Int.J.Curr.Microbiol.App.Sci (2020) *9*(3): 1567-1578

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 3 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.903.184

Comparative Study of Sewage Sludge from Different STPs and Various Doses of Phosphorus on Physicochemical and Macro nutrient in Soil Depth under (*Vigna radiata* L.)

Bhagyashree Kesherwani[1]*, Tarence Thomas[2], Vikram Singh[3] and Schchida Nand Singh[3]

[1]*Department of Environmental Science & NRM, Sam Higginbottom University of Agriculture, Technology & Science Prayagraj -211007,U.P., India.*
[2]*Department of Soil Science &Agriculture Chemistry, Sam Higginbottom University of Agriculture, Technology & Science Prayagraj -211007,U.P., India.*
[3]*Department of Agronomy, Sam Higginbottom University of Agriculture, Technology & Science Prayagraj -211007,U.P., India*

**Corresponding author*

A B S T R A C T

Sewage sludge (SS), a byproduct of treated wastewater by sewage treatment plants (STPs) are rich in organic C, and other macro –micro nutrients, which if properly managed can be used to improve organic fertility in intensively cropped degraded soil. A field experiment was conducted to examine the role of sewage sludge from different sewage treatment plants with various doses of phosphorus on physicochemical and macronutrient in soil depth under (*Vignaradiata* L.). Sandy loam soil, during *Zaid* seasons of 2017at the Nursery of Forestry, Department of Environmental Sciences & NRM in SHUATS, Prayagraj.Nineteen treatments were employed using three different areas STPs sewage sludge (SS) they are Naini STPs (A_1), Rajapur STPs (A_2) and Pritamnagar STPs (A_3) of two different doses of SS (10 t ha^{-1} and 15 t ha^{-1}) with two-level of phosphorus (60kg ha^{-1} and 30kg ha^{-1}) to find the effect and accumulation of macronutrient after application of SSin soil 0-15 & 15-30 cm depths. The results showed a positive effect of sewage sludge on physical and chemical parameters on treated soil. BD (g cm^{-3}) and Solid space (%) was significantly decreased and highest data was recorded in particle density(g cm^{-3}), pore space %, EC, OC% in both soil 0-15 & 15-30 cm depth in treatment T_3 (Naini 15 t ha^{-1}) after application of sewage sludge as compared to control T_1.pH was a basic parameter of soil it showed slightly acidic at higher concentration of SS in Treatment T_3 as compare to T_9(Rajapur 15 tha^{-1}) and T_{15}(Pritamnagar 15 t ha^{-1}). The study revealed that quality of Pritamnagar SS showed positive results compare to other SS of different STP because it had low pH with higher amount of NPK which enhance the soil health and the latest technology was used for treatment process of waste. Lower concentration of SS application was beneficial for soil productivity and agriculture for a short period of time.

Keywords

Sewage sludge, sewage treatment plants, physiochemical, macronutrient and concentration

Article Info

Accepted:
12 February 2020
Available Online:
10 March 2020

Introduction

Increasing human population is fast depleting the natural resources due to over-exploitation and is causing environmental imbalance leading to disastrous consequences (Dhameja, 2006). Sewage sludge is a complex substance composed of high macronutrient (e.g., nitrogen, phosphorus, calcium, and sulfur), micronutrient (e.g., copper and zinc) and organic matter contents, municipal sewage sludge (SS) is recognized as a source of valuable fertilizer. However, SS also contains contaminants such as heavy metals and pathogens, which may lead to environmental or health risks (Bartl *et al.*, 2002; Mosquera–Losada *et al.*, 2010) and this can limit the direct application of sewage sludge to soil fertilization. Without proper treatment, it may pose an impending threat to the environment and human health. Uttar Pradesh has 73 numbers of sewage treatment plants having a treatment capacity of 2646.84 MLD. Out-off, 07 STPs of capacity 89.59 MLD are Non-Operational, 03 STPs of capacity 170 MLD are Under Construction and 01 STP of capacity 15 MLD is proposed. In Allahabad, total number of operational STPs is six.

In this study three different STPs sites taken for comparison study of quality test of sewage sludge of different STPs to evaluate the effect of sewage sludge with two various levels of phosphorus to check the impact on different soil depth under green gram (*Vigna radiata* L.).It served to indicate the heavy metals' contamination status of the site and revealed the abilities of various plant species to take them up and accumulate them from the soil covered with sewage sludge. This accumulation patterns varied with the soil type, weather factors, quality of sewage sludge and plant species and its phenology (Mahler *et al.*, 1980). Sewage sludge increase soil nutrients, and soil organic matter content thus, it has a positive effect on biological, physical, and chemical properties of the soil (Głab *et al.*, 2018) .Sewage sludge is used to increase micro and macro nutrient of soil from which the quality of soil and productivity of crop yield improved after application in agriculture field. Therefore, the purpose of this study was to investigate the influence of sewage sludge with phosphorus application on soil physicochemical and macronutrient parameters including BD, PD, PS, SS, pH, EC, OC% and NPK of post-harvest soil.

