand 62.40%, silt 25.00% and clay 12.50%) with bulk density of 1.51 Mg/m<sup>3</sup>, water-holding capacity of 31.64%, pH of 5.00, organic carbon of 0.60%, cation-exchange capacity of 5.60 mol<sub>c</sub>/kg, available N of 277.76 kg/ha, available P of 10.08 kg/ha, available K of 72.08 kg/ha, exchangeable Ca of 1.32 mol<sub>c</sub>/kg, exchangeable Mg of 0.80 mol<sub>c</sub>/kg and available S of 10.00 mg/kg.

The experiment initiated in 1987–88 was composed of 12 treatments × 4 replications = 48 plots, each of 10 m × 10 m (=100 m<sup>2</sup>) dimensions. The details of the treatments are presented in Table 1. The recommended levels (100%) of N, P and K were 45, 30 and 40 kg/ha, respectively, for both winter rice and autumn rice on the basis of soil-test value of 1987. Chemical sources of N, P and K were urea, single super phosphate (SSP) and muriate of potash (MOP) respectively. Half of urea, whole quantity of SSP and MOP were applied basal at the time of puddling for rice. The remaining urea was applied (sharing equally) as top-dressing at the time of maximum tillering stage and panicle-initiation stage of rice crop. Nutrient content of the different organic sources are presented in Table 2. On the basis of nutrient content, requirement of FYM, crop stubbles and *Azolla* were calculated and applied as per different treatments under study. *Azolla* was inoculated @ 5 q/ha for 50% replacement and 2.5 q/ha for 25% replacement and allowed as dual cropping for complete mat formation which in turn produced 10 tonnes/ha (with 5 q/ha inoculation) and 5 t/ha (with 2.5 q/ha inoculation). After mat formation, *Azolla* was incorporated into the soil. The winter rice crop (cv. 'Ranjit') was transplanted in 20 cm × 20 cm spacing in the first week of July and the autumn rice (cv. 'Disang') was transplanted in 20 cm × 15 cm spacing on last week of March, each year. All other crop-management practices were practiced as per the standard recommendation of the state.

Soil samples were collected from effective root-zone depth of the crops (0–30 cm) after harvest of the winter rice and autumn rice from each plot and were air dried, processed to pass through a 2 mm sieve and stored in polythene bags. Bulk density was determined in undisturbed soil core, and water-holding capacity was determined by Keen-Rackowski Box method referring the textbook of Baruah and Borthakur (1997). Processed samples were analyzed for pH in 1:2.5 soil-water suspensions by using glass electrode pH meter (Jackson, 1973). Organic carbon was estimated by wet digestion method of Walkley and Black (1934). The CEC of the soil was deter-

mined by leaching the soil with neutral normal ammonium acetate solution using the distillation method or ammonium saturation method as described by Sankaram (1966). The per cent base saturation (B.S.) of the soil was estimated with the help of the following formula:

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

Available nitrogen, phosphorus and potassium content in soil were determined respectively by alkaline potassium permanganate method (Subbiah and Asija, 1956), Bray and Kurtz No.1 method and flame photometrically (Jackson, 1973). Plot, wise plant samples collected at the time of harvesting were chopped, dried, grinded and digested in concentrated  $\text{H}_2\text{SO}_4$  for determination of N content (modified kjeldahl's method) and in tri-acid mixture for determination of P (yellow colour development method) and K (flame photometric method) contents (Jackson, 1973).

All data were subjected to the analysis of variance (ANOVA) appropriate to the design using the windows-based statistical package for the social science (SPSS, 2001). Test of significance of the treatment difference was done on the basis of the *f*-test (Gomez and Gomez, 1984). The least significant differences (LSD) between the treatments were compared at a 5% level of probability.

## RESULTS AND DISCUSSION

### *Physico-chemical properties of soil*

The soil pH has increased at the conjunctive use of organic and inorganic sources of nutrients over a period of 27 years with rice–rice cropping sequence under the climatic condition of Asom (Table 3). Maximum 11.60% increase in soil pH was recorded when 50% recommended NPK dose through fertilizers + 50% N through FYM (compost) was applied to winter rice and 100% recommended NPK dose through fertilizers were applied to autumn rice. Increase in pH with integrated treatments may be defined as the deactivation of  $\text{Al}^{3+}$  and concomitant release of basic cations due to addition of organic matter under long run condition. However, Singh *et al.* (2007) did not notice much variation in soil pH for the period of 20 years in rice–wheat cropping system in north-east India. Decrease in pH of soil over initial was recorded in the control (no-fertilizer, no-organic manure) treatment after 27 years of rice–rice cropping sequence.

