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INTEGRATED EFFECTS OF VERMICOMPOST, CLIMATIC FACTORS AND SOIL MIXING ON SELECTED SOIL FERTILITY INDICATORS

MITHUN KUMAR SAHA, MD. HARUNOR RASHID KHAN, SUMA AKTER AND MD. BAYAZID HOSSAIN*

Department of Soil, Water and Environment, University of Dhaka, Dhaka-1000, Bangladesh

Keywords: Vermicompost, climatic factors, soil mixing, soil fertility indicators.

Abstract

A field experiment was carried out to investigate the effects of vermicompost (0, 10, and 15 tha^{-1}), climatic elements i.e. soil moisture (50%, 70%, and 100%) and elevation of soil temperature (1 to 2^0C) on the physico-chemical properties and nutrient availability of post-harvest calcareous-acid mixed soils after rice production. A total of 18 treatments assembling the afore-mentioned doses was applied. The analyses of the soils demonstrated significant variation in effects ($p \leq 0.05$) of the treatments on both the available nutrient status and the physico-chemical properties of soils. Except for available sulfur; soil p^H, EC, organic carbon (OC), available nitrogen, phosphorous, potassium, calcium, and sodium were detected in the higher amounts in 1:1 (calcareous : acid-soils) mixed soils than those of 1:3 mixed counterpart both in initial and post-harvest soil conditions. The highest levels of soil p^H, OC, available P and Zn were determined in the treatment $T_{13.}$ Whereas, treatment T_6 proved to be the best dose for the highest availability of Ca and Mg. The treatments $T_{1,}$ $T_{2,}$ $T_{11,}$ and T_{16} were recorded to have the lower OC, available N, P, Ca, Mg, Zn and S contents in soils. In particular, the availability of Na was found to be in lesser amounts in all the subplots. In a nutshell, most of the treatments exerted favourable influence in maintaining a healthy level of soil physico-chemical parameters owing to their inherent characteristics.

Introduction

Bangladesh is known to the world a land of fertile soils and agriculture is the base of its growing economy. In the recent past it has shown her capacity to be self-sufficient in food production even with the little arable land in comparison to the huge population. However, with the concentration focused on crop yield we often forget about soil health, which can bring horrendous prospects on sustainable food production. Moreover, climate change is considered as an aggravating actor in this respect and is thought to pour water on a drowned mouse. A way out of this absolute crisis, would be the maintenance of soil fertility and efficient use of marginal soils in response to climatic irregularities.

Alarming and intensive acid soils prevail in the northern part of Bangladesh covering nearly 27% of lands[1]. Another chunk of 0.7 M ha land with active and potential acid

*Author for correspondence: <mithunsaha37@du.ac.bd>.

sulfate soils is located in the coastal region of this country[2]. Again, soils that belong to Ganges alluvium, especially, regions near the Padma River pose significant calcareousness problems. Brady and Well (2017) addressed the problems associated with these soils[3]. They cited that with phytotoxic concentration of aluminum, manganese, iron, and deficiencies of essential calcium, magnesium and molybdenum acid soils can be unsuitable for many plants. Furthermore, they mentioned that calcareous soils may lack iron, zinc, manganese, boron, zinc, and is furnished with base cations. The pH is also to the opposite side of the pH scale for these two soil category. As normal growth of most plants is significantly hampered in both these soils, a hypothesized solution can be the incorporation of such soils. The resultant mixed soils may be a remedy to the scarcity or excessiveness of the aforementioned elements and thereby prove productive. Zhang and Li (2002) concluded from an experiment that acidity was neutralized one year after the excavation and exchange of calcareous soils by acid soils[4]. The electric conductivity value was also changed after manipulation. Thus, soil manipulation can be useful condition for the availability of essential nutrients for plant growth and thereby increase production. Alongside, such manipulation we have to focus on organic amendments. Among many such amendments, vermicompost can be chosen. Vermicompost is a nutrient-rich, microbiologically-active organic amendment that results from the interactions between earthworms and microorganisms during the breakdown of organic matter. It not only provides nutrition to plants, but also improves soil fertility and soil structure[5-6].

Global warming is an established scenario and cliché but its impact is felt everywhere. Bangladesh is no alien to the adversities of global warming. The two key factors relevant to the climate irregularities and plant growth are temperature and moisture[7]. Soil temperature is subjected to daily fluctuations and seasonal fluctuations. Excessive or lowered soil temperature in turn affects the physical, chemical and biological characteristics of it. Again, warming accelerated crop growth, and shortened the growth stages while the water use efficiency and crop yield is decreased[8]. Against the mentioned background, the experiment was conducted to find out whether the combined effects of the temperature, moisture and vermicompost is beneficial or not in terms of crop production and nutrient availability and also to find out the effectiveness of soil mixing as a probable solution to soil calcareousness and acidity.

Materials and Methods

Manipulated soil beds were prepared for the experiment at the department of Soil, Water and Environment, University of Dhaka by mixing calcareous and acid soils in different ratios. Calcareous soils of the Sara series, collected from West Gangabardi, Faridpur; and Acid soils of the Pirgacha series, collected from Binnapara, Dinajpur were air dried, run through 2mm sieve and finally mingled into 1:1 and 1:3 ratios to prepare 30cm x 30cm artificial soil beds. The initial soil properties of the mixed soils have been listed in table 1. As test plants, BINA Dhan 11 and BRRI Dhan 34 were transplanted. Vermicompost at three different doses (0, 10 and 15 tha^{-1}) were applied, whereas, soil moisture were maintained at 50, 70 and 100% field moisture conditions. Metal pipes inserted under the soil beds and hot water was poured to increase soil temperatures to 1 and 2^0C over the diurnal ones (26-28^0C). Heat treatment was continued for 6 hours a day for a 15 day-set after 25, 50, and 75 days of transplantation. To record the temperature, soil thermometers were used. Table 2 represents the treatments used in the experiment. After harvesting the rice, soils were collected and processed for physico-chemical analysis. Soil texture, gravimetric water content, soil reaction, electric conductivity, organic carbon, cation exchange capacity, available nitrogen, phosphorous, sulfur, calcium, magnesium, zinc, potassium and sodium were measured following standard methods (Table 1). Minitab and MS Excel were operated for statistical purposes.

