Current Journal of Applied Science and Technology

34(1): 1-10, 2019; Article no.CJAST.47994
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Integrated Nutrient Management of Rice Soil in Hilly Region of Meghalaya, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author RCW carried out the experiment and recorded the observations. Author SM helped in statistical analysis of the data and compilation of the manuscript (along with managed the literature searches). Author GKG helped in formulation of the experimental design and the overall planning of the experiments including treatments, parameters to be studied etc. Author DS contributed in writing of the manuscript and interpretation of the data. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2019/v34i130117
Editor(s):
(1) Dr. Diony Alves Reis, Federal University of the West of Bahia, Brazil.
Reviewers:
(1) Toungos, Mohammed Dahiru, Adamawa State University, Nigeria.
(2) Jaime Cuauhtemoc Negrete, Autonomous Agrarian Antonio Narro University, Mexico.
Complete Peer review History: http://www.sdiarticle3.com/review-history/47994

Original Research Article

Received 29 December 2018
Accepted 16 March 2019
Published 30 March 2019

ABSTRACT

An experiment was conducted to study the effect of integrated use of inorganic fertilizers (S and Zn coupled with recommended doses of NPK) in conjunction with organic manure (FYM) on availability of different macro and micro elements including organic carbon in a hilly soil of Meghalaya, India. Two Field trials were conducted consecutively for 2 years (2013-14 and 2014-15) with Rice variety Arize-6444 at Nongpoh village in Ri-Bhoi District of Meghalaya to fulfil the objectives of the experiment. The field experiment was conducted following Randomized Block Design. Altogether 11 treatments with 3 replications were included in the experiment. Results revealed that irrespective of treatments, exchangeable NH_4^+, soluble NO_3^-, available P_2O_5 and K_2O decreased with the period of crop growth. However, changes in organic C in soil showed an opposite trend of

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results. Regardless of treatments, organic C content enhanced with increment in the age of rice crop. Among the treatment combinations, significantly higher amount of exchangeable NH_4^+, soluble NO_3^-, available P_2O_5 and K_2O is accumulated in the soil which received recommended doses of N, P and K along with FYM at 10 tonnes ha^{-1} as well as 40 kg S ha^{-1} and 5 kg Zn ha^{-1} (T_8). Results further pointed out that balanced fertilization increased the availability of nutrients (particularly N, P and K) which maintained throughout the cropping season of rice. However, SO_4^{2-}-S content reduced with crop duration. No drastic variation is observed in DTPA-extractable Zn content in soil over the whole cropping season of rice. Incorporation of FYM in the treatment combinations improved and maintained available nutrients including organic C in soil particularly in the 2nd season of rice cultivation.

Keywords: Integrated nutrient management; organic carbon; available macro and micro nutrients; rice crop; hilly soil.

1. INTRODUCTION

Rice is the main food crop of the state of Meghalaya which accounts for about 60% of the cultivable area. But the state productivity is still quite low (below 2.0 t ha^{-1}) compared to the overall Indian average productivity (2.85 t ha^{-1}) [1].

Sulphur (S) is involved in some amino acid synthesis, enzymatic activities in plants. It is important for chlorophyll formation and nitrogen metabolism. Zinc activates some enzymes for the synthesis of certain proteins. It plays an essential role in DNA transcription and starch to sugar conversion. It also helps plants to withstand very low temperatures. It has been reported by a number of workers [2-3], that some of the plant nutrients (especially S and Zn) are becoming deficient in hilly regions of Indian soils. To overcome that lack of S and Zn (including other nutrients), integrated and balanced application of these nutrients through fertilizer materials are required beside appropriate amount of organic manures which in turn will not only enhance fertility status of the soil but will also increase the yield and quality parameters of crops [4-5].

The present investigation was, therefore, carried out to study the changes in different available nutrients including organic carbon in soil treated with different combinations of S and Zn as well as recommended doses of inorganic and organic fertilizers using rice as a test crop.

2. MATERIALS AND METHODS

Field experiments with rice were conducted successively for two years (2013-14 and 2014-15) in a farmer's field situated at Nongpoh in Ri-Bhoi district of Meghalaya. Nongpoh is located at 25.90° N latitude and 91.77° E longitude. It has an average elevation of 485 metres The field was generally cultivated with rice crop.