Materials and Methods

Study areas and sample collection

The field experiment was conducted to evaluate the effect of sewage sludge on soil physicochemical properties included micronutrient was observed in different STPs sewage sludge at Nursery of Forestry, Department of Environmental Sciences & NRM in SHUATS, Prayagraj,(U.P.). Mean ambient temperature varied from 20^{o}C to 43^{o}C during the experimentation period from March to May 2017. Maximum and minimum relative humidity varied from 40.8 to 73.75% and from 20.2 to 33.0%, respectively. Initial soil was collected from the field at 0-15 and 15-30 cm depths. Sewage sludge was collected from different STPs of Prayagraj, district, U.P. they are Pikh Patti near Old Bridge Naini (STP A_1), Rajapur (STP A_2), Kodra, Pritam Nagar (STP A_3).

Experimental designs

Experiment was set up in Randomized Block Design with nineteen treatments and three Replications, (2m × 2m size) in summer season at Nursery of Forestry, SHUATS, Prayagraj. Collected sewage sludge from different STPs, was air dried and grounded uniformly to get homogenous mass and mixed uniformly according to their treatment combinations (mixed before sowing at @ of 10t ha^{-1} and 15t ha^{-1}, respectively in each plots). Treatment were designed T_1:RDF 100% (Control), T_2:(Naini 10 t ha^{-1}), T_3: (Naini 15 t ha^{-1}) T_4:(Naini 10 t ha^{-1} +60kg ha^{-1}), T_5: (Naini 15 t ha^{-1} +60kgha^{-1}) T_6: (Naini 10 tha^{-1} + 30kg ha^{-1}),T_7: (Naini 15 t ha^{-1} +30kg ha^{-1}), T_8: (Rajapur 10 tha^{-1}), T_9 :(Rajapur 15 tha^{-1}), T_{10}: (Rajapur 10 t ha^{-1} +60kg ha^{-1}) T_{11}:(Rajapur 15 t ha^{-1} +60kgha^{-1}),T_{12}:(Rajapur 10 t ha^{-1} + 30kg ha^{-1}),T_{13}:(Rajapur 15 t ha^{-1} +30kg ha^{-1}),T_{14}: (Pritamnagar 10 t ha^{-1}),T_{15}:(Pritamnagar 15 t ha^{-1}),T_{16}:(Pritamnagar 10 tha^{-1} + 60kg ha^{-1}),T_{17}:(Pritamnagar 15 t ha^{-1} + 60 kgha^{-1}),T_{18}: (Pritamnagar 10 t ha^{-1} +30kg ha^{-1}),T_{19}: (Pritamnagar 15 t ha^{-1} + 30kg ha^{-1}). After maintaining identical moisture levels in each plot, green gram seeds were sown manually and plant spacing was row to row 30 cm and plant to plant 10 cm.

Soil and sewage sludge analysis

Post-harvest soil samples were collected from experimental field at the depth 0-15cm and 15-30 cm layer. Evaluate the initial physiochemical properties of the soil and as well as three sites of sewage sludge from different STPs. Samples were air-dried, crushed, passed through a sieve of 2 mm mesh size and then stored separately for further analyses. The pH of samples was measured with the help of pH meter and electrical conductivity (EC) by conductivity meter. For organic Carbon (%) in the soil and sewage sludge were analyzed from wet oxidation methods (Walkley and Black 1947).Nitrogen was determined by alkaline permanganate method (Subbiah and Asija 1956). A spectrophotometer analyzer (Model KB 8S, Germany), respectively, $NaHCO_3$ extraction method was used for available phosphorous (P) analysis (Olsen *et al.,* 1954) and potassium (K) was estimated by flame photometric method (Toth and Prince 1956).

Results and Discussion

Characteristic of soil and sewage sludge

Physical and chemical analysis of un-amended soil of agriculture farm had sandy loam in texture, lower bulk density & solid space % and slightly high in particle density & pore space % , neutral pH (7.65), low EC (0.31), Organic carbon % (0.43) and available NPK (158.93, 11.41 and 148.78 kg ha^{-1}) was observed respectively (Table 1).The sewage sludge of different STP used for soil amendment was lower in pH and had higher electric Conductivity, Organic Carbon %, and available NPK (mg kg^{-1}) shown in (Table 2).All of three STP Naini sewage sludge show lowest pH and highest EC and OC % as compare to sewage sludge of other two STPs.