Table 1. Physico-chemical properties of mixed soils as used in the experiment.

Properties	Calcareous:Acid (1:1) mixed soil	Calcareous:Acid (1:3) mixed soil
Texture [9]	Silt Loam	Silt Loam
Gravimetric Water Content (%) [10]	2.87	1.88
Soil Reaction (pH) [11]	6.60	6.30
Electrical Conductivity (μS/cm) [12]	143.40	121.40
Organic Carbon (%) [13]	0.67	0.58
Cation Exchange Capacity (cmol/kg) [14]	24.50	23.00
Available NH_4^+(mg/kg) [11]	8.52	7.78
Available NO_3^-(mg/kg) [11]	49.00	42.22
Available P (mg/kg) [15]	10.40	11.93
Available K (cmol/kg) [11]	0.30	0.42
Available S (mg/kg) [16]	22.30	26.00
Available Ca (cmol/kg) [11]	14.50	11.87
Available Mg (cmol/kg) [11]	1.30	1.79
Available Na (cmol/kg) [11]	0.21	0.32
Available Zn (mg/kg) [11]	1.99	2.1

Table 2. Denotation of treatments applied in the experiment.

Treatment Number	Treatment Denotation	Explanation
T_1 (control)	$^{*}St_0{}^{\#}V_0{}^{\&}M_{50}$	
T_2	$St_1V_0M_{70}$	
T_3	$St_1V_{15}M_{100}$	
T_4	$St_2V_{10}M_{100}$	$^{*}St_0$ is the normal soil temperature and St_1, St_2 indicates 1^0C and 2^0C rise in soil temperature over the diurnal ones for a particular period, respectively.
T_5	$St_2V_{15}M_{100}$	
T_6	$St_2V_{15}M_{70}$	
T_7	$St_2V_{10}M_{70}$	
T_8	$St_1V_{10}M_{70}$	
T_9	$St_1V_{15}M_{70}$	$^{\#}V_0$, V_{10}, V_{15} are the doses of vermicompost of 0 t ha^{-1}, 10 t ha^{-1} and 15 t ha^{-1}, respectively.
T_{10}	$St_1V_{10}M_{100}$	
T_{11}	V_0M_{100}	
T_{12}	$V_{10}M_{100}$	
T_{13}	$V_{15}M_{100}$	$^{\&}M_{50}$, M_{70}, M_{100} indicates 50%, 70% and saturated soil moisture conditions, respectively.
T_{14}	$V_{15}M_{70}$	
T_{15}	$V_{10}M_{70}$	
T_{16}	V_0M_{70}	
T_{17}	$V_{10}M_{50}$	
T_{18}	$V_{15}M_{50}$	

Results and Discussion

Changes in Soil reaction (pH): Soil reaction is the most important physico-chemical property that affects nutrient availability in soil. The initial pH values of 1:1, 1:3 (calcareous-acid) mixed soils and vermicompost were 6.60, 6.31 and 7.24, respectively. The analyses of post-harvest soils evidenced that the soil pHs were improved by maintaining the range of near neutral pH values. The pH of the 1:1 and 1:3 (calcareous-acid) mixed post-harvest soils ranged between 6.61 and 7.37 and between 6.37 and 6.87, respectively (Fig 1). The lowest pH was detected for the treatment T_1 ($St_0V_0M_0$), whereas the highest pH value was for the treatment T_{13} ($V_{15}M_{100}$) for both the soils. The higher doses of vermicompost and moisture level increased soil reaction whether alone or in combination but showed an overall decreasing trend with the rise in temperature. This might be due to the fact that temperature rise may have increased organic matter mineralization in soils. Maheswarappa (1999) reported improvement in pH of soils in response to vermicompost treatments[17]. Vermicompost was able to fruitfully maintain a normal pH in soil after the cultivation of rice. Yagi *et al.* (2003) also found that vermicompost increased the level of pH over manure when treated in combination with limes[18].

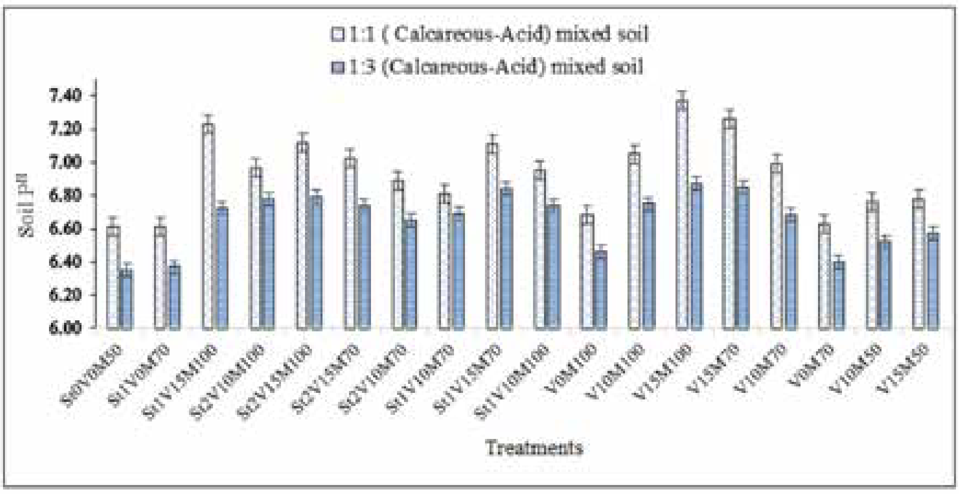

Fig. 1. Effects of different treatments on the pH values of soils. St=soil temperature, V=vermicompost, M=soil moisture.

