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Effect of Incorporation of Sewage Sludge and Fly Ash on Soil Physico-Chemical Properties and Okra in Inceptisols of Prayagraj U.P

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present research was conducted to determine whether it would be feasible to grow Okra in amended soil utilising sewage sludge and fly ash. Different types of nutrients and heavy metals were found in both soil amendments and for growth of the plant and crop yield they are used as ameliorate in acidic soils. In the research trial, soil properties like Bulk density, Particle density and pH are found to be positively non-significant and Pore space, Water holding capacity, EC, OC, Nitrogen, Phosphorus, Potassium, Iron, Manganese, Zinc and copper are found to be positively significantly low to medium range, which comprises yellowish brown sandy loam textured neutral to alkaline soil that is non-saline in nature among all the treatment combination applied.

Keywords: Sewage sludge; fly ash; soil; Okra; nutrients and heavy metals.

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1. INTRODUCTION

"Okra (*Abelmoschus esculentus* (L.) Moench] is an important annual fruit vegetable commonly grown in the tropics and warmer temperate regions of the world" [1]. "Okra is generally a self-pollinating crop belonging to the Malvaceae" [2]. "It probably originated in Ethiopia and is widely spread all over tropical, subtropical and warm temperate regions of the world. Okra plays an important role in the human diet by supplying fats, proteins, carbohydrates, minerals and vitamins. Moreover, its mucilage is suitable for certain medical and industrial applications. therefore, young fruits of okra have reawakened beneficial interest in bringing this crop into commercial production. Okra requires warm temperatures. The optimum temperatures are in the range of 20-30°C, with minimum temperatures of 18°C and maximum of 35°C" [3,4]. "Okra needs rather high quantity of water despite having considerable drought resistance. The plant forms a deeply penetrating tap root with dense shallow feeder roots reaching out in all directions in the upper 45 cm of soil. The composition of okra pods per 100 g edible portion (81% of the product as purchased, ends trimmed) is: water 88.6 g, energy 144.00 kJ (36 kcal), protein 2.10 g, carbohydrate 8.20 g, fat 0.20 g, Fibre 1.70 g, Ca 84.00 mg, P 90.00 mg, Fe 1.20 mg, β-carotene 185.00 µg, riboflavin 0.08 mg, thiamin 0.04 mg, niacin 0.60 mg, ascorbic acid 47.00 mg. Moreover, okra mucilage is suitable for industrial and medicinal applications" [5]. "The edible part of okra or its capsule (pod) measures approximately 15–20 cm in length and has a pyramidal-oblong, pentagonal, hispid appearance. Historically, okra pods were utilized for various purposes, such as in food, appetite boosters, astringents, and as an aphrodisiac. Furthermore, okra pods have also been recommended to cure dysentery, gonorrhea, and urinary complications" [6]. "Extracts of young okra pods have also been reported to display moisturizing and diuretic properties, whereas the seeds of this plant have been reported to possess anticancer and fungicidal properties" [7]. In India characteristically, the sewage sludge contained total nitrogen (15400-1920 mg Kg^{-1}), available nitrogen (4600 -6300 mg Kg^{-1}), available phosphorus (44-60 mg Kg^{-1}) and available potassium (290-410 mg Kg^{-1}). Besides this higher contents of different heavy metals like arsenic (8-23 mg Kg^{-1}), Cd (2-9 mg Kg^{-1}), Cr (66-1098 mg Kg^{-1}), Hg (7-32 mg Kg^{-1}), Ni (12-596 mg Kg^{-1}) and Pb (26-154 mg Kg^{-1}) were reported by Dubey et al. [8]. Kumar and Chopra [9] and Kumar et al. [10] also reported higher contents of nutrients and heavy metals in the sewage sludge.

