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Effect of temperature on nutrient availability in sludge amended soil

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Abstract

Temperature is one of the important factors in availability of nutrients. Three type of soils i.e. alluvial red and black soil were used, sludges were mixed with soils at the rates of 0, 25 and 50 g sludge kg^{-1} soil (dry weights. The sludge amended soil was thermally treated at 50°C, 100°C and 200°C and availability of macro and micro nutrients were analysed. Nitrogen availability increased with the increase in temperature, because due to higher temperature mineralisation of nitrogen increased. Phosphorus availability also increased because high temperature decomposition of organo-phosphorus was increased that ultimately increased availability of phosphorus. But potassium availability was not significantly increased with increase in temperature. Because potassium is mostly bounded with the mineral lattice, so at 200°C temperature no change was possible in lattice structure and it was only element that 100% present in mineral form. Organic matter/carbon content was decreased significantly with increase in temperature; because of exhaustion of organic carbon occurs as carbon di-oxide. Micronutrients like iron (Fe), manganese (Mn), zinc(Zn) and copper(Cu) availability was increased with increase in temperature due to high organic compound or cheleted compounds become decomposed and released and increased their availability in soil significantly.

Key words- temperature, micronutrients, nitrogen, phosphorus, potassium and sewage sludge

Introduction

Sewage is the liquid part of the domestic and industrial wastes. Sludge is the semi solid part of the domestic and industrial wastes that has been sediment or acted upon bacterial. Sewage sludge contains significant quantities of inorganic as well as inorganic chemicals that can have harmful environmental effects. Soil amendment with sewage sludge from municipal wastewater treatment plants is now a day a common practice for both increasing soil organic matter and nutrient contents and waste disposal. In comparison

with inorganic fertilizer, the sludge contains low nutrients especially phosphorus and potassium. Sludge contains 3% N, 2% P_2O_5 and 0.5% K_2O (Biswas and Mukherjee, 1990). In India, total 50 million cubic meters of untreated sewage is discharged each year and combined, the 22 largest cities in the country produce over 7,267 million liters of domestic wastewater per day, of which slightly over 80 per cent is collected for treatment. Annual production of solid waste in India has been estimated to be 2,000 million tonnes. In spite of their low nutrient content they can supplement use of chemical fertilizer because of their huge production potential. On an average NH_4^+, NO_3^- -N and organic nitrogen components comprise 47, 3 and 50% of the available nitrogen in sludge, respectively (Sommers, 1977).The knowledge about the effect of temperature nutrient availability is scanty. Therefore, present study was conducted to study the effect of temperature on nutrient availability in sludge amended soil.

Materials and methods

Soil samples collected from three different locations were air dried at room temperature under shade. Air dried samples were grinded manually by wooden grinder and passed through a 2 mm sieve. The soil samples were stored in capped plastic containers. Sludge sample were dried at room temperature under shade. Soil samples of specific weight (100g) were taken in 150 ml conical flask. The dried sludge were added with the soil sample at the rate of 0, 50 and 100 ton per ha (0, 25 and 50 g kg^{-1} soil) then mixed thoroughly followed by water is added to maintain moisture content at field capacity (table 1). The mouth of the conical flasks was plugged with non-adsorbent cotton.

Table 1- Treatment details

Symbol	Treatment
T_1	Black soil
T_2	Black soil + sludge @ 50 ton/ha
T_3	Black soil + sludge @ 100 ton/ha
T_4	Red soil
T_5	Red soil + sludge @ 50 ton/ha
T_6	Red soil + sludge @100 ton/ha
T_7	Alluvial soil
T_8	Alluvial soil + sludge @50 ton/ha
T_9	Alluvial soil + sludge @ 100 ton/ha
T_{10}	Sludge (100%)

Then the conical flasks were placed in a BOD incubator at a constant temperature of 25°C for 20 weeks. The samples were taken for observation at an interval of 2, 4, 8, 12, 16 and 20weeks. During incubation moisture content were maintained at field capacity. Soil

