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Accumulation of dry matter and nitrogen in the shoots of maize (*Zea mays* L.) and nitrogen leaching as affected by organic and chemical nitrogen fertilizers in Guilan province

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ABSTRACT:

The experiment was carried out during 2014 cropping season as split plot arrangement in a randomized complete block design with three replications of *Zea mays* in agricultural and natural resources research center of Guilan Province, Rasht, Iran. Three maize varieties including 703, 704 and 705 (as main plot) and rates of nitrogen supplementation including N_1= zero (as check), N_2= 100 kg/ha, N_3=200 kg/ha, N_4 =300 kg/ha and N_5= 8500 kg/ha, N_6= 17000 kg/ha and N_7= 25500 kg/ha as vermicompost (as sub plot) comprised the experimental factors. In this experiment, the interaction effects between maize varieties and nitrogen rates showed significant differences for wet and dry weight of leaf and stem, nitrogen content of leaf, stem and corn hear. The results showed that the interaction effects between 705 variety × 300 kg N/ha had the greatest stem dry weight and nitrogen content. But, the greatest leaf dry weight of 704 variety obtained as affected by 25500 kg vermicompost per hectare. In this research, application of 25500 kg vermicompost per hactar caused to increase nitrogen content of leaf in 703 variety, compared to other studied treatments. Basis on the results of this experiment, the interaction effects between 703 variety × 100 kg N/ha, had the greatest nitrogen content of maize hear. Generally, the results showed that leaching of nitrogen increased due to enhance of nitrogen fertilizer utility per unit area. The rate of nitrogen leaching at 100, 200 and 300 kg N/ha treatments was 24, 44.95 and 47.03 percent, respectively. But, the mortality of nitrogen due to use of vermicompost fertilizer was less than chemical nitrogen fertilizer.

Keywords:

Food security, Nitrate Leaching, Nitrate Accumulation, Maize, Nitrogen Fertilizer.

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INTRODUCTION

In many cases, the use of chemical fertilizers has caused environmental pollution and ecological damage, which increases their production costs. Increasing population and demand for garden and agronomy crops is leading to an increase in indiscriminate use of chemical fertilizers and pollution in the world (Cordell, 2009; Adesemoye *et al*., 2009). Also, the most important problems of traditional agriculture are waste and consuming chemical fertilizers, especially nitrogen fertilizers. The loss of large amounts of nitrogen and entering nitrate into groundwater causes pollution and loss of fresh water supplies for humans (Hikam *et al*., 2001). The researchers have found that 40 to 70 percent of nitrogen gas fertilizers leaks into the environment, and investigating ways to reduce the use of chemical fertilizers and reduction of environmental pollution are a serious and undeniable need (Wu *et al*., 1997).

One of the important measures to protect the environment and achieve sustainable development is replacement and reduction of chemical fertilizers or combining them with organic fertilizers (Eghbal *et al*., 1995). In this context, the use of organic manure compost and biofertilizers is considered as an alternative for increasing consumption of fertilizers (Lourduraj and Yadav, 2005).

Previous research has shown that the rate of releasing of nitrogen fertilizers from compost is lower than the chemical fertilizer so that 35 and 20 percent of nitrogen in organic fertilizers will be available to the plant during the first and second years, respectively. Organic matter is considered as a source of nutrients in the soil that will provide enhancing plant growth basis by slow and gradual release of nutrients (Eghbal *et al*., 2001).

The positive effect of vermicompost on the growth of plants such as tomatoes (Hasheminejad *et al*., 2004) have been reported. Moreover, the effect of vermicompost on crops depending on the type of crop, crop systems, features of vermicompost, compost process and age of compost and type of earthworms is differently reported (Zaller, 2007). Also, maize is one of the most important food crops which is as food sources for human consumption and increasingly being used for livestock feed in Iran. Hence, corn crops play major roles in the Iranian agriculture sector. Nitrogen fertilizer is one of the most important factors which influences the morpho-physiological characteristics of plants. Despite the environmental contamination caused by nitrogen fertilizer applying, an increase of available nitrogen has major impact on crops growth and their grain yields. For these reasons, to evaluate corn seed yield, dry matter and nitrogen accumulation in shoots and nitrogen leaching as affected by organic and chemical fertilizers of nitrogen in maize an experiment was conducted in 2014 at Guilan Agricultural and Natural Resources Research and Education Center.

