Indian Journal of Agronomy **69** (3): 257–262 (September 2024)
DOI: 10.59797/ija.v69i3.5519

Research Paper

Impact of fertilizer levels and treated sewage water on heavy metal uptake, growth, agrometeorological indices, and quality of wheat

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Received: May 2024; Revised accepted: August 2024

ABSTRACT

A field experiment was conducted at Vegetable Research Farm, CCS Haryana Agricultural University, Hisar, Haryana, India to study the agro-physiological, agrometeorological, heavy metals, and quality parameters of wheat under different fertilizer levels and treated sewage water application on sandy loam soil. Among varieties, significantly higher yield attributes *viz* effective tillers and yield were observed with variety HD 3086 being at par with WH 1105 over HD 2967, WH 1124, and DBW 90. A higher value of agrometeorological indices viz. thermal (2.67 kg/ha/^{0}C day), helio-thermal (0.77 kg/ha degree day hr), and photothermal (0.23 kg/ha degree day hr) use efficiencies were found with variety HD 3086 over other varieties. Among fertilizer levels, significantly higher yield attributes and grain yield were found with 125 % RDF over 75 and 100 % RDF. Significantly higher values of thermal, heliothermal, and photothermal use efficiencies were observed with the application of 125 % RDF over 75 and 100 % RDF Neither the varieties nor the fertility levels bring any significant variation in normalized difference vegetation index and canopy temperature. However, varying levels of fertilizer did have a substantial impact on chlorophyll content. Similarly, quality parameters viz. hectoliter weight and protein content were not affected significantly by varieties and fertilizer levels. However, sedimentation value was significantly affected by varieties and fertilizer levels. Heavy metal concentration was found in wheat grain, but these were within the permissible limit.

Key words: Heavy metals, Quality, Treated sewage water, Wheat, Yield

Wheat is considered to be a prominent cereal crop cultivated throughout diverse climatic conditions as a source of carbohydrates, vital amino acids, dietary fiber, and minerals. Wheat grain contains more protein than other cereals and provides the characteristic substance "Gluten" which is essential for bakers (Jesal *et al*. 2024). Rapid population growth and urbanization, exhaustive water consumption, and climate change are critical factors for the depletion of freshwater resources. In the present era, the issue of water shortage poses a significant challenge due to the global decline in groundwater resources, and the future, may not be sufficient to meet the growing needs of agriculture and allied sectors (Avasthe *et al.,* 2023). The issue of water scarcity poses a significant challenge to crop cultivation in arid regions across the globe (Barman *et al.,* 2021). Wastewater in arid and semi-arid areas is a valuable irrigation source and fertilizing material that contributes to economic growth and food security. In situations when freshwater is scarce and the availability of canal water, or high-quality water is limited, major attention has been paid to reusing wastewater for irrigation of various crops. Farmers have explored the use of inferior-quality water as a substitute for good-quality water in crop production (Dotaniya *et al.,* 2022). Untreated or poorly treated wastewater can have harmful effects on soil, plants, and the environment, and be dangerous to humans. Depending upon the source of wastewater from city to city (Rattan *et al*., 2005), it may contain high concentrations of salts and heavy metals. The high concentrations of salts may adversely affect the physiological processes and growth of wastewater-irrigated plants (Hajihashemi *et al.,* 2020). Disposing of sewage and industrial effluents into natural water sources resulted in soil and water pollution. Hence, proper use of such non-conventional water resources will be environmentally sound disposal practices and water augmentation for

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sustainable agriculture in water-scarce countries with relatively minimum pollution of surface or groundwater. Reusing treated wastewater may nourish crops, prevent water contamination, and lessen the strain on freshwater supplies (Mishra *et al*., 2023). Crop productivity increases when wastewater is reused depending on soil type, climate, crop, and irrigation practices. Adequate nutrient management is crucial for harvesting the quality yield. Nitrogenous fertilizers play a vital role in yield enhancement, however only 20–50% of the soil-applied nitrogen is recovered by the annual crops (Singh *et al*., 2024). Hence, it was hypothesized that the conjoint application of nitrogen fertilizers with treated sewage water can improve the growth and quality of wheat varieties grown in semi-arid regions. To achieve the above hypothesis different varieties were screened for physiological parameters and quality under various levels of fertilizers grown under sewage treatment water.