Sewage sludge effect on physical parameters of post-harvest soil

A field experiment was conducted to investigate the effects of sewage sludge on different soil depth. In all application rates, sewage sludge decreased bulk density of the soil significantly (Table 3 & Fig. 1). However, its effectiveness decreased during the experimental period. Naini STP sewage sludge was most effective at the rate of 15 t ha^{-1}. Decrease in the effectiveness of sewage sludge could be attributed to the mineralization of sludge-borne organic matter with time, as suggested by (Wong *etal*. 1998). The highest application rate of sewage sludge decreased bulk density by 1.09 and 1.12 (g cm^{-3})in 0-15 and 15-30 cm depth of soil respectively, as compared to the control plot. The decrease in bulk density could be due to the low bulk density of initial sewage sludge of Naini STP (0.676 g cm^{-3}). Ojeda *et al.,* (2003) reported that a higher organic matter proportion in sludge not only decreased the bulk density but also increased the aggregate stability. Ramulu (2002) also observed that organic matter added to the soil as sewage sludge composts improved soil properties such as bulk density, porosity, and water-holding capacity. Particle density was increased with the application of sewage sludge (Table 3 & Fig.1).The effects of sewage sludge application were also observed in pore space% and solid space % (Table 3).

However, this effect was significant throughout the experiment. Sewage sludge application increased pore space by 53.89 & 61.37 % in treatment T_3 at both 0-15 and 15-30 cm depths respectively. Similar experiment was done by (Glab *et al.,* 2018) when compost was added it significantly increased volume of pores as compared with the un-amended soil. Sewage sludge also decreased solid space% significantly in all application rates (Table 3). This effect was much more pronounced in treatment T_3 which was 38.62 & 38.63 % at both 0-15 and 15-30 cm depths respectively as compare to control T_1.

Sewage sludge effect on chemical parameters of post-harvest soil

The effect of sewage sludge application on soil pH was found statistically significant (Table 4). Sewage sludge application significantly decreased soil pH. This decrease could be due to low pH value (5.8, 6.1 and 6.5) of initial sewage sludge of different STPs.

This study also revealed that application of SS reduces soil pH by 6.92 & 7.04 at both0-15 and 15-30cm depths respectively. Soil pH is a critical soil parameter in sewage sludge applied lands, because it significantly affects the bioavailable forms of metals. Similar result also found by others that pH was decreased due to organic acids produced during mineralization (Veeresh *et al.,* 2003). Soil electrical conductivity (EC) increased with sewage sludge application (Table 4& Fig.3). Variations were obtained during the time of experiment. The highest EC value was recorded in treatment T_3 at higher concentration of 15 t ha^{-1}of SS as compare to other treatments. However, this effect decreased with time. Decrease in soil EC could be attributed to the loss of sewage sludge effectiveness and irrigation, which helped leaching (Perez-Murcia *et al.,* 2006; Gasco and Lobo, 2007).

Organic carbon percentage also increased after amendment of sewage sludge in soil, maximum was observed in treatment T_3 and T_2 comparison to control T_1 shown in (Table 4& Fig.3).Result was showed because initially sewage sludge was rich in organic carbon, organic matter and nutritional value (Table 2). Similar result was expressed by (Reddy *et al.,* 2001) and according to them application of sewage sludge and urban compost in 1:1 ratio resulted in high organic carbon content in soil.

(Poornesh *et al.,* 2004) also stated that, the application of urban garbage compost increased the organic carbon content in soil. Organic inputs are not only important for the increase of agricultural productivity, but also for the supply of some critical nutrient elements.(Upadhyay *et al.,* 2013)revealed that sludge application resulted in an increase in available nitrogen, phosphorus, potassium and organic matter content. Sludge application also significantly increased the yield of carrot.

It was observed that statistical analysis of data of Available Nitrogen, Phosphorus and potassium (kg ha^{-1}) of post-harvest soil observed significant in all treatment. Increased of Nitrogen was observed (Table 4& Fig. 4) in treatment T_4Naini 10 t ha^{-1} +60kg ha^{-1}by 75.34% & 75.39 % at both depths as compare to control T_1.Nitrogen increased was observed higher at lower concentration of SS with higher level of phosphorus in soil may be due to green gram is leguminous crop which fixed atmospheric nitrogen and various doses of phosphorus also enhances the N availability to soil as well as crop. Similar findings were also reported by (Ahmed *et al.,* 2010) researches show an increase of soil total nitrogen content as the dose of applied sewage sludge increases.

