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Original Research

Agronomic traits of forage maize (*Zea mays* L.) as influenced by zeolite application and spraying of nano-fertilizers

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ABSTRACT:

This experiment was conducted at the Islamic Azad University of Sanandaj, Iran. This split plot experiment is based on randomized complete block design with three replications. The main plots consisted of foliar spraying of nano fertilizers which included iron chelate, zinc, potassium and NPK fertilizers and control. The subplots consisted of the soil application of zeolite including 1kg m^{-2}, 500 g m^{-2} and control. Results showed that the plant height improved with fertilizers applications under no application of zeolite. Plant height increased by 12% for Fe, 14% for K, 14% for zinc and 16% for macro elements (NPK) in non zeolite application treatment. The chlorophyll increased with zinc fertilizers applications under no application of zeolite, and it was increased by NPK fertilizer application under the low and high zeolite condition. The protein content increased with zinc fertilizers applications under no and low application of zeolite, and it was increased by NPK and iron fertilizer application under the high zeolite condition. The total biomass was increased with iron and NPK fertilizers applications under no application of zeolite. Total biomass increased by 30% for iron, 31% for potassium, 10% for zinc, 40% for NPK and 15% for control when zeolite application increased from 0 to 1000 g m^{-2}. The highest leaf (5556 kg ha^{-1}) and stem biomass (3851 kg ha^{-1}) was obtained in NPK treatment. Leaf and stem biomass was increased as zeolite levels. The highest leaf (5644 kg ha^{-1}) and stem biomass (3504 kg ha^{-1}) was obtained in 1000 g m^{-2} treatment.

Keywords:

Iron, nano-fertilizer, potassium, zeolite, zinc.

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INTRODUCTION

Forage corn (*Zea mays* L.) has valuable resource of digestible starch, water-soluble carbohydrates and has a low fiber and is produced in many countries worldwide, but production in Iran is reduced due to concerns with water and nutrient deficiency (Shamabadi and Faeznia, 2013). Recently, use of new methods such as using superabsorbent polymers and nano fertilizers has attracted much interest as reasonable farmers for improving yield and growth of crops under water stress conditions. Zeolite is one of the measures considered highly effective, biologically justified and environmentally safe, especially on degraded soils having unfavorable productive traits for forage production (Polat *et al*., 2004).

Zeolite inhibits loss of water and minerals, making them available absolutely when needed (Polat *et al*., 2004). Inclusion of zeolite in fertilizers management for agriculture is essential as besides serving as soil conditioner. The role of zeolite in increased crop yield has been reported by several researchers (Valente *et al*., 1982; Noori *et al*., 2006).

The distinct selectivity of zeolite for cations, such as NH_4^+ and K^+, has also been abused in the preparation of chemical fertilizers that improve the nutrient-retention ability of the soils by promoting a slower release of these elements for uptake by plants.

Figure 1. Growth of *Zea mays* in the field

In addition to use of macro elements (NPK), foliar spraying of microelements such as zinc, copper, magnesium and iron have been shown to be convenient for field use, have a good effectiveness and very rapid plant response (Fernández *et al*., 2013). The nano-forms of these elements are already applied as nano-fertilizers, which can feed plants gradually in a controlled manner, conversely to what occurs in the case of common fertilizers. One of the profits of using nano-forms is that using can be done in smaller amounts than when using common fertilizers. These nano-fertilizers can be more efficient, reducing soil pollution and other environmental risks that may occur when using chemical fertilizers (Davarpanaha *et al*., 2016).

In north western Iran, soils are sandy and with high pH, and therefore they are poor in nutrients and water storage. The aim of this study was to test the effects of zeolite application and nano fertilizers on the agronomic traits of forage maize in an important agricultural area in North Western Iran.

MATERIALS AND METHODS

We conducted experiments at Islamic Azad University of Sanandaj located at the Kurdistan provinces of Iran (35º16′ North, 47º1’ East, 1405 m above sea level). Some of the initial soil physicochemical properties in the surface layer (0-30 cm) were: pH 7.32 (1:2.5 in water), 1.04% organic matter (OM), 8.14 mg kg^{-1} Olsen phosphorus, 312 mg kg^{-1} extractable potassium, 0.617 mg kg^{-1} zinc and 60.3 mg kg^{-1} iron and clay-loam texture (29% sand, 41% clay and 30% silt). We arranged experiments in split plot based on the randomized complete block design with three replications. The main plots were the different kinds of fertilizers including iron chelate, zinc, potassium and NPK fertilizers at the rates of 2g/L and control. The subplots included application of zeolite at 1kg/m^2, 500 g/m^2 and control.