Electrical Conductivity (EC): The electrical conductivity is an important index that affects nutrient availability to plants. The EC values of the post-harvest soils increased significantly ($p \leq 0.05$) with the application of vermicompost alone or in combination with moisture and temperature. In 1:1 and 1:3 (calcareous-acid mixed) post-harvest soils, the lowest and the highest EC values were attained from the T_1 and T_5 treatments (Table 3). The EC values increased up to 63% over control for the treatment T_5 ($St_2V_{15}M_{100}$) in 1:1 (calcareous-acid) mixed soil and up to 74% for the same treatment in 1:3 mixed soil. Another treatment that imposed notable impact on EC was T_3. The increase in EC values of soil can be attributed to the additional nutrients by the filler materials and vermicompost.

Table 3. Effects of different treatments on the EC values (µS cm^{-1}) of soils.

Treatment No.	Treatment Denotation	Change in EC values (µS cm^{-1}) of post-harvest soils			
		1:1 mixed soil	*IOC (%)	1:3 mixed soil	*IOC (%)
T_1 (control)	$St_0V_0M_{50}$	161.3 p	0	138.0 j	0
T_2	$St_1V_0M_{70}$	178.0 n	10.35	147.1 i	6.59
T_3	$St_1V_{15}M_{100}$	249.7 b	54.80	225.1 c	63.11
T_4	$St_2V_{10}M_{100}$	244.8 c	51.77	231.6 b	67.82
T_5	$St_2V_{15}M_{100}$	263.0 a	63.05	240.3 a	74.13
T_6	$St_2V_{15}M_{70}$	241.1 d	49.47	229.0 bc	65.94
T_7	$St_2V_{10}M_{70}$	224.8 g	39.37	203.1 f	47.17
T_8	$St_1V_{10}M_{70}$	217.3 j	34.72	200.7 f	45.43
T_9	$St_1V_{15}M_{70}$	226.4 f	40.36	220.0 d	59.42
T_{10}	$St_1V_{10}M_{100}$	237.1 e	46.99	227.0 c	65.49
T_{11}	V_0M_{100}	189.6 m	17.54	178.0 h	28.98
T_{12}	$V_{10}M_{100}$	198.5 l	23.06	186.2 g	34.93
T_{13}	$V_{15}M_{100}$	238.2 e	47.67	200.0 f	44.93
T_{14}	$V_{15}M_{70}$	221.6 q	37.38	210.6 e	52.61
T_{15}	$V_{10}M_{70}$	214.8 k	33.17	189.1 g	37.02
T_{16}	V_0M_{70}	170.4 o	5.64	143.0 i	3.62
T_{17}	$V_{10}M_{50}$	223.3 h	38.44	210.0 e	52.17
T_{18}	$V_{15}M_{50}$	237.1 e	46.99	225.0 c	63.04

In a column, means followed by a common letter are not significantly different at 5% level by Tukey's Range Test and *IOC indicates increase over control.

Organic Carbon (OC) : Organic carbon is an indicating factor of soil health. The initial organic carbon (OC) content was 0.67% and 0.58% in 1:1 and 1:3 (calcareous-acid) mixed soils, and that decreased for the treatments T_1, T_2, T_{11} and T_{16} in both soils after harvesting (Table 4). The overall effect of vermicompost on OC content of soils was significant ($p \leq 0.05$) and the effect was most pronounced with the treatment T_{13} ($V_{15}M_{100}$). The effects of the treatment T_3 was statistically similar with T_{13}, regarding the OC of 1:1 (calcareous-acid) mixed soils. The rise in temperature to 2^0C tended to decrease the OC content of soil but the effect of moisture was not clearly understood. Such phenomenon may be caused due to the stimulated oxidation of organic matter by microbes. As most subplots showed a tendency to an increment in the OC levels in soils even after crop production, the treatments hence proved conducive to the soil health. Vasanthi and Kumaraswamy (1999)[19] also suggested that OC content and fertility status were higher for the soils receiving vermicompost along with fertilizers rather that fertilizers alone.

Table 4. Effects of different treatments on the organic carbon contents (%) of soils.

Treatment No.	Treatment Denotation	Organic carbon content in post-harvest soils (%)			
		1:1 mixed soil	*IOC (%)	1:3 mixed soil	*IOC (%)
T_1 (control)	$St_0V_0M_{50}$	0.59 g	0	0.51 h	0
T_2	$St_1V_0M_{70}$	0.61 g	3.38	0.53 h	3.92
T_3	$St_1V_{15}M_{100}$	0.84 a	42.37	0.63 fg	23.53
T_4	$St_2V_{10}M_{100}$	0.75 de	27.11	0.68 def	33.33
T_5	$St_2V_{15}M_{100}$	0.82 abc	38.98	0.63 fg	23.53
T_6	$St_2V_{15}M_{70}$	0.78 bcd	32.20	0.62 g	21.57
T_7	$St_2V_{10}M_{70}$	0.73 de	23.72	0.60 g	17.65
T_8	$St_1V_{10}M_{70}$	0.74 de	25.42	0.75 abc	47.06
T_9	$St_1V_{15}M_{70}$	0.76 de	28.81	0.77 ab	50.98
T_{10}	$St_1V_{10}M_{100}$	0.77 cde	30.50	0.69 de	35.29
T_{11}	V_0M_{100}	0.60 g	1.69	0.52 h	1.96
T_{12}	$V_{10}M_{100}$	0.78 bcd	32.20	0.71 cd	39.21
T_{13}	$V_{15}M_{100}$	0.86 a	45.76	0.79 a	54.90
T_{14}	$V_{15}M_{70}$	0.83 ab	40.67	0.73 bcd	43.13
T_{15}	$V_{10}M_{70}$	0.77 cde	30.50	0.71 cd	39.21
T_{16}	V_0M_{70}	0.59 g	0	0.52 h	1.96
T_{17}	$V_{10}M_{50}$	0.67 f	13.56	0.61 g	19.61
T_{18}	$V_{15}M_{50}$	0.72 ef	22.03	0.64 efg	25.49

In a column, means followed by a common letter are not significantly different at 5% level by Tukey's Range Test and *IOC indicates increase over control.

