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Evaluation of Nitrogen Application and Municipal Solid Waste Compost on Wheat Yield in a Calcareous Soil

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Authors
Mohsen Seilsepour, *Ph.D. Student*[1]
Somayeh Moharami, *Ph.D.*[2*]

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[1] Ph.D. Assistant Professor, Greenhouse Cultivation Research Department, Tehran Agricultural and Natural Resources Research and Education Center, AREEO, Varamin, Iran.
[2] Ph.D. Assistant Professor, Department of Environment, Faculty of Natural Resources, Semnan University, Semnan, Iran.

*** Correspondence**
Address: Semnan Province, Mahdishahr, Darband Street, Faculty of Natural Resources, Semnan University, Semnan, Iran.
POX: 35641-11556
Cell Phone Number: 09123028557
Fax Number: 02333626888
Email: s.moharami@semnan.ac.ir

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ABSTRACT

Aims: Achieving sustainable agricultural production, maintaining soil fertility, and reducing environmental hazards are the main challenges to providing food security in countries with growing populations. In the direction of sustainable crop production, this study examined the impact of municipal solid waste (MSW) compost with nitrogen fertilizer (N-fertilizer) on wheat yield.

Materials & Methods: The nine treatments were organized by a randomized complete block design with three replicates. The following were the treatments: N-fertilizer at 0, 100, and 200 kg.ha^{-1} and composting waste at 0, 10, and 20 t.ha^{-1}. At maturity, the components of wheat yield were measured.

Findings: The experiment's results showed that the effect of MSW compost with N-fertilizer and their interaction on grain yield and biological function were significant. The highest 1000-grain weight (40.00 gr) and biomass yield (13833 kg.ha^{-1}) were obtained using 20 t.ha^{-1} of compost with 200 kg.ha^{-1} N (C20N200 treatment) while the highest harvest index (HI) (52.7) and grain yield (7000 kg.ha^{-1}) were in treated soil with 20 t.ha^{-1} of compost and 100 kg.ha^{-1} N (C20N100 treatment). Also, the highest grain protein (11.93 %) was in treated soil with 10 t.ha^{-1} of compost and 200 kg.ha^{-1} N (C10N200 treatment).

Conclusion: The results showed that applying these treatments increases wheat yield, indicating that MSW compost and N-fertilizer can increase plant growth. The main issues with using MSW compost in agricultural soils are the presence of soluble salts and macro-micronutrient buildup. Given Iran's long history of dry and semi-arid climates, keeping an eye on the amount of salt added to the soil due to the application of organic waste is crucial.

Keywords: MSW; N-Fertilizer; Biomass Yield; Calcareous Soil; Grain Protein.

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Introduction

Considering the world's increasing population, researchers are facing the main challenge of using various technologies and means of agricultural production to provide enough food. Agricultural production relies on smart agriculture, mechanization, and chemical fertilizers [1]. Chemical fertilizers are the most common method of increasing crop yield [2]. Nevertheless, overuse of chemical fertilizers results in decreased soil quality, soil acidification, eutrophication of surface water, and a rise in crop pest and disease incidence [3,5]. Due to the lack of organic matter (OM) in the soils, chemical fertilizers are necessary. As a result, applying organic fertilizers in the field is recommended to improve the quality of soil and agricultural products, protect the environment, and reduce the emission of greenhouse gases [6-8]. Unfortunately, a dry climate in Iran, non-rotational crops, collection, burning, and removal of plant residues from agricultural lands have caused less soil OM. Therefore, the application of chemical fertilizers needs to be more balanced and follow the needs of plants, so chemical fertilizers, especially nitrogen fertilizers (N-fertilizer), have been more than 10 % since the 1981s [9]. Among many factors limiting crop yield, N is one of the major ones [10]. Farmers have added large quantities of mineral N-fertilizer to increase crop yield. Therefore, finding a method to reduce this fertilizer's excessive use is necessary. Applying municipal solid waste (MSW) compost as fertilizer can help improve soil physical properties while preserving soil fertility. One of the environmental concerns is the disposal of MSW. MSW composting is a common way for towns to add soil amendments appropriate for farming usage. Using compost in agricultural soils is one waste management strategy that increases the content of organic matter (OM) and adds nutrients like nitrogen (N), phosphorous (P), and sulfur (S) [11, 12]. Many studies have reported that the use of compost has caused an increase, decrease, and no changes in crop yields [13-16]. The different effects of compost on yield and plant growth can be related to the difference in the C-N ratio, nutrient content, and maturity of composts [13]. The use of MSW compost in agriculture is one of the cost-effective ways for disposal of MSW [17, 18]. However, using MSW compost causes the environment to be contaminated with heavy metals. One of the aspects of sustainable agriculture is the combined use of chemical and organic fertilizers so that part of the plant's needs are provided by organic fertilizers such as MSW compost instead of chemical fertilizers. It is an effective way to increase the concentration of nutrients in the soil and crop production, reduce the adverse effects of chemical fertilizers, and increase their efficiency by producing humus [19]. Several studies indicated that adding compost and N-fertilizer could significantly increase grain and biomass production [20, 21]. Hamdi et al. (2002) showed that the application of urban compost with chemical fertilizer (120 kg.ha^{-1}) has caused the best yield of wheat grain [22]. Phullan et al. (2017) concluded that composting with chemical fertilizer increases wheat grain performance and nutrient sorption in areas such as N, P, and K [23].