Composite soil sample (0-15 cm depth) was collected from the experimental field before the start of experiment. The collected soil sample was air-dried, ground and passed through 0.5 mm sieve. Then the soil sample was analysed for different physical, chemical and physico-chemical properties and the results are presented in Table 1. The field experiments were conducted following simple Randomized Block Design. Rice variety Arize-6444 was selected for the experimentation purpose. The plot size was 4m x 2m. Spacing of 25 cm x 25 cm was maintained. 30 days old rice seedlings were transplanted in line sowing with three plants hill^{-1}. Altogether 11 treatments were adopted to study the effect of Integrated Nutrient Management (INM) practices. All treatments were replicated thrice. The treatments are:

T_0 = Control
T_1 = $N:P_2O_5:K_2O$
T_2 = T_1+ FYM
T_3 = T_2+ Zn_1
T_4 = T_2 + Zn_2
T_5 = T_2 + S_1
T_6 = T_2 + S_2
T_7 = T_3 + S_1
T_8 = T_3+ S_2
T_9 = T_4 + S_1
T_{10} = T_4 + S_2

[Where, $N:P_2O_5:K_2O$ = $N:P_2O_5:K_2O$ at 80:60:40 kg ha^{-1} as Urea, Single Super Phosphate (SSP) and Muriate of Potash (MOP) respectively. FYM = 10 t FYM ha^{-1}; Zn_1 = 5 kg Zn ha^{-1} as Zn-EDTA; Zn_2 = 10 kg Zn ha^{-1} as Zn-EDTA; S_1 = 20 kg S ha^{-1}as elemental S; S_2 = 40 kg S ha^{-1}as elemental S].

Table 1. Physical, chemical and physico-chemical properties of the initial soil sample collected from the experimental field

Parameters	Values	Methods adopted
pH	5.19 (Soil: water=1:2.5) 4.76 (Soil:$CaCl_2$=1:2.5)	Glass electrode pH meter [6]
Electrical conductivity	0.10dSm^{-1}(at 25°C)	Electrical Conductivity Meter [6]
Oxidizable organic carbon	0.93%	Wet digestion method [7]
Cation Exchange Capacity	10.70(C mol p^{+}kg^{-1})	Ammonium Acetate Leaching [8]
Mechanical separates		
Sand Silt Clay	48.56% 22.00% 29.44%	Hydrometer Method [9]
Textural class	Sandy clay loam	ISSS system (Soil textural triangle)
Water Holding Capacity	44.06%	Keen Rackzaw Ski [10]
Exchangeable NH_4^+ Soluble NO_3^-	107.70 kg ha^{-1} 25.28 kg ha^{-1}	Bremner and Keeney's Method [11]
Available P_2O_5	23.66 kg ha^{-1}	Spectro photometer [12]
Available K_2O	305.80 kg ha^{-1}	Flame photometry with Ammonium acetate [13]
Available S	10.50 kg ha^{-1}	Turbidimetric method with $CaCl_2$ and nephelometer [14]
DTPA-extractable Zn	0.33 mg Kg^{-1}	DTPA extraction and atomic absorption spectrophotometer [15]

FYM was applied during land preparation which corresponds to 25th day before the transplanting. Full dose of P and K and half dose of N fertilizers were incorporated as basal application. The rest half of N was applied in two split doses at tillering and flowering stages of the crop. S and Zn were applied as basal along with N, P and K fertilizers. The rice crop was raised with best possible management practices. Rhizosphere soil samples were collected at tillering, flowering and harvesting stages of rice and were analyzed for oxidizable organic carbon, exchangeable NH_4^+, soluble NO_3^-, available P_2O_5, available K_2O, available S and DTPA-extractable Zn.

Statistical analysis of the data was done by using SPSS software (SPSS 20, 2011) following methods meant for Randomized Block Design (RBD). The mean values (from 3 replications) were subjected to Post-Hoc tests like CD (Critical difference) test at 5% level of significance and calculation of SEm (Standard error of mean).