There was an increasing trend in organic carbon status of soil in case of all the treatments including the integrated treatments in rice–rice system over a period of 27 years (Table 3). The integrated use of chemical fertilizers with

**Table 1.** Treatment combinations used to study the long-term effect of integrated nutrient management (INM) in case of rice–rice sequence of Asom

Treatment	Rice (winter)	Rice (autumn)
T <sub>1</sub>	No fertilizer, no organic manure (control)	No fertilizer, no organic manure (control)
T <sub>2</sub>	50% recommended NPK dose through fertilizers	50% recommended NPK dose through fertilizers
T <sub>3</sub>	50% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T <sub>4</sub>	75% recommended NPK dose through fertilizers	75% recommended NPK dose through fertilizers
T <sub>5</sub>	100% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T <sub>6</sub>	50% recommended NPK dose through fertilizers + 50% N through FYM (compost)	100% recommended NPK dose through fertilizers
T <sub>7</sub>	75% recommended NPK dose through fertilizers + 25% N through FYM (compost)	75% recommended NPK dose through fertilizers
T <sub>8</sub>	50% recommended NPK dose through fertilizers + 50% N through crop stubble	100% recommended NPK dose through fertilizers
T <sub>9</sub>	75% recommended NPK dose through fertilizers + 25% N through crop stubbles	75% recommended NPK dose through fertilizers
T <sub>10</sub>	50% recommended NPK dose through fertilizers + 50% N through <i>Azolla</i>	100% recommended NPK dose through fertilizers
T <sub>11</sub>	75% recommended NPK dose through fertilizers + 25% N through <i>Azolla</i>	75% recommended NPK dose through fertilizers
T <sub>12</sub>	Conventional farmer's practice–25% N/ha of recommended dose as urea top-dressing	Conventional farmer's practice–1 tonne FYM/ha + 25% N as DAP

**Table 2.** Nutrient content (%) of different organic sources (on dry-weight basis)

Organic sources	N	P	K	S	Ca	Mg
FYM	0.90	0.30	0.60	0.30	1.30	0.97
Crop stubbles	0.70	0.10	0.50	0.15	0.60	0.50
<i>Azolla</i>	4.00	0.90	1.00	0.30	1.00	0.50

compost, crop stubble and green manure (*Azolla*) was found more effective in increasing the organic carbon content compared to the use of only chemical fertilizers. Highest organic carbon content (7.90 g/kg) in soil was recorded with 50% substitution of chemical fertilizers through crop stubble and through *Azolla* in case of winter rice over initial (6.00 g/kg). This increase in organic carbon may be due to regular supply of organic sources to the soil along with the 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. Lowest increase in soil organic carbon was recorded in the conventional practice of farmers involving 25% N/ha of recommended dose as urea top-dressing in winter rice and 1 tonne FYM/ha + 25% N as diammonium phosphate in autumn rice which might be inadequate to increase the organic carbon content of soil considerably. However, there was decreasing trend in soil organic carbon under long run when rice followed by rice cropping was done without any external supply of nutrients.

Changes in bulk density, water-holding capacity and cation-exchange capacity in soil during 1987–2000 and 2000–2014 (i.e. at the interval of 13 cycles) of winter rice–autumn rice sequence are presented in Figs. 1, 2 and 3. Decreasing trends in bulk density of soil were recorded over initial value in case of all the treatments except in the control plot under study. Maximum 11.26% decrease in soil bulk density was recorded in the rice–rice sequence from the treatment receiving 50% recommended NPK dose through fertilizers + 50% N through *Azolla* in case of winter rice and 100% recommended NPK dose through fertilizers in case of autumn rice. This was followed by 10.60% bulk density decrease in the treatment of 75% recommended NPK dose through fertilizers + 25% N through *Azolla* in case of winter rice and 75% recommended NPK dose through fertilizers in case of autumn rice. The reduction in bulk density of soil under integrated nutrient management may be attributed to better aggregation and increased porosity of soil caused due to increase in soil organic matter. The bulk density also slightly reduced under sole chemical fertilizers use treatments over initial could be due to the increased biomass production with consequent increase in organic matter content in soil (Bharadwaj and Omanwar, 1992; Khariche *et al.*, 2013). However, increase in bulk density in control plot (Fig. 1) indicated that without external supply of nutrients may lead to soil compaction under continuous monocropping with rice–rice system.