The most significant cereal and a vital component of both human and animal nutrition and health is wheat, which is grown strategically. Wheat grain is the primary source of energy and protein for many people in the world. Wheat contains various nutrients and vitamins in addition to human nutrition. It is crucial for feeding birds and cattle as well. Iran's most important crop is wheat, cultivated on 7,000,000,000 hectares annually, producing about 14.5 million tons with an average yield hovering around 2.07 t.ha^{-1} [24]. One of the essential actions for food

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security and increasing crop productivity is adding organic and inorganic fertilizers. Therefore, assessing the adequate supply of nutrients for sustainable crop products and soil fertility is essential. Due to the lack of water, soil and water salinity, and poor soil quality, increasing wheat cultivation in Iran is impossible. Therefore, to provide food for the growing population of Iran, it is necessary to increase wheat production per unit area. For this purpose, using organic and chemical fertilizers to improve soil fertility and increase wheat yield is promising. Chemical and organic fertilizers should be applied in tandem since wheat is crucial for ensuring food security. Reducing chemical fertilizer use would help reduce environmental pollution and promote sustainable agriculture.

Numerous nations have investigated the prospect of using compost with N fertilizer and other substances to boost agricultural output [25-27]. Limited studies have been done about the effects of MSW compost with N fertilizer use on wheat productivity in an Iranian land area. In light of the growing

Table 1) Some of the properties of the MSW compost and soil used for experimentation.

	Characteristics	Value	Allowed amount *
MSW compost	EC ($dS.m^{-1}$)[a]	4.60	Maximum 8.00 (in solution, 10% of dry matter)
	pH[a]	7.00	6-8 (in solution, 10% of dry matter)
	Organic carbon (%)	24.1	Minimum 15.0
	Moisture content (% ww)	22.0	Maximum 35.0
	Total N (%)	1.54	1.00-1.50
	Total P (%)	0.390	0.300-3.80
	Total K (%)	0.920	0.500-1.80
	Total Fe ($mg.kg^{-1}$)	8109	-
	Total Zn ($mg.kg^{-1}$)	660	1300
Soil	EC ($dS.m^{-1}$)[a]	1.20	-
	pH	7.80	-
	Saturation percentage	35.0	-
	Organic carbon (%)	0.380	-
	N (%)	0.040	
	Olsen-P ($mg.kg^{-1}$)	6.40	-
	Extractable K ($mg.kg^{-1}$)	200	-
	Clay (%)	24.00	-
	Silt (%)	44.00	-
	Sand (%)	32.00	-

[a] Measured in 1:5 solid, liquid solution.
* National Iranian Standard, No. 10716.

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significance of managing soil health through applying soil additives like compost [13, 14, 28], this study aimed to substitute chemical fertilizers with MSW compost to promote sustainable crop production.