MATERIALS AND METHODS

In order to evaluate dry matter and nitrogen accumulation in shoots of maize and nitrogen leaching as affected by organic and chemical fertilizers of nitrogen

Figure 1. Photos from field experiment and KSC 704 corn ears, Rasht, Iran.

Table 1. Analysis of variance (mean square) traits in corn varieties affected by different levels of nitrogen

The source changes	Shoot fresh weight (mg)	Leaf fresh weight (mg)	Maize fresh weight with husk (mg)	Shoot dry weight (mg)	Leaf dry weight (mg)	Maize dry weight with husk (mg)	Shoot nitrogen (mg)	Leaf nitrogen (mg)	Maize nitrogen (mg)
Block	90.1053926^{ns}	19.286305^{ns}	40.5707850^{ns}	11.78679^{ns}	44.6407^{ns}	86.1245538*	91.461^{ns}	18.16^{ns}	99.350^{ns}
Genotype	70.66819755**	33.21809422**	06.5358209^{ns}	71.12109464**	63.1046132**	43.121138^{ns}	91.2093^{ns}	30.42^{ns}	36.281^{ns}
Main mistake	70.2745171	17.272364	90.1382291	23.308241	59.54645	9.94904	31.351	12.11	41.121
Nitrogen	60.145766713**	28.7032263**	80.38132007**	90.11959859**	55.164202**	40.25783562**	50.6309**	92.76**	24.1107**
Interaction of genotype and nitrogen	40.7419638**	15.1868923**	30.1752070^{ns}	00.2052504**	71.19124**	00.213291^{ns}	78.627**	11.11*	91.166**
Subsidiary mistake	931853	80.229860	70.993566	271000	52.36810	20.132129	38.129	51.4	90.46
Total	-	-	-	-	-	-	-	-	-
Coefficient of Variation (CV %)	09.6	92.7	36.8	85.10	84.16	32.7	91.14	02.20	98.12

in crop an experiment was conducted in 2014 at the research center for agriculture and natural resources of Guilan located at longitude 49 degrees and 57 minutes and latitude 33 degrees and 39 minutes and a height of five meters above sea level (Figure 1). Before planting, a composite soil samples from a depth of 0-30 cm of three-point field for determining the physical and chemical properties were taken and sent to the laboratory.

The experiment was done in a split plot in a randomized complete block design with three replications. Treatments include maize varieties 703, 704 and 705 (as main plots) and nitrogenous fertilizers containing nitrogen N_1 = no fertilizer (control), N_2 = 200 kg/ha, N_3 = 300 kg/ha, and N_4 = 400 kg/ha and N_5 = 8500 kg/ha, N_6 = 17000 kg/ha and N_7 = 25500 kg/ha vermicompost (as a sub-plots), respectively. In this study, three hybrid varieties of single cross maize Ksc703, Ksc704 and Ksc705 were received from the Seed and Plant Improvement Institute of Iran. The maize varieties were modified and introduced by providing seed and plant improvement institute researchers which had high performance and were premature. Some agronomic characteristics such as plant height, ear height, the depth of grain, grain and biological yield are higher in studied hybrid maizes than other prevalent varieties.

In this experiment, each plot containing four lines with a length of five meter planting. Corn row spacing was 75 cm and the distance between two plants in rows was about 15 cm. All phosphate fertilizer on the basis of 100 kg per hectare was applied before planting and project implementation. As a source of nitrogen urea fertilizer was used in three stages, three to four leaf stages and tassel stage of corn and mechanical and hand weeding control were done.

To get the corn shoot dry weight, 10 plants were taken at random from each plot and the wet weight of leaf; stem and ear of corn with the husks were measured. Then, from each part, a larger sample was prepared and after fresh weight weighing, sample was dried in an oven under the temperature of 75° centigrade for 48 hours and the dry weight separately weighed by a digital scale with an accuracy of 0.001. The difference between fresh and dry weight per plant were calculated from moisture content and then shoot dry weight was obtained by subtracting moisture content. In this study, measuring the nitrogen shoots were performed separately for leaves, stems, corn and maize using Kjeldahl Auto analyzer (Ali -Ehyaie and Behbahanizadeh, 1994). Also, to determine the extent of soil contamination, pollution factor using equation (1) was calculated (Abrahim and Parker, 2008):

Table 2. Comparison of the measured traits in corn cultivars affected by genotype and nitrogen fertilizer interactions (kg/ ha)

