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Soil properties as influenced by biochar application under integrated nutrient management in acid Inceptisol of Meghalaya

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ABSTRACT

A field experiment was conducted during winter season of 2017-18 to study the impact of biochar under integrated nutrient management on soil properties and acidity indices after harvest of tomato crop in acid Inceptisol of Meghalaya. The randomized block design experiment replicated thrice consisted of three doses of biochar (B) @ 2, 3 and 4 t/ha, vermicompost (VC) @ 2.5 t/ha and two graded recommended doses of NPK fertilizers (RDF) @ 75 and 100% in sixteen treatment. The results revealed that soil pH increased with the graded doses of biochar, however with the addition 75% RDF with respective graded doses of biochar, pH decreased over biochar application alone. Addition of vermicompost further improved the soil pH. The same tendency was ascertained with the 100% RDF in combination with biochar alone and biochar with vermicompost. However, bulk density showed reverse trend and the lowest bulk density was observed in T_{16}-100% RDF +B @ 4 t/ha + VC @ 2.5 t/ha. The N, P, K and micronutrients content in postharvest soil samples increased with each doses of biochar alone over control. Though, with the inclusion of 75% RDF with respective graded dose of biochar had shown non-significant increase than biochar alone and control plot. Further, the values increased significantly in 75% RDF + graded doses of biochar + vermicompost in comparison to 75% RDF + graded doses of biochar plots. The same trend was observed with respect to 100% RDF + graded doses of biochar + vermicompost in comparison to 100% RDF + graded doses of biochar. It may be concluded that 100% RDF + biochar 4 t/ha + vermicompost @ 2.5 t/ha is the most appropriate combination for improving soil properties of acid Inceptisol.

Keywords: Biochar, integrated nutrient management, acid Inceptisol, soil prosperities, and nutrient availability.

INTRODUCTION

Soil acidity affects nearly 3.95 billion hectare land area globally (Sumner and Noble, 2003) which is about 30 per cent (%) of the world's ice-free land area. About 40.9% of America, 26.4% of Asia, 16.7% of Africa, 9.9% of Europe, and 6.1% of Australia and New Zealand have acid soils (Uexkull and Mutert, 1995). These soils cover a noteworthy part of at least 48 developing countries, especially located in tropical areas (Narro *et al.,* 2001). In India, 49 million hectare of cultivable land is acidic, of which 26 million hectare of land having soil pH less than 5.5 and the rest 23 million hectare of land having soil pH range 5.6 to 6.5. In North Eastern Hill (NEH) region including Sikkim, about 21 million hectare of acid soils are found with the maximum area under Arunachal Pradesh. Meghalaya soils exhibit different acidic ranges like moderately acidic soil (1.19 million hectare), and slightly acidic soils (1.05 million hectare) (Maji *et al.,* 2012).

Soil acidity impacts many biological and chemical reactions that control availability of plant nutrient and also the toxicity of several elements (Pagani and Mallarino, 2012). Crop productivity on these soils is mainly inhibited by aluminium (Al) and iron (Fe) toxicity, phosphorus (P) deficiency, less base saturation, impaired biological activity and other acidity-induced soil fertility and plant nutritional problems (Patiram, 1991; Manoj-Kumar *et al.*, 2012). The soil acidity stages and its related impacts on soil fertility and crop productivity are expected to advance in the changing climate scenario (Oh and Richter, 2004). Management of soil acidity and improvement in crop productivity on such soils is therefore imperative for enhancing food security. Meghalaya is one of the agriculturally important states in NEH of India with very high rainfall and typically high levels of soil acidity. Acidity-induced soil fertility constraints coupled with negligible use of chemical fertilizers are generally held responsible for lower crop productivity in the state. To overcome the problem of soil acidity, farmers use different type of soil amendments like manures, compost, lime, and bio-sorbents to make soil nutrients available to crops as well as to defend them from lethal elements. Among soil amendments, liming is good practice to overcome the acidity problem. However, it is not economical in Meghalaya. The alternate cheap and good organic source to overcome the soil acidity problem is biochar (Chan *et al.,* 2008, Yadav and Sanjay-Swami, 2018).