Materials & Methods

Soil and Compost Analysis

For this investigation, composite soil samples were extracted from the 0 to 30 cm layer. After being air dried, the dirt was sieved using a 2-mm screen. The techniques provided by Rowell were used to determine the qualities of the soil [29]. Soil pH and EC were measured in a 1:5 (w/v) soil-to-water ratio. Olsen's bicarbonate extractable Phosphorus (Olsen-P) was determined with a 0.5 mol l^{-1} sodium bicarbonate extraction (pH 8.5). Total P was measured after the digestion of soil samples in a HNO_3–$HClO_4$ mixture [30] and via the ammonium molybdenum-blue method [31]. The exchangeable K was extracted with ammonium acetate (1 *M* NH_4OAc pH 7.0) and was measured by a flame photometer [32]. Organic carbon (OC) was determined based on the Walkley and Black [33] method, while total N with the Kjeldahl procedure [34]. Also, the soil was analyzed for DTPA-extractable Fe and Zn [35]. The test was performed with three replicated. Table 1 shows the properties of the sample soil and MSW compost.

Experiment Design

A field experiment was conducted in loamy soil at the Tehran Agricultural and Natural Resources Research and Education Center (longitude 51° 37′ E and latitude 35° 20′ N) at an altitude of 1050 m above mean sea level. The experiment investigated how different concentrations of MSW compost and N-fertilizer affected wheat. According to the USDA Soil Taxonomy, soil is classified as Typic Haplocambids [36]. Nine treatments were set up in a randomized complete block design with three replicates on individual 6 * 0.8 m plots. The distance between neighboring plots was maintained at 1/5 meters to lessen the potential effects of any water leaks. The treatments included 1) composting waste at levels of 0, 10, and 20 t ha^{-1}, abbreviated as C0, C10, and C20, 2) N-fertilizer at 0, 100, and 200 kg ha^{-1} (i.e., 0, 50, and 100% of the recommended N) according to the soil test abbreviated as N0, N100, and N200, and 3) mixtures of treatments mentioned above, i.e., (1) C0N0 (without MSW compost and N-fertilizer) as control, (2) C0N100 (100 kg.ha^{-1} N-fertilizer), (3) C0N200 (200 kg.ha^{-1} N-fertilizer), (4) C10N0 (10 t.ha^{-1} MSW compost), (5) C10N100 (10 t ha^{-1} MSW compost + 100

Table 3) Analysis of variance of wheat yield and its components.

Source	Degree of freedom	Grain yield (kg.ha^{-1})	Biological yield (kg.ha^{-1})	Harvest index	The 1000-grain weight	Number of grains. $spikes^{-1}$	Number of spikes.m^{-2}	Spike length
Replication	2	3401111	970000	463	36.0	274	11444	440
Compost treatment	2	8814444**	19281111**	72.7*	93.0*	300**	17935**	1448**
Error	2	155555	797777	7.30	6.30	15.7	135	2.30
N-fertilizer treatment	2	9807777**	34203333**	18.9*	149**	286**	15641**	632**
Interaction of treatments	2	385555*	697777*	7.60 ns	5.80 ns	15.7 ns	940 ns	24.0 ns
Error	12	94629	202407	6.90	5.40	6.30	333	9.70

*Significant at $p<0.05$; **Significant at $p<0.01$; ns =not significant.

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kg ha^{-1} N-fertilizer), (6) C10N200 (10 t.ha^{-1} MSW compost + 200 kg.ha^{-1} N-fertilizer), (7) C20N0 (20 t ha^{-1} MSW compost), (8) C20N100 (20 t.ha^{-1} MSW compost + 100 kg.ha^{-1} N-fertilizer), (9) C20N200 (20 t.ha^{-1} MSW compost + 200 kg.ha^{-1} N-fertilizer). In each compost treatment consumed, the amount of N released from the compost, assuming that 10% of total nitrogen was mineralized [37], was calculated and deducted from the recommended N content (Table 2). Urea, triple superphosphate (TSP), and potassium sulfate were the sources of the N, P, and K, respectively (100 kg.ha^{-1} P_2O_5 and 100 kg.ha^{-1} K_2O). Based on the soil test, the micro-nutrients, including Fe, Zn, and B, were used from iron sulfate, zinc sulfate, and boric acid, respectively, with a concentration of five parts per thousand in two stages of stemming and tillering. The compost was made at the Tehran Municipal Recovery Organization's composting plant and combined with the disk at a soil depth of 15 cm. In this experiment, the cultivated crop included wheat (*Triticum aestivum*). Wheat was cultivated as a winter crop on November 11, 2018, and harvested on July 10, 2019. All recommended agronomic practices, such as irrigation timing, fertilization, sowing, eradication of weeds, and harvesting, were adopted according to the standard crop requirements.