(Baghina *et al.,* 2014) observed that sewage sludge application raised total nitrogen content of soil when variant where 15 t SS/ha. Weber *et al.,* (2007) also founded that available Nitrogen (kg ha^{-1})increased with increased concentration of sewage sludge application, was due to mineralization organic matter some other finding reported by (Hernandez- Apaolaza *et al.,* (2005) and Mantovi *et al.,* (2005).This result also clarified by Castro *et al.,* (2009); that applying sewage sludge could increase soil organic matter, N, and P contents McBride and Cherney (2004). In this experiment available Phosphorus was observed significantly increased in all treatment at both at 0-15 and 15-30 cm depths after application of SS with various doses of phosphorus. Maximum phosphorus was observed in treatment T $_{17}$Pritamnagar 15 t ha^{-1} + 60 kgha^{-1} due to higher amount of SS and phosphorus (Table 4). Increased was recorded by 9.30% and 9.04% at both depths of soil as compare to control T_1.

Similar study also revealed by other authors(Singh and Agrawal 2010) that, the soil phosphorus content increased with increase in dose of sewage sludge. Previous studies found that applying sewage sludge could increase soil organic matter, N, and P contents (Castro *et al.,* 2009; McBride and Cherney 2004).After application of SSpotassium also increased in treatment T_{15} Pritamnagar 15 t ha^{-1} by 76.20 and 76.33 % as compare to control T1 in both soil 0-15and 15-30 cm depths(Table 4& Fig.4). Similar study also founded by Saruhan *et al.,* 2010 that, the availability of K in soil increased with the increase in sewage sludge application rates. Sewage sludge effect on available potassium is insignificant, only highdoses causing an increase in potassium content.

Table.1 Physical and chemical analysis of initial soil at 0-15 and 15-30 cm depths

Physical	**0-15**	**15-30**
Texture Sand	58.12%	58.15%
Silt	24.62%	24.65%
Clay	15.26%	15.28%
Textural class	Sandy loam	Sandy loam
Bulk density	1.39 g cm^{-3}	1.41g cm^{-3}
Particle density	2.61g cm^{-3}	2.65g cm^{-3}
Pore space	49.76%	49.81%
Solid space	50.24 %	50.28%
Chemical		
pH	7.65	7.75
EC(dS m^{-1})	0.31	0.36
Organic carbon %	0.43	0.45
Available Nitrogen (kg ha^{-1})	158.93	158.96
Available Phosphorus (kg ha^{-1})	11.41	11.42
Available Potassium (kg ha^{-1})	148.78	148.85

Table.2 Physical and chemical analysis of sewage sludge from different sewage treatment plants

Parameters	Naini STP (A1)	Rajapur STP (A2)	Pritamnagar STP (A3)
pH (1:2)	5.8	6.1	6.5
EC (dS m^{-1})	1.8	1.20	1.09
Organic C (%)	9.52	7.62	6.71
Avail. N (mg kg^{-1})	598.32	466.34	490.15
Avail. P (mg kg^{-1})	33.64	48.24	31.42
Avail. K (mg kg^{-1})	351.21	344.43	378.25

Table.3 Comparative study of sewage sludge from different STP of Prayagraj, on Bulk density, Particle Density, PS % and SS % of post-harvest soil at 0-15 and 15-30 cm depths

Treatment	Bulk density(g cm^{-3})		Particle density(g cm^{-3})		Pore Space (%)		Solid Space (%)	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
T_1	1.37	1.35	3.53	3.55	52.13	57.70	42.44	42.30
T_2	1.18	1.17	4.96	4.44	52.44	60.55	38.83	39.45
T_3	1.09	1.12	5.58	5.58	53.89	61.37	38.62	38.63
T_4	1.21	1.22	4.94	4.93	52.80	58.55	41.66	41.45
T_5	1.24	1.20	4.88	4.86	52.86	58.54	41.57	41.46
T_6	1.23	1.24	4.92	4.87	52.84	58.44	41.60	41.56
T_7	1.22	1.23	4.98	4.86	52.83	58.44	41.61	41.56
T_8	1.12	1.12	4.46	2.44	53.43	60.23	39.77	39.77
T_9	1.10	1.11	5.56	5.52	53.74	61.16	39.08	38.84
T_{10}	1.20	1.24	4.84	4.93	52.81	58.44	41.56	41.56
T_{11}	1.24	1.23	4.83	4.83	52.83	58.43	41.60	41.57
T_{12}	1.24	1.23	4.85	4.91	52.84	58.42	41.53	41.58
T_{13}	1.23	1.23	4.77	4.84	53.45	60.24	39.75	39.76
T_{14}	1.12	1.13	4.44	4.43	52.93	58.56	38.95	38.84
T_{15}	1.13	1.11	5.51	5.46	53.71	61.16	41.51	41.44
T_{16}	1.24	1.24	4.24	4.25	52.80	58.36	41.64	41.64
T_{17}	1.23	1.27	4.20	3.87	52.87	58.46	41.46	41.54
T_{18}	1.23	1.23	4.27	4.23	52.82	58.39	41.41	41.61
T_{19}	1.23	1.22	3.97	3.95	52.80	58.38	41.64	41.62
F-test	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
C.D. at 5%	**0.053**	**0.031**	**0.345**	**0.058**	**2.42**	**2.53**	**0.743**	**0.253**
S.Ed. (±)	**0.026**	**0.015**	**0.170**	**0.029**	**1.19**	**1.25**	**0.366**	**0.125**