"Fly ash (FA), the by-product of coal combustion for energy production is a major environmental problem worldwide. FA management mainly includes its use for cement production, road-base construction, mine reclamation, mineral wool production, recovery of metals, and as aggregate substitute material. Recently FA has gained attention as a potential resource in terrestrial carbon sequestration. The incorporation of FA may also improve physical, chemical, and biological properties and thus benefit agricultural production" [11]. "Sewage sludge (SS) from the other hand, a by-product of the sewage effluents treatment, constitutes also a serious environmental problem requiring a safe and economical disposal. Due to its composition and properties, SS may be beneficially used in agriculture as substitute of fertilizers or soil amendment. It was found that co-application of FA and SS may enhance the beneficial effects from the soil application of these two by-products. However, FA and SS as inputs may have many benefits for agriculture like facing of nutrient deficiencies, while these by-products contain a number of toxic substances like toxic heavy metals and organic pollutants. Therefore, a proper attention should be paid on the impacts of the use of these materials on soil health, crop quality and heavy metal toxicity and leaching" [12].

"Therefore, the management of both by-products, i.e., FA and SS, is of significant importance for India. Research work showed that both by-products FA and SS may be used in a beneficial and sustainable way facing thus serious environmental problems" [13,14]. The purpose of the present study was to investigate the possibility to use FA and SS in Okra crop separately or together and its influence on yield and soil properties including essential nutrients content as well as toxic heavy metals accumulation.

2. MATERIALS AND METHODS

The experiment was laid out at Research Farm of SSAC, SHUATS, Prayagraj, Uttar Pradesh which is analysed by randomised block design with 12 treatments and 3 replications. The treatments comprises of three levels of sewage slugde, i.e. 0, 13, 26, 39 and 52 tonns ha^{-1} also levels of fly ash taken 0, 13, 26, 39 and 52 tonns ha^{-1} incorporated as soil application with or without NPK according to the treatment combination. The soil samples were collected randomly from two depths after harvest of okra. The soil is characterized after incorporation of Sewage sludge and fly-ash and the properties are:

Weight of oven dried soil (Mg)

a) Bulk density (Mgm^{-3}) = Volume of soil (m^{-3})

Mass of soil solid (Mg)

b) Particle density (Mgm^{-3}) = Volume of solids (m^{-3})

Bulk Density

c) % pore space = (1-Particle Density × 100)

Vol. of water absorbed by soil

d) Water holding capacity = Vol. of soil taken × 100

In chemical parameters through method by

e) Soil pH - by using Digital pH meter of globe instruments given by [15]
f) Soil EC (dSm^{-1})-Digital EC meter of globe instruments.
g) Organic Carbon (%) - through titration given by Walkley and Black method [16]
h) Available Nitrogen (Kg ha^{-1})-Kjeldhal Method [17]
i) Available Phosphorus (Kg ha^{-1})-Colorimetric method by using Jasper single beam U.V Spectrophotometer at 660 nm wavelength.
j) Available Potassium (Kg ha^{-1})- Flame photometric method by using Metzer Flame Photometer.
k) Available Fe, Mn, Zn and Cu (ppm)-Atomic Absorption Spectrophotometer by instrument perkinelnmer given by [18-22]

3. RESULTS AND DISCUSSION

As depicted in the Table 1, shows that the effect of sewage sludge and fly ash on the physical properties of soil at both depth in both the years. The B.D (Mgm^{-3}) was non-significant at both the depths and in both the years which was maximum in 1.26 in 2021 at 15-30 cm and minimum was 1.07 in 2020 at 0-15 cm. The PD (Mgm^{-3}) was non-significant in both the depths and in both the years which was maximum in 2.41 in 2021 at 15-30 cm and minimum was 2.1 in 2020 at 0-15 cm. The Pore-space (%) was significant in both the depths and in both the years which was maximum in 50.3 in 2021 at 15-30 cm and minimum was 45.7 in 2020 at 15-30 cm. The WHC (%) was significant in both the depths and in both the years which was maximum in 47.0 in 2020 at 0-15 cm and minimum was 40.16 in 2021 at 15- 30 cm.