MATERIALS AND METHODS

A field experiment was conducted during the rabi season of 2020–21 and 2021–22 at Vegetable Research Farm, CCS Haryana Agricultural University, Hisar, Haryana, India. The soil of the experimental site was sandy loam in texture, low in organic carbon (3.5 g/kg), and slightly alkaline in reaction (*p*H 7.6). The available N, P and K were 165, 17, and 295 kg/ha, respectively. The experiment was laid out in split plot design with varieties, viz 'HD 3086', 'HD 2967', 'WH 1105', 'WH 1124', and 'DBW 90' assisted in main plots and levels of fertilizer, viz. 75, 100, and 125% recommended dose of fertilizer (RDF) in subplots and was replicated thrice. The seedbed was prepared by applying canal water, and treated sewage water was used as an irrigation source for subsequent irrigation. At the sewage-treated plant, CCS Haryana Agricultural University, Hisar campus, the sewage collected from offices and residential areas was treated with the moving bed biological reactor method. The bioreactor that separates the sludge and treated water was designed to treat the sewage with an aerobic attached growth moving bed process. The properties of the treated sewage water sample are given in Table 1.

At the time of sowing half nitrogen and a full dose of phosphorus were applied as per the treatments and the rest of the nitrogen was top-dressed after the first irrigation. Single superphosphate and urea were used as the sources of phosphorus and nitrogen, respectively. The crop was sown on 11th November and 4th December in the growing seasons of 2020-21 and 2021-22, respectively using 100 kg seed/ha. Yield attributes and yield were recorded as per standard methods**.** Soil samples collected after crop harvesting were air-dried and ground to pass through a 2-mm sieve and analyzed for heavy metals (Lindsay and Norvell 1978). Hectolitre mass expressed as kilograms per hectoliter was measured with the hectoliter weight equipment having a standard volume of container/beaker, and the weight of grain was taken on an electronic balance. DS-sedimentation volume is basically a measurement of the sediment volume of a wheat flour suspension after it has been acidified. The sedimentation test is based on the fact that gluten protein absorbs water and swells considerably when treated with SDS lactic acid reagent. The extent of swelling depends upon the quality of gluten protein. It was determined by the method of Axford *et al*. (1979), using sodium-dodecyl sulfate lactic acid reagent (SDSLA). Different agro-meteorological indices and heat-use efficiencies (thermal, heliothermal, and photothermal use efficiency) were calculated as per the standard formula. The nutrient uptake (grain) by crop was worked out by the formula

$$\text{Nutrient uptake (kg/ha)} = \frac{\textit{Per cent N content in grain X grain yield } \left(\frac{kg}{ha}\right)}{100}$$

The recorded data were pooled and analyzed using the online statistical analysis package of OPSTAT (Sheoran *et al*., 1998).

RESULTS AND DISCUSSION

Agro-physiological parameters: Among varieties, differences were found to be non-significant concerning plant height (Table 2). However, significantly taller plants were observed with the application of 125 percent RDF over lower levels of fertilizer application. The variety HD 3086 produced a significantly higher tiller per square meter than other varieties, however, it was at par with variety WH 1105 with respect to effective tillers. Among fertility levels, the application of 125 percent RDF produced significantly higher effective tillers over 75 and 100 percent RDF. It was found that different varieties did not differ significantly concerning grain number per spike. Different fertility levels differ significantly in respect of grains per spike.

Table 1. Treated sewage water properties

Irrigation	EC (dS/m)	RSC (meq/l)	Heavy metals (ppm)						
			Co	Pb	Cd	Zn	Cu	Ni	Cr
	1.44	1.50	0.01	0.08	0.02	0.04	ND	0.04	0.02

