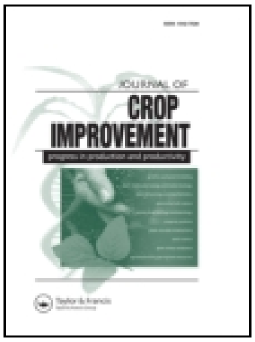

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How Organic and Chemical Nitrogen Fertilizers, Zeolite, and Combinations Influence Wheat Yield and Grain Mineral Content

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How Organic and Chemical Nitrogen Fertilizers, Zeolite, and Combinations Influence Wheat Yield and Grain Mineral Content

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*Nitrate leaching from agricultural soils represents substantial losses of N from fertilizer. Nitrogen leaching in sandy soil decreases fertilizer efficiency and can depress crop production. Materials with high cation-exchange capacity are hypothesized to reduce N leaching and increase N uptake in sandy soils. This randomized complete-block design study evaluated the influence of chemical, organic, and integrated fertilizer treatments and natural zeolite on growth, yield, and grain mineral content of wheat (*Triticum aestivum *L.) grown on sandy soils. Supply of N by urea and composted cattle manure amended with 10% (w/w) zeolite increased wheat growth, yield, and yield components. Similar results were obtained when zeolite was applied directly to soil. The highest grain Zn, Fe, and Mn contents were achieved in plots treated only with organic fertilizers. Chemical plots produced the highest N and protein content. Integrated fertilizer treatments amended with zeolite are an effective and environmentally sound method to improve wheat yield.*

KEYWORDS chemical fertilizer, integrated fertilizer management, manure, wheat, zeolite

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INTRODUCTION

Plowing, application of chemical fertilizers, and monocropping are conventional agricultural activities. The overall result of these activities has been a decline in fertility, an imbalance in soil nutrients, and low crop yields. Most farmers choose to use chemical fertilizers because they are easy to transport, are used efficiently for plant growth, and give high yields. However, it has been observed that the quantity of chemical fertilizer has to be increased with successive crops, apparently because of declining soil fertility. By contrast, organic fertilizers, such as composted manure and green manure, have beneficial effects on soil structure and nutrient availability, help maintain yield and quality of the crop, and are less costly than chemical fertilizers.

Organic matter is an important soil component for improving the physical properties of soil. It achieves this by lowering the bulk density of the soil, increasing water-holding capacity, and improving infiltration rates (Petersen, Drinkwater, & Wagoner 1999). This improvement is essential for sustaining the productivity of soils, particularly in arid and semiarid regions where there is low input of organic matter. Several studies have shown that organic farming improves soil fertility across time (Clark, Horwath, & Shennan 1998; Petersen, Drinkwater, & Wagoner 1999). Residual effects of organic materials on soil properties can improve soil quality for several years after application has ceased (Ginting et al. 2003). The effects of organic matter on the physical properties of soil depend on the amount, type, and size of organic materials added (Nelson & Oades 1998). The availability of organic manure can be increased by making compost from crop residues and composting cattle manure (Thy & Buntha 2005). Application of manure or composted manure increases soil nutrients and organic matter (Eghball 2002). Cattle manure is an organic source of nutrients that has also been shown to increase the level of organic matter in soil and improve soil quality (Wright et al. 1998). It usually needs to be incorporated into the soil to prevent loss of nutrients, particularly nitrogen, through volatilization or runoff.

Nutrient leaching is one of the most important problems in sandy soils that contain little organic matter. It is necessary to add organic matter or other soil amendments to these soils to prevent the loss of nutrients, especially nitrogen. One of the measures, which is considered to be highly effective, biologically justified, and environmentally safe, is the use of zeolites, a family of minerals (Polat et al. 2004). There are several types of zeolites, one of which is clinoptilolite. Clinoptilolite is a hydrated alumosilicate of alkali and alkaline earth metals with an infinite three-dimensional crystal structure, a polyhedric shape, and a large open cavity (Dakovic et al. 2007). Zeolites prevent the unnecessary loss of nutrients from soil and make them available exactly when needed (Podlešáková, Kremer, & Bičovský 1967). They are excellent carriers, stabilizers, and regulators of mineral fertilizers, and are themselves a source of certain nutrients (Bagdasarov et al. 2004). As carriers of nitrogen and potassium fertilizers, they increase the efficacy of these fertilizers by decreasing the application rates required for equal yields to be achieved (Polat et al. 2004). In addition, according to Torii (1978), zeolites improve the growth and development of plants.