Comparing with initial status of soil, water-holding capacity of soil was increased in case of all the INM treatments (Fig. 2). A slow decrease in water-holding capacity of soil was recorded in the control treatment (no-fertilizer,

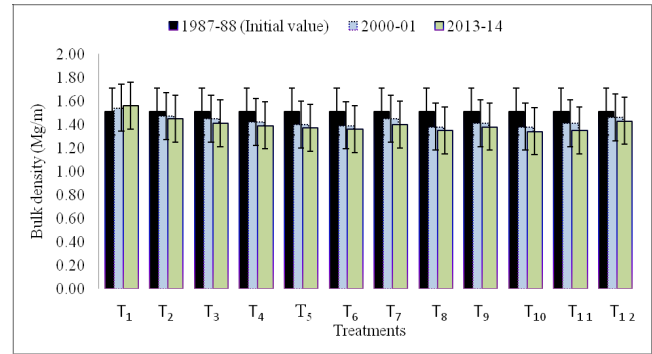


Fig. 1. Changes in soil bulk density in rice–rice sequence over initial status of soil (details of treatments are given in Table 1)

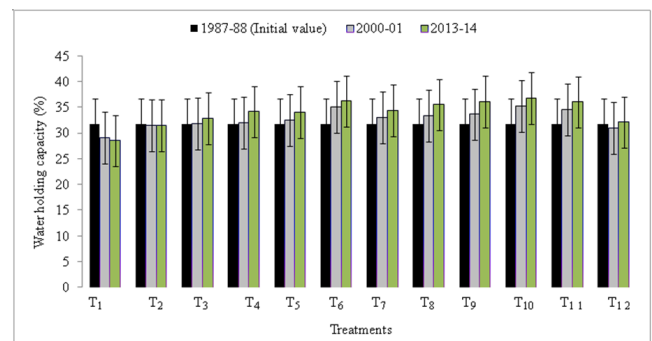
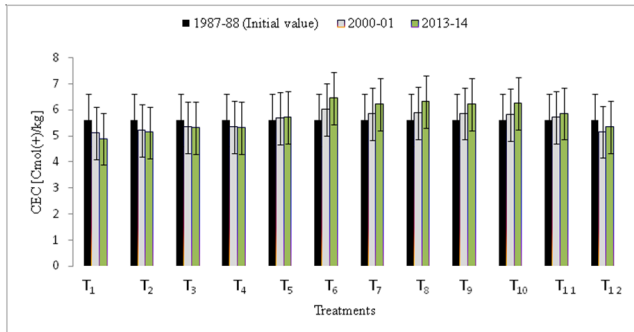


Fig. 2. Changes in soil water-holding capacity in rice–rice sequence over initial status of soil (details of treatments are given in Table 1)

no-organic manure), whereas water-holding capacity was maintained in the treatment of 50% RDF both to winter and autumn rice and in case of farmer's practice method. The highest increase in water-holding capacity of soil was observed when *Azolla* was applied to replace 50%N, followed by application of FYM to replace 50%N in case of winter rice. It is well known that better soil aggregation as a consequence of the addition of organics has favourable influence on water-holding capacity of soil.

In the present investigation, cation exchange capacity (CEC) of soil ranged from 5.10 to 6.00 and 4.88 to 6.45 Cmol(+)/kg during 1987–2000 and 2000–2014, respectively (Fig. 3). Combined application of organic and inorganic sources of nutrients showed a positive effect on CEC of soil, where as there were negative impact on CEC of soil due to no use or less use of chemical fertilizers (i.e. less than recommended dose of fertilizers) in the rice–rice system under long run (Fig. 3). Application of FYM and crop stubbles to replace the 50%N requirement in case of winter rice showed the highest increase in CEC of soil as compared to other treatments under this study. However, in case of balanced application of recommended 100% NPK fertilizers, the CEC of soil was maintained with not much variation under long term. Sepelha (2011) reported

that application of chemical fertilizers either alone or in conjunction with organic materials increased CEC of the soil significantly over the control. Continuous intensive cropping without supplying external sources of nutrients has led to an increase in soil bulk density and reduction in water-holding capacity and in cation-exchange capacity of soil, indicating gradual loss in soil quality under rice–rice cropping system. Such results are in conformity with the findings of Ghose and Pathak (2006).



