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Effect of direct and residual sewage-sludge application on physiological attributes of rice-wheat cropping system

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ABSTRACT

A two-year field experiment was conducted in 2017–19 to assess the growth and yield performance of rice–wheat cropping system (RWCS) as influenced by conjoint application of treated sewage sludge (TSS) and chemical fertilizer at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. The treatments comprised control, 100% RDF [recommended dose of nitrogen (N), phosphorus (P) and potassium (K)], 100% RDF +20 t/ha TSS, 100% RDF +30 t/ha TSS, 50% RDF +20 t/ha TSS, 60% RDF+20 t/ha TSS, 70% RDF +20 t/ha TSS, 50% RDF +30 t/ha TSS, 60% RDF +30 t/ha TSS, 70% RDF +30 t/ha TSS. The experiment was laid-out in randomized block design with three replications. The results showed that higher growth, yield attributes and yield of rice and wheat were recorded under 100% RDF with 20 t/ha and 30 t/ha TSS as compared to 100% RDF alone. However, 70% RDF+ 30 t/ha TSS had given equivalent or higher yield as compared to 100% RDF in RWCS. Conjoint application of TSS along with chemical fertilizer i.e. 70% RDF with 20 t/ha and 30 t/ha TSS provided higher yield advantage without any harmful/negative impact on soil system and could be recommended as potential organic amendment for sustainable agricultural production system.

Keywords: Greenness index, Rice-wheat cropping system, Treated sewage sludge, Yield

Treated sewage-sludge (TSS), a semi-solid organic waste containing good amount of C, N, P and micronutrients, is produced as a byproduct during sewage treatment of industrial or municipal wastewater (Swain *et al.* 2020). The application of sewage-sludge (SS) to agricultural land has many positive aspects, including greater availability and recycling of nutrients where nutrient resources, particularly micronutrient resources are being depleted (Kayikcioglu *et al.* 2019, Jatav *et. al.* 2021) and soil fertility enhancement of degraded soils due to intensive cropping system (Marotrao *et al.* 2021). The use of SS may ultimately reduce the need of synthetic fertilizers (Mandol *et al.* 2015). However, SS also contains heavy metals (HMs) which may affect the soil microbial population and related processes as they are fundamental for maintaining the soil conditions and ecosystem functions in positive manner. Therefore, agricultural application of SS requires strong guiding principles and monitoring system to avoid the risk of contamination of heavy metals. So, efficient use of TSS requires an individual assessment *vis-a-vis* natural variations encountered in agricultural field due to climate and soil type. Previous studies on SS application have shown improved crop growth and yield results with enhanced micronutrient and macronutrient status in soil (Latare *et al.* 2014, 2018; Sharma and Dhaliwal 2019) and greater microbial counts in soil (Jatav *et. al.* 2018). Several researchers also reported sludge as an amendment option for degraded land which improves soil physical properties such as bulk density, microaggregate, water retention, porosity, and hydraulic conductivity as compared to inorganic fertilizer (Swain *et. al.* 2021, Kumar *et al.* 2021). Nevertheless, sludge accumulation also led to undesirable modifications, such as decline in *p*H, rise in salinity and heavy metal contents in soil (Singh and Agrawal 2008). Continuous and higher dose of SS application can enhance the accumulation of toxic heavy metals such as lead (Pb), chromium (Cr) and mercury (Hg) which cast harmful impact on soil microbial populations and their activities. Thus, the aim of the present study was to explore the effect of conjoint application of TSS and fertilizer on growth, yield attributes and yield of rice–wheat cropping system (RWCS).