Table 1. ANOVA significance levels for plant height, chlorophyll, forage protein, leaf and stem weight and total biomass affected by foliar application and zeolite application.

Source of Variation	df	Plant height (%)	Leaf chlorophyll	Protein content (%)	Leaf biomass (kg/ha)	Stem biomass (kg/ha)	Total biomass (kg/ha)
Block	2	0.07 ^{ns}	191.8 **	0.52 ^{ns}	1769331.2 ^{ns}	225767.7 ^{ns}	3126882.7 ^{ns}
Foliar application (F)	4	0.10 **	53.7 *	1.91 ^{ns}	3252193.3 *	9412177.3 *	14748387.1 *
Error a	8	0.01	8.08	0.83	1252120.3	2401302.1	3919796.1
Zeolite (Z)	2	0.11 **	25.6 **	2.83 **	4681489.4 **	2964548.9 **	14306723.8 **
F×Z	8	0.01 **	17.08 **	5.40 **	245260.9 ^{ns}	65507.2 ^{ns}	1537802.1 *
Error	20	0.005	3.67	0.10	390188.4	343544.3	652169.7
C.V	-	3.18	4.92	4.52	12.47	18.98	9.97

ns, * and **, are , non-significant and significant at 1 and 5% probability levels, respectively.

Fertilizers were sprayed to leaves at 10 leaves with collars visible and the rest were sprayed at silking stage. The “Bolson” hybrid (FAO 600) was chosen for planting; this cultivar was medium early with high silage yield and wide adaptability. Planting date was April 22, 2015. Main plot size was 5×20 m and spaces between main plots were two meters.

At the R_1 stage, leaf chlorophyll content was measured by using a portable chlorophyll meter (Minolta-SPAD-502 Model) (Figure 1). Plant height was taken at the silking stage by measuring height of five plants from the four inner rows of each subplot. Nitrogen concentrations were measured by using the methods described by Chattha *et al*. (2015). The crude protein was calculated by multiplying of total nitrogen × 6.25. For measuring leaf, stem and total dry matter, the sampling area per plot was 2×3 m, at silking stage the sampling area was cut at the ground level. Samples were oven-dried at 60°C for eight days.

Data collected from our experiment were statistically analyzed by analysis of variance using the general linear model procedure in the Statistical Analysis System (SAS). The UNIVARIATE procedure within SAS was used to examine the residuals for normality and to check for outliers in the data. The means were separated using Fisher’s protected least significance difference (LSD) test at the 95% level of probability.

RESULTS

Plant height, leaf chlorophyll and protein content

The analysis of variance showed that plant height was affected by foliar application (F), zeolite (Z) and foliar application× zeolite interaction (Table 1). Means comparison showed that the plant height improved with fertilizers applications under no application of zeolite, but commonly was unchanged by fertilizer application under the low and high zeolite condition. For example, plant height increased by 12% for iron, 14% for potassium, 14% for zinc and 16% for NPK in non zeolite application treatment (Table 2). In non fertilized treatment (control), the plant height has a greatest increase when zeolite application increased from 0 to 1000 g m^{-2}. Results showed that, plant height increased by 9% for iron, 3% for potassium, 0% for zinc, 10% for NPK and 14% for control when zeolite application increased from 0 to 1000 g m^{-2} (Table 2). Across all zeolite levels, plant height was enhanced with NPK application compared with control. Plant height increased by 16% for no, 12 % for low and 12% in high zeolite treatment (Table 2). Regardless of fertilizers application, plant height was increased as zeolite levels increased.

Leaf chlorophyll was affected by foliar application (F), zeolite (Z) and foliar application× zeolite interaction (Table1). The chlorophyll increased with zinc fertilizers applications under no application of zeolite, and it was increased by NPK fertilizer application under the low and high zeolite condition (Table 2). Regardless

Table 2. Plant height, leaf chlorophyll, protein content and total biomass of forage corn influenced by foliar application × zeolite application.