ND, Not detected

Similarly, the variety HD 3086 produced significantly higher grain yield than other varieties, however, it was at par with variety WH 1105 concerning grain yield (Table 2). Correlation coefficients were also calculated, treatment having a higher effective tiller per plant produced higher grain yield due to a strong and positive correlation between effective tiller per plant and grain yield (Fig.1). The effects of experimental variables are reflected in the form of yield; hence, yield is the principal criterion for evaluating the efficiency of various treatments. It is a function of effective tillers, the number of grains per spike, and test weight. The use of domestic wastewater has favourably affected the yield and yield attributes of wheat crops due to its continuous application, which might enrich nutrients in topsoil and improve soil properties along with adequate nutrient supply under higher levels of fertilizers that finally result in higher growth parameters such as tillers and leaf area per plant. However, the growth may remain retarded when its supply is suboptimal, which may be ascribed directly to nutritional effects (Kumar *et al.,* 2021). Moreover, nitrogen concentration is indirectly related to one of the basic plant physiological processes, photosynthesis, as 70% of the nitrogen in plant leaves exists in the chloroplast, and most of it is used to synthesize photosynthetic apparatus. Neither the varieties nor the fertility levels bring any significant variation in normalized difference vegetation index and canopy temperature. However, varying levels of fertilizer did have a substantial impact on chlorophyll content. Specifically, the application of 125% RDF resulted in significantly higher chlorophyll content compared to the application of 75% RDF. No significant differences were observed in terms of chlorophyll content between the 100 and 125% RDF levels (Table 2).

Nutrient and heavy metal uptake: Heavy metal concentration was reported in wheat grain and increased with increasing levels of fertilizer but these were within the permissible limit (Fig.3a and b). Using treated wastewater for irrigation over an extended period may bring health concerns to people since it can build up and come into touch with food directly (Kim *et al*., 2015). Heavy metals tend to assemble in the surface soil due to their limited solubility and plant uptake. The mobility and availability of heavy metals depend on plant types, soil characteristics, temperature, pH, humidity, and organic matter content. Heavy metal uptake is lower in food crops and roots, whereas higher in leafy vegetables (Qureshi *et al*., 2016). The findings indicated that the application of fertilizer had a considerable impact on the uptake of nutrients N, P_2O_5, and K_2O. The administration of 125 percent RDF resulted in a notably greater uptake of nutrients compared to the application of 75 and 100 percent RDF (Table 3). Increased mineral nutrient absorption or enhanced NPK uptake by wheat grain was due to improved vegetative growth under the congenial environment of adequate moisture and nutrients. Treated sewage water may be high in organic matter and contain significant amounts of essential plant nutrients (Meena *et al.,* 2016). Accordingly, continuous irrigation with treated sewage wastewater is projected to increase the nutrient pool in soils and plants significantly. When soil is

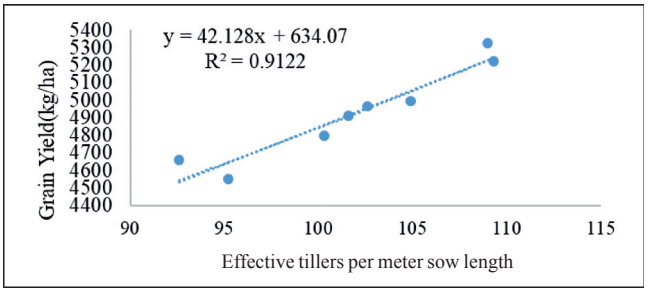

Fig. 1. Relation between effective tillers and grain yield

Table 2. Agro-physiological parameters of wheat as influenced by fertilizer levels under-treated sewage water application (2-year mean)

Treatment	Agronomical parameters				Physiological Parameters		
	Plant height (cm)	Effective tillers/ m^2	Grains/ spike	Grain yield (kg/ha)	NDVI	Chlorophyll content (SPAD)	Canopy Temperature (^{0}C)
Wheat varieties							
'HD 3086'	97.8	437.3	44.7	5222	0.73	47.5	27.3
'HD 2967'	99.5	401.3	42.1	4798	0.73	48.6	27.2
'WH 1105'	96.4	419.7	42.8	4997	0.72	47.6	27.1
'WH 1124'	99.4	370.4	45.3	4661	0.74	46.5	27.6
'DBW 90'	97.9	410.4	43.0	4964	0.73	48.5	26.7
CD (P=0.05)	NS	25.4	NS	262	NS	1.4	NS
Fertilizer levels							
75% RDF	95.7	380.9	41.3	4549	0.73	46.7	27.0
100% RDF	98.2	406.4	43.2	4910	0.72	47.9	27.3
125% RDF	100.8	436.2	46.3	5327	0.73	48.6	27.2
CD (P=0.05)	2.3	10.9	1.2	181	NS	0.9	NS