As depicted in the Table 2, shows that the effect of sewage sludge and fly ash on soil chemical properties. The pH was non-significant in both the depths and in both the years which was maximum in 7.58 in 2020at 15-30 cm and minimum was 6.88 in 2020 at 0-15 cm. The EC (dSm^{-1}) was significant in both the depths and in both the years which was maximum in 0.41 in 2021 at 15-30 cm and minimum was 0.25 in 2020 at 15-30 cm. The OC (%) was significant in both the depths and in both the years which was maximum in 0.78 in 2020 at 0-15 cm and minimum was 0.48 in 2020 at 15-30 cm. The Nitrogen ($kgha^{-1}$) was significant in both the depths and in both the years which was maximum in 438.67 in 2021 at 0-15 cm and minimum was 252.95 in 2020 at 15-30 cm. The Phosphorus ($kgha^{-1}$) was significant in both the depths and in both the years which was maximum in 46.64 in 2020 at 0- 15 cm and minimum was 20.42 in 2021 at 15- 30cm. The Potassium ($kgha^{-1}$) was significant in both the depths and in both the years which was maximum in 335.21 in 2021 at 0-15 cm and minimum was 167.24 in 2021 at 15-30 cm.

As depicted in the Table 3, shows that the effect of sewage sludge and fly ash on soil micronutrients. The Iron was significant in both the depth and in both the years which was maximum in 38.36 in 2021 at 0-15 cm and minimum was 4.4 in 2020 at 15-30 cm. The Manganese was significant in both the depths and in both the years which was maximum in 27.13 in 2021 at 0-15 cm and minimum was 5.42 in 2020 at 15-30 cm. The Zinc was significant in both the depths and in both the years which was maximum in 4.03 in 2021 at 0-15 cm and minimum was 1.01 in 2020 at 15-30 cm. The Copper was significant in both the depths and in both the years which was maximum in 4.55 in 2021 at 0-15 cm and minimum was 1.12 in 2020 at 15-30 cm.

Table 1. Effect of Incorporation of Sewage Sludge and Fly ash on soil Physical properties

Treatment/ depth	D_b (Mgm^{-3}) (2020)		D_b (Mgm^{-3}) (2021)		D_p (Mgm^{-3}) (2020)		D_p (Mgm^{-3}) (2021)		Percent pore space (2020)		Percent pore space (2021)		Water Holding Capacity (%) (2020)		Water Holding Capacity (%) (2021)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	1.22	1.25	1.23	1.26	2.25	2.3	2.32	2.41	45.78	45.65	46.3	46.82	41.83	40.16	42.11	40.42
T_2	1.08	1.13	1.10	1.15	2.12	2.15	2.18	2.27	48.06	47.44	49.08	50.04	45.43	43.61	45.38	43.57
T_3	1.13	1.17	1.15	1.20	2.13	2.16	2.19	2.28	46.95	45.83	47.46	47.97	45.72	43.89	45.67	43.84
T_4	1.14	1.18	1.16	1.22	2.16	2.21	2.22	2.31	47.22	46.61	47.73	48.24	43.71	41.96	43.66	41.92
T_5	1.15	0.20	1.18	1.22	2.18	2.26	2.25	2.34	47.25	44.15	47.76	48.26	43.75	42.00	43.7	41.95
T_6	1.10	1.12	1.13	1.15	2.13	2.18	2.19	2.28	48.36	47.62	48.86	49.35	45.21	43.40	45.17	43.36
T_7	1.09	1.14	1.11	1.15	2.15	2.2	2.21	2.3	49.3	48.18	47.32	49.76	44.57	42.78	44.52	42.74
T_8	1.20	1.22	1.22	1.23	2.21	2.27	2.28	2.37	45.7	46.26	46.23	46.75	42.16	40.47	42.82	41.10
T_9	1.17	1.20	1.18	1.24	2.18	2.2	2.25	2.34	46.33	45.45	46.85	47.36	43.11	41.39	43.06	41.34
T_{10}	1.16	1.19	1.18	1.21	2.17	2.23	2.24	2.32	46.54	46.64	47.06	47.57	43.08	41.35	43.03	41.31
T_{11}	1.12	1.16	1.13	1.19	2.14	2.19	2.2	2.29	47.66	47.03	48.17	48.67	46.55	44.69	46.49	44.63
T_{12}	1.07	1.11	1.09	1.14	2.1	2.13	2.16	2.25	49.31	48.32	49.54	50.3	47.05	45.17	47.00	45.12
F Test	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S	S	S	S	S	S
SEm±	-	-	-	-	-	-	-	-	0.52	0.85	0.64	0.62	1.02	0.75	0.8	0.71
CD (P=0.05)	-	-	-	-	-	-	-	-	1.53	2.48	1.89	1.82	2.98	2.2	2.36	2.08