Table.4 Comparative study of sewage sludge from different STP of Prayagraj, on pH, EC, OC% and NPK (kg ha^{-1}) of post-harvest soil at 0-15 and 15-30 cm depths

Treatments	pH		EC(dS m^{-1})		OC%		N (kg ha^{-1})		P (kg ha^{1})		K (kg ha^{-1})	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
T_1	7.56	7.51	0.40	0.47	2.74	2.56	97.88	97.56	50.03	51.18	92.74	93.48
T_2	6.99	7.05	0.77	0.82	3.31	3.14	239.85	239.31	50.13	51.24	321.48	326.78
T_3	6.92	7.04	0.83	0.88	3.42	3.24	264.85	264.31	51.64	52.75	363.65	368.95
T_4	7.16	7.15	0.66	0.71	3.23	3.05	397.07	396.53	52.74	53.88	311.51	316.81
T_5	7.15	7.16	0.69	0.74	3.23	3.03	228.91	228.37	52.57	53.68	307.45	312.75
T_6	7.22	7.23	0.66	0.71	3.26	3.07	286.87	286.33	50.42	51.53	307.66	312.96
T_7	7.30	7.25	0.72	0.77	3.29	3.11	294.73	294.19	52.50	53.62	305.43	310.73
T_8	7.85	7.83	0.74	0.79	3.07	2.88	203.34	202.80	50.10	51.17	332.64	337.94
T_9	7.91	7.85	0.80	0.85	3.18	2.98	211.44	210.90	50.30	51.41	377.83	383.13
T_{10}	7.61	7.79	0.68	0.73	3.13	2.92	329.09	328.55	52.85	53.96	344.67	349.97
T_{11}	7.85	7.77	0.65	0.70	3.06	2.88	237.78	237.24	51.27	52.38	360.38	365.68
T_{12}	7.74	7.57	0.62	0.67	3.08	2.89	211.49	210.95	50.00	51.16	348.15	353.45
T_{13}	7.71	7.55	0.70	0.75	3.17	2.92	212.07	211.53	50.20	51.31	360.10	365.40
T_{14}	7.61	7.63	0.73	0.78	2.94	2.74	231.96	231.42	50.91	52.02	345.22	350.51
T_{15}	7.62	7.65	0.74	0.79	2.95	2.75	242.04	241.50	51.86	52.97	389.78	395.08
T_{16}	7.53	7.53	0.64	0.69	2.91	2.73	341.14	340.60	54.28	55.39	335.65	340.94
T_{17}	7.53	7.55	0.71	0.76	2.92	2.74	279.46	278.92	55.16	56.27	346.97	352.27
T_{18}	7.50	7.51	0.73	0.77	2.83	2.64	241.83	241.29	52.37	53.48	343.56	348.86
T_{19}	7.51	7.53	0.72	0.77	2.85	2.67	249.58	249.04	52.44	53.55	343.61	348.91
F-test	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
C.D. at 5%	**0.093**	**0.073**	**0.03**	**0.04**	**0.053**	**0.043**	**0.055**	**0.037**	**0.034**	**0.043**	**0.031**	**0.054**
S.Ed. (±)	**0.046**	**0.036**	**0.01**	**0.02**	**0.026**	**0.021**	**0.027**	**0.018**	**0.017**	**0.021**	**0.015**	**0.027**