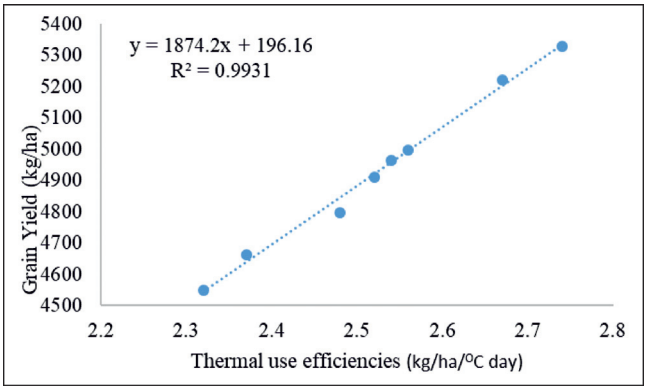

Fig. 2(a). Relationship between thermal use efficiency and grain yield

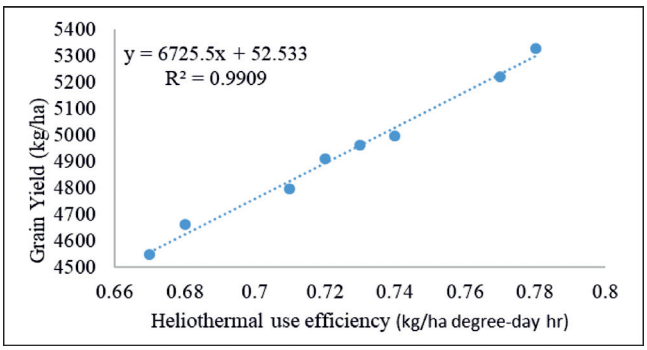

Fig. 2(b). Relationship between helio-thermal use efficiency and grain yield

irrigated with wastewater rather than freshwater, the hydrolysis activity is greater, which is connected to the microorganisms' breakdown of dissolved organic carbon. Increased activity may result in better soil fertility because 90% of soil processes are facilitated by soil bacteria (Furtak and Gajda, 2017). A significant increase in NPK

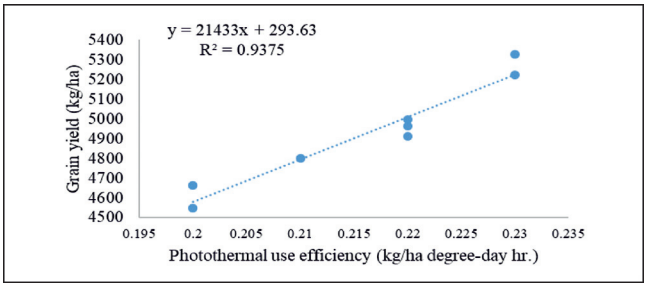

Fig. 2(c). Relationship between photo-thermal use efficiency and grain yield

content and uptake in wheat and barley crops with the use of municipal-treated wastewater was observed by Lal *et al.* (2015).

Quality parameters: The smaller the grain size, the more the number of grains taken per unit volume and more the hectoliter weight. Neither the varieties nor the fertility levels bring any significant variation in the quality parameters viz. hectoliter weight and protein content (Table 3). However, sedimentation value was significantly affected by varieties and fertilizer levels. Higher value of protein content might be due to higher nitrogen availability in soil which in turn increased the nitrogen uptake and ultimately improved the protein (Singh *et al.,* 2024) The sedimentation value of variety 'HD 3086' was found to be significantly greater compared to varieties 'WH 1124' and 'DBW 90'. However, there was no significant difference in sedimentation value between variety 'HD 3086' and varieties 'HD 2967' and 'WH1105'. The application of 125% RDF resulted in a significantly greater value compared to the application of 75% RDF. However, no significant difference was observed between the application of 125 and 100% RDF and between the application of 75 and

Table 3. Nutrient uptake, quality parameters, and agrometeorological indices of wheat as influenced by fertilizer levels under-treated sewage water application (2-year mean)