samples of specific weight (100 g) were taken in aluminum box. The dried sludge were added with the soil sample at the rate of 0, 50 and 100 ton per hectare (0, 25 and 50 g kg^{-1} soil) then mixed thoroughly. Then the aluminum boxes are placed in a hot air oven for thermal treatment at 50°C, 100°C and 200°C temperature for six hours. After six hour treatment the boxes were then cooled and available nutrients and micronutrients content was determined. The pH of the soils and sludge were measured in 1:2.5 (Soil/ Sludge: Water) suspension with the help of glass electrode digital pH meter (Systronics µ pH system 361).The soil/sludge water suspension was prepared in 1:2.5 (Soil/Sludge: Water) ratio. The electrical conductivity (Jackson, 1967) of filtrate of suspension was determined by conductivity meter. Organic carbon of soil and sludge was estimated by chromic acid wet digestion followed by titrimetric measurement of unreacted dichromate (Walkley and Black, 1934).The available nitrogen was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956). Phosphorus wasdetermined blue colourmethod using visible double beam spectrophotometer (Olsen *et al.*, 1965).The potassium was estimated by using Flame-Photometer (Hanway and Heidal, 1952).Available micro-nutrients and heavy metal were extracted with the help of mixed solution of 0.005 M DTPA, 0.01 M Calcium Chloride and 0.1 M Tri ethanol amine (TEA) at pH 7.3 (Lindsey and Norvell, 1978).

Results and discussion

Addition of sludge significantly increased the available nitrogen content in soil. In black soil available nitrogen content increased from 173.6 mg/kg (control) to 246.4 mg N/kg soil (**Fig. 1**).

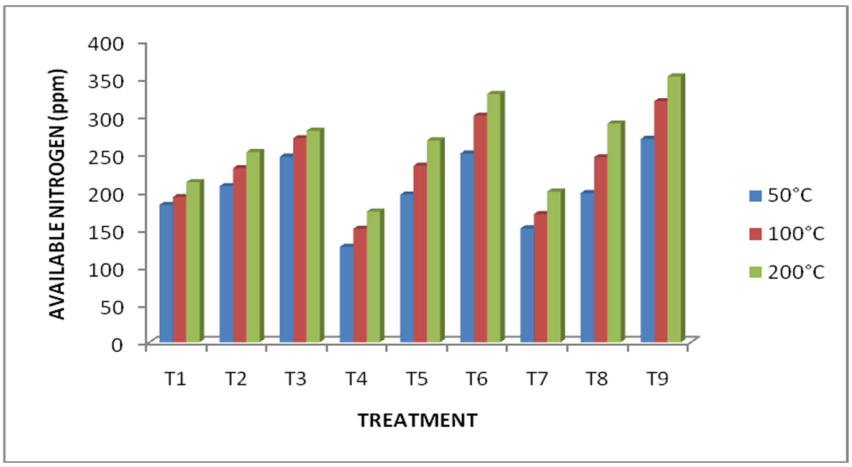

Fig. 1 Effect of temperature on nitrogen availability in sludge amended soil

In red soil, there is a predominant effect of sludge application on available nitrogen content, because red soil has low organic matter content therefore low available nitrogen content. Addition of sludge significantly increases available nitrogen content from 106.4mg N/kg to 250.5 mg N/kg. Temperature is a key factor for nitrogen mineralization. High temperature cause decomposition of organic matter and ultimately the nitrogen content increases. With the increase in temperature available nitrogen increases significantly. At higher temperature available nitrogen content increases from 173.6 mg N/kg to280.8 mg N/kg in black soil, 106.4 mg N/kg to 329.6 mg N/kg in red soil and 140 mg N/kg to 352.8 mg N/kg in alluvial soil is found from the above result, it has been found that increase in sludge application rate significantly increased available nitrogen content in black, red and alluvial soil that leads to higher productivity. Combine effect of temperature and sludge application rate significantly increase available nitrogen content in soil, and the effect is more predominant in red soil as compare to black and alluvial soil.

Table 2. Effect of temperature on phosphorus (ppm) availability in sludge amended soil

Treatments	**50°C**	**100°C**	**200°C**
Black soil	12	18	27
Black soil + sludge @ 50 ton/ha	19	31	55
Black soil + sludge @ 100 ton/ha	32	50	61
Red soil	9	13	26
Red soil + sludge @ 50 ton/ha	17	23	47
Red soil + sludge @100 ton/ha	22	31	56
Alluvial soil	12	20	31
Alluvial soil + sludge @50 ton/ha	26	47	61
Alluvial soil + sludge @ 100 ton/ha	52	70	82
Sludge (100%)	98	112	135
CD(p=0.05)	8.55	9.23	7.26

Major fraction of phosphorus is more tightly bound with the organic matter as well as mineral matter like oxides of Fe/Al, allophone, $CaCO_3$ etc. At lower temperature decomposition of organo-phosphorus compound is les, so at lower temperature (50°C) significant amount of available phosphorus is not found instead of higher sludge content. But at higher temperature (100°C and 200°C) substantial amount of available phosphorus is found due to thermal decomposition of organo-phosphorus compound. On the other hand phosphorus availability is also depends on soil type. Higher sludge application does

not increase available phosphorus content in soil. In red soil, phosphorus availability does not increase significantly with the higher rate of sludge application (50 and 100 ton/ha). Because as the phosphorus comes into soil solution due to thermal decomposition, it become adsorbed by the oxides of Fe /Al and make the phosphorus become unavailable. But fixation of phosphorus is not an acute problem in black and alluvial soil. So, significant amount of available phosphorus is found in increased sludge rate (Table: 2).