**Fig. 3.** Changes in cation-exchange capacity of soil in case of rice–rice sequence over initial status of soil (details of treatments are given in Table 1)

#### Primary nutrients status of soil

The continuous cropping under imbalance use of chemical fertilizers for 27 years showed depletion of soil nutrients while they were either maintained or enhanced due to integrated use of nutrients. Post-harvest available N and K status of soil were increased significantly in case of all the treatments receiving nutrients from combined supplementation of organic and inorganic sources, whereas available P status of soil was maintained at inte-

grated treatments over rest of the treatments (Table 4). In our long-term study, when recommended 50% NPK (through fertilizers) was applied along with 50% N through *Azolla* in winter rice and 100% recommended dose of NPK to autumn rice then post-harvest available N, P and K status were found to be highest. This may be due to the fact that *Azolla* act as soil fertility improver in case of rice cropping. However, a declining trend in soil-available N, P and K status was recorded in case of rice–rice cropping system in the control treatment (i.e. no-fertilizers, no-organic manures) and from all the treatments with less than 100% recommended NPK dose only through chemical fertilizers including farmer’s practice method. With the incorporation of *dhaincha* + *Azolla* and greengram + *Azolla* as green manuring in rice–wheat cropping system not only improves the fertility status of soil but also helps curtail down the use of fertilizer N to the tune of 68 kg/ha in the rice crop and up to 16 kg/ha in the subsequent wheat crop of the sequence (Baishya, 1988).

The changes in soil-available NPK after completion of 27 cycles (from 1987 to 2014) of winter rice–autumn rice sequence in the acid soil of Asom illustrated (Fig. 4), a negative NPK balance in the control treatment, farmer’s practice and in all other treatments with less than recommended chemical fertilizers dose. Thus, this is evident that nutrient integrations with organic and inorganic sources of nutrients resulted in net gain in soil NPK in rice–rice sequence under long-term situation. Such results were also reported by Regmi *et al.* (2006).

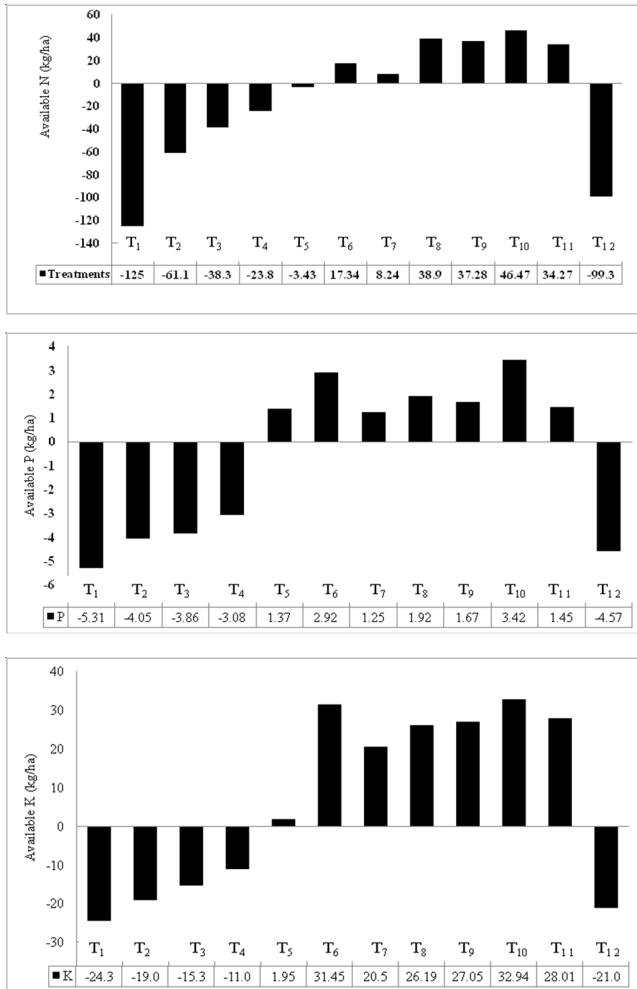
#### Uptake of nutrients

In the present study, total uptake of N, P and K nutrients by the rice–rice cropping system varied between 51.79 and