Treatment	Nutrient uptake (kg/ha)			Quality parameters			Agrometeorological indices		
	N	P	K	Hectolitre weight (kg/hl)	Sedimentation value (ml)	Protein %	TUE (kg/ha/°C day)	HTUE (kg/ha degree-day hr)	PTUE (kg/ha degree-day hr)
Wheat varieties									
'HD 3086'	83.6	18.0	19.5	77.6	37.8	13.3	2.67	0.77	0.23
'HD 2967'	75.6	18.7	19.1	77.3	37.3	13.2	2.48	0.71	0.21
WH 1105'	84.3	21.3	20.0	78.0	37.6	13.4	2.56	0.74	0.22
'WH 1124'	70.8	18.2	18.9	78.2	35.6	13.2	2.37	0.68	0.20
'DBW 90'	79.8	19.0	19.6	75.1	35.5	13.1	2.54	0.73	0.22
CD (P=0.05)	8.1	2.1	NS	NS	1.8	NS	0.14	0.03	0.01
Fertilizer levels									
75% RDF	65.3	16.0	16.0	76.7	35.6	13.1	2.32	0.67	0.20
100% RDF	78.8	19.1	18.7	76.3	36.6	13.2	2.52	0.72	0.22
125% RDF	92.5	22.1	23.6	78.7	38.1	13.5	2.74	0.78	0.23
CD (P=0.05)	6.7	1.1	1.5	NS	1.9	NS	0.10	0.02	0.01

100% RDF (Table 3). The sedimentation value is well known for measuring the quantity and quality of wheat gluten (Song *et al*., 2020), which also provides an idea about the protein content and bread-making quality of wheat grain (Bulut *et al*., 2013). Treated sewage irrigation water has a high amount of nitrogen in it. However, nitrogen takes part in many metabolic activities and is a major component of amino acids. Hence, the application of treated sewage water improved the quality of wheat grain in terms of protein content, sedimentation value, and hectolitre weight by affecting the flour P concentration and flour and plant tissue N concentrations.

Agro-meteorological efficiencies: Among varieties, higher values of agrometeorological indices viz. thermal (TUE), heliothermal (HTUE), and photothermal use efficiencies (PTUE) were found with variety HD 3086 over other varieties. Among fertilizer levels, significantly higher thermal, heliothermal, and photothermal use efficiency values were observed with 125 % RDF over 75 and 100 % RDF (Table 3). This might be due to more utilization of degree day as a heat unit concept of crop and to be greater vegetative growth (dry matter accumulation and yield) caused, by increasing fertility levels (Kumar *et. al.,* 2021). A strong and positive correlation was found between yield and agrometeorological efficiencies (Fig. 2a, b & c).

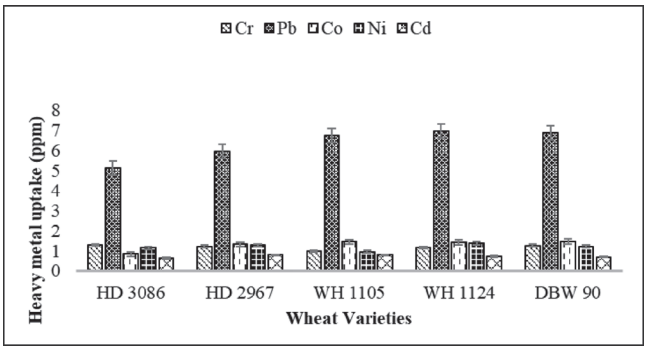

Fig. 3(a). Heavy metals uptake as influenced by wheat varieties

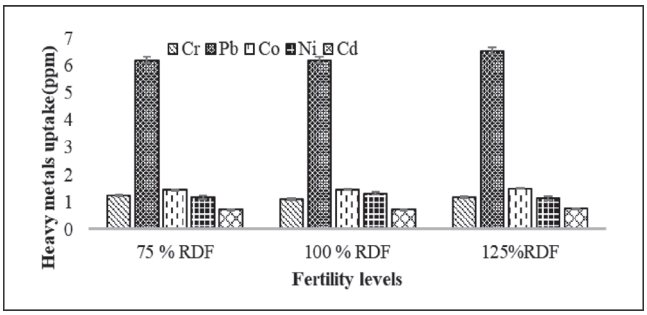

Fig. 3(b). Heavy metals uptake as influenced by fertility levels

The study concluded that variety 'HD 3086' was superior over other varieties concerning growth, productivity, and agrometeorological efficiencies when grown with a higher dose of fertilizer under-treated sewage water application under a semi-arid environment.

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