3. RESULTS AND DISCUSSION

3.1 Changes in the Oxidizable Organic Carbon Content

Results revealed that, irrespective of treatments and years of experimentation, organic carbon content was increased with the duration of crop growth (Table 2). The increment in organic carbon content with time is due to slow decomposition of organic manure i.e. FYM. Maximum quantity of organic carbon was accumulated in T_8 treatment. Comparatively larger amount of organic carbon was noticed in the 2nd year of experimentation. Continuous application of fertilizer nutrients in conjunction with FYM markedly enhanced the soil organic carbon from 0.93 to 1.68%. The results further pointed out that addition of sulphur and Zn along with recommended doses of N, P and K coupled with FYM increased organic carbon content in soil. Some researchers [16-17] also reported earlier that organic carbon in soil was improved with the application of N, P, K and FYM. Statistical analysis revealed that T_8 treatment is highly significant in comparison to control. It is noteworthy to mention that addition of 10 kg ha^{-1} Zn has failed to enrich organic carbon content to higher order in soil.

3.2 Changes in the Exchangeable Nh_4^+ Content

Regardless of treatments, in general, exchangeable NH_4^+ in soil was reduced from the tillering to harvesting stage of rice in the 1st year (Table 3). On the other hand, in the 2nd year, notwithstanding treatments, exchangeable NH_4^+ was found to decrease at flowering but again increased at harvesting stage of rice.

Table 2. Changes in the amount (g $100g^{-1}$) of organic C in soil at different growth stages of rice consecutively for two years (2013-14 and 2014-15) under different treatment combinations

Treatments	Different growth stages of rice					
	Tillering		Flowering		Harvesting	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_0= Control	0.87	0.79	0.96	0.91	1.02	1.03
T_1= $N:P_2O_5:K_2O$	0.89	0.94	1.07	1.08	1.43	1.44
T_2= T_1 + FYM	1.02	1.05	1.16	1.17	1.46	1.48
T_3 = T_2 + Zn_1	1.06	1.07	1.22	1.23	1.56	1.58
T_4= T_2 + Zn_2	1.09	1.05	1.29	1.30	1.56	1.58
T_5= T_2 + S_1	1.11	1.10	1.36	1.37	1.57	1.59
T_6 = T_2 + S_2	1.23	1.23	1.40	1.42	1.62	1.64
T_7= T_3 + S_1	1.34	1.34	1.45	1.47	1.62	1.64
T_8= T_3 + S_2	1.56	1.55	1.53	1.54	1.66	1.68
T_9= T_4 + S_1	1.09	1.09	1.34	1.35	1.56	1.58
T_{10}= T_4 + S_2	0.89	0.89	1.29	1.30	1.51	1.53
CD(P=0.05)	0.12	0.12	0.05	0.05	0.30	0.30
SEm ($\pm$)	0.04	0.04	0.01	0.02	0.10	0.10

[Where, $N:P_2O_5:K_2O$ = $N:P_2O_5:K_2O$ at 80:60:40 kg ha^{-1} as Urea, SSP and MOP; FYM = 10 t FYM ha^{-1}; Zn_1 = 5 kg Zn ha^{-1} as Zn-EDTA; Zn_2 = 10 kg Zn ha^{-1} as Zn-EDTA; S_1 = 20 kg S ha^{-1} as elemental S; S_2 = 40 kg S ha^{-1}as elemental S]

Table 3. Changes in the amount (kg ha^{-1}) of exchangeable NH_4^+ in soil at different growth stages of rice consecutively for two years (2013-14 and 2014-15) under different treatment combinations

Treatments	Different growth stages of rice					
	Tillering		Flowering		Harvesting	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_0= Control	107.60	108.68	124.80	125.36	103.30	208.03
T_1 =$N:P_2O_5:K_2O$	204.67	208.62	173.90	1120.00	161.67	325.17
T_2= T_1 + FYM	205.50	207.05	190.13	191.38	168.80	344.14
T_3 = T_2 + Zn_1	216.00	218.16	196.00	197.29	170.73	347.43
T_4= T_2 + Zn_2	217.10	221.70	201.57	202.95	173.87	354.08
T_5= T_2 + S_1	224.87	227.50	218.43	219.84	185.07	371.79
T_6 = T_2 + S_2	225.33	228.26	235.33	236.86	186.03	372.76
T_7= T_3 + S_1	228.30	232.50	241.50	242.90	200.53	402.02
T_8= T_3 + S_2	230.07	231.39	247.87	249.52	206.13	414.12
T_9= T_4 + S_1	218.53	220.69	209.67	211.12	184.83	368.68
T_{10}= T_4 + S_2	217.40	218.97	206.00	207.37	180.57	363.81
CD(P=0.05)	4.11	4.14	13.99	14.69	6.20	6.07
SEm($\pm$)	1.38	1.39	4.71	4.94	2.08	2.04