Since we are not completely aware of studies into the use of zeolite mixed with cattle manure during composting to mitigate the nitrogen leaching and improve of the productivity of agricultural crops, a study on the application of natural zeolites to improve plant productivity or as a remediation agent in environmental protection is needed. The aim of the present work was to study the effect of chemical, organic, and integrated fertilizers, along with two methods of zeolite application, on the quality and quantity of wheat grown on sandy soil. This experimental study will also provide additional information relevant to the application of zeolite on a large scale to sandy soil.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of the Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran (35°41′ N latitude, 51°19′ E longitude, and an altitude of 1215 m) during 2007. At this site, the yearly average precipitation was 298 mm, and the mean annual temperature was 18.8°C. The average precipitation and temperature (30-year long-term average and during 2007) are displayed in Figure 1. The total open pan evaporation from sowing to maturity was approximately 1,078 mm.

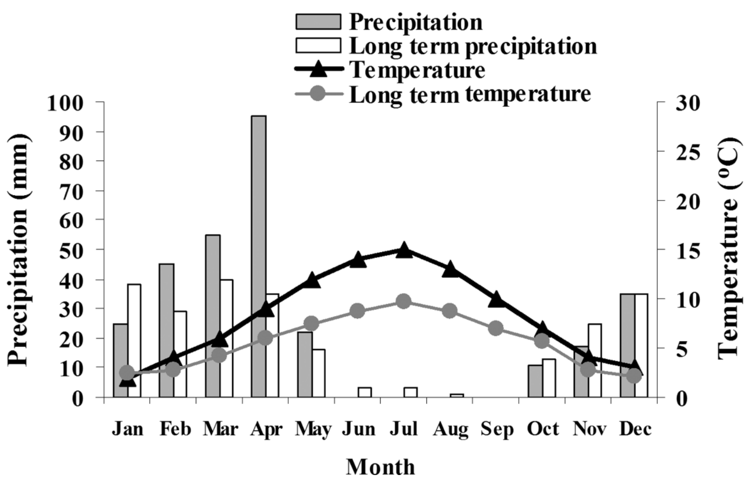

FIGURE 1 Monthly Precipitation and Air Temperature During January–December 2007 and 1978–2007 in Tehran, Iran.

The experimental field was tilled with a moldboard plow and disked in fall. The experimental plots were 3.5 m × 2 m, with 10 rows/plot. A 1-m alley was maintained between all plots to prevent the influence of lateral water movement. The experimental design was a randomized complete block with three replications. After preparation of the seedbed, a composite soil sample at a depth of 30 cm was taken from each plot before the application of treatment. Soil samples were air-dried, ground to pass through a 1-mm sieve, and analyzed for N, P, K, and micronutrients, including Cu, Zn, Fe, Mn, and organic C. Nitrogen was analyzed via the Kjeldahl method using a Kjeltec Auto 1030 Analyzer (Tecator); P was analyzed via the calorimetric method using a Jenway 6505 spectrophotometer (Olsen procedure); and K content was determined with a Jenway PFP7 flame-photometer J after extraction with ammonium acetate. Available Zn, Cu, Fe, and Mn were assayed by the DTPA method of Lindsay and Norvell (1978). In addition, organic C was measured with sulfuric acid using the Walkley and Black method (Walkley & Black 1934). The physical and chemical properties of the soil are shown in Table 1.

Three months before field preparation, cattle manure and zeolite were transported to the study site. The chemical characteristics of the cattle manure and zeolite were analyzed before composting; the results are presented in Tables 2 and 3, respectively. Fresh cattle manure contained 2.75% N.