Biochar is a carbonaceous solid material obtained from thermally degrading biomass in the absence of oxygen or presence of little oxygen. It is usually defined as burnt organic matter, created with the purpose to apply in the soils to impound carbon and improve soil physico-chemical properties (Lehmann and Joseph, 2009; Yadav *et al.,* 2021). It is produced by processes called pyrolysis, the direct thermal decomposition of biomass in the absence of oxygen that produces a mixture of solids (biochar), gas (syngas) and liquid (bio oil). Yield and quality of biochar depends on maintaining of specific temperature (Demirbas, 2004; Sanjay-Swami *et al.,* 2018). Temperature of 400-500° C produces more quantity of biochar, while temperatures above 700^0 C favour the yield of liquid and gas fuel components. The major resource required for the production of the biochar is organic residue. The NEH region produces huge amount of crop residue/weed biomass that can be converted into biochar and used for soil acidity management (Yadav and Sanjay-Swami, 2018, Yadav *et al.,* 2021). Soil health management in the fragile ecosystems of the NEH region should be based on recycling of available plant residues, agro-forestry, and integrated nutrient management (Sanjay-Swami, 2019). Biochar has numerous beneficial effects to soils used for agricultural purposes. The application of charcoal to the soil for improving its physical condition is an old practice (Renner, 2007). There are reports in the literature that biochar in combination with inorganic fertilizers had shown significant increase in yield of cowpea, maize and peanut (Yamato *et al.,* 2006), paddy (Zhang *et al.,* 2012), spring barley, winter wheat, carrots, spinach, oilseed rape, peas and beetroot (Hammond *et al.,* 2013). However, meager information is available on integrating biochar with organic manures and chemical fertilizers. Therefore, the present study was conducted to investigate the impacts of biochar as a major component under integrated nutrient management on residual soil properties, nutrient availability and soil acidity indices after harvest of tomato crop in acid Inceptisol of Meghalaya.

MATERIALS AND METHODS

Study site: The field trial was conducted at the Research Farm of School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Umiam, Ri-bhoi district, Meghalaya which is located at 91°18′ to 92°18′ E longitude and 25°40′ to 26°20′ N latitude with an altitude of 950 m above the mean sea level. The experimental area falls under subtropical humid climate with high rainfall and cold winter.

Experiment details: The experiment was conducted with 16 combinations of three doses of biochar (B) @ 2, 3 and 4 t/ha, two graded recommended doses of fertilizers (RDF) @ 75 and 100% and one dose of vermicompost (VC) @ 2.5 t/ha. The treatments namely, T_1- Control, T_2- 2 t/ha B, T_3- 3 t/ha B, T_4- 4 t/ha B, T_5- 75% RDF + 2 t/ha B, T_6- 75% RDF + 3 t/ha B, T_7- 75% RDF + 4 t/ha B, T_8- 75% RDF + 2 t/ha B + 2.5 t/ha VC, T_9- 75% RDF + 3 t/ha B + 2.5 t/ha VC, T_{10}- 75% RDF + 4 t/ha B + 2.5 t/ha VC, T_{11}- 100% RDF + 2 t/ha B, T_{12}- 100% RDF + 3 t/ha B, T_{13}- 100% RDF + 4 t/ha B, T_{14}- 100% RDF + 2 t/ha B + 2.5 t/ha VC, T_{15}- 100% RDF + 3 t/ha B + 2.5 t/ha VC, T_{16}- 100% RDF + 4 t/ha B + 2.5 t/ha VC were tested in Randomized Block Design (RBD). These treatments were randomly allotted in a unit plot size of 2 m × 2 m and replicated three times. The required quantity of vermicompost and biochar was applied fifteen days prior to transplanting as per the treatments and mixed well in the surface soil.

The 1/3 dose of N, full recommended doses of P and K were applied through urea, single super phosphate (SSP) and murate of potash (MOP), respectively on the day of sowing whereas, the remaining N was applied after 3 weeks of transplanting.

The experimental soil was found to be acidic in reaction having pH 5.1 and medium in available phosphorus (18.70 kg/ha). The detailed analysis of experimental soil is presented in Table 1. The biochar utilized in this study was prepared through pyrolysis by using waste from the plywood industry as a feedstock source at ICAR Research Complex for NEH Region, Umiam whereas vermicompost was procured from Rural Resource and Training Centre, Umran. The characteristics of biochar and vermicompost along with the method of analysis are given in Table 2.