Table 3- Effect of temperature on Potassium (ppm) availability in sludge amended soil

Treatment	**50°C**	**100°C**	**200°C**
Black soil	65.8	75.5	85.0
Black soil + sludge @ 50 ton/ha	78.2	90.5	112.7
Black soil + sludge @ 100 ton/ha	85.8	120.2	140.8
Red soil	50.2	55.4	72.8
Red soil + sludge @ 50 ton/ha	70.6	85.8	98.2
Red soil + sludge @100 ton/ha	85.4	95.8	120.5
Alluvial soil	67.3	75.8	85.0
Alluvial soil + sludge @50 ton/ha	78.6	88.8	110.6
Alluvial soil + sludge @ 100 ton/ha	89.7	110.6	140.2
Sludge (100%)	212.0	221.0	238.0
CD(p=0.05)	12.17	14.79	19.63

Potassium is one of the essential nutrients that are not found in organically bound form. Potassium is mainly present in four forms in soil: soil solution potassium (0.1-0.2%), exchangeable potassium (1–2%), non-exchangeable potassium (1–10%) and structural potassium (90 – 98%). Potassium availability is little affected by temperature and organic matter content. Higher sludge application rate causes significant increase in potassium content in all soil. High temperature (100°C and 200°C) is not able to destruct lattice structure of mineral because about 550°C temperature required breaking lattice structure. So 100°C and 200°C thermal treatment does not show much significant increase in potassium content in three types of soil (Table 3).

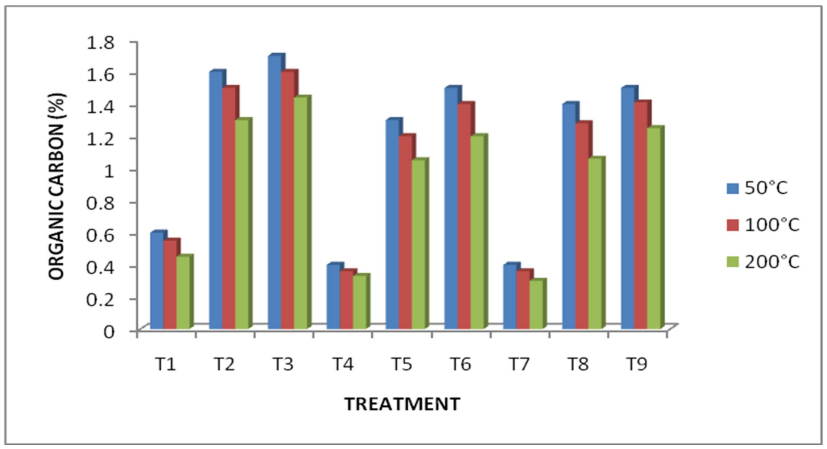

Fig.2: Effect of temperature on O.C. (%) in sludge amended soil

Organic carbon is an index of organic matter content in soil. Higher amount of organic matter leads to higher organic carbon content. Organic matter content is largely affected by the temperature, that's why the organic carbon content is less in tropical soil due to higher temperature. Organic carbon content is significantly increased with the increase in sludge application rate in three type of soil. Red soil shows more pronounced increase in organic carbon content in soil. Due to high temperature, decomposition of organic matter occurs so organic carbon content reduced (Fig.2.).

The word "micronutrients" represent some essential nutrients that are required in very small quantities are also called as 'trace element' is Fe, Mn, Zn, Cu, B, Mo, Ni and Cl. The micronutrients are present in soils mainly as their oxides, sulphides and silicates and are inherited from the soil forming rocks and minerals through transformation during various stages of soil development. Besides inorganic minerals, organic matter also contributes substantially to the total content of micronutrients in surface soils. Soil amendments and fertilizer materials add frequently to micronutrient pool in soils. Temperature is the key factor that determines the micronutrient availability in soil. On the other hand application of sewage sludge in the soil improves the micronutrient availability.