Two rows of cattle manure were heaped (5 m long, 0.8 m wide, and 0.7 m high) and then zeolite was incorporated into one row, at a ratio

TABLE 1 Physical and Chemical Soil Properties

Physical	Depth	Sand	Silt	Clay	Texture	FC	CEW	AW	B_d	pH
	0–30 cm	69%	20%	11%	Sandy loam	21%	9%	12%	1.45 g cm^{-2}	7.7
Chemical	**Depth**	**CEC**	**OM**	**N**	**P**	**K**	**Fe**	**Cu**	**Zn**	**Mn**
	0–30 cm	4.6 meq $(100\ g)^{-1}$	1.06%	0.07%	>12 ppm	>350 ppm	7.6 mg kg^{-1}	0.7 mg kg^{-1}	1 mg kg^{-1}	15 mg kg^{-1}

FC = field capacity; CEW = crop extractable water; AW = available water; B_d = bulk density; CEC = cation exchange capacity; OM = organic matter; N = total nitrogen; P = absorbable phosphorous; and K = absorbable potassium.

TABLE 2 Properties of Fresh Cattle Manure

EC	N	P	K	Na	OC	OM
21.2 dS m^{-1}	2.75%	0.56%	2.55%	1.22%	28.85%	49.91%
SC	$C.N^{-1}$	pH	Fe	Cu	Zn	Mn
240%	23	9	7435 mg kg^{-1}	25.5 mg kg^{-1}	109.3 mg kg^{-1}	267.6 mg kg^{-1}

EC = electrical conductivity; OC = organic carbon; OM = organic matter; and SC = saturated capacity.

TABLE 3 Percentage of Chemical Compounds in Applied Zeolite

SiO_2	AL_2O_3	K_2O	Na_2O	MgO	CaO
65	12.02	3	1.08	0.1	2.3
Fe_2O_3	MnO	TiO_2	P_2O_5	CEC	SO_3
1.5	0.04	0.03	0.01	200 meq $(100\ g)^{-1}$	–

of zeolite to manure of 1:10 (w/w). To prevent exposure to direct sunshine, the heaps were covered with straw. The temperature and moisture of the heaps were monitored every other day. The rows of manure were composted aerobically for 85 days. At the end of the composting process, the straw was removed and one composite sample from each row was collected and analyzed. Approximately 38% of the N was lost in the row without zeolite, whereas only 22% was lost from the row that contained zeolite during composting. Therefore, the final percentage of N was 2.1% and 1.7% in the rows with and without zeolite, respectively. It has been reported that 35% of N in composted manure is available after the first year after application (Eghball & Power 1999). Thus, the compost in the rows with and without zeolite contained 0.7% and 0.6% available N, respectively. In addition, chemical analysis of the composts showed that 1 kg of compost contained 7.5 g (with zeolite) and 6 g (without zeolite) of N. On the basis of the wheat requirement for N and the N content of the soil, we calculated that 120 kg N ha^{-1} was needed for wheat production. Nitrogen was supplied through urea and the two types of composted cattle manure (with and without zeolite), with the three sources combined in different proportions. Thus, 11.2 and 14 kg of the two types of compost (with and without zeolite, respectively) would be needed in the 7-m^2 plots to fulfill the complete N requirement of wheat (16 and 20 ton ha^{-1}, respectively). On the basis of this, different proportions of the two types of compost can be calculated.

At sowing time, 15 different treatments (Table 4) were randomly assigned to each plot in each replication (Table 4). There were five treatments that included 9 ton ha^{-1} zeolite, namely, T2, T7, T8, T11, and T14. In these treatments, 9 ton ha^{-1} zeolite was broadcast and mixed into the soil before sowing, and then composted cattle manure, urea, or a mixture of these was applied. For treatments that included urea, half of the urea was applied at sowing time and the rest was applied at the jointing stage. According to the results of the soil analysis, there was no need to apply P or K. Wheat seeds (cv Pishtaz) were sown in the middle of November. A sowing rate of 150 kg ha^{-1} was used to maintain a plant population of 4 million plants per hectare. Irrigation was applied as required during the growing season.