Available Nitrogen: The available nitrogen contents of the post-harvest soils were measured and found statistically significant ($p \leq 0.05$). The individual and combined application of vermicompost, moisture and temperature increased the available N (NH_4^++NO_3^-) contents in the soils, especially the effect of vermicompost was found most striking. The data showed that the nitrate (NO_3^-) was more pronounced than the ammonium (NH_4^+) concentration in the same plot. Initial available N contents were 57.50 and 50.00 mg kg^{-1} in 1:1 and 1:3 (calcareous-acid) mixed soils, respectively. After harvesting the crops at maturity, the treatments T_1, T_2, T_{11}, T_{16}, T_{17} and T_{18} were recorded for the decrement of available N contents in both the soils, while the rest of the treatments caused a notable increase in the N content (Fig 2). The treatment T_6 encountered the highest available N content in 1:1 mixed soil, followed by the treatment T_{14} over control (T_1). But in case of 1:3 mixed soil, the treatment T_{14}, followed by the treatment T_9 had the most statistically significant increment of N content over control. The decrement of N contents in some sub-plots might be attributed to the increased uptake of N by rice plants, there was no addition of vermicompost and/or there might be shortage of moisture. The increment in other sub-plots might be due to the release of NO_3^- and NH_4^+ from vermicompost and its associated congenial environment. Jayakumar *et al.* (2011) found that the organic carbon and available nitrogen, phosphorous and potassium contents showed an increase in vermicompost applied plots[20].

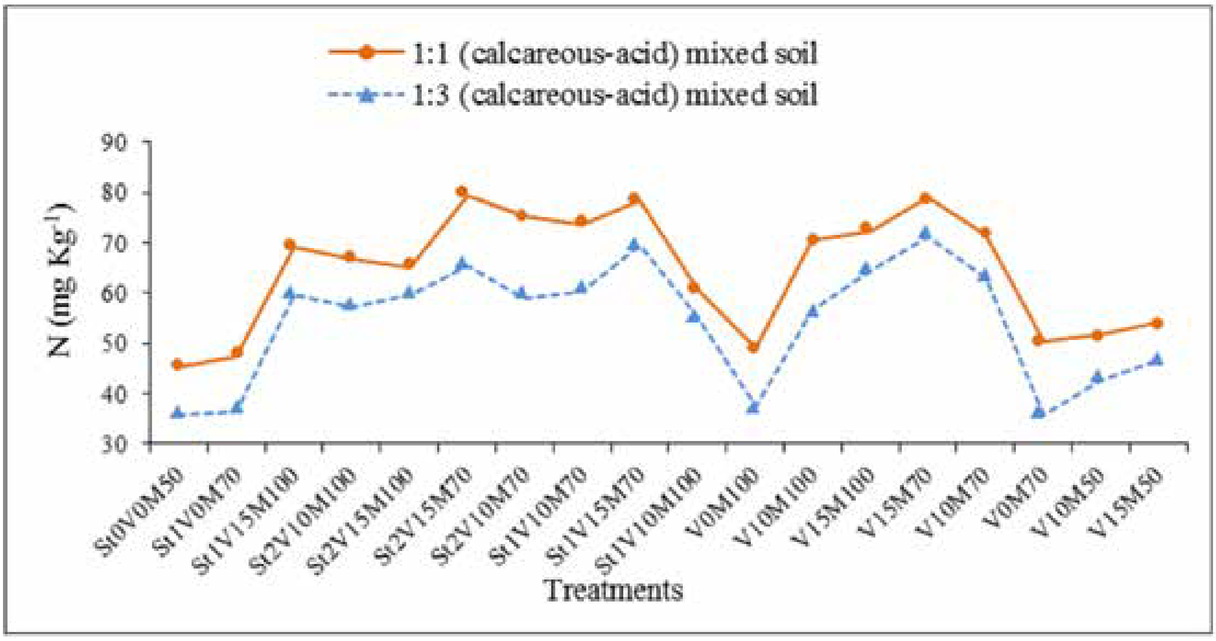

Fig. 2. Effects of different treatments on the available nitrogen contents (mg kg^{-1}) of soils. St=soil temperature, V=vermicompost, M=soil moisture.

Available Phosphorous: The present study revealed that the availability of P was found to be increased by the application of vermicompost, moisture and temperature. The effects of vermicompost, applied with different moisture and temperature levels, were also found to be significant ($p \leq 0.05$). The initial P contents in 1:1 and 1:3 (calcareous-acid) mixed soils were 10.40 mg kg^{-1} and 11.98 mg kg^{-1}, respectively. The decrements in available P contents were recorded for the treatments T_1, T_2, T_{11} and T_{16} in both soils and these effects were the opposite for other treatments (Fig. 3). The combined effects of vermicompost along with moisture or with moisture and temperature were more pronounced in 1:1 (calcareous-acid) mixed soil, resulting to the highest available P content for the treatment T_{13}. But their effects on P availability in 1:3 (calcareous-acid) mixed soil were not that explicit, as many different treatments like T_3, T_5, T_{10}, T_{12} and T_{13} were found statistically similar concerning to the availability of P in both soils. However, the overall impacts of vermicompost and moisture on P availability were positive but the effects of rising temperature up to 2^0C was not well understood. The improvement in P level might be due to favourable pH and the application of vermicompost, a well-known source for P. Srikanth (2000) also found the improvement in available P content with vermicompost amended post-harvest soils(21).