MATERIALS AND METHODS

An experiment with two cropping cycles of rice (*Oryza sativa*: Arize 6444)–wheat (*Triticum aestivum*: HD 2967) was conducted during 2015–16 (I-rice and I-wheat) and

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2016–17 (II-rice and II-wheat). Then present investigation comprising the next two cycles of rice-wheat system was set up during 2017–18 (III-rice and III-wheat) and 2018–19 (IV-rice and IV-wheat) without disturbing the field design of the previous experiment at the Agricultural Research Farm, Banaras Hindu University, Varanasi (Uttar Pradesh), India. The research farm is situated at latitude 25°19′N and longitude 83°10′E with an altitude of 128.93 m amsl. The experimental soil had alkaline nature (*p*H 8.24), with low salt (EC 0.15 dS/m), and organic carbon (OC) content (4.60 g/kg), along with poor available N (141.72 kg/ha) medium available P (17.42 kg/ha), available K (132.74 kg/ha) and sulfur (14.65 mg/kg). In the initial soil, iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) were observed to be 42.65, 2.17, 1.02 and 11.41 mg/kg, respectively. The TSS used in this experiment had *p*H: 7.02, EC: 3.25 dS/m, OC: 7.98%, total N: 1.85%, total P: 1.40% and total K: 1.20%. While the total micronutrient and heavy metal content (mg/kg) in TSS was Fe: 500.32, Cu: 246.87, Zn: 200.25, Mn: 258.45, Cd: 8.25, Cr: 44.31, Ni: 17.23 and Pb: 52.13 mg/kg. In the experiment, ten treatments were replicated thrice using randomised block design. Treatments in the present study were T_0: control (no NPK or TSS), T_1:100%RDF (N-P_2O_5-K_2O at 150-75-75, and 120-60-60 kg/ha for rice and wheat, respectively), T_2:T_1+TSS 20 t/ha, T_3:T_1+ TSS 30 t/ha, T_4:50% RDF + TSS 20 t/ha, T_5:60% RDF + TSS 20 t/ha, T_6:70% RDF + SS 30 t/ha, T_7:50% RDF + TSS 30 t/ha, T_8:60% RDF + TSS 30 t/ha, T_9:70% RDF + TSS 30 t/ha. The half dose of N and full dose of P and K were applied during sowing of the crop as basal dose while remaining half dose of N was applied in two equal splits at 30 and 60 DAT/S.

RESULTS AND DISCUSSION

Growth parameters: Plant height of rice and wheat in both years responded significantly to conjoint application of treated SS and chemical fertilizer over T_1 while no such impact was evident in greenness index (SPAD value) (Table 1). The plant height varied from 64.95–104.22 cm and 61.83–102.32 cm in rice crop during first and second year, respectively. The significantly highest plant height (102.41 and 102.32 cm) was reported in treatment T_3 followed by T_2 and T_1 during both first and second year, respectively. The treatment T_3, T_2, T_9 and T_8 noted an increment of 60.46, 57.67, 47.02 and 28.64% over the control. Data showed that plant height significantly varied from 61.59–102.55 cm and 64.86–103.80 cm in wheat crop during first and second year, respectively. The significantly highest plant height (102.55 cm and 103.80 cm) was reported in treatment T_3 followed by T_2 and T_1 during first and second year, respectively. These results were parallel to the findings reported by Togay *et al.* (2008), Latare *et al.* (2014, 2018), Sharma and Dhaliwal (2019). The greater plant height with conjoint application might be explained by slow release of nutrients in sufficient amounts by TSS.

Yield components: The maximum number of tillers per running meter was found in treatment T_3 followed by T_2 in rice during both the years (Table 2). The tillers running per meter in T_3 and T_2 noted an increment of 12% and 10.08% in III-rice and 14% and 9.9% in II-rice, respectively, over T_1. In wheat crop, the tillers running per meter in treatment T_3 and T_2 noted an increment of 23% and 14% in III-wheat and 18.54% and 14% in IV wheat, respectively, over T_1. Data also revealed that in wheat crop, T_3 was significantly superior to all the treatments except T_2 during both the years.

Among all the treatments, highest number of tillers per hill (14.46) were recorded with T_3 in III-rice crop which was significantly higher than T_1 but not with T_2 (Table 2). However, T_2 and T_3 reported an increase of 20.06% and 30.37% in number of tillers per hill as compared to T_1 in III-rice. In IV-rice, among all the treatments, highest number

Table 1 Effect of conjoint application of sewage-sludge and fertilizer on growth attributes of rice and wheat