In June 2008, 1 m^2 of the crop was harvested completely by hand and agronomic traits were recorded, including plant height, total biomass, ear

TABLE 4 Different Treatments Applied in This Experiment

Chemical	T1: 100% of nitrogen required supplied from urea
	T2: 100% of nitrogen required supplied from urea + 9 ton ha^{-1} zeolite mixed into the soil
Organic	T3: 100% of nitrogen required supplied from composted cattle manure
	T4: 100% of nitrogen required supplied from composted cattle manure amended with 10% (w/w) zeolite
	T5: 70% of nitrogen required supplied from composted cattle manure
	T6: 70% of nitrogen required supplied from composted cattle manure amended with 10% (w/w) zeolite
	T7: 100% of nitrogen required supplied from composted cattle manure + 9 ton ha^{-1} zeolite mixed into the soil
	T8: 70% of nitrogen required supplied from composted cattle manure + 9 ton ha^{-1} zeolite mixed into the soil
Integrated	T9: 50% of nitrogen required supplied from composted cattle manure and 50% from urea
	T10: 50% of nitrogen required supplied from composted cattle manure and 50% from urea amended with 10% (w/w) zeolite
	T11: 50% of nitrogen required supplied from composted cattle manure and 50% from urea + 9 ton ha^{-1} zeolite mixed into the soil
	T12: 70% of nitrogen required supplied from urea and 30% from composted cattle manure
	T13: 70% of nitrogen required supplied from urea and 30% from composted cattle manure amended with 10% (w/w) zeolite
	T14: 70% of nitrogen required supplied from urea and 30% from composted cattle manure + 9 ton ha^{-1} zeolite mixed into the soil
Control	T15: control (without any treatments)

length, number of ears per m^2, number of grains in each ear, weight of 1,000 grains, final grain yield, and harvest index. The grains were separated by a laboratory thrasher, and total biomass was measured by weighing the entire harvested part of the plant.

The N, P, and K contents in the grains were analyzed using the methods described above. Total Zn, Cu, Fe, and Mn were analyzed by digesting the plant samples in a diacid mixture of HNO_3 and $HClO_4$ in a 3:1 ratio. The content of micronutrients in the soil extracts and plant digests was estimated with an atomic absorption spectrophotometer.

Data were subjected to analyses of variance using the generalized linear model (GLM) procedure of SAS for Windows version 9.1 (SAS Inst., Cary, NC). The assumptions relative to the analyses of variance were tested by ensuring that the residuals were random and homogeneous, with a normal distribution about a mean of zero. Duncan's new multiple range test was used to measure statistical differences between treatment methods and controls (Steel & Torrie 1980). In this experiment with 15 treatments, it was possible to construct 14 orthogonal contrasts to test differences between treatments. We constructed the five most important contrasts with respect to qualitative traits, namely, comparisons between: 1) chemical and organic treatments; 2) chemical and integrated treatments; 3) organic and integrated treatments; 4) with and without the addition of zeolite; and 5) method of zeolite application into the compost or into the soil.

RESULTS

Plant growth, number of ears per m^2, and number of grains in each ear were affected significantly by the different treatments (Table 5). The treatments also affected Zn, Fe, Mn, N, and K content and grain protein significantly (Table 6).

Comparison of means among treatments showed that the highest plant growth, yield, and yield components were observed in plots fertilized with integrated chemical and organic treatments. In addition, control plots (no fertilizer) had lower values for agronomic traits than the fertilized plots (Table 7). However, in some cases, the differences were not significant. In contrast, the highest mineral content in grains was achieved in plots fertilized by either chemical or organic treatments (Table 8). The application of zeolite had a significant effect on agronomic traits, especially in those plots in which 50% of the N requirement was supplied by composted cattle manure and 50% by urea (Table 7). It was noticeable that these traits benefited more when zeolite was applied during the composting of manure than when it was applied directly to the soil. Zeolite application increased the Mn, K, and Fe content as compared with no application of zeolite. These