[Where, $N:P_2O_5:K_2O$ = $N:P_2O_5:K_2O$ at 80:60:40 kg ha^{-1} as Urea, SSP and MOP; FYM = 10 t FYM ha^{-1}; Zn_1 = 5 kg Zn ha^{-1} as Zn-EDTA; Zn_2 = 10 kg Zn ha^{-1} as Zn-EDTA; S_1 = 20 kg S ha^{-1} as elemental S; S_2 = 40 kg S ha^{-1}as elemental S]

The decline in exchangeable NH_4^+ with duration of crop growth in the 1^{st} year is due to its utilization by the growing crop [18] as well as conversion to NO_3^- form of N [19] and loss through volatilization process [20]. Same explanation can be furnished for the observed decrease in exchangeable NH_4^+ up to flowering stage of rice in the 2^{nd} year of experiment (Table 3). The escalation of exchangeable NH_4^+ at harvest particularly in the FYM treated plots is due to the mineralisation of FYM and accumulation of exchangeable NH_4^+ in soils after meeting the crop requirement (Kanaujia, 2016) [18]. Increment of exchangeable NH_4^+ at harvest was more in the plots which have received both S and Zn accompanied with recommended doses of N, P, K and FYM. Balanced fertilization encouraged micro-organisms to proliferate [21] and in turn intensified exchangeable NH_4^+ content in these treated plots.

Statistical analysis of the data revealed that treatment T_8 is highly significant with respect to control in terms of exchangeable NH_4^+ build-up over the whole period of crop growth. Thus, it is clear from the results (Table 3) that application of S at 40 kg ha^{-1} and Zn at 5 kg ha^{-1} along with recommended doses of N, P and K with FYM at 5 tonnes ha^{-1} retained highest amount of exchangeable NH_4^+ in soil cropped continuously for two years with rice.

3.3 Changes in the Soluble No_3^- Content

Results further showed that, soluble NO_3^- tended to decrease in both the years over the whole growing period of rice (Table 4). Comparatively, Larger quantity of NO_3^--N was observed in soils which received combined application of S and Zn added with recommended doses of N, P and K as well as FYM. Results further showed that significantly higher amount of NO_3^--N was found in soil treated with S at 40 kg ha^{-1} and Zn at 5 kg ha^{-1} along with recommended doses of N, P and K as well as FYM at 5 t ha^{-1} (T_8). This increment is due to the conversion of exchangeable NH_4^+ to NO_3^- by nitrifying bacteria whose proliferation and activities were at the peak under balanced fertilization system. The present finding is at par with earlier work carried out by Balasubramanian and Palaniappan (1991) [22]. Closer examination of the data in Table 4 further revealed that the reduction in NO_3^--N over the whole cropping season of rice is around 10 kg ha^{-1} in T_8 treatment whereas, the depletion in NO_3^--N is more marked in other treatment combinations adopted in the experiment. The decrease in NO_3^--N is due to its utilization by the growing rice crop. However, the accumulation of NO_3^--N is highest in T_8 treatment due to balanced nutrition.

3.4 Changes in the Available P_2O_5 Content

Results in Table 5 revealed that heedless of the treatments and years of experimentation, available P_2O_5 decreased with increase in the period of crop growth of rice. The depletion in available P over the cropping season is due to its utilization by the growing crop [23] as well as its fixation or retention by the soil constituents [24]. Comparatively higher amount of available P is remained in soil system after the harvest which received S at 40 kg ha^{-1} and Zn at 10 kg ha^{-1} in addition to FYM at 5 tonnes ha^{-1} as well as recommended doses of N, P and K fertilizers. Statistical analysis of the results in Table 5 also revealed that significantly higher amount of available P is retained in soil which received both S and Zn accompanied by recommended doses of N, P and K as well as FYM over that of control plots. The elevation in available P in FYM treated systems is due to transformation of organic P to inorganic forms by the organic