After harvesting of tomato crop, surface soil sample (0-15 cm) were collected from all plots treatment-wise and analyzed for soil properties, nutrient availability and acidity parameters.

Soil acidity indices

Soil acidity indices were estimated using standard methods and calculated using the under mentioned formulas:

$$CEC\ (cmol_c\ kg^{-1}) = \Sigma\ (Ca^{2+}, K^{+}, H^{+}, Al^{3+})$$

Where Ca, Mg, K, H and Al are in centimoles of positive charge per kilogram.

$$\text{Base saturation (\%)} = \Sigma\ (Ca, Mg, K, Na) \times 100/CEC$$

$$\text{Acidity saturation (\%)} = (H + Al) \times 100/CEC$$

Statistical analysis

The data obtained from the experiment were analyzed for analysis of variance (ANOVA) and the difference between treatment means was tested for their statistical significance with appropriate critical difference (CD) at 5% level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Electrical conductivity

The data pertaining to electrical conductivity (EC) of post-harvest soil as influenced by biochar as a component of INM is given in Table 3. The lowest EC was recorded 0.39 dS/m with 100% RDF + 4 t/ha B + 2.5 t/ha VC application which increased by 0.07 units in the treatment receiving 100% RDF + 2 t/ha B + 2.5 t/ha VC, 100% RDF + 2 t/ha B and 75% RDF + 2 t/ha B giving highest value of 0.46 dS/m. This was also observed to be at par over all other treatments corroborate the findings of Usman *et al.* (2016), Cely *et al.* (2015) and Masto *et al.* (2013) who reported that biochar derived from diverse source materials like wood waste, wood sieving, weeds can be used as a soil amendment to control soil salinity.

Bulk density

The bulk density varied from 1.33 to 1.44 g/cc (Table 3). The highest bulk density was recorded

Table 1. Physico-chemical properties of experimental soil along with methods followed for analysis

Parameters	Value	Methods	References
pH	5.10	Potentiometry	Jackson, (1973)
EC(dS/m)	0.45	Conductometry	Jackson, (1973)
Bulk density (g/cm^3)	1.43	Clod method	Campbell and Henshall, (2001)
Available N (kg/ha)	261.00	Alkaline potassium permanganate method	Subbiah and Asija, (1956)
Available P_2O_5 (kg/ha)	18.70	Brays No. 1	Jackson, (1973)
Available K_2O (kg/ha))	235.15	Flame photometer method	Jackson, (1973)
DTPA extractable micronutrients (ppm)			
Iron	6.18	Atomic absorption spectrophotometry	Lindsay and Norwell, (1978)
Zinc	36.48		
Manganese	48.43		
Copper	16.78		
Soil acidity indices (cmol(p+)/kg)			
Exchangeable acidity	3.02	Titrimetric determination	Jackson, (1973)
Exchangeable aluminium	2.25	Titrimetric determination	Jackson, (1973)
Exchangeable Ca & Mg	1.33	Complexometric titration method	Jackson, (1973)
Cation exchange capacity	7.33	Ammonium acetate saturation method	Jackson, (1973)

Table 2. Characteristics of biochar and vermicompost used in the study along with methods followed for analysis

Parameters	Biochar	Vermicompost	Methods	References
pH	8.60	7.30	Potentiometry	Jackson, (1973)
EC (dS/m)	1.77	-	Conductometry	Jackson, (1973)
Nitrogen (%)	0.61	2.11	Kjeldahl digestion and distillation method	Jackson, (1973)
Phosphorus (%)	0.22	1.23	Vanadomolybdate method	Jackson, (1973)
Potassium (%)	1.01	1.53	Flame photometer method	Jackson, (1973)
DTPA extractable micronutrients (ppm)				
Iron	0.06	250.20	Atomic absorption spectrophotometry	Lindsay and Norwell, (1978)
Zinc	1.72	1095.00		
Manganese	0.04	53.00		
Copper	0.12	248.60		

Table 3. Impact of biochar as a component of integrated nutrient management on soil EC (dS/m), bulk density (g/cc), available N, P and K (kg/ha) after harvest tomato crop