TABLE 5 Effect of Different Types of Nutrition Management on Some Agronomic Traits of Wheat

SOV	d.f.	Plant height	Total biomass	Ear length	Number of ears per m^2	Number of grain in ear	1000 grains weight	Final yield	Harvest index
Block	2	*	ns	ns	ns	ns	ns	*	ns
Treatment	14	**	**	**	**	**	ns	**	ns
Error	28	9.47	5806.04	1.12	7869.65	10.10	1.12	1730.75	79.68
CV		5.94	12.07	14.65	15.79	14.25	14.65	16.06	21.54

*, ** = significant at the 0.05 and 0.01 probability levels, respectively; ns = not significant.

TABLE 6 Effect of Different Types of Nutrition Management on Content of Micro and Macro Elements and Grain Protein

SOV	d.f.	Cu	Zn	Fe	Mn	N	P	K	Protein
Block	2	**	**	**	**	**	**	**	**
Treatment	14	ns	**	**	**	**	ns	**	**
Error	28	0.00	0.84	0.56	0.15	0.00	0.00	0.00	0.07
CV		13.51	3.43	2.53	1.36	2.29	19.45	1.54	2.29

*, ** = significant at the 0.05 and 0.01 probability levels, respectively; ns = not significant.

TABLE 7 Comparison of Means of Some Agronomic Traits of Wheat Affected by Different Types of Nutrition Management

Treatments		Plant height (cm)	Total biomass (g)	Ear Length (cm)	Number of ears per m^2	Number of grains per ear	Weight of 1000 grains (g)	Final Yield (kg ha^{-1})	Harvest index (%)
Chemical management	T_1	50.83cd	616.67def	7.33bcd	542.22cd	21.49d	32.7a	2566.7bcde	43.09a
	T_2	50.90cd	653.33cde	6.76cd	560.00bcd	20.64d	34.1a	2659.0bcd	40.59a
Organic management	T_3	48.23cd	535.00defg	6.16cd	466.67cd	20.66d	38.2a	2367.7cde	44.31a
	T_4	50.40cd	580.00def	6.86cd	537.78cd	20.54d	36.7a	2433.3bcde	41.97a
	T_5	48.28cd	490.00fg	5.53d	411.11de	17.02de	33.0a	1800.0ef	36.66a
	T_6	48.05cd	513.33efg	5.73d	464.44cd	20.06d	32.0a	2366.7cde	48.03a
	T_7	49.06cd	573.33def	7.23bcd	500.00cd	20.68d	34.5a	2433.3bcde	42.61a
	T_8	46.86d	506.67fg	6.33cd	422.22cd	17.60de	33.2a	2233.3de	43.94a
Integrated management	T_9	53.08bc	680.00bcd	7.31bcd	591.11bc	23.19bcd	31.1a	2766.7bcd	40.32a
	T_{10}	61.89a	832.33a	10.00a	801.90a	30.33a	29.1a	3666.7a	39.44a
	T_{11}	61.30a	828.67a	10.00a	796.77a	29.16a	30.0a	3190.01b	40.93a
	T_{12}	52.03bcd	675.00bcd	7.01bcd	573.33bcd	22.66cd	33.2a	2733.3bcd	41.12a
	T_{13}	58.63a	797.50ab	9.00ab	764.13a	28.67ab	31.4a	3153.3abc	44.65a
	T_{14}	56.98ab	781.00abc	8.16abc	707.67ab	27.91abc	31.4a	3116.7abc	38.54a
Control	T_{15}	40.55e	405.00g	5.28d	283.11e	13.66e	27.7	1366.7f	35.12a

Values within each column followed by the same letter are not significantly different ($P < 0.05$).

differences were seen when statistical comparisons were made between treatments T3 and T4, T9 and T10, and T12 and T13 (Table 8).