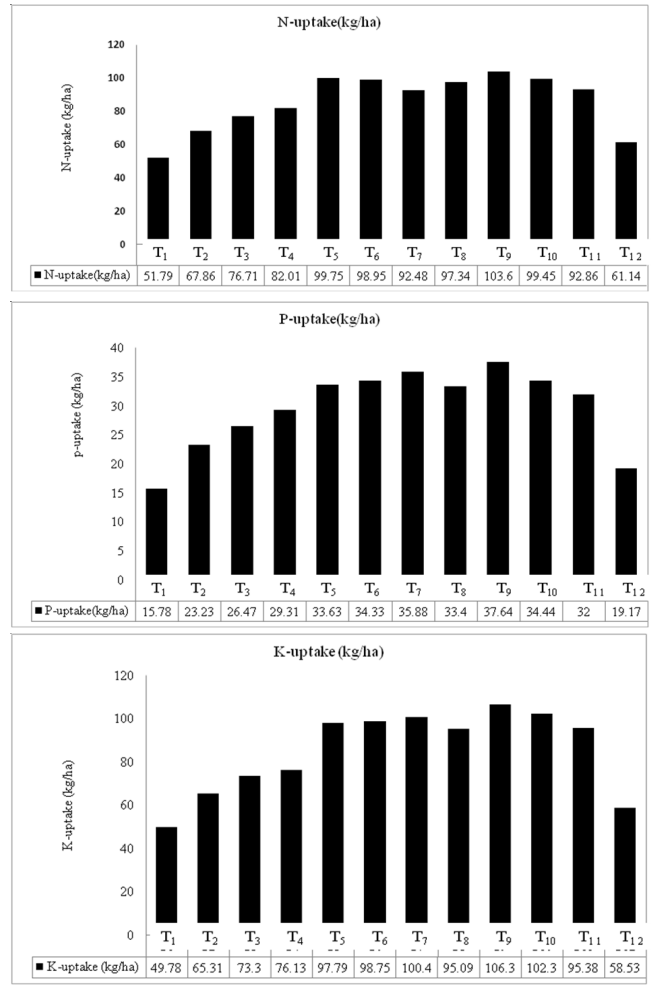
**Table 3.** Effect of long-term integrated nutrient management treatments on pH and organic carbon status of soil under rice–rice cropping system (data given are mean value of minimum 5 years)

Treatment	Soil pH					Soil organic carbon (g/kg)				
	1987–92	1992–97	1997–02	2002–07	2007–13	1987–92	1992–97	1997–02	2002–07	2007–13
T <sub>1</sub>	5.05	5.08	5.05	5.00	4.90	5.7	5.5	5.4	5.1	4.3
T <sub>2</sub>	5.13	5.08	5.10	5.15	5.28	6.1	5.8	6.5	6.7	6.9
T <sub>3</sub>	5.12	5.09	5.13	5.17	5.37	6.1	5.9	6.6	6.8	7.0
T <sub>4</sub>	5.10	5.12	5.14	5.26	5.42	6.3	5.9	6.6	7.0	7.3
T <sub>5</sub>	5.20	5.10	5.13	5.15	5.39	6.5	6.0	6.7	7.1	7.4
T <sub>6</sub>	5.24	5.26	5.36	5.46	5.58	7.1	7.0	7.3	7.5	7.8
T <sub>7</sub>	5.15	5.18	5.20	5.32	5.40	7.0	6.9	7.1	7.4	7.6
T <sub>8</sub>	5.16	5.23	5.34	5.45	5.56	7.1	7.3	7.5	7.6	7.9
T <sub>9</sub>	5.16	5.20	5.32	5.40	5.50	6.5	6.6	7.0	7.5	7.7
T <sub>10</sub>	5.17	5.22	5.32	5.34	5.55	7.3	7.4	7.6	7.7	7.9
T <sub>11</sub>	5.10	5.17	5.22	5.32	5.49	6.7	6.9	7.1	7.1	7.2
T <sub>12</sub>	5.10	5.08	5.08	5.05	5.08	6.0	5.7	5.9	6.4	6.5
Initial value				5.00				6.0		

Details of treatments are given in Table 1



**Fig. 4.** Balance of available N, P and K in soil (after 27 years) as affected by long-term integrated nutrient management practices on rice–rice cropping sequence (details of treatments are given in table 1)



**Fig. 5.** Effect of long term integrated nutrient management treatments (after 27 years) on average NPK uptake (kg/ha) by rice–rice cropping sequence (details of treatments are given in Table 1)

**Table 4.** Effect of long-term integrated nutrient management treatments on post-harvest primary nutrients status of soil under rice–rice cropping sequence [Data (kg/ha) are the mean value of minimum 5 years]