Treatment		Shoot fresh weight (mg)	Leaf fresh weight (mg)	Shoot dry weight (mg)	Leaf dry weight (mg)	Shoot nitrogen (mg)	Leaf Nitrogen (mg)	Maize nitrogen with husk (mg)
Variety 703	Zero	67.13312^{f}	67.4106^{e}	00.5419^{cd}	33.780^{c}	00.49^{de}	23.4^{d}	56.34^{d}
	100 kilogram nitrogen	67.15477^{e}	00.4898^{de}	67.4437^{de}	67.977^{bc}	33.57^{d}	67.7^{d}	83.76^{a}
	20 0kilogram nitrogen	00.17289^{d}	33.6240^{c}	00.4281^{de}	00.972^{b}	33.66^{cd}	67.10^{cd}	26.67^{ab}
	300 kilogram nitrogen	67.20577^{bc}	67.6888^{bc}	33.4462^{de}	33.1038^{bc}	00.94^{bc}	23.13^{b}	26.59^{bc}
	5.8 ton vermicompost	33.8881^{h}	00.3582^{e}	67.3287^{ef}	00.714^{c}	33.52^{de}	10.7^{d}	10.38^{d}
	17 ton vermicompost	33.9955^{gh}	e67.4244	67.3080^{ef}	33.821^{bc}	67.65^{cd}	97.8^{cd}	13.58^{b}
	5.25 ton vermocompost	00.12111^{fg}	33.4548^{e}	00.5336c	33.864^{bc}	67.70^{cd}	20.11^{c}	10.59^{b}
Variety 704	Zero	67.14214	00.5763^{cd}	67.4039^{de}	33.1325^{ab}	33.36^{e}	20.8^{cd}	30.37^{d}
	100 kilogram nitrogen	67.19266^{ef}	00.5122^{de}	00.5336^{c}	67.1082^{bc}	00.89^{bc}	56.10^{cd}	87.49^{c}
	200 kilogram nitrogen	33.21447^{b}	67.5503^{d}	67.5470^{cd}	33.1109^{b}	00.97^{bc}	83.11^{bc}	23.57^{b}
	300 kilogram nitrogen	33.23955^{a}	67.6814^{bc}	67.7129^{b}	33.1257^{ab}	67.133^{a}	07.15^{b}	17.70^{ab}
	8.5 ton vermicompost	00.9296^{h}	33.5718^{cd}	00.2922^{f}	33.1271^{ab}	67.61^{cd}	60.9^{cd}	17.47^{cd}
	17 ton vermicompost	00.1611^{de}	33.6583^{bc}	67.3757^{e}	67.1316^{ab}	67.76^{c}	57.11^{bc}	33.54^{bc}
	5.25 ton vermicompost	67.18025^{cd}	00.7881^{ab}	67.4838^{d}	67.1538^{a}	67.79^{c}	5.12^{bc}	33.56^{bc}
Variety 705	zero	00.14385^{ef}	33.5785^{cd}	00.6668^{bc}	67.1246^{ab}	67.49^{de}	30.8^{cd}	03.36^{d}
	100 kilogram nitrogen	67.15617^{e}	33.6329^{c}	67.6069^{c}	00.1453^{a}	33.75^{cd}	53.9^{cd}	77.50^{e}
	200 kilogram nitrogen	33.17144^{de}	33.7255^{b}	00.5438^{cd}	67.1536^{a}	33.94^{bc}	90.11^{bc}	70.57^{bc}
	300 kilogram nitrogen	67.22399^{ab}	00.8333^{a}	67.8049^{a}	33.1440^{a}	33.149^{a}	57.13^{bc}	60.64^{b}
	5.8 ton vermicompost	61.10992^{g}	67.5592^{cd}	00.3868^{e}	33.770^{c}	33.49^{de}	90.6^{d}	80.32^{d}
	17 ton vermicompost	00.14318^{ef}	67.7103^{bc}	33.3131^{ef}	33.892^{bc}	33.53^{de}	67.10^{cd}	67.41^{cd}
	5.25 ton vermicompost	00.18222^{cd}	00.8537^{a}	00.5700^{cd}	67.1506^{a}	33.107^{b}	17.20^{a}	73.58^{bc}

Means in each column and each group with common letters are not significantly different at the 5% level LSD test.