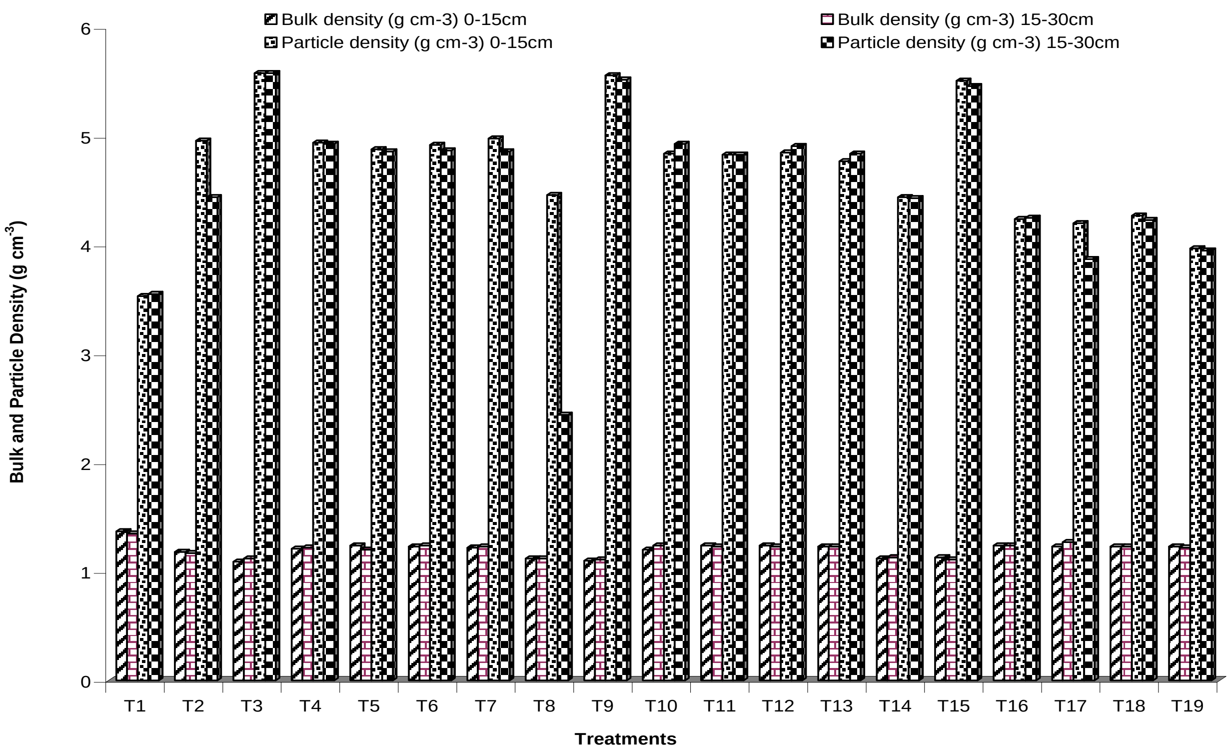

Fig.1 Comparative study of sewage sludge from different STP of Prayagraj, on Bulk density, Particle Density (g cm^{-3}) of post-harvest soil at 0-15 and 15-30 cm depths