Zeolite	Plant height (m)						Leaf chlorophyll (spad number)					
	Foliar application						Foliar application					
	Fe	K	Zn	NPK	control	Mean	Fe	K	Zn	NPK	control	Mean
1000	2.45 $^{a A}$	2.36 $^{ab A}$	2.28 $^{a A}$	2.56 $^{a A}$	2.28 $^{a A}$	2.39	43.25 $^{a A}$	39.84 $^{ab AB}$	37.54 $^{a BC}$	43.03 $^{a A}$	36.11 $^{a C}$	39.95
500	2.31 $^{ab A}$	2.47 $^{a A}$	2.35 $^{a A}$	2.40 $^{ab A}$	2.13 $^{ab A}$	2.33	39.14 $^{a ABC}$	41.56 $^{a AB}$	37.74 $^{a BC}$	42.61 $^{a A}$	35.61 $^{a C}$	39.33
0	2.24 $^{b A}$	2.28 $^{b A}$	2.27 $^{a A}$	2.31 $^{b A}$	1.99 $^{b B}$	2.21	39.88 $^{a AB}$	37.42 $^{b AB}$	41.10 $^{a A}$	36.20 $^{b BC}$	32.62 $^{a C}$	37.44
Mean	2.33	2.37	2.30	2.42	2.13		40.76	39.60	38.80	40.61	34.78	
	Protein content (mg/ml)						Total biomass (kg ha^{-1})					
	Fe	K	Zn	NPK	control	Mean	Fe	K	Zn	NPK	control	Mean
1000	9.00 $^{a A}$	7.63 $^{a A}$	5.83 $^{c B}$	8.11 $^{a A}$	7.80 $^{a A}$	7.67	10810 $^{a A}$	9062 $^{a AB}$	7945 $^{a B}$	11404 $^{a A}$	6524 $^{a B}$	9149.2
500	6.55 $^{b B}$	6.54 $^{c B}$	9.54 $^{a A}$	7.10 $^{b B}$	6.77 $^{ab B}$	7.30	8383 $^{b A}$	8404 $^{a A}$	7439 $^{a A}$	8726 $^{ab A}$	6623 $^{a A}$	7915.1
0	6.46 $^{b BC}$	6.99 $^{b B}$	8.68 $^{b A}$	6.01 $^{c C}$	5.90 $^{b C}$	6.81	8296 $^{b A}$	6879 $^{b AB}$	7202 $^{a AB}$	8094 $^{b A}$	5632 $^{a B}$	7221.0
Mean	7.33	7.06	8.02	7.07	6.82		9163.3	8115.4	7529.0	9408.1	6259.7	

Means followed by different letters are statistically different at $P<0.05$ by LSD test (slicing was used). Small letters and capital letters signify differences among zeolite and foliar application treatments, respectively.

of fertilizers application, leaf chlorophyll was increased as zeolite levels increased.

Protein content was affected by zeolite (Z) and foliar application× zeolite interaction (Table1). The protein content increased with zinc fertilizers applications under no and low application of zeolite, and it was increased by NPK and iron fertilizer application under the high zeolite condition (Table 2). Regardless of fertilizers application, protein content was increased as zeolite levels increased. Results showed that, protein content increased by 39% for iron, 9% for K, 34% for NPK and 32% for control and decreased by 32% for zinc when zeolite application increased from 0 to 1000 g m^{-2} (Table 2).

Leaf, stem and total biomass

Leaf, stem and total biomass were affected by zeolite (Z) and foliar application (Z) and total biomass was affected by foliar application× zeolite interaction (Table 1). The total biomass increased with iron and NPK fertilizers applications under no application of zeolite (Table 2). Regardless of fertilizers application, total biomass was increased as zeolite levels increased. Results showed that, total biomass increased by 30% for iron, 31% for potassium, 10% for zinc, 40% for NPK and 15% for control when zeolite application increased from 0 to 1000 g m^{-2} (Table 2). The highest leaf (5556 kg ha^{-1}) and stem biomass (3851 kg ha^{-1}) was obtained in NPK treatment. Leaf and stem biomass was increased as zeolite levels increased. The highest leaf (5644 kg ha^{-1}) and stem biomass (3504 kg ha^{-1}) was obtained in 1000 g m^{-2} treatment (Table 3).