Treatment	1987–92			1992–97			1997–02			2002–07			2007–13		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
T <sub>1</sub>	253.5	7.12	54.1	227.0	6.32	52.7	203.5	6.00	50.6	179.6	5.45	49.1	152.8	4.77	47.7
T <sub>2</sub>	264.1	7.88	62.5	253.1	7.70	60.7	240.3	7.12	56.2	231.2	6.67	54.1	216.7	6.03	53.0
T <sub>3</sub>	272.1	8.77	69.6	264.1	8.00	65.9	257.8	7.54	61.9	248.4	7.00	58.8	239.4	6.22	56.8
T <sub>4</sub>	274.2	9.05	70.0	269.5	8.67	68.8	263.7	8.00	65.7	260.0	7.44	62.8	253.9	7.00	61.0
T <sub>5</sub>	283.0	10.00	71.1	279.1	10.56	70.6	280.0	11.02	68.7	278.8	11.11	71.8	274.3	11.45	74.0
T <sub>6</sub>	284.9	13.13	72.2	286.2	13.18	74.1	288.1	14.06	78.6	290.9	13.15	89.5	295.1	13.00	103.5
T <sub>7</sub>	279.6	11.87	70.7	281.3	12.58	71.8	283.0	14.58	81.7	284.3	13.02	88.7	286.0	11.33	92.6
T <sub>8</sub>	287.0	12.93	73.3	293.2	13.38	75.3	293.1	14.16	82.6	295.0	12.97	90.9	316.7	12.00	98.3
T <sub>9</sub>	285.8	12.23	71.0	290.1	13.00	73.5	297.9	13.28	81.9	304.2	12.71	90.4	315.0	11.75	99.1
T <sub>10</sub>	288.2	14.00	73.5	297.9	14.52	75.4	298.0	14.96	83.8	310.1	14.13	97.4	324.2	13.50	105.0
T <sub>11</sub>	285.0	11.50	72.8	291.5	13.04	70.8	292.0	13.96	80.5	300.5	12.03	86.6	312.0	11.53	100.1
T <sub>12</sub>	256.3	9.40	60.6	230.2	8.44	58.3	211.5	8.64	55.2	195.6	6.53	53.6	178.5	5.51	51.0
Initial value (1987–88)													277.8	10.08	72.1

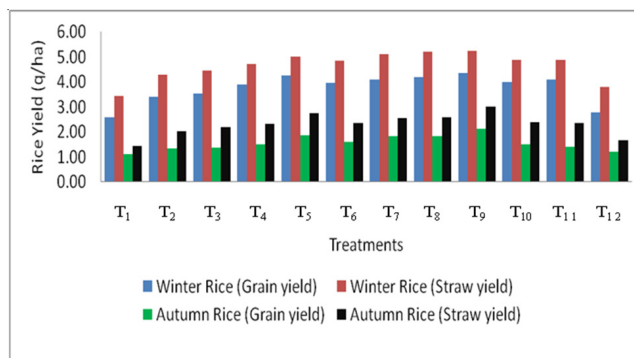
Details of treatments are given in Table 1

103.63, 15.75 and 37.64 and 49.78 and 106.31 kg/ha, respectively (Fig. 5). Among the treatments receiving less than that of 100% recommended NPK dose of fertilizers through chemical sources only, greater uptake of N was recorded than P and K. However, in case of integrated (organic + inorganic) treatments, K uptake was greater than that of N and P. Application of 75% recommended dose of fertilizers through inorganic sources to both winter and autumn rice and 25% N through crop stubbles to winter rice only showed higher total uptake of major nutrients by the crops than the other treatments. Greater uptake of major nutrients by the crops in case of INM treatments may be attributed to more favourable soil conditions due to addition of organic sources of nutrients that might have helped in mineralization of soil nutrients leading to build-up of their higher availability in soil. Such beneficial effects of integrated use of organics with chemical fertilizers confirm the findings of Santhy *et al.* (1998) and Gogoi *et al.* (2010). The lowest NPK uptake by the rice-rice sequence was recorded in the control, followed by conventional farmer's practice method under the climatic condition of Assam.

**Long-term INM effect on yield of the cropping sequence**

Effect of different treatments on grain and straw yields of rice-rice sequence from 1987-88 to 2013-14 (as 5 years average) revealed that the grain and straw yields of rice were significantly influenced by different INM treatments under longer period of time (Table 5). There were decreases in yields under long run when rice followed by

rice cropping was done without any external supply of nutrients. Same trend was also recorded in case of 50% recommended dose of fertilizers as well as in case of farmer's practice methods where farmers used only urea as top-dressing for supplying 25% N/ha in winter rice and 1 tonne FYM/ha + 25% N as DAP in Autumn rice. An increasing trend was observed in the yield of rice-rice sequence with continuous integrated supply of organic and inorganic source of nutrients in winter rice. The higher average grain and straw yields of winter and autumn rice (Fig. 6) obtained from the sequence were recorded when 75% recommended NPK dose through fertilizers along with 25% N through crop stubbles were applied to winter rice and 75% recommended NPK dose through fertilizers



**Fig. 6.** Yield of rice-rice system as affected by long-term integrated nutrient management treatments (data given are mean values for 27 years at the A.A.U, Jorhat; details of treatments are given in Table 1)

**Table 5.** Yield of rice-rice sequence as affected by long-term INM treatments [Data given (in tonne/ha) are mean value of minimum 5 years]