Table 2) Amount of mineralized N from the MSW compost.

Treatments	Total N (kg.ha^{-1})	Mineralized N content (kg.ha^{-1})
C0	0.000	0.000
C10	154	15.4
C20	308	30.8

Crop Sampling

Wheat crops were taken at different treatments. Samples were then weighted to determine their dry biomass weights after being dried for 48 hours at 75 ^{0}C. At maturity, wheat yield and its constituent parts were measured. The harvest index was obtained according to the following equation [38]:

$$Grain\ yield\ (kg.ha^{-1})/Biomass\ (kg.ha^{-1}) \quad \text{Eq. (1)}$$

Statistical Analysis

To compare the means based on homogeneous sets of data, one-way analysis of variance (ANOVA) and Duncan's multiple range tests ($p \leq 0.05$) were employed. MSTATC 4.0 software was used for all statistical analyses.

Findings & Discussion

Grain Yield, Biomass Yield, The 1000-grain Weight and Harvest Index

To achieve optimal crop yield, plants must have adequate and balanced nutrients. However, due to improper soil management and low soil fertility, soils could be more favorable. For this purpose, farmers usually recommend the use of chemical fertilizers. However, due to high prices, farmers cannot provide the recommended rates [39]. When chemical fertilizer and compost are applied together, nutrients are used more efficiently and readily for plant uptake [40]. Table 3 shows the analysis of variance results for wheat yields in different treatments. The findings demonstrate that, at the 1% level, the effects of MSW compost and N application on grain production and biomass yield were substantial. Also, the interaction of compost and N-fertilizer on grain yield and biomass yield is significant at a 5% level (Table 3). Compared with the control, an increment of 45.0 and 49.0% of grain yield was noted when 20 and 200 t.ha^{-1} of compost and N were applied, respectively (Figure 1A). The interaction of MSW compost with N-fertilizer is also significant. So, at all levels of using MSW compost, N showed increases in the grain yield; however, at 20 t.ha^{-1} of compost, there is no statistically significant difference between levels of N100 and N200. The results of this study are consistent with similar studies of other researchers who stated that MSW compost application and N fertilizer substantially surge wheat grain yield. Kabato et al. (2022) showed that using compost and NP fertilizers together