Table 4. Changes in the amount (kg ha^{-1}) of soluble NO_3^- in soil at different growth stages of rice consecutively for two years (2013-14 and 2014-15) under different treatment combinations

Treatments	Different growth stages of rice					
	Tillering		Flowering		Harvesting	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_0= Control	25.60	25.50	23.76	24.26	18.52	18.76
T_1 = $N:P_2O_5:K_2O$	31.00	30.78	27.50	28.08	22.40	22.63
T_2= T_1 + FYM	37.90	37.63	28.13	28.73	22.40	22.70
T_3 = T_2 + Zn_1	43.30	42.99	32.27	32.92	22.63	22.94
T_4= T_2 + Zn_2	44.00	43.71	33.57	34.24	24.80	25.13
T_5= T_2 + S_1	47.33	47.00	33.90	34.58	29.83	30.24
T_6 = T_2 + S_2	49.30	48.94	33.93	34.62	31.50	31.94
T_7= T_3 + S_1	49.50	49.14	44.80	45.70	33.60	34.05
T_8= T_3 + S_2	56.00	55.63	50.53	51.51	44.80	45.40
T_9= T_4 + S_1	45.20	44.91	33.63	34.31	28.20	28.59
T_{10}= T_4 + S_2	45.13	44.85	33.63	34.31	26.87	27.24
CD(P=0.05)	2.37	2.35	5.10	5.09	1.26	1.33
SEm($\pm$)	0.79	0.79	1.71	1.71	0.42	0.45

[Where, $N:P_2O_5:K_2O$ = $N:P_2O_5:K_2O$ at 80:60:40 kg ha^{-1} as Urea, SSP and MOP; FYM = 10 t FYM ha^{-1}; Zn_1 = 5 kg Zn ha^{-1} as Zn-EDTA; Zn_2 = 10 kg Zn ha^{-1} as Zn-EDTA; S_1 = 20 kg S ha^{-1} as elemental S; S_2 = 40 kg S ha^{-1}as elemental S]

acids [25]. The present results corroborate with the earlier works carried out by Yaduvanshi [24] and Tadesse et al. [26]. The results clearly pointed out that balanced fertilization with macro and micro nutrients intensifies the available P content in soil [27].

3.5 Changes in the Available K_2O Content

More or less similar trend of results is observed for available K_2O (Table 6) as was found for available P (Table 5) in soil. The effect of treatment was also same on available K

Table 5. Changes in the amount (kg ha^{-1}) of available P_2O_5 in soil at different growth stages of rice consecutively for two years (2013-14 and 2014-15) under different treatment combinations

Treatments	Different growth stages of rice					
	Tillering		Flowering		Harvesting	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_0= Control	23.70	24.41	18.66	18.91	16.23	15.81
T_1 = $N:P_2O_5:K_2O$	28.53	29.38	21.46	21.72	17.66	17.18
T_2= T_1 + FYM	29.78	30.67	21.70	21.97	18.02	17.53
T_3 = T_2 + Zn_1	30.34	31.25	21.74	22.01	18.09	17.60
T_4= T_2 + Zn_2	30.72	31.64	22.46	22.74	19.08	18.57
T_5= T_2 + S_1	33.09	34.08	23.77	24.09	20.29	19.76
T_6 = T_2 + S_2	34.85	35.90	25.22	25.56	21.83	21.99
T_7= T_3 + S_1	35.93	37.00	25.22	25.56	22.42	22.57
T_8= T_3 + S_2	37.00	38.11	29.18	29.61	24.34	24.50
T_9= T_4 + S_1	32.89	33.88	23.51	23.82	19.79	19.93
T_{10}= T_4 + S_2	32.77	33.12	22.58	22.86	19.63	19.77
CD(P=0.05)	1.02	1.07	2.15	2.28	1.08	1.18
SEm(±)	0.34	0.36	0.72	0.77	0.36	0.39

[Where, $N:P_2O_5:K_2O$ = $N:P_2O_5:K_2O$ at 80:60:40 kg ha^{-1} as Urea, SSP and MOP; FYM = 10 t FYM ha^{-1}; Zn_1 = 5 kg Zn ha^{-1} as Zn-EDTA; Zn_2 = 10 kg Zn ha^{-1} as Zn-EDTA; S_1 = 20 kg S ha^{-1} as elemental S; S_2 = 40 kg S ha^{-1}as elemental S]