Table 3. Calculating the percentage of nitrogen leaching at different levels of nitrogen fertilizer (urea)

Nitrogen leaching (percent)	Nitrogen loss (kg/ha)	Absorbed nitrogen (kg/ha)	Available nitrogen (kg/ha)	Studied treatments Kg N/ ha
-	87-87 = 0	87	Zero + 87 = 87	N_1 = Zero Kg N/ha
24.06	187-142 = 45	142	100 + 87 = 187	N_2 = 100 Kg N/ha
44.95	287-158 = 129	158	200 + 87 = 287	N_3 = 200 Kg N/ha
47.03	387-205 = 182	205	300 + 87 = 387	N_4 = 300 Kg N/ha

CF= [C] Nitrogen / [C] Background (1)

In this regard, 'CF' is contamination severity, '[C] nitrogen' is amount of nitrogen in experiment field soil at the end of the season, and '[C] background' is amount of nitrogen from soil sample area. After collecting and recording data, data analysis using SAS statistical software for data comparison test Least Significant Difference (LSD) at 5% was performed and excel and word software for drawing graphs were used.

RESULTS

Accumulation of nitrogen in corn shoots

Analysis of variance showed that the interaction of genotype and nitrogen fertilizer on nitrogen storage in shoot was significant (Table 1). In addition, comparison of the interaction between the treatments and nitrogen fertilizer on nitrogen concentration in the shoot showed that the most amount of nitrogen was dedicated to variety 705 and application 300 kg N per hectare that in the same conditions, it did not show any significant difference to the amount of nitrogen accumulation in variety 704 (Table 2).

Accumulation of nitrogen in corn leaves

In this experiment, interaction of genotype and nitrogen fertilizer on nitrogen concentration of leaves was significant. In this study, application of 5.25 tons of vermicompost in variety 703 in compared to the other treatments caused an increase in leaf nitrogen concentration (Table 2).

The accumulation of nitrogen in maize

Based on the results of data analysis, interaction of genotype and nitrogen fertilizer on nitrogen concentration in maize were significant at 1% levels (Table 1). Comparison of interaction between the treatments and nitrogen fertilizer on nitrogen concentration in maize showed that the greatest amount of nitrogen in maize was obtained from variety 703 supplying 100 and 200 kg N per hectare, although, there was no significant difference with 704 variety at 300 kg N per hectare treatment. The results showed that with increase in use of nitrogen from urea resource, shoot dry and fresh weight increased as well as concentration of nitrogen in the tissues and maize.

Table 4. Calculating the percentage of nitrogen leaching at different levels of organic nitrogen fertilizer vermicompost

Leaching (percent)	The difference between available and absorbed nitrogen (kg)	The amount of nitrogen absorbed (kg)	Total amount of nitrogen absorbed (kg)	The amount of available nitrogen vermicompost * (kg)	Studied treatments
13.46	17.2	110.56	40.76+87 = 127.76	8500 kg × 1.37% × 35% = 40.76	N_5 = 8500 Kg N/ha
18.51	31.19	137.33	81.52+87 = 168.52	17000 kg × 1.37% × 35% = 81.52	N_6 = 17000 Kg N/ ha
19.44	40.68	168.59	122.27+87= 209.27	25500 kg × 1.37 % × 35% = 122.27	N_7 = 25500 Kg N/ ha

* The release of nitrogen in the compost in the growing season have been reported as about 35% (Eghbal *et al.,* 2001).

Table 5. Classification of soil pollution levels according to pollution severity (Bhuiyana *et al.*, 2010)

S. No	Pollution degree	The severity of pollution (CF)
1	No pollution	0
2	Average pollution	1
3	Average to sever pollution	2
4	Sever pollution	3
5	Sever to too sever pollution	4
6	Too sever pollution	5

Leaching of nitrogen fertilizer

According to the results of this test, the accumulation and storage of nitrogen in shoot in no treatment (control), 100, 200 and 300 kg N per hectare were 87, 142, 158 and 205 kg per hectare respectively. In this case, if the minimum availability of soil nitrogen in experiment field is equal to the nitrogen absorbed by corn in the treatment of no nitrogen fertilizer consumption (control) which was about 87 kg per hectare, numerical value of 87 kg N per hectare should be added to all studied treatments. Therefore, the amount of nitrogen available to plants in each treatment is as follows: **(**Table 3)

The vermicompost fertilizer leaching

The results showed that the use of while using vermicompost, by increase in the amount of organic fertilizer, the amount of nitrogen leaching will be increased (Table 4). Also, researchers classified soil contamination levels (Table 5) based on the severity of the infection into six categories (Bhuiyana *et al*., 2010). In this experiment, the amount of nitrogen in total soil samples (Table 1) was 175.0 percent and the amount of experiment soil nitrogen at the end of the season was 282.0 percent. Thus, the pollution factor of equation (1), was calculated 61.1 and found that the degree of contamination in the range of moderate to severe (Bhuiyana *et al*., 2010).

