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EFFECT OF RICE HUSK ASHES AND IRRIGATION WATER QUALITY ON THE GROWTH AND PRODUCTIVITY OF WHEAT

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SUMMARY

The study aimed to assess the effects of using rice husk ashes to treat the quality of non-fresh irrigation water on the growth and productivity of the wheat cultivar Al-Rashid in plastic pots. The research occurred during the 2022–2023 season at the Thi-Qar Governorate, Iraq. The randomized complete block design with split-plot arrangement had two factors and three replications. The main plots were the irrigation water quality (W), comprising river water 2.1 dSm^{-1} (W1), city sewage water 6.4 dSm^{-1} (W2), and drainage water 12.3 dSm^{-1} (W3). The subplots were the ashes of rice husks (T) burned at temperatures of 1000 °C (T1), 800 °C (T2), 600 °C (T3), and 400 °C (T4). The burned rice husk (T1) showed a significant positive effect on the growth and yield traits, i.e., plant height, leaf area, tillers per plant, grains per spike, and grain yield (113.67 cm, 62.86 cm^2, 9.73 tillers $plant^{-1}$, 65.22 grains $spike^{-1}$, and 7.438 t ha^{-1}, respectively). Drainage water caused a decrease in average values of studied traits compared with the river water. The river water exhibited a significant positive effect and provided the highest means for the above traits (118.42 cm, 63.66 cm^2, 10.32 tillers $plant^{-1}$, 71.58 grains $spike^{-1}$, and 7.967 t ha^{-1}, respectively). The interaction of river water (2.1 dSm^{-1}) and burned rice husks (1000 °C) (T1 and W1) gave the maximum grain yield (8.212 t ha^{-1}).

Keywords: Wheat, lack of water revenues, rice husk ashes, irrigation water quality, growth and yield traits

Key findings: The study revealed that increasing the temperature of burning rice husks to treat irrigation water can improve the mean values of studied traits.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) occupies an important position among cereals regarding production and utilization. Wheat is a dominant crop for a large part of humanity, grown over large areas worldwide with diverse environmental conditions. Consequently, wheat is the economic source of fiber, protein, and calories in the human diet. Wheat flour-derived products also require diverse quality features. The wheat flour has many uses in different food products, which are mostly determined by the quantity and quality of gluten proteins (Weegels *et al*., 1996). Gluten consists of proteins that give strength, structure, and texture to diverse forms of bread.

Water is the source of life in which human civilization arose and developed, and with its loss, much civilization collapsed and disappeared. The problem of providing fresh water became a primary challenge in the continuation of the crop production process to achieve a balance between population growth and the food produced to ensure food security (Masmoudi and Masmoudi, 2020).

Many countries, including Iraq, tended to search for alternatives to compensate for insufficient fresh water. In particular, they use other types of water resources (drainage, city sewage, sewage, and well water) despite the negative effects on cultivated soils. However, the use of non-traditional technologies can reduce these effects and, thus, the possibility of using them to continue the crop production process and get optimum yields (Ati *et al.,* 2020).

Studies on the type of irrigation water effects showed the salt level (2 dSm^{-1}) gave the highest rates in some characteristics; however, the salt level (8 dSm^{-1}) provided the lowest rates in most studied traits, such as plant height and flag leaf area (Al-Zewany and Al-Semmak, 2017). Plant residues are biological products obtained from different plants that remain in fields after harvesting the main crop. These residues constitute the great wealth often lost due to being untapped. Perhaps the most important of these is the rice husks, which have an effective role in treating non-fresh water (Sarkar *et al.,* 2020).

Rice husk wastes are available in large quantities in rice production factories. Burning of rice husks at high temperatures leads to producing ash containing a high percentage of pure silica, which reaches 95% and has microporosity and a high surface area (Rehman *et al.,* 2018). The ash of rice husk contains several effective aggregates that can absorb and remove the pollutants and salts found in the water used for irrigation. In addition, the ash forms an adsorption complex that catches and retains the nutrients, prevents them from being lost by volatilization and washing, and releases them to the soil solution gradually. Moreover, it increases the biomass in the soil and promotes an environment suitable for plant growth. The ash also improves the productivity of soil in combination with other materials, such as clay, and could be an alternative to improve tomato production (Yasir,2021 b; Virrarreal-Sanchez *et al.*, 2022).