Treatment	Greenness index (SPAD)				Plant height (cm)			
	2017	2017–18	2018	2018–19	2017	2017–18	2018	2018–19
	III-Rice	III-Wheat	IV-Rice	IV-Wheat	III-Rice	III-Wheat	IV-Rice	IV-Wheat
T_0	26.65b	24.78c	24.81c	22.76d	64.95d	61.59d	61.83d	64.86e
T_1	32.89ab	36.32ab	33.69ab	34.66ab	90.13c	89.10abc	89.69bc	92.76bcd
T_2	38.66a	39.23ab	36.86a	37.24a	102.41ab	99.64ab	99.27ab	101.06ab
T_3	39.23a	41.92a	38.95a	38.51a	104.22a	102.55a	102.32a	103.80a
T_4	29.53ab	32.86b	27.93bc	27.76cd	86.30c	84.96c	83.22c	84.61d
T_5	31.66ab	34.90ab	28.40bc	30.17bc	88.08c	85.46bc	84.62c	85.79d
T_6	34.50ab	37.74ab	32.58ab	32.29abc	88.95c	88.62abc	87.23c	87.54cd
T_7	31.59ab	34.37ab	29.09bc	30.36bc	89.38c	91.90abc	86.40c	93.20abcd
T_8	35.15ab	37.27ab	32.02abc	32.67abc	93.10bc	92.34abc	91.01abc	94.11abcd
T_9	37.06a	38.17ab	34.29ab	34.58ab	95.49ab	93.22abc	91.11abc	97.18abc

Treatment details given under Materials and Methods.

Table 2 Effect of conjoint application of sewage-sludge and fertilizer on yield attributes of rice and wheat

Treatment	Tillers per running meter				Tillers per hill in rice		Tillers square per meter in wheat	
	2017	2017–18	2018	2018–19	2017	2017–18	2018	2018–19
	III-Rice	III-Wheat	IV-Rice	IV-Wheat	III-Rice	IV-Rice	III-Wheat	IV-Wheat
T_0	39.13d	28.07f	35.11e	39.13d	5.63d	5.03c	176.04f	170.30e
T_1	89.96bc	74.06bcde	86.74bcd	89.96bc	11.58bc	12.74ab	352.01de	358.96bcd
T_2	99.03a	84.54ab	95.35ab	99.03a	14.15ab	14.10ab	415.44ab	403.45ab
T_3	100.92a	91.27a	98.59a	100.92a	14.64a	14.51a	436.63a	420.50a
T_4	80.44c	63.82e	77.41d	80.44c	10.80c	10.69b	331.35e	316.86d
T_5	85.08bc	66.74de	82.78cd	85.08bc	11.59bc	10.99ab	344.50de	330.99cd
T_6	89.96abc	71.08cde	85.10bcd	89.96abc	12.60abc	11.16ab	381.27bcd	359.64bcd
T_7	89.68abc	72.54cde	86.01bcd	89.68abc	11.81bc	10.86ab	358.70cde	345.29cd
T_8	93.12abc	76.05bcd	87.81abcd	93.12abc	12.23bc	11.39ab	371.69cde	359.17bcd
T_9	96.24ab	80.14bc	91.63abc	96.24ab	13.75abc	11.68ab	396.91abc	371.69bc

Treatment details given under Materials and Methods.

of tillers per hill was reported in T_3 (14.51) which were 2.91% and 13.89% higher than the treatment T_2 and T_1, respectively. However, T_3 was significantly superior to all the treatments except T_2 and T_9 in III-rice crop while in IV-rice, T_3 was at par with all the treatment except T_0 and T_4.

The tillers/m^2 varied from 176.04–436.63 and 170.30–420.50 in wheat crop during first and second year, respectively (Table 2). The highest tillers/m^2(436.63) was reported in treatment T_3 followed by T_2 (403.45) and T_9 (176.04) during the first year and similar trend was recorded in second year. The results agreed with the findings of Latare *et al.* (2014) who explained that higher dose of sludge with chemical fertilizer increased tiller number, dry matter, tillering capacity and plant height both in rice and wheat crop, due to the adequate amount of organic matter and nutrient, and cationic micronutrients. This has direct involvement in many enzyme-mediated pathways, regulatory functions, auxin production and synthesis and transport of carbohydrates to the sink.