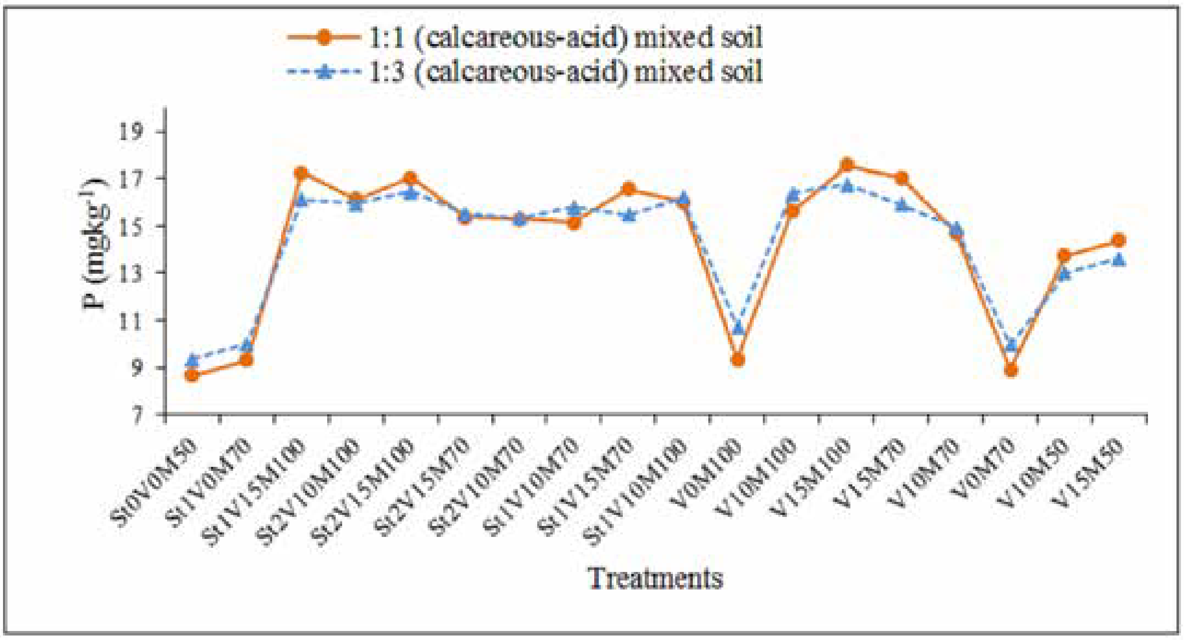

Fig. 3. Effects of different treatments on the available phosphorous contents (mg kg^{-1}) of soils. Where, St=soil temperature, V=vermicompost, M=soil moisture.

Available Sulfur: The present investigation was conducted to enquire into the effects of different treatments on the sulfur contents of post-harvest soils. The effects of the treatments were found to be positively significant ($p \leq 0.05$) on the S content of the soils by the application of vermicomposts, moisture and temperature alone or in combination. The initial available S content of 1:1 (calcareous-acid) mixed soil was 22.30 mg kg^{-1} and 26.00 mg kg^{-1} for that of 1:3 (calcareous-acid) mixed soil. For both soils, a decreasing trend in available S contents were found for the treatments T_1 (control), T_2, T_{11} and T_{16} but the rest of the treatments contributed to the accumulation of S in soil to some extent (Fig. 4). The best dose for S availability was T_{14} ($V_{15}M_{70}$) for 1:1 mixed soil and T_9 for 1:3 mixed soil. In the post-harvest soils, the availability of S was much greater in 1:3 mixed soil than that of in

1:1 mixed soil. The content of available S increased with the higher doses of vermicompost application. With the same dose of vermicompost and temperature level, the moisture level of 70% ameliorated the S content of the soils to the most. The effect of increasing temperature did not follow a smooth trend in increasing or decreasing the S availability of soils. Sundararasu (2017) also demonstrated the increment of P, N, Ca, Mg, Zn and Fe along with S in the post-harvest soils of gourd field when vermicompost was applied for the cultivation[22].

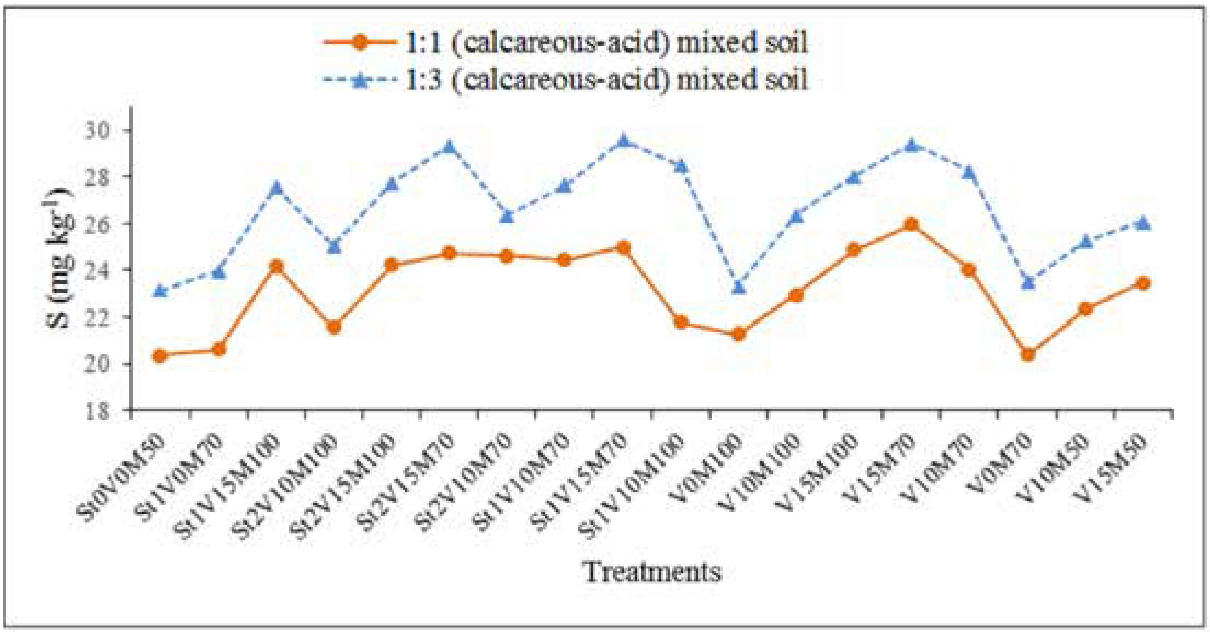

Fig. 4. Effects of different treatments on the available sulfur contents (mg kg^{-1}) of soils. St=soil temperature, V=vermicompost, M=soil moisture.