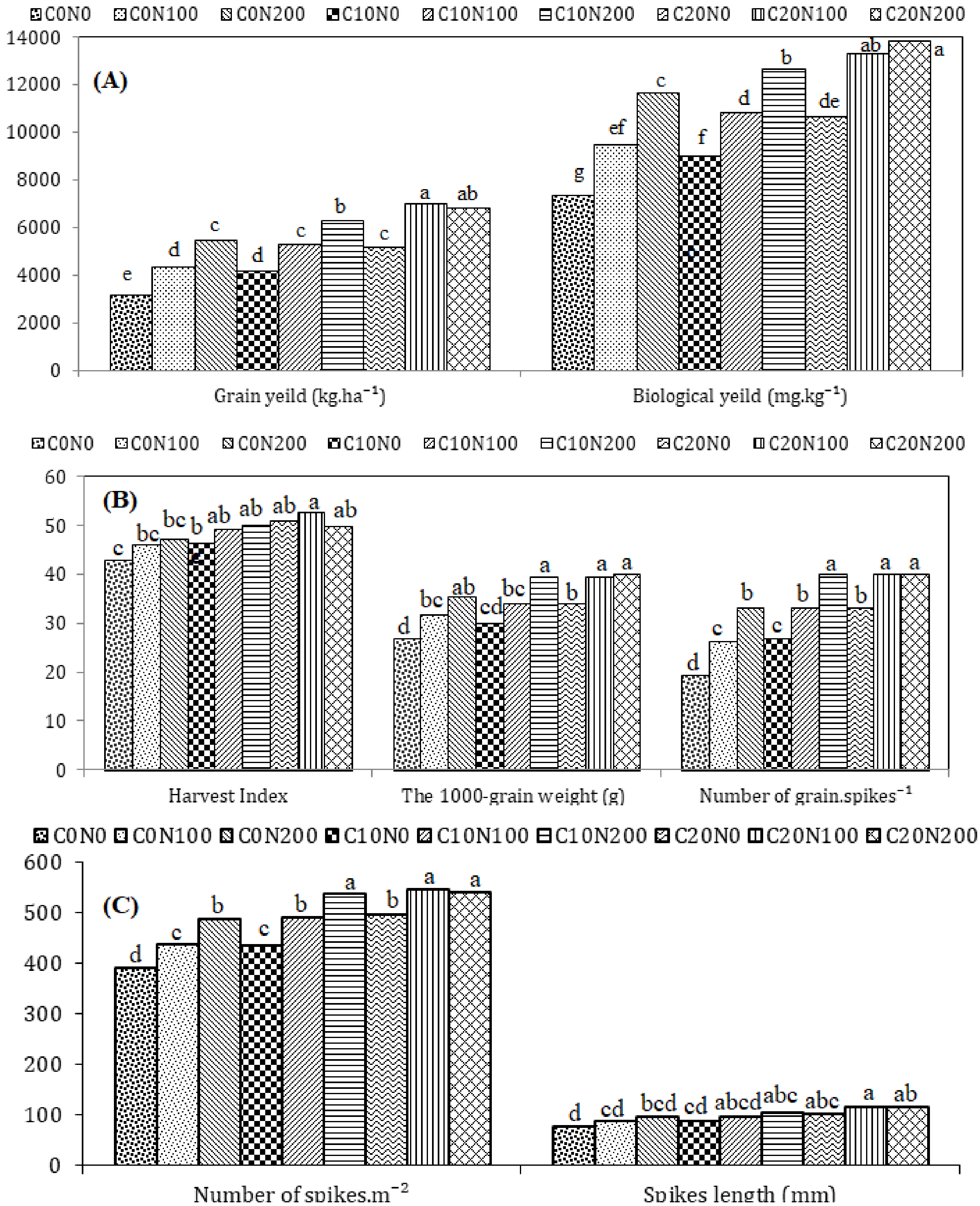

Figure 1) Effect of MSW compost and N-fertilizer on wheat yield. Means with the same letter are not significantly different at p<0.05.

significantly and positively impacted wheat grain production [39]. Calderon et al. (2018) investigated the effects of compost input on dryland wheat and indicated that beef feedlot compost effectively improves wheat grain quality [41]. Cherif et al. (2009) found that wheat grain yields are considerably surged by adding farmyard manure, MSW compost, and chemical fertilizers to the soil [27]. Hamdi et al. (2002) presented that the application of urban compost together with chemical fertilizer (120 t.ha^{-1}) has increased the wheat grain yield [22]. Shiralipour et al. (1992) stated that the employment of composts with fertilizing management programs produced the highest yields of vegetables [42].

The data indicated that the highest biological yield was related to the C20N200 treatment (13833 Kg), a significant difference at the 1% level with the control treatment. The findings presented that consumption of compost and N increased the yield of Biomass (Figure 1A). No statistically significant difference exists between N100 and N200 at 20 t.ha^{-1} of compost. Hu and Qib (2013)

Table 4) Analysis of variance of wheat grain qualitative characteristics

Source	Degree of freedom	Protein (%)	Concentration of Fe (mg.kg^{-1})	Concentration of Zn (mg.kg^{-1})
Replication	2	0.500	9.20	20.4
Compost treatment	2	3.80**	998**	768**
Error	4	0.900	1.50	16.9
N-fertilizer treatment	2	4.00**	3.20 ns	4.40 ns
Interaction of treatments	4	0.500 ns	1.70 ns	3.10 ns
Error	12	0.40	1.10	2.90

*Significant at $p<0.05$; **Significant at $p<0.01$; ns =not significant.