Treatments	EC	Bulk density	Av. N	Av. P	Av. K
T_1 – Control	0.45	1.44	221.13	12.35	215.16
T_2 - 2 t/ha B	0.44	1.38	227.65	13.67	219.19
T_3 - 3 t/ha B	0.42	1.34	231.71	14.83	221.22
T_4 - 4 t/ha B	0.41	1.32	234.13	15.76	222.98
T_5 - 75% RDF + 2 t/ha B	0.46	1.41	242.45	17.44	227.65
T_6 - 75% RDF + 3 t/ha B	0.45	1.36	249.12	19.14	230.06
T_7 - 75% RDF + 4 t/ha B	0.43	1.33	254.60	20.64	232.81
T_8 - 75% RDF + 2 t/ha B + 2.5 t/ha VC	0.44	1.39	247.13	25.27	230.84
T_9 - 75% RDF + 3 t/ha B + 2.5 t/ha VC	0.43	1.34	258.33	27.39	234.54
T_{10} - 75% RDF + 4 t/ha B + 2.5 t/ha VC	0.42	1.30	266.67	27.86	237.51
T_{11} - 100% RDF + 2 t/ha B	0.46	1.43	245.75	20.85	229.15
T_{12} - 100% RDF + 3 t/ha B	0.44	1.37	254.13	22.07	232.78
T_{13} - 100% RDF + 4 t/ha B	0.42	1.34	261.13	23.41	234.93
T_{14} - 100% RDF + 2 t/ha B + 2.5 t/ha VC	0.46	1.40	251.21	28.15	236.29
T_{15} - 100% RDF + 3 t/ha B + 2.5 t/ha VC	0.42	1.35	266.62	30.34	240.62
T_{16} - 100% RDF + 4 t/ha B + 2.5 t/ha VC	0.39	1.33	277.13	31.35	243.08
SE(m)±	0.02	0.07	5.63	1.24	4.94
CD($p \leq 0.05$)	NS	NS	16.27	3.59	14.28

*RDF (Recommended doses of fertilizers), B (Biochar), VC (Vermicompost)

1.44 in control plots and it decreased by the application of biochar and vermicompost. The application of 100% RDF + 4 t/ha B + 2.5 t/ha VC recorded lowest bulk density as 1.33 g/cc. The minimum bulk density with the supplying of biochar as well as vermicompost may be due to increased organic carbon in the form of biochar and vermicompost. Moreover, it might be decreased because of low bulk density of the used materials. The soil porosity has also been modified due to the application biochar and vermicompost, where the soil aeration has been increased. Similar to this, Singh and Sanjay-Swami (2020) and Sanjay-Swami *et al.* (2020) also reported decreased bulk density with the incorporation of organic material in the form of *Azolla,* vermicompost and FYM in acid Inceptisol of Meghalaya.

Soil available macro nutrients

The highest content of soil available nitrogen, phosphorus and potassium were recorded in the treatment receiving 100% RDF + 4 t/ha B + 2.5 t/ ha VC (Table 3). It increased from initial soil N status by 6% and 25% over control, from initial soil P status by 67 and 153% over control and from initial soil K status by 3 and 12% over control. This may be owing to N immobilization and decreased loss of N by leaching in the presence of recalcitrant biochar materials (Rondon *et al.,* 2007). The biochar has the ability to act as a slow release N fertilizer, so the availability of N increased (Chan and Xu, 2009; Steiner *et al.,* 2008). The available P content enhanced due to high porous nature of biochar which provides favourable environment for mycorrhizal fungi. It make unavailable P available to plants by secretion of P-solubilizing organic acid (Gul and Whalen, 2016; Warnock *et al.,* 2007). Uzoma *et al.,* (2011) also reported increase in P availability as a result of enhanced soil pH with the application of cow manure biochar after harvest of maize. Similarly, the application of biochar increased the CEC of the soil thereby it can increase the capability of soil to hold K. The availability of K in soil might be increased by enhancing pH of soil by application of biochar as increase in pH of soil may force the strongly attached K on clay particles and pulled into the soil solution (Manolikaki and Diamadopoulos, 2016; Smider and Singh, 2014; Singh and Sanjay-Swami, 2020; Sanjay-Swami and Singh, 2020).