Table 2. Effect of Incorporation of Sewage Sludge and Fly ash on soil Chemical properties

Treatment/depth	pH (2020)		pH (2021)		EC (dS m^{-1}) (2020)		EC (dS m^{-1}) (2021)		OC (%) (2020)		OC (%) (2021)		Available Nitrogen (kg ha^{-1}) (2020)		Available Nitrogen (kg ha^{-1}) (2021)		Available Phosphorus (kg ha^{-1}) (2020)		Available Phosphorus (kg ha^{-1}) (2021)		Available Potassium (kg ha^{-1}) (2020)		Available Potassium (kg ha^{-1}) (2021)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	7.58	7.62	7.46	7.58	0.29	0.28	0.28	0.32	0.52	0.5	0.45	0.43	276.08	258.42	256.08	268.89	29.2	27.68	28.64	25.62	185.6	172.28	191.6	173.78
T_2	7.33	7.45	7.35	7.41	0.28	0.27	0.32	0.36	0.5	0.48	0.52	0.48	257.16	240.68	267.46	252.95	20.42	20.16	19.42	18.75	179.16	167.24	195.36	175.64
T_3	7.1	7.16	7.32	7.36	0.3	0.29	0.34	0.38	0.6	0.58	0.56	0.52	275.13	252.38	297.23	269.53	27.92	26.98	30.84	28.54	219.52	204.26	249.42	217.86
T_4	7.18	7.24	7.42	7.47	0.25	0.24	0.3	0.34	0.62	0.6	0.55	0.46	279.8	265.98	302.68	277.65	30.7	29.02	29.35	27.78	241.42	232.17	258.62	246.97
T_5	6.98	7.06	7.15	7.19	0.26	0.25	0.33	0.37	0.66	0.64	0.58	0.54	293.68	280.14	315.88	294.47	31.98	31.44	30.21	28.96	255.16	243.64	272.26	257.34
T_6	6.88	7.01	7.22	7.26	0.28	0.27	0.31	0.36	0.73	0.71	0.53	0.51	309.63	295.16	330.43	309.53	34.46	36.52	34.68	32.88	263.82	256.87	281.62	264.57
T_7	7.3	7.36	7.3	7.32	0.26	0.25	0.34	0.39	0.57	0.55	0.59	0.55	291.56	285.31	312.26	301.76	22.06	23.25	24.76	21.57	220.64	208.24	238.74	216.74
T_8	7.31	7.41	7.42	7.5	0.27	0.26	0.32	0.37	0.66	0.64	0.62	0.57	329.54	320.14	350.34	336.68	28.55	27.28	28.54	24.55	251.41	238.16	269.31	244.96
T_9	7.01	7.12	7.21	7.27	0.28	0.27	0.34	0.37	0.68	0.66	0.65	0.59	344.6	331.74	366.26	345.56	33.16	32.25	34.58	31.86	261.12	250.68	278.32	263.48
T_{10}	6.92	7.05	7.19	7.23	0.31	0.3	0.36	0.4	0.73	0.71	0.67	0.61	368.2	350.54	381.82	368.37	36.23	36.26	37.35	33.21	290.4	277.61	309.14	285.41
T_{11}	6.9	7.04	7.15	7.19	0.32	0.29	0.35	0.39	0.74	0.72	0.7	0.64	379.9	370.44	403.19	389.69	38.28	37.36	41.82	36.34	298.16	289.36	318.26	296.66
T_{12}	7.29	7.41	7.36	7.51	0.34	0.32	0.37	0.41	0.78	0.75	0.76	0.66	407.92	403.67	430.02	417.25	46.64	46.18	44.89	39.78	317.31	305.42	335.21	317.52
F Test	NS	NS	NS	NS	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
SEm±	-	-	-	-	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	4.65	3.86	4.69	4.02	0.55	0.46	0.44	0.40	3.52	4.36	4.29	4.42
CD (P=0.05)	-	-	-	-	0.01	0.01	0.02	0.01	0.03	0.02	0.02	0.02	13.64	11.32	13.76	11.80	1.61	1.35	1.28	1.18	10.32	12.80	12.58	12.96