The scarcity of fresh water compels researchers to use the non-traditional, inexpensive, and other available methods in treating non-fresh water with their possible use in crop production processes (Yasir,2021 a). Furthermore, benefiting from rice husks and converting them from a polluting source to a source of soil and water reformer is feasible using scientific methods. The presented study aimed to determine the effects of rice husk ashes and different types of irrigation water on the growth and yield traits of wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

The said wheat experiment transpired in the crop season of 2022–2023 using plastic pots with a capacity of 2.5 kg, at the Suq-Al-Shuyoukh District, Thi-Qar Governorate, Iraq (longitude 46.26° E and latitude 31.05° N). The study aimed to assess the effects of using rice husk ashes to treat the quality of non-fresh irrigation water on the growth and productivity of the wheat cultivar Al-Rashid. Using the randomized complete block design with split-plot arrangement had two factors and three replications. The main plots contained the first factor of irrigation water quality (W), such as river water 2.1 dSm^{-1} (W1), city sewage water 6.4 dSm^{-1} (W2), and drainage water 12.3 dSm^{-1} (W3). Meanwhile, the subplots contained the second factor, comprising the ashes of rice husks (T) calcined at temperatures of 1000 °C (T1), 800 °C (T2), 600 °C (T3), and 400 °C (T4).

The duration for burning the rice husks was three hours, mixing the ash with the soil prepared for packing in plastic pots (2.5 kg with a diameter of 30 cm) with a mixing ratio of 10 t ha^{-1} soil (Al-Halfy *et al.,* 2021**)**. On November 14, 2022, wheat cultivar Al-Rasheed grains, planted in pots, had the rate of 10 grains per pot. Fertilization (N: P) followed the fertilizer recommendations prepared by the Ministry of Agriculture, with applications in three growth stages, i.e., tillering, elongation, and booting.

Data recoded and statistical analysis

The data recording ensued on the growth and yield-related traits. The data on plant height, leaf area, and proline content bore estimations according to Bates *et al.* (1973). Noting the data on the tillers per plant, grains per spike, 1000-grain weight, and grain yield also took place. All the recorded data incurred analysis according to the analysis of variance (ANOVA) as per the RCBD scheme (Steel and Torrie, 1980). The least significant difference ($LSD_{0.05}$) test helped compare and further separate the means. The study used the computer software GenStat12 for all the statistical analyses.

RESULTS

Plant height

The results showed a significant effect of burning levels of the rice husk ashes, the irrigation water types, and their interaction on the plant height in wheat (Table 1). The treatment of burned rice husk ash at 1000 °C (T1) revealed the tallest average of plant height (113.67 cm), while the ash treatment of the burned rice husks at 400 °C (T4) displayed the shortest plant height average (101.78 cm). The river water 2.1 dSm^{-1} (W1) exceeded by giving the highest average for the said trait (118.42 cm). However, the drainage water of 12.3 dSm^{-1} (W3) gave the lowest average of plant height (97.25 cm). The interaction between W1 and T1 showed the supreme average value for this trait (129.00 cm), while the interaction between the treatments W3 and T3 gave the least (95.33 cm).

Leaf area

The outcomes exhibited significant effects of the studied factors and their interactions on wheat's leaf area (Table 2). The burned rice husk ash (T1) exceeded by giving the broadest average for leaf area (62.86 cm^2), which did not differ significantly from another treatment (T2), which gave 60.22 cm^2. Conversely, the burned rice husk ash (T4) provided the narrowest average for the said trait (54.33 cm^2). The irrigation water type (W1) excelled by giving the widest average leaf area (63.66 cm^2), which did not differ significantly from another treatment (W2). It gave the leaf area of 58.87 cm^2, while the irrigation water type (W3) showed the lowest average (53.83 cm^2). The interaction between the treatments W1 and T1 gave the maximum average of leaf area (66.77 cm^2), and the interaction between the treatments W3 and T4 had the lowest average for the said trait (48.37 cm^2).

Proline content

The burned rice husk ash (T4) showed superiority by giving the highest average of proline content (5.686 mg L^{-1}), which did not differ significantly from two other burned rice husk ash treatments (T3 and T2). They gave values of 5.250 and 5.120 mg L^{-1}, respectively (Table 3). However, the burned rice husks (T1) revealed the lowest average of proline content (4.793 mg L^{-1}) in wheat. On irrigation water, the type W3 exceeded by giving the topmost average (6.964 mg L^{-1}), whereas the irrigation water type W1 gave the lowermost average (3.473 mg L^{-1}). The interaction between the two treatments W3 and T4 provided the maximum average of proline content (7.490

Table 1. Effect of rice husk ashes and irrigation water types on the plant height in wheat.