Iron (Fe) is the fourth most abundant element in earth's lithosphere following O, Si and Al which mostly occurs as ferromagnesian silicates. Most of the Fe released by weathering is precipitated as oxides or hydroxides, only a small part of Fe is incorporated into the secondary silicate minerals or complexes by soil organic matter. Iron availability in sludge amended soil increases with the increase in the rate of sludge application. Temperature also having significant effect on increasing the availability of Fe content in soil. With the increment of temperature the available Fe content is increased in all types of soil. In black soil, the Fe content is increased about 37.49%, 79.71% and 65.70% at 50°C, 100°C and 200°C respectively from the preceding temperature. Significant increase in Fe

content is not found at lower temperature range but at higher temperature Fe content increased significantly. Because at higher temperature the organically bound iron and loosely bound mineral Fe are released due to decomposition of organic and mineral matter (Obrador*et al.,* 2000). On the other hand application rate having significant effect on increasing Fe content but at a decreasing rate. With the increase in rate of sludge application the rate of increase in iron content decrease from 39 – 35.58% as the sludge rate increase from 50 – 100 ton/ ha. There is a substantial interaction effect of temperature and sludge application rate in increasing Fe content in soil. In red soil, Fe is the dominant element. The iron oxide imparts red colour to the soil. But the plant available Fe content is quite lesser. There is a 50% increase in iron content due higher temperature treatment and 20% increment due to increased sludge rate. In alluvial soil, similar pattern was found. The Fe content increases with the increase in temperature and rate of sludge application. About 20% increase in Fe content due to increase in sludge rate. The availability of Fe content increased from 24.60–89.46 mg/kg soil by the thermal and sludge treatment (Delibacak *et al.*, 2008) (Fig.3).

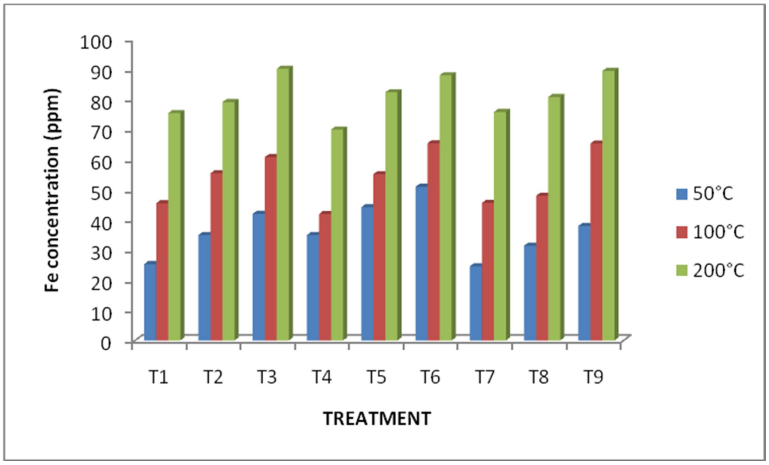

Fig. 3- Effect of temperature on iron availability in sludge amended soil

Manganese (Mn) content also increased in three types of soil with the increment of temperature and sludge application. These is a significant increase in Mn content with the sludge application at 50 ton/ha than100 ton/ha sludge.The Mn content significantly increases with the increase in temperature. There is a mark rise in Mn availability at higher temperature at 200°C. at lower temperature thermal treatment and sludge application does not significantly increase Mn content because low temperature is not able to release organically and minerologically bound Mn (Fig: 4).

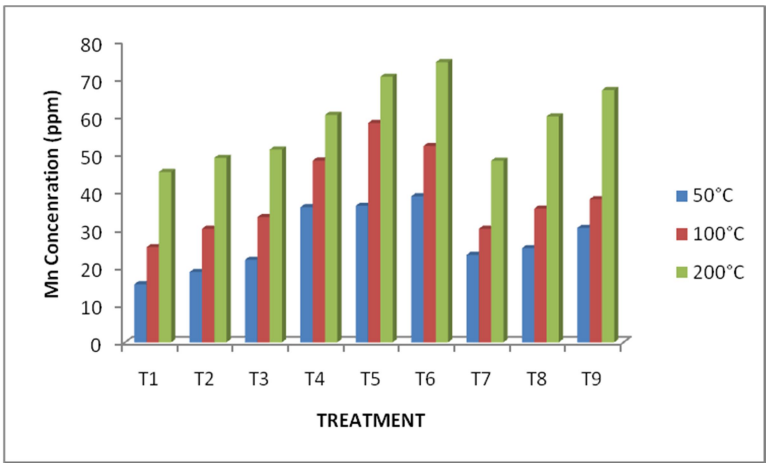

Fig. 4: Effect of temperature on manganese availability in sludge amended soil

Zinc (Zn) is the most reactive micronutrient in the soil. It is largely influenced by temperature, organic matter etc. with the increment of temperature and sludge content the Zn content increases (Rappaport *et al*., 1988). It is found that Zn content become double by the subsequent increment of temperature and sludge content (Delibacak *et al.*, 2008)(Fig.5).