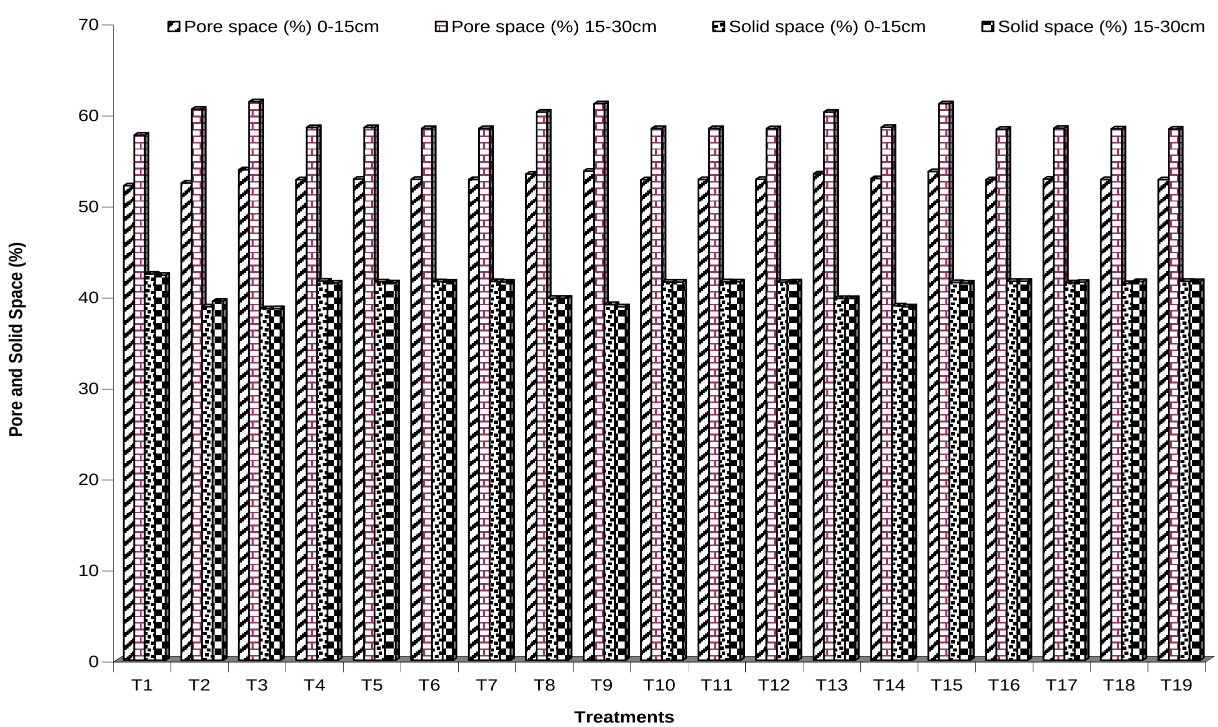

Fig.2 Comparative study of sewage sludge from different STP of Prayagraj, on Pore space and Solid space (%) of post-harvest soil at 0-15 and 15-30 cm depths

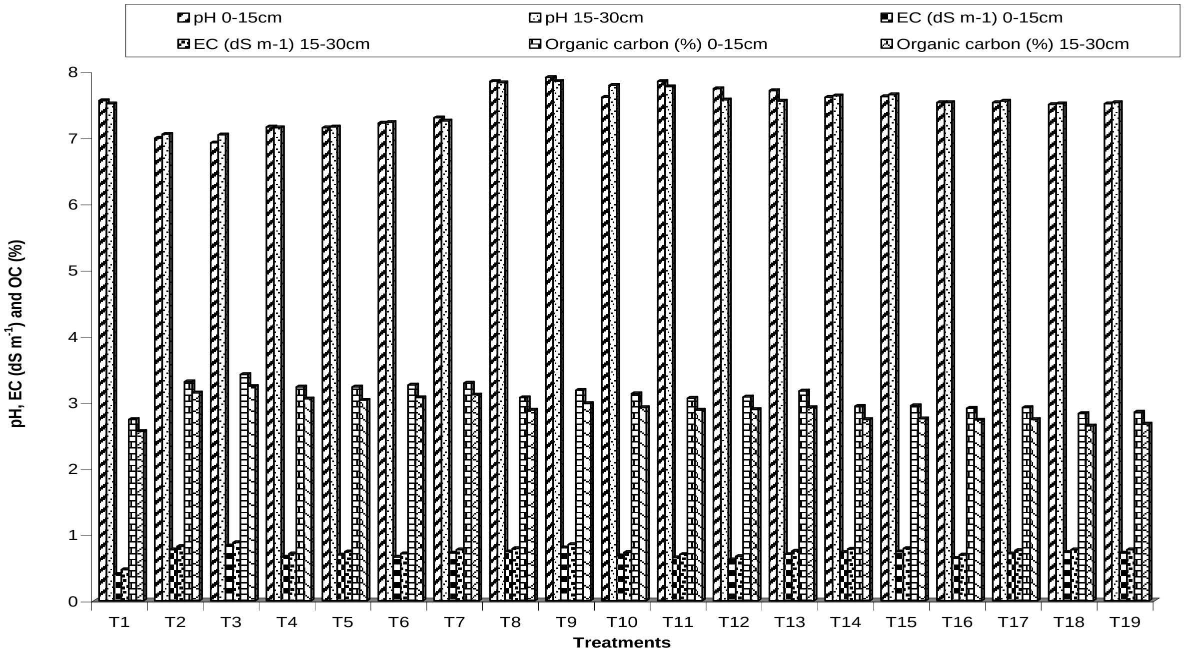

Fig.3 Comparative study of sewage sludge from different STP of Prayagraj, on pH, EC and OC% of post-harvest soil at 0-15 and 15-30 cm depth