Grain and straw yield: The grain yield ranged between 17.67–66.64 q/ha and 15.06–63.68 q/ha in III-rice and IV-rice, respectively. By the application of TSS and fertilizer, the yield of both the crops was significantly improved in all the treatments except without fertilizer (Fig 1). In both the years, in III-rice and IV-rice, a significantly higher grain yield was recorded in T_3 i.e., combination of 30 t/ha TSS + 100% RDF followed by T_2. In wheat crop, the highest yield was obtained in treatment T_3 (52.40 and 49.90 q/ha), followed by T_2 (49.33 and 47.27 q/ha) and T_9 (45.65 and 44.25 q/ha) in III and IV-wheat, respectively. The treatment T_3, T_2 and T_9 exhibited an increase of ~22.74, 15.55 and 6.93% in III-wheat 15.18, 9.11 and 2.14% in IV-wheat as

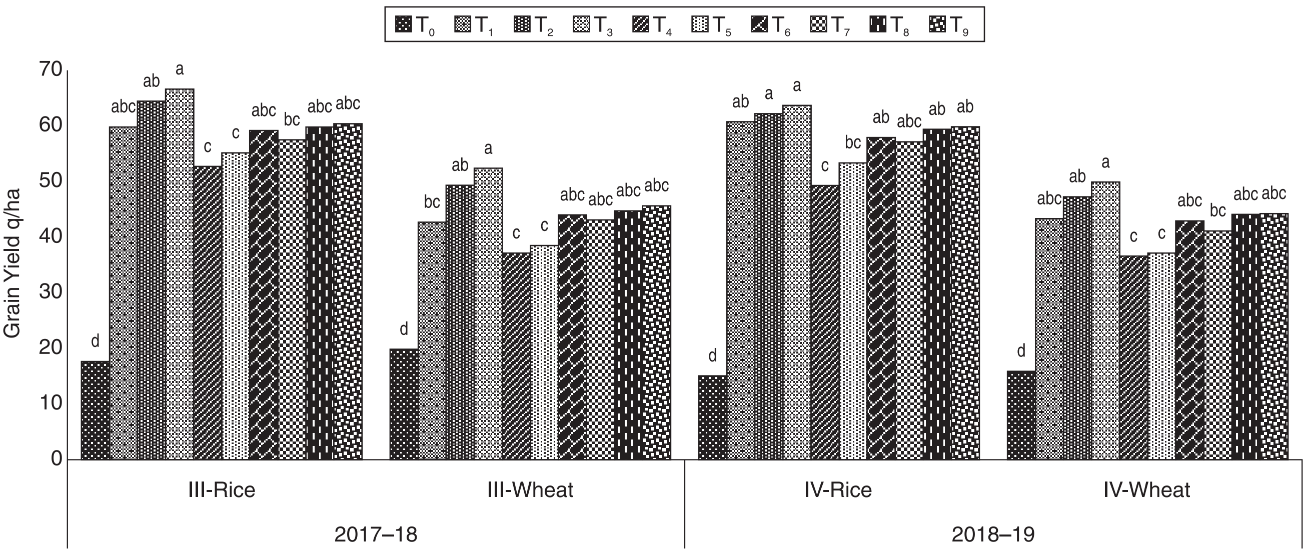

Fig 1 Effect of conjoint application of sewage-sludge and fertilizer on grain yield of rice and wheat.