Irrigation types	Rice husk ashes				Means (cm)
	T1	T2	T3	T4	
W1	129.00	118.00	116.00	110.67	118.42
W2	111.00	110.00	105.67	99.00	106.42
W3	101.00	97.00	95.33	95.67	97.25
Means (cm)	113.67	108.33	105.67	101.78	

$LSD_{0.05}$ Irrigation: 0.886, Rice husk ashes: 0.713, Irrigation x Rice husk ashes: 1.251

Table 2. Effect of rice husk ashes and irrigation water types on the leaf area in wheat.

Irrigation types	Rice husk ashes				Means (cm^2)
	T1	T2	T3	T4	
W1	66.77	64.19	62.38	61.29	63.66
W2	65.20	60.90	56.03	53.34	58.87
W3	56.62	55.58	54.75	48.37	53.83
Means (cm^2)	62.86	60.22	57.72	54.33	

$LSD_{0.05}$ Irrigation: 8.013, Rice husk ashes: 4.702, Irrigation x Rice husk ashes: 9.398

Table 3. Effect of rice husk ashes and irrigation water types on the proline content in wheat.

Irrigation types	Rice husk ashes				Means (mg L^{-1})
	T1	T2	T3	T4	
W1	2.943	3.660	3.370	3.920	3.473
W2	4.960	5.040	5.150	5.647	5.199
W3	6.477	6.660	7.230	7.490	6.964
Means (mg L^{-1})	4.793	5.120	5.250	5.686	

$LSD_{0.05}$ Irrigation: 0.278, Rice husk ashes: 0.193, Irrigation x Rice husk ashes: 0.357

mg L^{-1}), but the interaction between the treatments W1 and T1 disclosed the minimum average for the said trait in wheat (2.943 mg L^{-1}).

Tillers per plant

The burned rice husk ashes, irrigation water types, and their interaction revealed a notable effect on the tillers per plant in wheat (Table 4). The burned rice husk ash (T1) exceeded by giving the utmost average of tillers $plant^{-1}$ (9.70), which did not differ substantially from another treatment (T2), which gave 9.45 tillers $plant^{-1}$. However, the burned rice husk ash (T4) demonstrated the lowest average of the said trait (8.33 tillers $plant^{-1}$). The irrigation water type (W1) excelled by resulting in the most average (10.32 tillers $plant^{-1}$), while the irrigation water type (W3) exhibited the least average (7.70 tillers $plant^{-1}$). The interaction between the treatments W1 and T1 gave the highest average (11.06 tillers $plant^{-1}$), while the interaction between the treatments W3 and T4 indicated the fewest number for the said trait (6.36 tillers $plant^{-1}$).

Grains per spike

For grains per spike, the burned rice husk ashes, irrigation water types, and their interactions revealed remarkable variations in wheat (Table 5). The burned rice husk ash (T1) exceeded with the most number of grains per spike (65.22 grains $spike^{-1}$). Although it did not differ significantly from two other treatments of burned rice husk ashes (T2 and T3), which provided 64.67 and 62.00 grains $spike^{-1}$, respectively. However, the burned rice husk ash (T4) revealed the fewest average number

Table 4. Effect of rice husk ashes and irrigation water types on the number of tillers in wheat.

Irrigation types	Rice husk ashes				Means (tillers plant^{-1})
	T1	T2	T3	T4	
W1	11.06	10.65	9.79	9.77	10.32
W2	9.27	9.52	8.95	8.87	9.16
W3	8.85	8.18	7.42	6.36	7.70
Means (tillers plant^{-1})	9.73	9.45	8.72	8.33	
$LSD_{0.05}$ Irrigation: 0.774, Rice husk ashes: 0.897, Irrigation x Rice husk ashes: 1.448					

Table 5. Effect of rice husk ashes and irrigation water types on the number of grains per spike in wheat.