Table 6. Changes in the amount (kg ha^{-1}) of available K_2O in soil at different growth stages of rice consecutively for two years (2013-14 and 2014-15) under different treatment combinations

Treatments	Different growth stages of rice					
	Tillering		Flowering		Harvesting	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_0= Control	109.33	112.23	60.67	101.42	79.60	78.59
T_1 = $N:P_2O_5:K_2O$	118.67	121.83	103.00	105.08	85.00	84.72
T_2= T_1 + FYM	126.67	60.07	105.00	105.35	87.33	87.04
T_3 = T_2 + Zn_1	125.00	128.30	107.33	107.63	89.60	91.92
T_4= T_2 + Zn_2	143.33	147.20	110.00	110.32	94.67	94.35
T_5= T_2 + S_1	145.00	148.93	112.33	112.83	93.67	93.31
T_6 = T_2 + S_2	145.67	149.61	110.00	110.32	98.33	98.12
T_7= T_3 + S_1	150.00	154.00	118.33	118.70	60.00	99.67
T_8= T_3 + S_2	153.33	157.47	125.00	125.62	102.33	101.99
T_9= T_4 + S_1	122.33	125.61	107.33	107.61	95.00	94.70
T_{10}= T_4 + S_2	125.00	128.30	101.33	101.67	90.67	90.37
CD(P=0.05)	0.50	0.95	NS	NS	NS	1.31
SEm(±)	3.19	3.35	4.87	4.85	4.53	4.43

[Where, $N:P_2O_5:K_2O$ = $N:P_2O_5:K_2O$ at 80:60:40 kg ha^{-1} as Urea, SSP and MOP; FYM = 10 t FYM ha^{-1}; Zn_1 = 5 kg Zn ha^{-1} as Zn-EDTA; Zn_2 = 10 kg Zn ha^{-1} as Zn-EDTA; S_1 = 20 kg S ha^{-1} as elemental S; S_2 = 40 kg S ha^{-1}as elemental S]

content as that of available P in soil. The decrease in available K with increase in the period of crop growth is due to its utilization by rice. Addition of FYM enriched the K content in soil over that of control. The build-up of available K due to FYM addition might be due to additional K applied through it. Similar findings were earlier reported by Wahlang et al. [25] and Kanaujia [17].

3.6 Changes in the Available S Content

Results in Table 7 pointed out that, available S reduced with period of time. This decrease in available S is due to its utilization by the growing rice plants. Furthermore, highest amount of available S was observed in T_8 treatment like that of available N and K. Addition of S at 40 kg ha^{-1} successively for two years resulted in accumulation of highest amount of available S in this treatment. Perusal of data in Table 7 further revealed that addition of FYM increased S content in soil over that of control. Mineralization of organic S present in FYM also encouraged the build-up of available S pool in FYM treated plots. Thus, it may be said that application of recommended dose of N, P and K along with FYM improves fertility status of soils [28] and addition of S further accentuates available S [29].

3.7 Changes in the DTPA-Extractable Zn Content

No drastic variation in Zn content in soil was observed throughout the growing period of rice (Table 8). However, irrespective of treatments, DTPA-extractable Zn was decreased with the period of crop growth in both the years of experiments. Perusal of the data in Table 8 further revealed that addition of FYM enriched the DTPA-extractable Zn content in soil. This is due to the production of organic acids through decomposition of FYM which in turn increased the availability of Zn in soils [30]. Highest amount of DTPA-extractable Zn was remained in soil which received recommended doses of N, P and K accompanied with FYM as well as S at 40 kg ha^{-1}and Zn at 5 kg ha^{-1}. Addition of higher amount of Zn (10 kg ha^{-1}) failed to enhance DTPA-extractable Zn to higher order in soil. This is perhaps due to fixation of Zn with organic compounds produced during decomposition of FYM [31]. Statistical analysis of the results revealed that all the treatments differ significantly with respect to accumulation of DTPA-extractable Zn in soil. Results further showed that significantly larger amount of available Zn was maintained in T_8 treatment. It could be concluded that continuous application of mineral

Table 7. Changes in the amount (kg ha^{-1}) of available S in soil at different growth stages of rice consecutively for two years (2013-14 and 2014-15) under different treatment combinations