Table 3. Effect of Incorporation of Sewage Sludge and Fly ash on Available Micro-nutrients in soil

Treatment/depth	Available Iron (mg kg^{-1}) (2020)		Available Iron (mg kg^{-1}) (2021)		Available Manganese (mg kg^{-1}) (2020)		Available Manganese (mg kg^{-1}) (2021)		Available Zinc (mg kg^{-1}) (2020)		Available Zinc mg kg^{-1}) (2021)		Available Copper (mg kg^{-1}) (2020)		Available Copper (mg kg^{-1}) (2021)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	6.62	4.4	6.951	4.62	6.22	5.42	6.53	5.69	1.04	1.01	1.29	1.06	2.04	1.12	2.142	1.8375
T_2	18.42	16.05	19.341	16.8525	13.24	11.04	13.90	11.59	1.23	1.84	1.09	0.88	2.24	1.87	2.352	1.9635
T_3	17.68	15.42	18.564	16.191	14.56	12.36	15.29	12.97	1.5	1.52	1.58	1.16	3.09	2.45	3.2445	2.5725
T_4	19.85	17.2	20.8425	18.06	15.42	13.34	16.19	14.01	2.45	1.9	2.57	1.99	3.85	2.86	4.0425	3.003
T_5	28.94	25.42	30.387	26.691	17.84	15.45	18.73	16.22	3.02	2.45	3.72	3.10	4.1	3.24	4.305	3.402
T_6	33.233	30.2	34.8946	31.71	19.46	17.24	20.43	18.10	3.12	2.32	4.03	3.19	3.9	3.01	4.095	3.1605
T_7	26.78	23.54	28.119	24.717	15.54	13.24	16.32	13.90	2.04	1.85	1.09	0.89	2.2	2.65	2.31	1.7325
T_8	21.2	19.85	22.26	20.8425	17.42	15.32	18.29	16.09	2.53	1.72	1.61	1.08	2.94	1.98	3.087	2.079
T_9	21.85	20.23	22.9425	21.2415	21.09	19.05	22.14	20.01	2.65	1.94	2.78	2.04	3.04	2.24	3.192	2.352
T_{10}	20.82	19.24	21.861	20.202	21.45	19.62	22.52	20.60	2.98	2.16	3.13	2.20	3.68	3.01	3.864	3.1605
T_{11}	30.54	27.34	32.067	28.707	22.34	20.45	23.46	21.47	3.18	2.48	3.25	2.52	3.94	3.36	4.137	3.36
T_{12}	36.54	33.08	38.367	34.734	25.84	23.64	27.13	24.82	3.54	2.85	3.71	2.99	4.34	3.78	4.557	3.969
F Test	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
SEm±	0.40	0.25	0.53	0.40	0.16	0.24	0.31	0.23	0.05	0.04	0.04	0.04	0.05	0.04	0.06	0.05
CD (P=0.05)	1.16	0.75	1.55	1.17	0.46	0.72	0.91	0.67	0.13	0.10	0.13	0.11	0.16	0.13	0.19	0.13

4. CONCLUSION

The research study has revealed that the use of sewage sludge and fly ash has improved the soil physico-chemical properties, the combined use of FA and sewage sludge has been proposed to reduce the bioavailability of heavy metals these ameliorant has potential liming capabilities, decreasing pH and having a long-term residual effect. It can be seen as a slow-release supply of components needed for plant growth, as well as a good source of nutrients required for plant growth. At the same time some toxic metal at higher level reduce the productivity of yield. The high concentration of micro nutrient and macronutrient presents in sewage sludge and fly ash increases the yield of okra.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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