Irrigation types	Rice husk ashes				Means (grains spike^{-1})
	T1	T2	T3	T4	
W1	74.33	73.33	71.33	67.33	71.58
W2	62.67	62.33	61.67	57.67	61.08
W3	58.67	58.33	53.00	46.33	54.08
Means (grains spike^{-1})	65.22	64.67	62.00	57.11	
$LSD_{0.05}$ Irrigation: 11.71, Rice husk ashes: 5.16, Irrigation x Rice husk ashes: 12.32					

of grains per spike (57.11). For the irrigation water, type W1 was exceeding with the topmost average number of grains per spike (71.58), which did not differ significantly from another irrigation water type treatment (W2), disclosing 61.08 grains spike^{-1}. The irrigation water type W3 showed the lowest average of 54.08 grains spike^{-1}. The interaction between the treatments W1 and T1 exhibited the highest average of 74.33 grains spike^{-1}, while the interaction between the two factors W3 and T4 gave the least average (46.33 grains spike^{-1}).

1000-grain weight

The results indicated a significant effect of the burned rice husk ashes and irrigation water types and their interactions on the wheat's 1000-grain weight (Table 6). The burned rice husk ash (T4) excelled by displaying the 1000-grain weight maximum average (42.29 g), which did not vary considerably from two other treatments of burned rice husk ashes (T3 and T2). These provided the average values of 41.96 and 41.47 g, respectively. However, the burned rice husk ash (T1) gave the minimum average for the said trait (40.88 g). The irrigation water type (W3) also exceeded by giving the highest average of 44.38 g, while the irrigation water type (W1) provided the 1000-grain weight the lowest average (39.20 g). The interaction between two treatments W3 and T4 outperformed by delivering the optimum average (45.57 g), while the interaction between the treatments W1 and T1 had the lowest average for the said trait (38.37 g).

Grain yield

The burned rice husk ashes and irrigation water types and their interactions revealed considerable variations for grain yield in wheat (Table 7). The burned rice husk ash (T1) was leading with the high grain yield (7.438 t ha^{-1}), while the burned rice husk ash (T4) showed a low average value, amounting to 6.700 t ha^{-1}. The irrigation water type W1 showed superiority by giving the highest grain yield (7.967 t ha^{-1}), and the irrigation water type W3 granted a low average grain yield (6.389 t ha^{-1}). The interaction between the two factors W1 and T1 was superior by displaying the maximum mean yield of 8.212 t ha^{-1}, but the interaction between W3 and T4 showed the minimum grain yield (5.699 t ha^{-1}).

Table 6. Effect of rice husk ashes and irrigation water types on the weight of 1000 grain in wheat.

Irrigation types	Rice husk ashes				Means (g)
	T1	T2	T3	T4	
W1	38.37	39.20	39.70	39.53	39.20
W2	40.67	41.47	41.53	41.77	41.36
W3	43.60	43.73	44.63	45.57	44.38
Means (g)	40.88	41.47	41.96	42.29	
$LSD_{0.05}$ Irrigation: 2.311, Rice husk ashes: 1.228, Irrigation x Rice husk ashes: 2.593					

Table 7. Effect of rice husk ashes and irrigation water types on total grain yield in wheat.

Irrigation types	Rice husk ashes				Means (t ha^{-1})
	T1	T2	T3	T4	
W1	8.212	8.080	7.960	7.616	7.967
W2	7.372	7.173	6.876	6.786	7.052
W3	6.729	6.620	6.509	5.699	6.389
Means (t ha^{-1})	7.438	7.291	7.115	6.700	
$LSD_{0.05}$ Irrigation: 0.114, Rice husk ashes: 0.089, Irrigation x Rice husk ashes: 0.158					

DISCUSSION

The burning of rice husks at high temperatures (400–1000 °C) leads to the production of ashes containing a high percentage of pure silica, which reaches more than 95%, and the formation of micropores and a high surface area (Ugheoke and Mamat, 2012). The surface area of rice husk ash depends on silica oxides, and therefore, the nanopores improve the physical, chemical, and biological properties of the soil, which directly affects the crops' yield (Bittelli *et al.,* 2015; Al-Saidan *et al*.,2019). This also enhances ash efficiency by retaining and holding salts in the soil. In addition, it can retain and increase the moisture content, available nutrients, aeration, improve soil fertility, and increase the activity of microorganisms in the root zone, which further encouraged root growth (Onwuka and Osodeke, 2012). It also reflected in vegetative growth through an increase in plant height, leaf area, and number of tillers (Yasir,2021 c; Virrarreal-Sanchez *et al.,* 2022).