Treatments	Different growth stages of rice					
	Tillering		Flowering		Harvesting	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_0= Control	8.01	8.09	7.08	7.30	6.98	6.96
T_1 = $N:P_2O_5:K_2O$	8.22	8.31	7.72	7.96	7.21	7.18
T_2= T_1 + FYM	9.85	9.95	9.40	9.68	9.01	8.98
T_3 = T_2 + Zn_1	9.85	9.95	9.48	9.76	9.05	9.02
T_4= T_2 + Zn_2	9.90	10.00	9.63	9.92	9.05	9.02
T_5= T_2 + S_1	16.72	16.88	15.36	15.82	10.35	10.32
T_6 = T_2 + S_2	18.67	18.85	15.48	15.95	12.45	12.41
T_7= T_3 + S_1	18.97	19.16	16.07	16.55	12.62	12.58
T_8= T_3 + S_2	19.02	19.21	16.34	16.83	12.77	12.73
T_9= T_4 + S_1	16.06	16.22	12.06	12.42	10.29	10.25
T_{10}= T_4 + S_2	15.24	15.39	12.05	12.41	10.22	10.19
CD(P=0.05)	0.11	0.14	0.07	0.09	0.08	0.09
SEm(±)	0.03	0.05	0.02	0.03	0.02	0.03

[Where, $N:P_2O_5:K_2O$ = $N:P_2O_5:K_2O$ at 80:60:40 kg ha^{-1} as Urea, SSP and MOP; FYM = 10 t FYM ha^{-1}; Zn_1 = 5 kg Zn ha^{-1} as Zn-EDTA; Zn_2 = 10 kg Zn ha^{-1} as Zn-EDTA; S_1 = 20 kg S ha^{-1} as elemental S; S_2 = 40 kg S ha^{-1}as elemental S]

Table 8. Changes in the amount (mg kg^{-1}) of DTPA-extractable Zn in soil at different growth stages of rice consecutively for two years (2013-14 and 2014-15) under different treatment combinations

Treatments	Different growth stages of rice					
	Tillering		Flowering		Harvesting	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_0= Control	0.32	0.34	0.40	0.43	0.27	0.29
T_1 = $N:P_2O_5:K_2O$	0.40	0.42	0.45	0.48	0.32	0.34
T_2= T_1 + FYM	0.46	0.49	0.53	0.57	0.35	0.37
T_3 = T_2 + Zn_1	0.54	0.58	0.60	0.64	0.41	0.43
T_4= T_2 + Zn_2	0.58	0.61	0.64	0.69	0.43	0.45
T_5= T_2 + S_1	0.82	0.87	0.74	0.80	0.55	0.57
T_6 = T_2 + S_2	0.85	0.90	0.79	0.85	0.61	0.64
T_7= T_3 + S_1	0.91	0.97	0.83	0.89	0.65	0.69
T_8= T_3 + S_2	0.99	1.05	0.88	0.94	0.70	0.74
T_9= T_4 + S_1	0.70	0.74	0.70	0.76	0.49	0.51
T_{10}= T_4 + S_2	0.63	0.67	0.67	0.73	0.44	0.47
CD(P=0.05)	0.11	0.11	0.08	0.09	0.04	0.04
SEm(±)	0.03	0.03	0.02	0.03	0.01	0.01

[Where, $N:P_2O_5:K_2O$ = $N:P_2O_5:K_2O$ at 80:60:40 kg ha^{-1} as Urea, SSP and MOP; FYM = 10 t FYM ha^{-1}; Zn_1 = 5 kg Zn ha^{-1} as Zn-EDTA; Zn_2 = 10 kg Zn ha^{-1} as Zn-EDTA; S_1 = 20 kg S ha^{-1} as elemental S; S_2 = 40 kg S ha^{-1}as elemental S]

fertilizers with FYM helps to build up fertility status of soil. The present trend of results finds support of prior findings [32-33].

4. CONCLUSION

Integrated Nutrient Management enhanced the organic carbon content in rice soils of hilly regions of Meghalaya. Combined application of both organic and inorganic fertilizers improved the available nutrient content in soil as well as maintain for longer period during a cropping season.

ACKNOWLEDGEMENT

The 1st Author is grateful to Govt. of India for providing financial assistance in the form of Rajiv Gandhi National Fellowship (RGNF).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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