DTPA extractable iron, zinc, manganese and copper

There was improvement in the content of DTPA extractable Fe, Zn, Mn and Cu with the application of biochar (Table 4). The content of Fe, Zn, Mn and Cu varied from 5.7 to 7.05, 32.16 to 36.61, 43.67 to 49.71 and 14.62 to 16.64 mg/kg, respectively. The maximum content of Fe, Zn, Mn and Cu was found with the application of 100% RDF + 4 t/ha B + 2.5 t/ha VC whereas the lowest contents were recorded in control, however the Cu content showed non-significant increase. The increase in micronutrients availability might be due to supplying of sufficient amount Fe, Zn, Mn and Cu through vermicompost resulting in enhanced availability of Fe, Zn, Mn and Cu by mineralization of organic matter and release during decomposition of vermicompost. These results support the earlier findings of Jatav *et al.,* (2018), and Sanjay-Swami and Singh, (2020).

Soil acidity indices

Soil reaction

The soil pH in post harvest soil varied from 5.1 in control to 5.30 in the treatment receiving 100% RDF + 4 t/ha B + 2.5 t/ha VC (T_{16}). It is non-significant with all the treatments. The soil pH enhanced due to the suppling of biochar could be due to alkaline, porous nature and more surface area of biochar which increases the soil cation exchange capacity (CEC). Another cause for an increase in soil pH may be the high content of calcium carbonate and release of basic cations of biochar (Chintala *et al.,* 2014). Many researchers had reported a rise in pH by the insertion of biochar (Jatav *et al*., 2018; Yadav *et al.,* 2021).

Exchangeable acidity (cmol(p+)/kg), exchangeable aluminium (cmol(p+)/kg) and acid saturation (%)

The influence of biochar on exchangeable acidity (cmol(p+)/kg) of post-harvest soil as a constituent of integrated nutrient management showed statistically non-significant results between treatments but exchangeable aluminium (cmol(p+)/

Table 4. Impact of biochar as a component of integrated nutrient management on DTPA extractable Fe, Zn, Mn and Cu (mg/kg) after harvest tomato crop

Treatments	Fe	Zn	Mn	Cu
T_1 – Control	5.70	32.16	43.67	14.62
T_2 - 2 t/ha B	6.01	32.21	43.73	14.64
T_3 - 3 t/ha B	6.12	32.25	43.79	14.66
T_4 - 4 t/ha B	6.18	32.27	43.81	14.67
T_5 - 75% RDF + 2 t/ha B	6.21	33.46	45.43	15.21
T_6 - 75% RDF + 3 t/ha B	6.33	33.47	45.44	15.21
T_7 - 75% RDF + 4 t/ha B	6.45	33.49	45.47	15.22
T_8 - 75% RDF + 2 t/ha B + 2.5 t/ha VC	6.81	36.28	49.26	16.49
T_9 - 75% RDF + 3 t/ha B + 2.5 t/ha VC	6.90	36.34	49.34	16.18
T_{10} - 75% RDF + 4 t/ha B + 2.5 t/ha VC	7.02	36.53	49.60	16.60
T_{11} - 100% RDF + 2 t/ha B	6.28	33.49	45.47	15.22
T_{12} - 100% RDF + 3 t/ha B	6.39	33.50	45.48	15.22
T_{13} - 100% RDF + 4 t/ha B	6.48	33.51	45.50	15.23
T_{14} - 100% RDF + 2 t/ha B + 2.5 t/ha VC	6.85	36.55	49.63	16.61
T_{15} - 100% RDF + 3 t/ha B + 2.5 t/ha VC	6.94	36.58	49.67	16.62
T_{16} - 100% RDF + 4 t/ha B + 2.5 t/ha VC	7.05	36.61	49.71	16.64
SE(m)±	0.27	0.84	0.95	0.89
CD($p \leq 0.05$)	0.79	2.43	2.74	NS

*RDF (Recommended doses of fertilizers), B (Biochar), VC (Vermicompost) kg) recorded statistically significant among the treatments (Table 5). However, lowest exchangeable acidity and aluminium (cmol(p+)/kg) were recorded with the application of 100% RDF + 4 t/ha B + 2.5 t/ha VC. This may be because of the fact that organic manure and biochar have ability to consume protons which reduce the acidity. The exchangeable aluminium (cmol(p+)/kg) came down due to increase in pH of the soil. Further, this may also owing to precipitation of aluminium or formation of chelation with organic colloids or formation of aluminium complexation with organic acids (Hati *et al.,* 2008). Similar outcome were reported by several researchers (Narambuye and Haynes, 2006; Opala *et al.,* 2012; Singh and Sanjay-Swami, 2020). The same trend as observed in exchangeable acidity and exchangeable aluminium (cmol(p+)/kg) was also observed for acid saturation.