Available Potassium: Initial potassium contents of 1:1 and 1:3 (calcareous-acid) mixed soils were 0.30 and 0.42 cmol kg^{-1}, respectively. The results of the analyses of the post-harvest soils are depicted below (Fig 5). The figure illustrates that the available K content of 1:3 (calcareous-acid) mixed soil decreased more dramatically to that of 1:1 soil and hence the K content was much greater in 1:1 soil than that of in 1:3 soil. The effects of different treatments were significant ($p \leq 0.05$) on the K availability of both soils. Despite the fact that the available K content decreased in most sub-plots compared to that of in initial soils, the vermicompost applied sub-plots were found to be furnished with more available K than non-amended ones. Regardless of vermicompost application, the soil moisture level of 70% was found to decrease the available K, while the decrement was more pronounced with the 100% moisture level, though the effects were not significant. The effect of temperature was relatively less pronounced compared to the other treatments. The highest K availability was found for the combined application of vermicompost 15 tha^{-1} and moisture level 70%

(T_{14}) and the lowest value was obtained from the treatments T_2 and T_{11} in 1:1 soil and with T_2 in 1:3 soil. The overall decreasing trend might be due to the thorough uptake of K^+ by rice plants and 100% soil moisture might have caused leaching of K^+ from rest of the sub-plots to some extent.

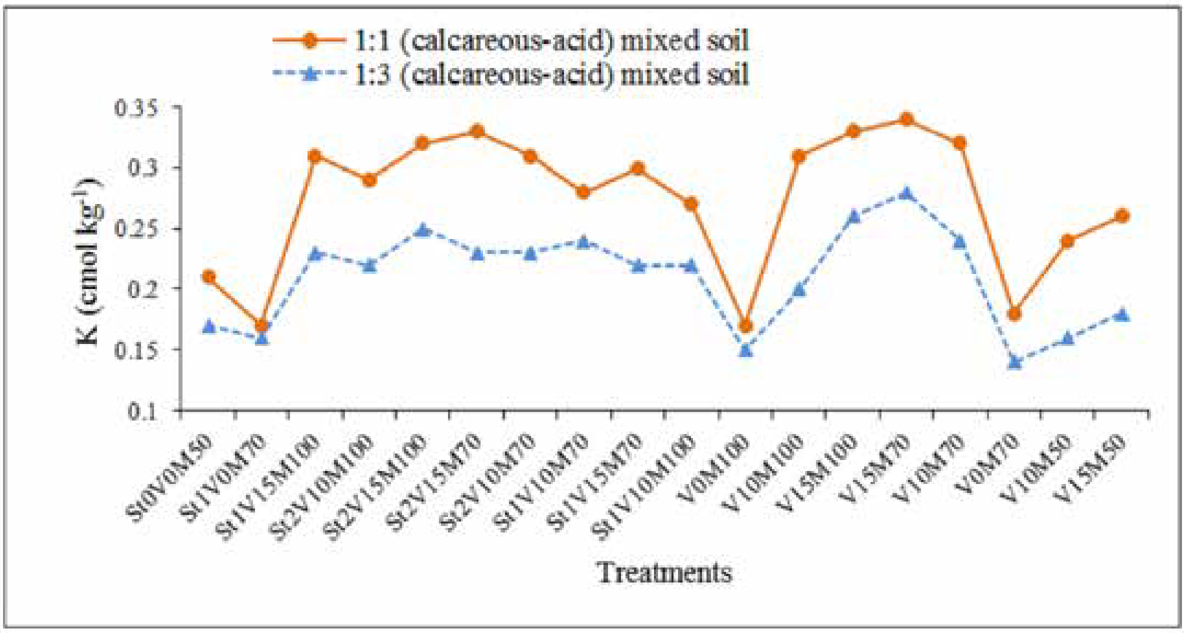

Fig. 5. Effects of different treatments on the available potassium contents (cmol kg^{-1}) of soils. St=soil temperature, V=vermicompost, M=soil moisture.

Available Calcium: The initial 1:1 and 1:3 (calcareous-acid) mixed soils contained respective available Ca of 14.50 and 11.87 cmol kg^{-1}. The statistical analyses showed that the treatments had significant influence ($p \le 0.05$) on the available Ca contents of post-harvest soils. The results indicate that in post-harvest soils, the available Ca fraction increased in most sub-plots, except for the treatments T_1, T_2, T_{11}, T_{16}, T_{17} and T_{18} in 1:1 soil and for T_1, T_2, T_{11} and T_{16} in 1:3 soil (Fig 6). The highest available Ca content was recorded for the treatment T_6 ($St_2V_{15}M_{70}$) in both soils. Like other nutrients, Ca availability increased with the concomitant increase of vermicompost doses. Besides, the combined effect of vermicompost and moisture had a better influence on the available Ca fraction rather than the individual application of vermicompost. The combined effects of vermicompost, moisture and temperature were also favourable in increasing available Ca content in the soils. Such phenomenon might have been occurred due the increased mineralization of vermicompost by the stimulated microbes with the increase in temperature. The results resembles with Uz *et al.* (2016) who investigated the effect of vermicompost on chemical and biological properties of an alkaline soil with high lime content during Celery production and found better available Ca concentration in post-harvest soils[23].