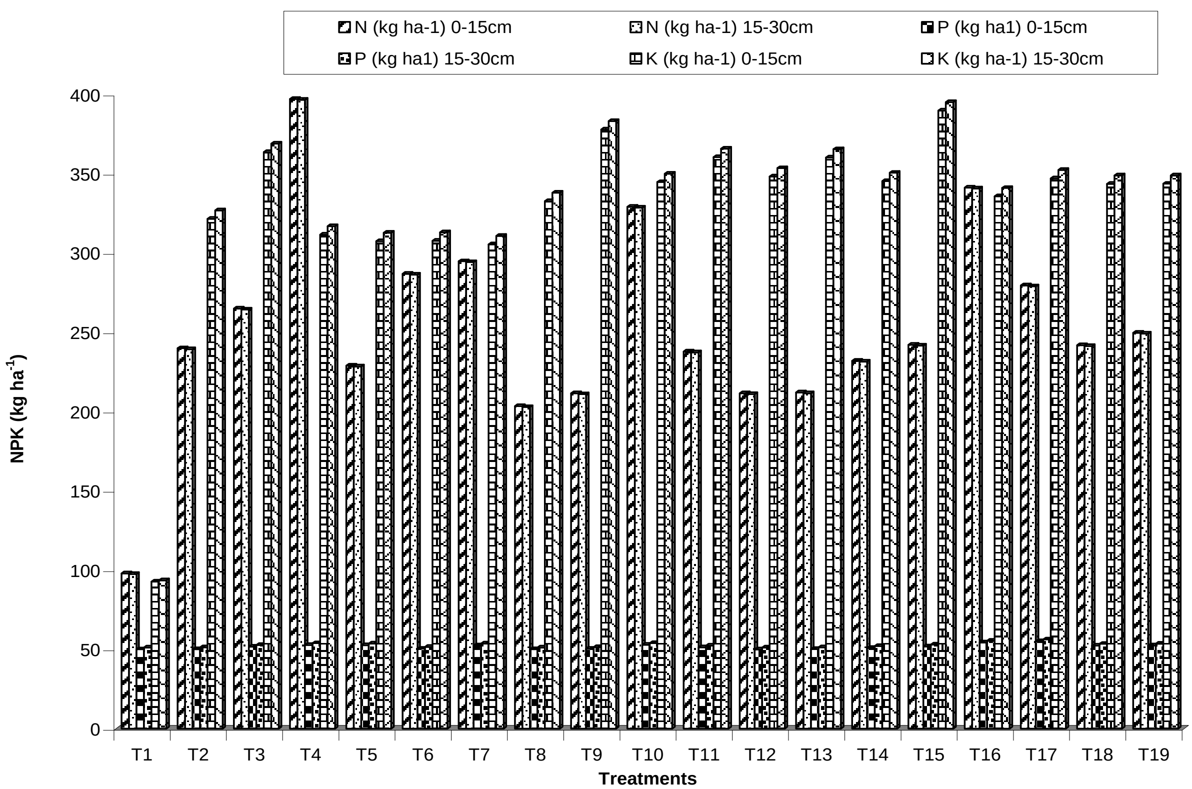

Fig.4 Comparative study of sewage sludge from different STP of Prayagraj, Son N, P and K (kg ha^{-1}) of post-harvest soil at 0-15 and 15-30 cm depths

Comparative study of sewage sludge from different STPs observed that SS of Naini STP, showed positive result in physical parameters butit's decreased the pH and enhance EC value of soil as comparison to other STPs sewage sludge due to which it increases the toxicity in soil and crop.

Comparatively pritamnagar sewage sludge was most appropriate for agriculture field because pH was recorded neutral with higher amount of NPK was observed which increased the health and fertility of soil.

In pritamnagar STP treatment techniques was advanced than other two STPs due to quality wise waste was much healthier than others. In this experiment results revealed that sewage sludge application significantly improved the physical and chemical properties of soil relative to untreated soil.

The physiochemical parameters of post-harvest soil such as BD, PD, PS%,SS%, pH, EC, OC%, N,P and K depend on soil texture, treatment process and quality of sewage sludge .The lowest BD and highest PD value were observed when the highest SS concentration were applied. Vise-versa PS% reduce and SS% increased by higher concentration of SS at the time of study. Chemical parameters significantly improves after application of SS, such as EC, OC%,N, P and K except pH of soil compare to untreated soil.

Overall, it was concluded that the both concentration (10 and 15 t ha^{-1}) of SS application might be useful for attributes for improving the health, quality and fertility of experimented soil because sewage sludge have sufficient amount of organic matter, N, P, K and micronutrients which will be good option to use as fertilizers in agricultural productivity *vis-a- vis* cost effective disposal of environmentally solid waste.

Acknowledgements

The authors are thankful to Head, Department of Environmental Science & NRM and Head, Department of Soil Science and Agriculture Chemistry, SHUATS, Prayagraj, U.P. for providing field and laboratory facilities during the time of research.

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How to cite this article:

Bhagyashree Kesherwani, Tarence Thomas, Vikram Singh and Schchida Nand Singh. 2020. Comparative Study of Sewage Sludge from Different STPs and Various Doses of Phosphorus on Physicochemical and Macro nutrient in Soil Depth under (*Vigna radiata* L.). *Int.J.Curr.Microbiol.App.Sci.* 9(03): 1567-1578. doi: https://doi.org/10.20546/ijcmas.2020.903.184