__Original Research Article__

Integrated Nutrient Management of rice soil in hilly region of Meghalaya, India

ABSTRACT

Irrespective of treatment combinations, exchangeable NH_4^+, soluble NO_3^-, available P_2O_5 and K_2O decreased with the age of rice crop. However, changes in organic C in soil showed an opposite trend of results. Irrespective of treatments, organic C content increased with increase in duration of crop. Comparatively, 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 also revealed that T_8 treatment is highly significant with respect to control. Again, irrespective of treatments and years of experimentation, balanced fertilization enhanced exchangeable NH_4^+, soluble NO_3^- , available P_2O_5 and K_2O in soil with increase in the period of crop growth. However, on the other hand, available S content decreased and no drastic variation is observed in DTPA-extractable Zn content in soil over the whole cropping season of rice.

Keywords: INM, available nutrients, rice crop, hilly soils

1. INTRODUCTION

Rice is the main food crop of the state of Meghalaya which accounts for about 60% of the cultivable area. **B**ut 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 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 along with recommended doses of inorganic and organic fertilizers using rice as a test crop.

2. MATERIAL 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 samples were air-dried, ground and passed through 0.5mm sieve. 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 25cm x 25cm was maintained. 30 days old rice seedlings raised in seedling bed were transplanted in line sowing with three plants hill^{-1}. Altogether 11 treatments were adopted to study the effect of INM practice. 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]

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.

Table 1. Physical, chemical and physico-chemical properties of the initial soil samples 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	48.56 %	
Silt	22.00 %	Hydrometer Method [9]
Clay	29.44 %	
Textural class	Sandy clay loam	ISSS system (Soil textural triangle)
Water Holding Capacity	44.06 %	Keen Rackzaw Ski [10]
Exchangeable NH_4^+	107.70 kg ha^{-1}	
Soluble NO_3^-	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	0.33mg Kg^{-1}	DTPA extraction and atomic absorption spectrophotometer [15]

3. RESULTS AND DISCUSSION

3.1 CHANGES IN THE OXIDIZABLE ORGANIC CARBON

Irrespective of treatments and years of experimentation, organic carbon tended to increase with increase in the period of crop growth (Table 2). The increase in organic carbon content with time is due to slow decomposition of organic matter *i.e*. FYM. Results revealed that maximum amount of organic carbon is accumulated in T_8 treatment. Again, comparatively higher amount of organic carbon is accumulated 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 increased with the application of N, P, K and FYM. Statistical analysis of the results (Table 2) also revealed that T_8 treatment is highly significant in comparison to control. It is noteworthy to mention that addition of higher amount of Zn (10 kg ha^{-1}) fails to increase organic carbon content in soil.

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]

3.2 CHANGES IN THE EXCHANGEABLE NH_4^+

Irrespective of treatments, in general, exchangeable NH_4^+ in soil decreased from the tillering to harvesting stage of rice in the 1st year (Table 3). On the other hand, in the 2nd year, irrespective of treatments, exchangeable NH_4^+ was found to decrease at flowering but again increased at harvesting stage of rice. The decrease in exchangeable NH_4^+ with increase in the period of crop growth in the 1st 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 2nd year of experiment (Table 3). The increase in exchangeable NH_4^+ at harvest particularly in the FYM treated plots is due to mineralisation of FYM and accumulation of exchangeable NH_4^+ in soils after meeting the crop requirement (Kanaujia, 2016) [18]. Closer examination of the data revealed that accumulation of exchangeable NH_4^+ at harvest is more in the plots which received both S and Zn along with recommended doses of N, P, K and FYM. Balanced fertilization encouraged micro-organisms to proliferate [21] and in turn accumulated comparatively higher amount of exchangeable NH_4^+ in these treated plots.

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]

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} leads to accumulate highest amount of exchangeable NH_4^+ in soil cropped consecutively for two years with rice.

3.3 CHANGES IN THE SOLUBLE NO_3^-

Irrespective of treatments, soluble NO_3^- tended to decrease in both the consecutive years over the whole growing period of rice (Table 4). Data in Table 4 further revealed that comparatively higher amount of NO_3^--N is accumulated in soils which received combined application of S and Zn along with recommended doses of N, P and K as well as FYM. Results further showed that significantly higher amount of NO_3^--N is accumulated 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 observed result is due to conversion of exchangeable NH_4^+ to NO_3^- by nitrifying bacteria whose proliferation and activities are 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 decrease in NO_3^--N over the whole cropping season of rice is around 10kg ha^{-1} in T_8 treatment whereas, the decrease 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.

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]

3.4 CHANGES IN THE AVAILABLE P_2O_5

Results in Table 5 revealed that irrespective of treatments and years of experimentation, available P_2O_5 decreased with increase in the period of crop growth of rice. The decrease 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} along with 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 accumulated in soil which received both S and Zn along with recommended doses of N, P and K as well as FYM over that of control plots. The increase in P in FYM treated systems is due to transformation of organic P to inorganic forms due to production of organic acids [25]. The present results corroborate with the earlier works carried out by Yaduvanshi (2001) [24] and Tadesse *et al.* (2013) [26]. The results thus clearly pointed out that balanced fertilization with macro and micro nutrients increased available P content in soil [27].

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($\pm$)	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]

3.5 CHANGES IN THE AVAILABLE K_2O

More or less similar trend of results is observed in for available K_2O (Table 6) as was found for available P (Table 5) in soil. The effect of treatment was also same on accumulation of available K as that of available P in soil. Same explanation is applicable for accumulation of highest amount of available K in T_8 treatment. The decrease in available K with increase in the period of crop growth is due to its utilization by rice. Addition of FYM increased 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.* (2017) [25] and Kanaujia (2016) [17].

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($\pm$)	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]

3.6 CHANGES IN THE AVAILABLE S

Irrespective of treatments and years of experimentation, available S decreased with increase in the period of growth of rice (Table 7). The decrease in available S with time is due to its utilization by the growing rice plants. Furthermore, highest amount of available S is accumulated in T8 treatment like that of available N and K. Addition of S at 40 kg ha^{-1}consecutively for two years leads to accumulate highest amount of 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 encourages to build up 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]. Addition of S further accentuates available S [29].

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($\pm$)	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]

3.7 CHANGES IN THE DTPA-EXTRACTABLE ZN

No drastic variation in Zn content in soil is observed throughout the growing period of rice (Table 8). However, irrespective of treatments, DTPA-extractable Zn decreased with increase in the period of crop growth in both the years of experiments. Perusal of the data in Table 8 further revealed that addition of FYM increased DTPA-extractable Zn content in soil. This is due to production of organic acids through decomposition of FYM which in turn increases the availability of Zn in soils [30]. Highest amount of DTPA-extractable Zn is accumulated in soil which received recommended doses of N, P and K along 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}) fails to increase higher order DTPA-extractable Zn 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 higher amount of available Zn is accumulated in T8 treatment. Therefore, it could be concluded that continuous application of mineral fertilizers along with FYM helps to build up fertility status of soil. The present trend of result finds support of prior findings [32-33].

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($\pm$)	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]

4. CONCLUSION

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

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