Exchangeable Ca^{+2} + Mg^{+2} (cmol(p+)/kg) and base Saturation (%)

The highest exchangeable Ca^{+2} + Mg^{+2} was recorded 2.07 cmol(p+)/kg in the treatment receiving 100% RDF + 4 t/ha B + 2.5 t/ha VC (Table 5). However, the Ca^{+2} + Mg^{+2} showed increase with application of biochar and vermicompost. This may be because of increase in pH of the soil that leads to enhance the formation of organic anions during decomposition of organic matter (Narambuye and Haynes, 2006) which consumed acidity causing protons (Haynes and Mokolobate, 2001) and solubilise inherent Ca and Mg content present in organic matter. Application of biochar and vermicompost improved the soil physical condition which provided the suitable environment for microbiological activity which improve mineralization and increase in content of exchangeable Ca^{+2} + Mg^{+2}. Singh and Sanjay-Swami, (2020) had also reported similar results with incorporation of *Azolla* in Inceptisol. Base saturation also followed the same trend (Table 5) as observed for exchangeable Ca^{+2} + Mg^{+2}.

CONCLUSION

Based on the findings of the above investigation, it may be concluded that biochar is an effective component of integrated nutrient management under acidic soil conditions. The application of 4 t/ha biochar in combination with 100% RDF + 2.5 t/ha vermicompost may be recommended as most appropriate combination for improving nutrient

Table 5. Impact of biochar as a component of integrated nutrient management on soil acidity indices after harvest tomato crop

Treatments	pH	Exchangeable acidity (cmol(p+)/kg)	Exchangeable Al (cmol(p+)/kg)	Exchangeable Ca & Mg (cmol(p+)/kg)	CEC (cmol(p+)/kg)	Base saturation (%)	Acid saturation (%)
T_1 – Control	5.10	3.02	2.25	1.30	7.33	18.05	81.95
T_2 - 2 t/ha B	5.16	2.81	1.96	1.48	8.84	20.95	79.05
T_3 - 3 t/ha B	5.20	2.70	1.81	1.70	10.08	22.95	77.05
T_4 - 4 t/ha B	5.22	2.64	1.71	1.79	10.59	24.04	75.96
T_5 - 75% RDF + 2 t/ha B	5.11	2.98	2.22	1.32	7.94	18.13	81.87
T_6 - 75% RDF + 3 t/ha B	5.18	2.76	1.88	1.57	9.35	22.37	77.63
T_7 - 75% RDF + 4 t/ha B	5.23	2.69	1.67	1.83	10.81	24.66	75.34
T_8 - 75% RDF + 2 t/ha B + 2.5 t/ha VC	5.14	2.86	2.07	1.40	8.39	19.84	80.16
T_9 - 75% RDF + 3 t/ha B + 2.5 t/ha VC	5.23	2.69	1.67	1.83	10.81	24.65	75.35
T_{10} - 75% RDF + 4 t/ha B + 2.5 t/ha VC	5.28	2.41	1.42	1.98	11.66	26.72	73.28
T_{11} - 100% RDF + 2 t/ha B	5.09	3.07	2.32	1.26	7.60	18.00	82.00
T_{12} - 100% RDF + 3 t/ha B	5.16	2.81	1.96	1.48	8.84	20.98	79.02
T_{13} - 100% RDF + 4 t/ha B	5.21	2.67	1.77	1.74	10.31	23.49	76.51
T_{14} - 100% RDF + 2 t/ha B + 2.5 t/ha VC	5.12	2.92	2.16	1.35	8.11	18.67	81.33
T_{15} - 100% RDF + 3 t/ha B + 2.5 t/ha VC	5.22	2.64	1.71	1.79	10.59	24.04	75.96
T_{16} - 100% RDF + 4 t/ha B + 2.5 t/ha VC	5.30	2.89	1.32	2.07	12.17	27.87	72.13
SE(m)±		0.14	0.09	0.09	0.51	1.27	1.87
CD($p \leq 0.05$)		NS	0.28	0.26	1.48	3.67	5.41

availability and soil acidity indices of acid Inceptisol of Meghalaya.

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