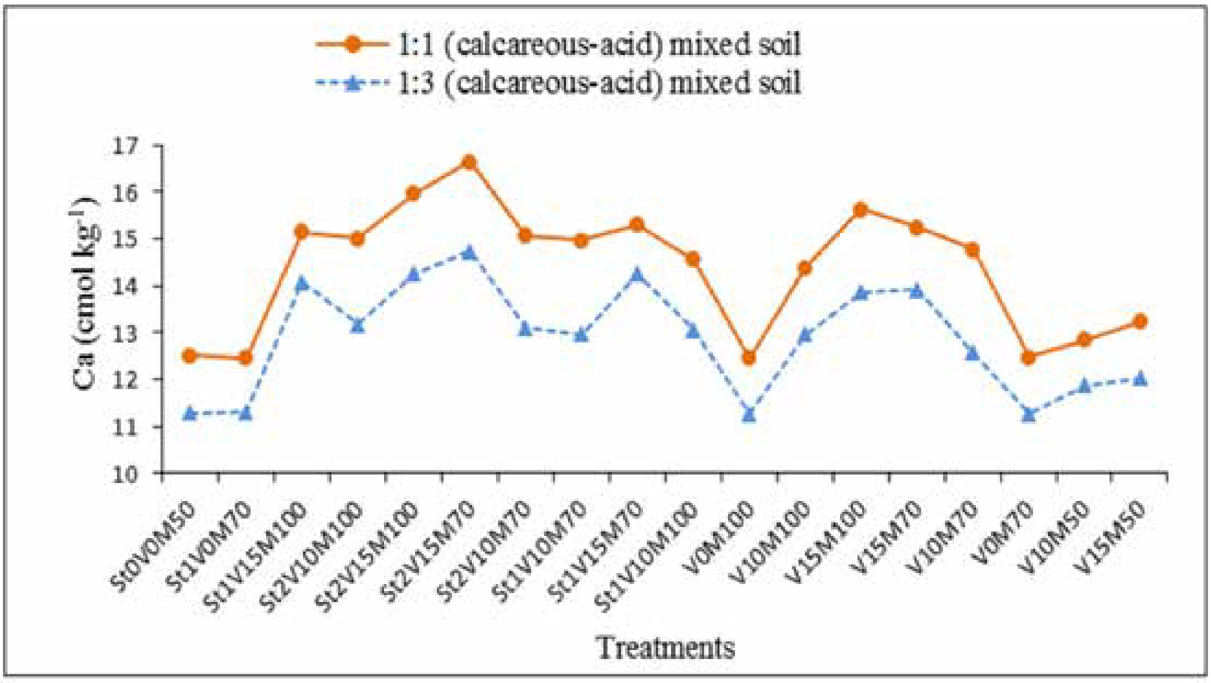

Fig. 6. Effects of different treatments on the available calcium contents (cmol kg^{-1}) of soils. St=soil temperature, V=vermicompost, M=soil moisture.

Available Magnesium: The available magnesium contents of the post-harvest soils was analyzed and presented (Fig 7). The results revealed that the treatments imposed a positive significant ($p \le 0.05$) influence on the Mg availability of soils. The estimation demonstrates that the available Mg contents increased in most of the sub-plots of 1:1 and 1:3 (calcareous-acid) mixed soils than that of their initial contents of 1.3 and 1.79 cmol kg^{-1}, respectively. On the contrary, the treatments T_1, T_2, T_{11} and T_{16} in 1:1 mixed soil and the treatments T_1, T_2, T_{11}, T_{16}, T_{17} and T_{18} in 1:3 mixed soil, where the lower amounts of available Mg content was determined. The highest available Mg value was measured in the sub-plot that received the treatment T_6 ($St_2V_{15}M_{70}$). In combination with moisture and temperature, the vermicompost dose of 15 t ha^{-1} resulted in more available Mg than that the dose 10 t ha^{-1} in soils. Increasing temperature to 1^0C and 2^0C also increased the availability of Mg in most sub-plots. However, increasing moisture level to 100% were found to decrease the available Mg contents in 1:1 mixed soil, although in 1:3 mixed soil, no exact relation between Mg availability and saturated moisture condition was found. Angelova *et al.* (2013) checked the effects of organic amendments on the chemical properties of soil and found an apparent increase in Ca and Mg contents in composts and vermicompost amended soils[(24)].

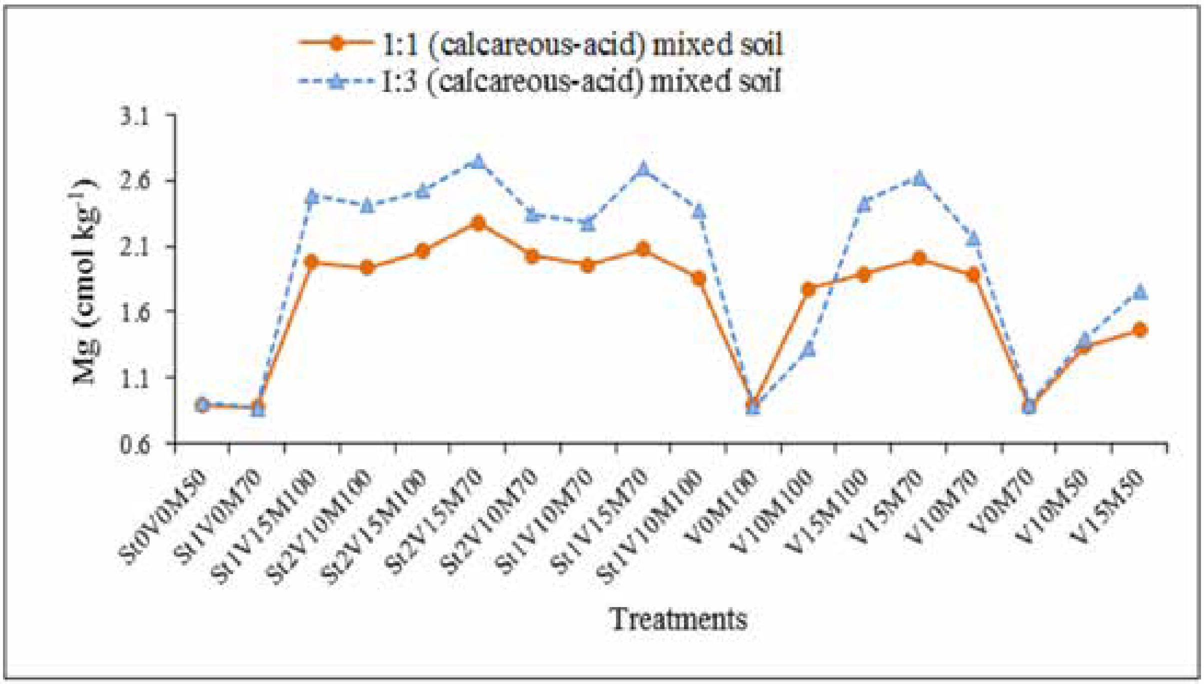

Fig. 7. Effects of different treatments on the available magnesium contents (cmol kg^{-1}) of soils. St=soil temperature, V=vermicompost, M=soil moisture.