The highest plant heights were obtained under treatments T10, T11, T13, and T14. Although there were no significant differences among these treatments, the maximum plant height was obtained under T10 or T11 (Table 7). In treatments T10 and T11, 50% of the N was supplied by urea, whereas in T13 and T14, 70% of the N was supplied by urea. Thus, the findings indicate that plant height showed no significant response to the increased amount of urea, presumably because more N was lost from the soil when the proportion of N from urea was higher than that from organic matter. The use of integrated treatments was the best means to attain improved plant growth and grain production. This was confirmed when total biomass was measured. Similar results were found when we compared the effect of chemical, organic, and integrated management on yield and yield components. We observed that the integrated treatments, especially T10, T11, T13, and T14, led to significantly greater ear length, number of ears per m^2, number of grains in each ear, and final yield than the chemical, organic, or control treatments (Table 7).

The final yield was improved by adding zeolite to the cattle manure during composting, but direct application of zeolite to the soil led to no increase in yield. An increase in yield was observed with T10 and T11 (Table 7). There was no significant difference among treatments with regard to weight of 1,000 grains and harvest index (Table 7).

The analysis of mineral nutrients demonstrated that the treatments had no significant effect on Cu and P content (Table 8). The highest Zn and Fe contents were achieved with treatments T3, T4, and T7, and there were no significant differences among these treatments. In addition, the plots that were treated with T4 and T7 had significantly higher levels of Mn and K than the other plots (Table 8). Nitrogen content and protein percentage were significantly higher in the chemical-treated plots than in those that received only organic or integrated fertilizer (Table 8).

Zeolite application had no significant effect on the Zn content of the grain, but this was higher in the organic plots (Table 8). By contrast, zeolite had a significant effect on the Fe content of the grain, as shown by comparing T13 with T12 (Table 8). Among the treatments, zeolite only increased the Fe content of the grain. In the organic and integrated groups, the addition of zeolite to the cattle manure during composting increased the Mn content of the grain, but direct application of zeolite into the soil had no such significant effect (Table 8). The K content of the grain was affected significantly by the addition of zeolite to the manure in T4 and T10 as compared with plots that did not receive zeolite (Table 8).

Orthogonal contrasts showed that there were significant differences between the treatments with regard to qualitative grain traits. However, no such differences were detected for Cu and P content (Table 9).

TABLE 8 Comparison of Means of Content of Micro and Macro Elements and Grain Protein Affected by Different Types of Nutrition Management

Treatments		Cu (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	N (%)	P (%)	K (%)	Protein (%)
Chemical management	T_1	0.41a	23.10e	24.90e	27.25f	2.07a	0.40a	0.24h	12.98a
	T_2	0.43a	24.50de	25.40e	27.25f	2.06a	0.43a	0.25gh	12.90a
Organic management	T_3	0.47a	30.95a	35.60a	30.60b	1.80de	0.41a	0.27b	11.30de
	T_4	0.48a	32.30a	36.70a	31.35a	1.82de	0.40a	0.31a	11.40de
	T_5	0.43a	26.20cd	30.20bc	28.40e	1.71f	0.36a	0.26de	10.70f
	T_6	0.45a	26.30c	30.45bc	28.80de	1.77ef	0.42a	0.26de	11.10ef
	T_7	0.46a	31.45a	35.90a	30.70ab	1.84de	0.40a	0.31a	11.50de
	T_8	0.44a	25.70cd	30.05bc	28.30e	1.79de	0.42a	0.26de	11.20de
Integrated management	T_9	0.49a	28.50b	30.85bc	29.20cd	1.84de	0.33a	0.26de	11.50de
	T_{10}	0.41a	28.65b	31.15b	30.55b	1.85cde	0.37a	0.27bc	11.60cde
	T_{11}	0.42a	28.85b	31.05bc	29.65c	1.87bcd	0.40a	0.26cd	11.70bcd
	T_{12}	0.42a	24.50de	26.15de	27.25f	1.87bcd	0.37a	0.25fg	11.70bcd
	T_{13}	0.40a	25.40cd	29.65c	28.30e	1.92bc	0.41a	0.26ef	12.00bc
	T_{14}	0.40a	25.25cd	26.80d	27.40f	1.93b	0.41a	0.26ef	12.10b
Control	T_{15}	0.41a	20.25f	22.10f	23.60g	1.47g	0.41a	0.23i	9.24g

Values within each column followed by the same letter are not significantly different ($P < 0.05$).