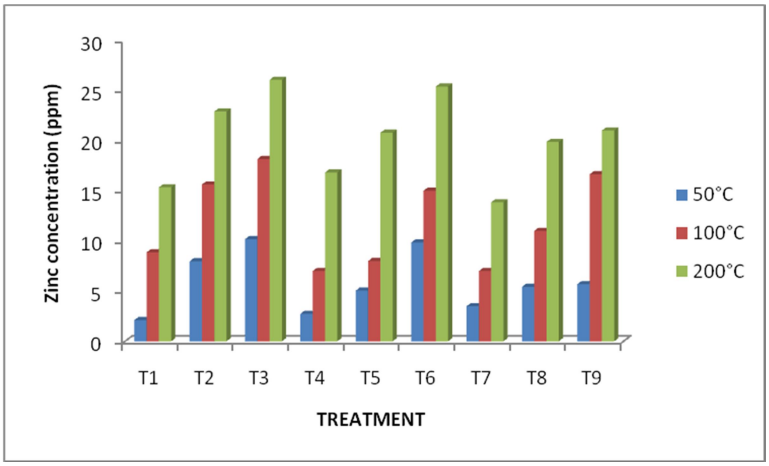

Fig. 5- Effect of temperature on zinc availability in sludge amended soil

Copper (Cu) content increases with the thermal treatment and sludge application at a constant rate. At lower temperature the Cu content does not significantly increase with the increase in sludge content but at higher temperature 100°C and 200°C the Cu content significantly increased. Because, among the micronutrients Cu become fixed with the organic matter at higher amount. So at low temperature the Cu is strongly bound to the

organic compound of the sludge and soil. As the temperature increases to the level of 100°C and 200°C, decomposition of organic matter and organic compound takes place and release the bound Cu in available form (Fig.6).

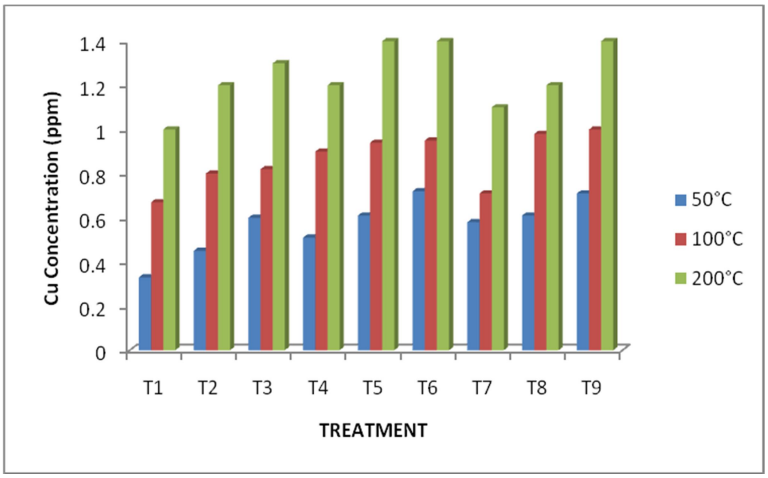

Fig. 6: Effect of temperature on copper availability in sludge amended soil

Temperature influenced significant effect in nitrogen, phosphorus and sulphur mineralization. With the increase in temperature there will be a possibility to increase available nitrogen, phosphorus and sulphur and micronutrients like iron, manganese, zinc and copper. From the above study it will be concluded that sludge amendment with soil improves the nutrients availability of soil that ultimately leads to higher crop productivity.

Conclusion

Nitrogen availability increased with the increase in temperature due to higher mineralisation. Phosphorus availability also increased because of high temperature leads decomposition of organo-phosphorus was increased that ultimately increased availability of phosphorus. But potassium availability was not significantly increased with increase in temperature. Because potassium is mostly bounded with the mineral lattice, so at 200°C temperature no change was possible in lattice structure and it was only element that 100% present in mineral form. Organic matter/carbon content was decreased significantly with increase in temperature; because of exhaustion of organic carbon occurs as carbon di-oxide. Micronutrients like iron (Fe), manganese (Mn), zinc(Zn) and copper(Cu) availability was increased with increase in temperature due to high organic compound or cheleted compounds become decomposed and released and increased their availability in soil significantly.

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