DISCUSSION

Our results showed that foliar and zeolite application treatments had an important role in the growth of plants. So that chlorophyll accumulation in plants leaf affected by foliar application, iron element had an important role in chlorophyll formation and NPK elements increased total biomass. Soleymani *et al*. (2012) con-

Table 3. Leaf and stem biomass of forage corn influenced by foliar and zeolite application.

		Leaf biomass (kg ha^{-1})	Stem biomass (kg ha^{-1})
Foliar application	Fe	5436.4 ^{ab}	3726.9 ^{a}
	K	5101.9 ^{ab}	3013.5 ^{b}
	Zn	4903.8 ^{b}	2625.2 ^{bc}
	NPK	5556.9 ^{a}	3851.3 ^{a}
	control	4038.0 ^{c}	2221.7 ^{c}
Zeolite application	1000	5644.5 ^{a}	3504.8 ^{a}
	500	4776.7 ^{b}	3138.4 ^{a}
	0	4601.1 ^{b}	2620.0 ^{b}

Means followed by different letters are statistically different at $P<0.05$ by LSD test.

cluded that zinc fertilizers increased soluble carbohydrate accumulation very likely due to association of zinc in photosynthesis, chlorophyll synthesis, starch formation and enzyme carbonic anhydrase, accelerating carbohydrate formation and total biomass, so that these results are in consistency with our findings (Prasad *et al*., 2012).

Jin *et al.* (2008) reported that iron has an important role in the synthesis of chlorophyll, photosynthesis improvement and plant growth regulation. Safyan *et al*. (2012) reported that nano iron has the highest concentration of chlorophyll in comparison to the other treatments. In protein content zinc element had an additive role for protein formation that showed an important role in the protein content of plants; Potarzycki and Grzebisz (2009) concluded that among micronutrients, iron and zinc are the most important nutrient and its essential has been demonstrated for corn production, so deficiency of iron can reduce seed protein content because of the direct positive effect of iron on protein synthesis (Cakmak, 2008).The plant height was affected by NPK foliar application treatments so that NPK elements had an increasing effect on plant height. According to the findings of Prasad *et al*. (2012) concluded that nano nitrogen fertilizers increased the plant height of peanut as compared with chemical nitrogen fertilizer. The positive effects of foliar spray of iron and NPK on dry matter and plant height as observed in the present study have also been reported in different studies for rice, safflower, chickpea and soybean (Rameshaiah *et al*., 2015). The observed increase of plant height in priming treatments may be due to the improved foundation of seedling, minimization of time between seed planting and emergence and the synchronization of emergence, and promoted use of nutrient and soil moisture (Valadkhan *et al*., 2015). Recent studies reported that nanoparticles can enter through stomata or the base of trichomes in leaves (Uzu *et al*. 2010). These findings are in agreement with our results showing that spraying nano-fertilizers caused significant difference in traits. However, the exact mechanism of nanoparticle uptake by plants is yet to be elucidated.

Leaf biomass affected by iron element accumulation so that with increase of iron element in plants, leaf dry weight was increased and the stem dry weight was also affected by NPK elements. All traits affected by zeolite application treatment showed the importance of its application which ultimately can increase a soil's water holding capacity. Mao *et al.* (2011) reported that materials such as zeolite, superabsorbent polymer, and crop residue can increase a soil's water holding capacity as well as its nutrient absorption and release to escape harm caused by stress to the photosynthetic system. So zeolite added to the soil can improve the condition of the soil for maintaining moisture and nutrients, which results in a significant reduction of agricultural costs of water and fertilizer (Polat *et al*., 2004).With application of zeolite total biomass of plants increased showed that the importance of zeolite compound in water accumulation and yield increase. Bernardi *et al.* (2011) concluded that some studies have also reported increased corn and sorghum yields achieved by applying zeolite.

CONCLUSION

Growth and yield of forage corn were affected by nano fertilizers as iron, NPK and zinc application. It appears to be that the use of iron nano and NPK particles causes an increase in biomass and protein content. Eventually, the results showed that nano fertilizers and zeolite application in the future caused improving forage corn growth and yield in field areas. Therefore, these parameters can be used to assess the importance of micro elements in plants. Successively, from effect of crop residue and zeolite on the growth factors of plant, it was clear that the application of these materials would be more suitable for growth and productivity of these crops. In addition, zeolite can support soil moisture and nutrients for several years after its application.

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