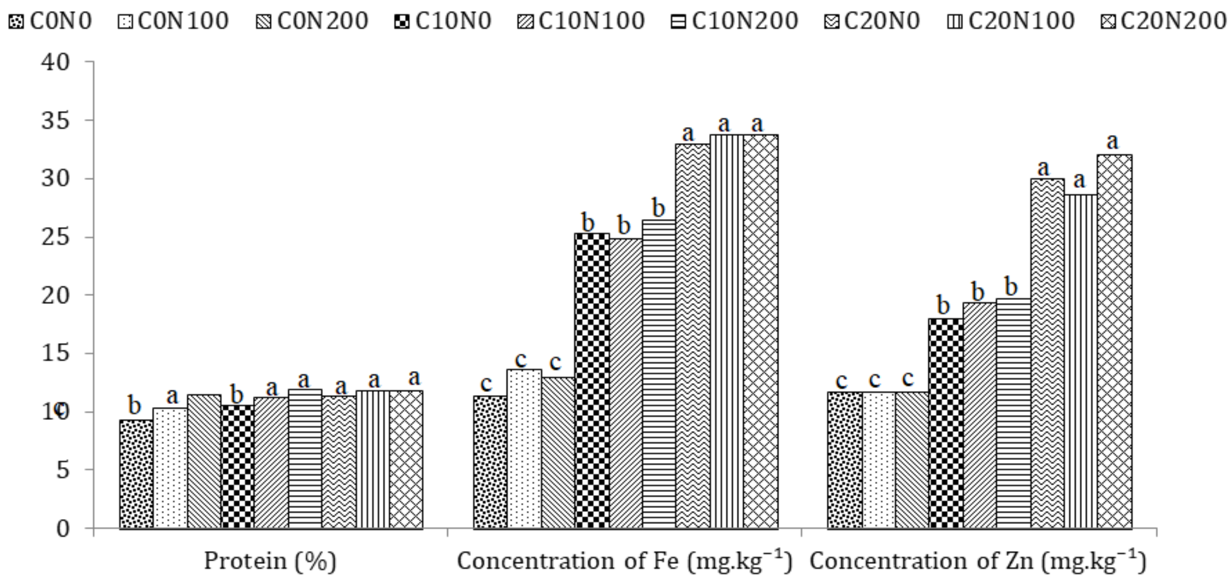

Figure 2) Effect of MSW compost and N-fertilizer on some quality characteristics of wheat grain. Means with the same letter are not significantly different at $p<0.05$.

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demonstrated that, as compared to the usage of compost without EM and the control, the application of effective microorganisms (EM) significantly boosted the production of biomass and wheat grain [43]. Aredehey and Berhe (2016) obtained the opposite results. Therefore, the MSW compost is one of the potential fertilizer sources that can improve crop yield [26].

Figure 1 shows that the highest 1000-grain weight was found for the C20N200 treatment (40.0 g), whereas the lowest 1000-grain weight was recorded for control. The application of fertilizers significantly impacted the 1000-grain weight of wheat [44-46]. The weight of 1000 grains increased with compost consumption and N-fertilizer compared with the control 20.4 and 26.7%, respectively. The field study findings present that the maximum yield of wheat and its components are obtained from combined compost and 100 $kg.ha^{-1}$ N. Wheat's 1000-grain weight was significantly impacted by fertilizer treatment [44–46]. When mineral fertilizers were used in addition to organic materials, wheat's 1000-grain weight increased considerably [47,48].

The harvest index significantly increased with compost consumption and N-fertilizer compared to the control, 11.8 and 4.90%, respectively. For wheat surveyed in different treatments, the harvest index ranged from 43.0 to 52.7 (Figure 1B). The highest harvest index was obtained from the C20N100 treatment (Figure 1B).