Treatments	1987-92		1992-97		1997-2002		2002-07		2007-13		Economics of production during 2007-13		
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Cost of cultivation (× 10 <sup>3</sup> ₹/ha)	Gross returns (× 10 <sup>3</sup> ₹/ha)	Benefit: cost ratio
T <sub>1</sub>	4.21	5.80	4.08	5.11	3.60	4.94	3.30	4.62	2.91	3.91	16.0	16.9	1.05
T <sub>2</sub>	4.75	6.70	4.78	6.67	4.72	6.21	4.31	5.74	4.24	5.55	18.0	28.0	1.56
T <sub>3</sub>	4.78	6.96	4.80	6.86	4.74	6.37	4.70	6.30	4.72	6.50	19.0	31.9	1.68
T <sub>4</sub>	4.82	7.39	4.80	6.73	5.19	6.87	5.14	6.79	5.24	7.20	19.0	34.7	1.83
T <sub>5</sub>	4.63	6.06	5.57	7.42	6.48	8.35	6.67	8.21	7.00	8.72	19.9	46.3	2.33
T <sub>6</sub>	4.65	5.94	5.36	7.72	5.38	6.86	5.80	7.39	6.46	8.21	19.3	40.3	2.09
T <sub>7</sub>	4.85	6.23	5.44	7.76	5.93	7.78	6.61	8.31	6.70	8.37	19.1	45.8	2.40
T <sub>8</sub>	4.99	6.46	5.59	7.78	5.61	7.34	6.69	8.62	7.14	8.74	19.6	41.9	2.14
T <sub>9</sub>	5.17	6.79	5.58	7.77	7.11	8.85	7.24	9.04	7.30	8.80	19.3	49.7	2.58
T <sub>10</sub>	5.09	6.53	5.19	7.79	5.13	6.77	5.31	7.15	6.25	7.90	18.9	37.3	1.97
T <sub>11</sub>	4.86	6.33	5.30	7.59	5.31	7.04	5.61	7.48	6.17	7.91	18.9	39.1	2.07
T <sub>12</sub>	4.34	5.62	4.03	5.44	4.20	5.48	3.86	5.50	3.66	5.37	17.2	22.0	1.28
SEm±	0.51	0.94	0.65	0.80	0.52	0.74	0.50	0.68	0.63	0.71	-	-	-
CD (P=0.05)	1.00	1.94	1.33	1.63	1.08	1.60	1.00	1.40	1.30	14.11	-	-	-

Details of treatments are given in Table 1

were applied to autumn rice. These results corroborate the findings of Weerasinghe *et al.* (2014). Without any organic manure and fertilizer applications, grain and straw yields of rice were lowest which were followed by farmer's practice method.

### Economics

The highest gross returns and benefit: cost ratio were obtained with application of 75% recommended NPK dose through fertilizers to both the crop of winter and autumn rice plus crop stubbles application (to supply 25% N) to winter rice only (Table 5). This was followed by the treatment of 25% N application through FYM to winter rice plus 75% recommended NPK dose through fertilizers to both winter and autumn rice. The lowest cost of cultivation, gross returns and benefit: cost ratios were recorded in control which was without any external supply of nutrients.

The integrated nutrient management practices which have been applied continuously for 27 years in rice-rice cropping system showed that adoption of easily available options of practicing *Azolla* as green manuring, addition of crop stubbles and FYM/compost in conjunction with chemical fertilizers in balanced form are efficient for building-up of soil properties in one way and increasing the crop yield in other. Use of organic sources of nutrients to substitute up to 50% of the recommended dose of chemical fertilizers increases the organic matter content in soil which is the key attribute of soil quality showing far-reaching effect on improvement in soil bulk density, water-holding capacity, pH and cation-exchange capacity of soil. Nutrient integrations with organic and inorganic sources also increase the availability and uptake of major nutrients besides maintaining a positive yield trend in rice-rice cropping system under long run.