TABLE 9 Orthogonal Contrasts to Test Differences Between Treatments on Grain Qualitative Traits

Contrasts	d.f.	Cu	Zn	Fe	Mn	N	P	K	Protein
Chemical versus organic	1	ns	**	**	**	**	ns	**	**
Chemical versus integrated	1	ns	**	**	**	**	ns	**	**
Organic versus integrated	1	ns	**	**	**	**	ns	**	**
With zeolite versus without zeolite	1	ns	ns	**	**	**	ns	**	**
Zeolite applied to the compost versus applied to the soil	1	ns	**	**	**	**	ns	**	**

*, ** = significant at the 0.05 and 0.01 probability levels, respectively; ns = not significant.

DISCUSSION

In organic production systems, soil fertility is controlled by the addition of organic matter, such as cattle manure, vermin-composts, and the zeo-compost used in this study. Fertility with respect to N is maintained through synchronization across space and time of net N mineralization from organic pools of N in the soil and the uptake of inorganic N by plants. The synchronization process depends on the constant renewal of pools of organic N in the soil with biologically available N (Delate & Canbardella 2004). In the present study, total biomass, grain yield, and yield components increased with the application of integrated chemical and organic N fertilizers when zeolite was added to cattle manure or applied to the soil. Lower grain yields in the plots treated only with organic manure might have been associated with the lower amounts of nutrients readily available during the initial years of organic production as nutrient cycling processes change from inorganic N fertilization to organic amendments (Reider, Herdman, & Drinkwater 2000), as well as the slower rates of release of N from organic materials as compared with chemical fertilizers (MacRae, Hill, & Mehuys 1993). Furthermore, on the basis of the physical properties of the soil, it seems that, in those plots that received chemical fertilizer, leaching of N was the most important reason for yield reduction. Statistical analysis to compare the plots that were untreated and treated with zeolite indicated that zeolite was effective at promoting growth and grain yield, especially when it was applied to cattle manure during the composting process. Zeolite has a high cation-exchange capacity, and thus it can improve soil cation-exchange capacity and enhance the availability of elements around roots (Ming & Boettinger 2001). In zeolite, N is bonded to the negative exchange station and is released at a suitable time for absorption by plants, which can lead to an increase in yield. Overall, the increased water retention capacity because of the addition of cattle manure (Adediran et al. 2004) and increased cation-exchange capacity due to the application of zeolite (Shaw & Andrews 2001) enhance total biomass. The best results were in plots treated with integrated chemical and organic fertilizer in combination with zeolite, namely, treatments T10, T11, T13, and T14.

Apart from increasing the humus content of soil, cattle manure has a favorable effect through decreasing the acidity of soil because of the significant proportion of H_2CO_3, which reacts with the soil adsorption complex (Glisic et al. 2009). Thus, the content of Zn, Fe, and Mn increased with organic treatments. In the integrated plots, a decreased ratio of compost to chemical fertilizer led to a decrease in Zn, Fe, and Mn in the grain, whereas zeolite had a significant effect on Fe and Mn content. Increased mineral content was because of the increased availability of cations that resulted from zeolite application.

Reddy, Rao, and Rupa (2000) reported that the application of manure increases the absorption of K. We also found that K content in the grain increased in organic plots. The increase in N and protein content in the grain that resulted from the application of chemical fertilizer was due to the enhancement of free N levels in plant tissues and increased protein synthesis.

Our research showed that the best fertilizer treatments for the production of wheat were an integrated treatment and an organic treatment in which zeolite was combined with cattle manure during composting (T10 and T4). These treatments improved grain yield and quality, respectively. Although our results suggest a beneficial effect of cattle manure mixed with zeolite for wheat seed production, more studies are needed to confirm these findings before any recommendation. In addition, further research during different years and different places will be required.

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