DISCUSSION

The results showed that in spite of similarity of 704 variety fresh weight at 300 kg level of nitrogen from urea and 25,500 kg of organic fertilizer from vermicompost per hectare, the highest leaf dry weight was obtained from the effect of vermicompost (Table 2). It can be assumed that the nitrate uptake increase during the consumption of high levels of nitrogen from urea chemical fertilizer source, causing the plant to absorb more water after drying appears in the form of a significant reduction in dry matter yield of different organs of corn. From the results it can be concluded that vermicompost showed more of an impact on the fresh weight and dry weight of corn leaves, nitrogen application from urea *via* dry weight gain could increase fresh forage yield and dry maize. The results showed that 300 kg nitrogen application from urea could increase fresh and dry weight of corn cob alike in all cultivars that is consistent with the results of Nesaz *et al*. (2016).

So, it seems that high yielding varieties of maize to promote corn production and grain yield more nitrogen from urea need to be analyzed more quickly compared with vermicompost and available in the form of absorbable. The results showed that with increasing nitrogen application, absorption and storage of nitrogen in corn stalks increased and depending on the cultivar were different. So that the highest shoot nitrogen depend on dry weight was obtained in 300 kg N per hectare treatment.

The results showed that increased consumption of nitrogen fertilizers per hectare of nitrogen leaching enter into groundwater rose. So when consuming 100 kg N per hectare, about 24 percent of the used nitrogen will be unavailable to the plants and enters into the ground water. But in treatments of 200 and 300 kg N ha nitrogen leaching is 95.44 and 03.47 percent, respectively (Table 3). Generally, losses of nitrogen in organic fertilizers and as a result of chemical leaching, nitrate have been reported between 25 and 90% (Elton *et al*., 2002). Some researchers have shown that 40 to 70 percent of nitrogen fertilizers used in conventional farming is leaking into the environment (Babiker *et al*., 2004). Also, the researchers showed that the use of animal manure as the only source of nitrogen increases the nitrogen losses and the amount of leaching in animal manure compost is reported as 35% (Kirchmann and Bergstrom, 2001). Furthermore, the nitrate leaching in research on corn under chemical feeding have been reported about twice the organic feeding system (Nyamangara *et al*., 2003), which confirms the results of the test.

In general, the losses of nitrogen from chemical (urea) and organic sources (vermicompost) of nitrogen fertilizer was similar. However, nitrogen losses and environmental pollution caused by nitrogen fertilizer chemical was far more than vermin-compost and at different levels of vermicompost compared with the amount of chemical fertilizer, the nitrogen losses was lower. Thus, the results showed that environmental pollution of vermicompost was far less than fertilizer nitrogen that is consistent with the test results of Nyamangara *et al*. (2003). It seems that vermicompost at different levels due to slow release nitrogen, nitrogen absorption by plant roots increases. For this reason, the amount of nitrogen losses and entering the groundwater is reduced. Therefore, the use of vermicompost, in addition to modifying soil texture and structure can be an effective step towards increase production and biomass and prevent environmental pollution especially groundwater. Pollution factor was calculated as 61.1 in this study and showed that the degree of contamination in area is moderate to severe. Thus, inspired by natural ecosystems, replacing nitrogen fertilizers by organic fertilizers can be useful to prevent from the growing trend of agricultural soils and groundwater pollution.

CONCLUSION

In general, the results showed that in the presence of excess nitrogen on agricultural field, the greater the amount of nitrogen was absorbed by plant and stored in shoots and vermicompost fertilizer in comparison to chemical fertilizer urea increased photosynthesis depending on the type of genotype. Also, the results showed that about half of the urea fertilizer used in corn plants were removed by leaching. In addition, results showed that the concentration of nitrates in the corn shoots were different depending on the type of nitrogen fertilizer. Nitrogen losses and environmental pollution caused by the use of vermicompost fertilizer in contrast with chemical nitrogen fertilizer showed a significant decrease. Thus, the use of vermicompost to reduce the environmental pollution caused by the use of nitrogen fertilizer is recommended.

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