### REFERENCES

- Ali, R.I., Awan, T.H., Ahmad, M., Saleem, M.U. and Akhtar, M. 2012. Diversification of rice-based cropping systems to improve soil fertility, sustainable productivity and economics. *The Journal of Animal and Plant Sciences* **22**:108–12.
- Baishya, A. 1988. Comparative economic study and energetics approach of integrated nitrogen management in rice-wheat cropping system under different water regimes. *Ph.D. Thesis* submitted to Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.
- Baruah, T.C., Borthakur, H.P. 1997. *A Text Book of Soil Analysis*. Vikas Publishing House Pvt. Ltd, New Delhi, India.
- Bharadwaj, V. and Omanwar, P.K. 1992. Impact of long-term fertilizing treatments on bulk density, water contents and microbial population of soil. *Journal of Indian Society of Soil Science* **40**: 553–55.
- Fischer, G. and Heilig, G.K. 1998. Population momentum and the demand on land and water resources. (In:) *Land resources: On the edge of the Malthusian Precipice*, (eds) pp. 9–28. (Greeland, D.J., Gregory, P.J. and Nye, P.H.). The Royal Society, London.
- Ghose, T.J. and Pathak, A.K. 2006. Long-term effect of continuous fertilization on rice yields, nutrient response, nutrient uptake and soil quality parameters in rainfed rice-rice cropping sequence. A soil care and quality soil management. *Poster presented in The 18<sup>th</sup> World Congress of Soil Science*, held in 2006. pp. 166–10.
- Gogoi, Bhabesh, Barua, N.G. and Baruah, T.C. 2010. Effect of integrated nutrient management on growth, yield of crops and availability of nutrients in inceptisol under rainfed rice (*Oryza sativa*)-niger (*Guizotia abyssinica*) sequence of Assam. *Indian Journal of Agricultural Sciences* **80**(1): 56–60.
- Gomez, K.A., Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*. edn 2, Wiley Interscience Publishers and John Willy & Sons, New York.
- Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd, New Delhi, India.
- Katyal, V. and Gangwar, B. 2000. Long-term effect of integrated nutrient management on crop productivity of rice (*Oryza sativa*)-rice system. *Indian Journal of Agricultural Sciences* **70**: 110–13.
- Khariche, V.K., Patil, S.R., Kulkarni, A.A., Patil, V.S. and Katkar, R.N. 2013. Long-term integrated nutrient management for enhancing soil quality and crop productivity under intensive cropping system on Vertisols. *Journal of Indian Society of Soil Science* **61**: 323–32.
- Meelu, O.P., Singh, Y. and Singh, B. 1994. Green manuring for crop productivity improvement. *FAO World Soil Resources Reports*, No. **76**. FAO, Rome.
- Nambiar, K.K.M. 1994. *Soil Fertility and Crop Productivity under Long Term Fertilizer Use in India*, pp. 144. Indian Council of Agricultural Research, New Delhi.
- Prasad, R., Prasad, L.C. and Agarwal, R.K. 2010. Genetic diversity of Indian germplasm of aromatic rice. *Oryza* **46**: 197–201.
- Regmi, A.P., Ladha, J.K., Pathak, H., Pasuquin, E., Bueno, C., Dawe, D., Hobbs, P.R., Joshy, D., Maskey, S.L. and Pandey, S.P. 2006. Yield and soil fertility trends in a 20-year rice-wheat experiment. *Better Crops International* **17**: 30–31.
- Sankaram, A. 1966. *Laboratory Manual for Agricultural Chemistry*. Asia Publishing House, Bombay, Maharashtra.
- Santhy, P., Muthuvel, P., Murugappa, V. and Selvi, D. 1998. Long-term effect of continuous cropping and fertilization on crop yield and soil fertility status. *Journal of Indian Society of Soil Science* **46**: 391–95.
- Sepehya, S. 2011. Long-term effect of integrated nutrient management on dynamics of nitrogen, phosphorus and potassium in rice-wheat system. *Ph.D. Thesis*, Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India, pp.179.
- Singh, K., Bansal, S.K. and Moinuddin. 2007. Effect of continuous cropping for twenty years on some properties of the intensively cultivated alluvial soil and nutrient indexing of rice. *Journal of Indian Society of Soil Science* **56**: 265–69.
- SPSS. 2001. *Statistical package, Version 11.0 for Windows*, SPSS Inc, Chicago, IL.
- Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the de-

- termination of available nitrogen in soils. *Current Science* **25**: 259–60.
- Subbiah, S.V., Ramamoorthy, K., Kumar, R.R.M. and Singh, S.P. 2001. Studies on yield maximization through balanced nutrient ratios in irrigated low land rice. *Rice Communication Newsletter* **46**: 59–61.
- Timsina, J. and Connor, D.J. 2001. Productivity and management of rice–wheat systems: Issues and challenges. *Field Crops Research* **69**: 93–132.
- Walkley, A. and Black, I.A. 1934. An examination of the different method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29–38.
- Weerasinghe, P., Lathiff, M.A., Sirisena, D.N., De Silva, S.H.S.A. and Jayalath, H.K.P. 2014. Influence of the long-term application of organic manure on the productivity of rice in non-calci brown soils of Sri Lanka. Research article available in: [www.goviya.lk-agrilearning/paddy/Paddy\\_Research/Paddy.../A8.pdf](http://www.goviya.lk-agrilearning/paddy/Paddy_Research/Paddy.../A8.pdf).