Chemical and physical properties of ashes depend mainly on the burning temperature and period, which affect the porous structure and surface area. The temperature also influences the silica bonds and the physical properties (bulk density, surface area, and number of pores) (Imyim and Prapalimrungsi, 2010). The dominant nutrients in the ashes are potassium, phosphorus, and calcium, and rice husks consist of silica, cellulose, and lignin, and heating them at high temperature breaks down the organic material to obtain silica (Quispe *et al.,* 2017). Adding ashes to the soil causes an increase in the readiness of nutrients in the soil and enhances its fertility, with the ashes working as organic fertilizer. The silica found in the ashes of rice husks has a chief role in increasing the plant's absorption of nutrients and, thus, boosting the growth and productivity of the plant (Kim *et al.,* 2016).

The superiority of the river water may be due to its low salt content compared with the other types of water used in the irrigation. The drainage water may lead to accumulating more salts in the irrigated soil. This could further increase with the city's sewage water in the cultivated soil, which leads to holding water and reducing its readiness. Moreover, increasing salts leads to physiological problems within the plant by raising the osmotic pressure in the soil solution, hindering the entry of water and nutrients into crop plants (Eissa *et al.,* 2019). This disability further elevates the concentration of salts in the used water, causing difficulties of water absorption and nutrients by the roots and affecting the size and number of the root system. The salt content also inhibits enzymatic activity in the growth, expansion, and elongation of cells, inhibiting the activity of some physiological activities, such as building protein and respiration, and, eventually, plant growth and development (Nofal *et al.,* 2019). The irrigation with drainage water may reduce the leaf area, which occurred to changes in the biochemical characteristics to avoid water loss through reducing the size of the cells (Al-Zewany and Al-Semmak, 2017).

By using the drainage water, a considerable increase was evident in the average values of the proline content. Perhaps the reason refers to the fact that proline acts as an osmotic regulator and maintains cell components and stress resistance, resulting from the increased concentration of salts in the used irrigation water. Likewise, it may be due to the non-transformation of amino acids into proteins. The demolition of the protein originally found in the cells, where proline is an essential component, and its accumulation, indicate the plant's sensitivity and tolerance to the elevated salt concentration present in the soil and water (Gupta and Thind, 2017). The irrigation water with an increased salinity level may cause a decrease in vegetative growth traits, including the number of tillers per plant. The salt's accumulation in plants could cause a reduction in photosynthesis, which reduces materials represented during the production of tillers, and the competition becomes greater among the growth traits, and eventually, shows the decline (Kandil *et al.,* 2012).

The superiority of the river water for the number of grains may refer to the lack of salts found in the irrigation water, increasing the availability of moisture and the nutrients transferred to the crop plants. Thus, it provided a greater opportunity to increase the grains per spike compared with the other types of water used in irrigation (Eissa *et al.,* 2019). The negative effect of water quality (river water < city sewage < drainage water) on grain yield was evident through increasing the salt concentration. Consequently, it boosted the concentration of salts in the soil, as greatly reflected on the total grain yield of the drainage water versus the river water (Masmoudi and Masmoudi, 2020).

The interaction between the river irrigation water of 2.1 dSm^{-1} (W1) and burned rice husks at 1000 °C (T1) was superior by showing the highest average grain yield, while the interaction between W3 and T4 showed the lowest grain yield. The ashes of burned rice husks can efficiently reduce and retain salts found in the water used for irrigation due to the presence of many voids. These are responsible for the adsorption of salts, as well as the presence of effective aggregates associated with the ions dissolved in the water (Imyim and Prapalimrungsi, 2010; Mohammed and Al-Janabi, 2022; Alsinjari, 2024). This ability's enhancement could occur by increasing the temperature of burning rice husks. The reason may be due to the increased porosity and spongy structure that the ashes possess, which gives them the high ability to hold the largest number of ions within the voids in the spongy structure of silica (Virrarreal-Sanchez *et al.,* 2022). This could also refer to the presence of carboxylic aggregates and silica oxides on ashes' surfaces (the higher the burning temperature of rice husks), which increase the adsorption efficiency and reduce the dissolved salts in the irrigation water (Kim *et al.,* 2016; Afzal *et al.,* 2023).

CONCLUSIONS

The study showed the possible use of rice husk ashes with a burning temperature of 1000 °C to treat the irrigation water (city's sewage water and drainage water). These will resolve the water scarcity problems and achieve the balance between population growth and food production.

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