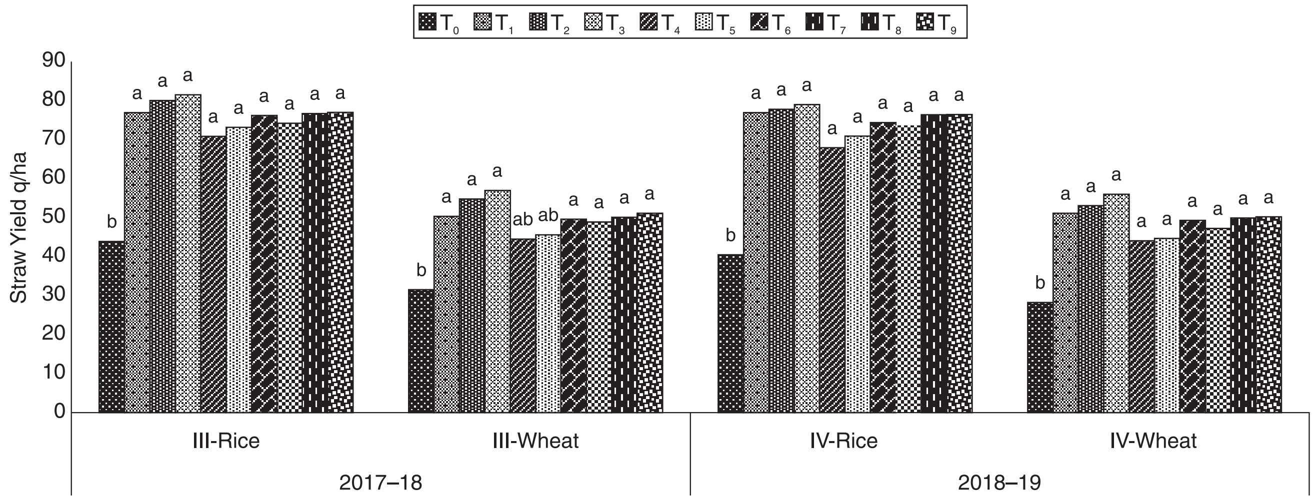

Fig 2 Effect of conjoint application of sewage-sludge and fertilizeron straw yield of rice and wheat.

compared to T_1. Sharma and Dhaliwal (2019) also reported that combined application of 5 and 10 t/ha sludge along with fertilizer is necessary for the maintenance of soil fertility and for optimum plant nutrient supply and sustaining the productivity of rice-wheat crop in Punjab, India. The results of the present study are also supported by Rehman and Qayyum (2020), who noted that SSL treatment increased the growth and yield of rice and wheat, which might be due to higher uptake of water and nutrients by plants.

The straw yield in III-rice and III-wheat ranged between 43.89–81.50 q/ha and 31.50–56.95 q/ha, respectively (Fig 2). The straw yield in IV-rice and IV-wheat ranged between 40.44–78.96 q/ha and 28.23–55.99 q/ha, respectively. Among all the treatments, T_3 recorded highest straw yield of rice (81.50 and 78.96 q/ha) and wheat crop (56.95 and 55.99 q/ha) during both the years of experiment, respectively. In both the years in rice and wheat crops, a higher straw yield was recorded in T_3 followed by T_2. In III-rice crop, the straw yield of treatments T_2, T_3 and T_9 increased by 4.07%, 5.98% and 0.07%, respectively, overtreatment T_1. In the case of II-rice, the treatment T_2 and T_3 were increased 1.10 and 2.64% higher than T_1. In III-wheat crop, straw yield in T_2, T_3 and T_9 showed 8.83, 13.18 and 1.58% increment over T_1. Whereas, in case of IV-wheat, only treatment T_2 and T_3 showed 3.81 and 9.61% increment over T_1, respectively. It was found that application of SS which improved various yield and yield attributes like productive tillers, panicle length, number of grains per panicle per ear and number of tillers resulted in higher grain and straw yield. The possible reasons for the increased yield and yield attributes due to the application of SS might be the increase in the availability of different essential nutrients (N, P, S and micronutrients) for root development, increase in the number of tillers, improved length and width of leaves (photosynthetic surface). Latare *et al.* (2014, 2018), Sharma and Dhaliwal (2019) reported that long-term combined application of chemical fertilizer with organic manure statistically boosted the obtainable N, P and K compared to chemical only with improvement of soil properties, resulting in maximum grain yield of rice and wheat crops. The SS delivers a treasure of available nutrients for plants, improves soil properties (Zhang *et al.* 2006), and proliferation of microbial population (Jatav *et al.*2018) thus promoting amount of nutrients by microbial process.

Application of 20 or 30 t/ha SSL conjunction with 100% RDF significantly enhanced the yield of rice-wheat system as compared to 100% RDF alone. However, in view of environmental concern it is concluded that the application of chemical fertilizer at a reduced rate along with less application of TSS [T_6 (70% RDF+TSS 20)] could be recommended as a feasible dose for the utilization of TSS in rice-wheat system.

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