Available Zinc: The effects of the combined acpplication of vermicomposts, moisture and temperature on the availability of zinc contents in post-harvest soils are shown in the figure 8. The application of the afore-said treatments had a significant ($p \le 0.05$) positive influence on the available Zn contents in soil. The initial Zn contents of the 1:1 and 1:3 (calcareous-acid) mixed soils were 1.99 and 2.10 mg kg^{-1}, respectively. Except for the treatments T_1, T_2, T_{11} and T_{16}, the available Zn contents were found to be increased. The treatment T_{13} was the most efficient dose in increasing Zn availability in both 1:1 and 1:3 (calcareous-acid) mixed soils, although the treatment T_5 resembled to T_{13} statistically for the 1:1 soil. The increasing doses of vermicompost applied in combination with a constant moisture and temperature level furnished a marked influence on the availability of Zn in the soil. A relatively higher moisture level also imposed a relatively increasing trend where no temperature rise was ensured. The effects of rising temperature to 1^0C and 2^0C were quite positive. As a whole, the combined application of the treatments was found significant at higher levels for the Zn availability in the soils and thereby a better uptake of Zn by plants was noticed. Such increment in Zn availability might be due to favourable pH in post-harvest soils and the mineralization of Zn rich vermicompost. Azarmi *et al.* (2008) examined the influence of vermicompost on soil chemical and physical properties in tomato field and found better Zn availability in post-harvest soils[25].

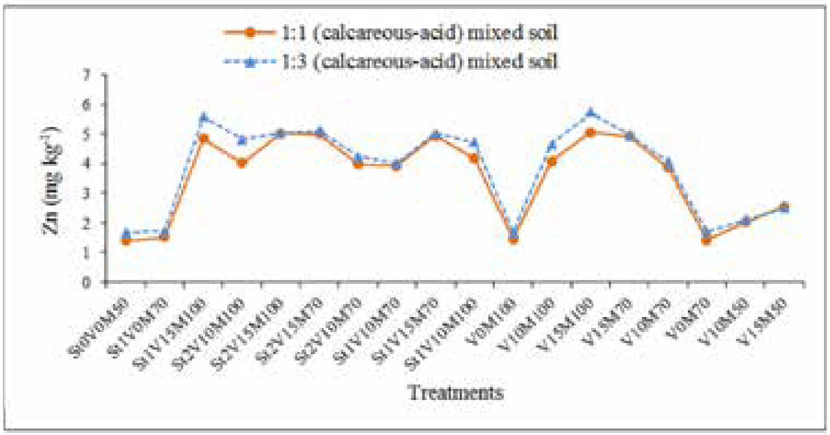

Fig. 8. Effects of different treatments on the available zinc contents (mg kg^{-1}) of soils. St=soil temperature, V=vermicompost, M=soil moisture.

Available Sodium: Initially, the available sodium contents were 0.21 and 0.32 cmol kg^{-1} in 1:1 and 1:3 (calcareous-acid) mixed soils, respectively. But the available Na contents in the post-harvest soils was in the range between 0.07 and 0.18 cmol kg^{-1} in 1:1 mixed soil and between 0.04 and 0.15 cmol kg^{-1} in 1:3 mixed soil (Fig 9). The effects of the treatments on the available Na contents of soils were evaluated significant ($p \leq 0.05$). Among the three treatments, viz. vermicompost, moisture and temperature, increase in one's level keeping the other two constant, decreased the Na availability in both soils whether significantly or in insignificant quantity. In the case of vermicompost amended soils, the combination of 10 t ha^{-1} vermicompost and 70% soil moisture reduced the Na availability to the lowest degree. The moisture level of 100% reduced the Na availability to plants and it might be attributed to the leaching of Na^+ ions. The overall combined impacts of vermicompost, moisture and temperature were more pronounced in decreasing the available Na fraction in 1:3 mixed soil.

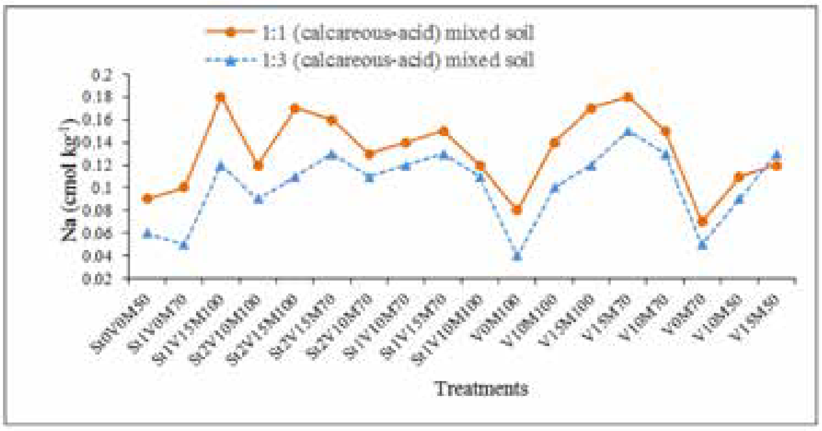

Fig. 9. Effects of different treatments on the available sodium contents (cmol kg^{-1}) of soils. St=soil temperature, V=vermicompost, M=soil moisture.

Conclusion

Climate change is an established phenomenon worldwide. Abrupt changes in the temperature and moisture level undoubtedly affect agriculture and soil health. The study revealed that the problem of soil calcareousness and soil acidity could be overcome by mixing them in varying ratios. At the same time, organic amendments like vermicompost can be a viable solution to the sustainable maintenance and improvement of the soil nutrients necessary for better crop production. The results of the study certainly manifests potential hope for our concern in question i.e. maintaining available nutrient status and other properties of soil. The moisture level of 70%, with soil temperature rising to 2^0C and higher doses of vermicompost acted like a stimulant to nutrient availability in marginal soils. Further research with different plants and organic amendments is recommended.

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