Number of Spikes.m^{-2}, Number of Grain. $Spikes^{-1}$ and Spike Length

The number of spikes.m^{-2} of wheat was significantly increased by applying MSW compost and N-fertilizer ($P< 0.01$). The highest number of spikes.m^{-2} of crops was recorded in the C20N100 treatment and the minimum in control. The result shows that by increasing N alone, we will see an increase in the number of spikes.m^{-2} in the limited range. However, suppose a combination of N-fertilizer and compost are supplied to the plant to treat C20N100. In that case, we see a significant increase (28.7%), indicating compost's positive effect on the number of spikes.m^{-2} and the appropriate replacement for chemical fertilizers. The use of organic compost, while increasing soil fertility in the long-term, causes the solubility of the elements and better sorption of the plant. Baethgen et al. (1995) showed that the number of spikes.m^{-2} of malting barley increased with N fertilizer application in all years [10]. All treatments have increased the length of the wheat spike (Figure 1C). Abate et al. (2017) reported that wheat height increased compared to the control treatment due to the application of MSW compost alone or in combination with N-fertilizer [49].

Characteristics of Wheat Grain

The results of different treatment effects on yield components of wheat are summarized in Table 4. Our findings show that applying compost and N-fertilizer significantly increased grain protein percentage compared with control 12.6 and 13.1%, respectively. Nitrogen has a crucial role in protein synthesis. The highest protein percentage of grain was obtained from the C20N100 treatment (11.8%). At this level of compost application, the higher consumption of N-fertilizer did not significantly affect protein content (Figure 2). Ashfaq et al. (2022) stated that N increases the quality of plants by increasing protein production in plants [50]. The main factor in wheat's end-use is wheat's protein [41]. The soil fertility, agronomical practices, drought stresses, and heat factors significantly affect wheat protein content [45,46, 51].

Compared to control soil, amended soil with compost can increase wheat grain protein by more than 14% [52]. The optimal iron and zinc concentration in wheat grain has been reported between 40 to 70 and 30 to 50, respectively [53]. According to the obtained

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results, Fe and Zn deficiency in wheat grain was observed in all treatments. Nevertheless, the mean comparison demonstrated a considerable difference between the control treatment and applying fertilizer and compost. Since MSW compost increased the grain Zn and Fe concentration, grain Zn and Fe content increased. Our results show that using these treatments is an effective strategy to enhance the content of these nutrients (Figure 2). One of the primary sources of zinc for the human body is wheat. The increase in plant Fe uptake using MSW compost may be due to the production of chelating agents through the decomposition of MSW compost. These chelating agents facilitate the availability of Fe and other micronutrients for plant uptake. Velu et al. (2014) stated that the Zn content of wheat grain can range from 14.30 to 74.4 $mg.kg^{-1}$ [54]. Ranjkesh (2015) demonstrated that applying N fertilizer increased the impact of MSW compost on wheat plants' uptake of Fe [55].

Conclusion

This study shows that N fertilizer, MSW compost, and their interactions significantly impact wheat quality when considering the effects of N rates and compost on wheat yield components. The combined addition of MSW compost and N-fertilizer is more compatible with MSW compost or N-fertilizer alone. This study's findings presented that applying N-fertilizers alone cannot provide the absolute need for wheat growth. Combining chemical fertilizer and compost, in addition to increasing wheat yield, also saves the cost of mineral fertilizer, similar to results reported in the literature [39] and [56-57]. Among the treatments, C20N100 and C20N200 treatments outscore all other treatments for wheat yield and its components. Therefore, a mixture of 20 $t.ha^{-1}$ of compost is needed for 200 $kg.ha^{-1}$ N and 20 $t.ha^{-1}$ of compost and 100 $kg.ha^{-1}$ N among different mixtures used in this research provided the best conditions for grain yield, the 1000-grain weight, biomass yield, and harvest index, grain protein, respectively. More research should be done in several locations with various climates. In different regions, considering climatic conditions, soil texture, and the source of municipal waste composting, entire recommendations can be made.

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Conflicts of interest: The authors declare that they have no competing interests.
Data availability statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.
Ethical Permission: None declared by Authors

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