International Journal of Modern Agriculture, Volume 10, No.2, 2021
ISSN: 2305-7246

OPTIMIZATION OF ORGANIC, BIOLOGICAL, AND CHEMICAL FERTILIZERS CONSUMPTION ON YIELD, YIELD COMPONENTS, AND NITRATE ACCUMULATION IN CORN GRAIN

Saadat DahPahlavan, Amin Farnia*, Mojtaba Jafarzadeh Kenarsari, Shahram Nakhjavan

Department of Agronomy, Borujerd Branch, Islamic Azad University, Boroujerd, Iran.
*Corresponding author

Abstract

These days, the application of organic and biofertilizers to optimize the use of chemical fertilizers as well as improve crop quality and maintain soil fertility in sustainable agricultural systems, has gained special significance. A split split-plot experiment was carried out in a randomized complete block design and with 4 replications and two consecutive years in 2018 and 2019, to investigate the effect of combined application of biological, organic, and chemical fertilizers on yield and quality of single-cross Simon corn grain. Nitrogen treatment was used in three levels of zero, 150 and 300 kg/ha or by using 46% urea fertilizer and vermicompost treatment was used in three levels of 0, 6 and 12 tons per hectare and mycorrhiza treatment was considered in two levels of application and non-application. The results display that the effect of mycorrhiza fertilizer on 100-grain weight and final yield and quality traits was significant. The effect of vermicompost fertilizer on nitrate and grain yield components was significant. The effect of application of nitrogen fertilizer on all items was significant. Findings show that by consuming 6 tons per hectare of vermicompost along with mycorrhiza or 50% nitrogen fertilizer, the best grain quality can be achieved in terms of the lowest amount of nitrate accumulation in the grain without significant reduction in yield.

Keywords; Nitrogen, Vermicompost, Mycorrhiza, Corn, Quality, Yield.

Introduction

According to some researchers, one of the greatest agricultural achievements of humanity is the cultivation and development of corn worldwide (O'Lery, 2016). In line with estimates and forecasts of the International Maize and Wheat Improvement Center (CIMMYT), corn production will reach 830 million tons by 2020. Excessive application of chemical fertilizers has caused environmental issues, low efficacy of fertilizer use, decreased product quality, soil degradation, lack of micronutrients, toxicity to soil microorganisms, and decreased farmers' incomes (Singh et al., 2017). Consumer concerns about food quality, environmental health, and soil protection have increased the trend towards sustainable agriculture (Lazcano et al., 2011). The utilization of vermicompost, besides increasing the population of beneficial soil microorganisms (mycorrhizal fungi), by providing plant access to essential nutrients such as nitrogen, phosphorus, and soluble potassium improves crop yields. Vermicompost is an organic fertilizer that can improve food quality without interfering with the health of food products (Simsek-Ersahin, 2011). Mycorrhizal fungi are among the key microorganisms in most undamaged soils, which based on some estimates, their hyphae make up about 70% of the biomass of the soil microbial community. All plants have some kind of symbiotic Mycorrhizal interaction. Fungi receive carbon from the host plant in this symbiosis. The host also enjoys other benefits such as increasing the absorption of trace elements such as nitrogen, potassium, and magnesium (Hojdeh, 2011). It has been reported that the presence of mycorrhizal fungus in the root environment of maize has a positive influence on plant growth, which can be associated with the production and secretion of plant growth stimulants or some growth-regulating hormones such as cytokinin, which is produced by mycorrhiza in soil. Produced (Zhao et al., 2015). Nitrogen, as one of the most essential trace nutrients for the growth and development of most crops, plays an important role in the construction of protein molecules, enzymes, coenzymes, nucleic acids, and cytochromes (Kumar et al., 2013). The use of chemical fertilizers at high levels and for a long time to achieve maximum yield (similar to what happens in Nahavand plain) causes environmental issues, decreased product quality, weed infestation competing with crops, and the prevalence of pests and diseases (Amani Machiani et al., 2018; Liu & Lal, 2015). Thus, the use of biofertilizers has been considered by agricultural producers and researchers. The high nutrients requirement for corn as a demanding plant has caused the high consumption of chemical inputs and also increased its production costs. Moreover, this issue causes problems such as environmental pollution, low efficacy of fertilizer use, a decrease in the quality of crops, soil degradation, lack of nutrients in the soil, toxicity to soil microorganisms, and reduced farmers' incomes (Sing et al., 2017). Factors that cause nitrate accumulation in different plants are complex and many studies have been done on the mechanism of nitrate accumulation has occurred. The main cause of nitrate accumulation is nitrate reductase activity and plant growth rate, which is related to photosynthetic carbon metabolism. Along with genetic factors, growth conditions also play a decisive role in plant nitrate accumulation. These include managing the consumption of nitrogen fertilizers, how to maintain the crop, soil moisture, light intensity, and temperature (Hmelak and Koenik, 2013). Nitrite in the stomach can react with amines, amides and organic matter containing nitrogen and form carcinogenic groups, which are called N-nitrosamine compounds (Jeffrey et al., 2012). Exposure to N-nitrosamine compounds increases the risk of gastric, esophageal, and gallbladder cancers (Manuela et al., 2010). The permissible daily dose of nitrate and nitrite in the body is 0-3.7 and 0-0.07 mg/kg body weight, respectively. It is the body (FAO/WHO, 2003a, b) that is often used in everyday human life beyond these standards (Sobko et al., 2010; Hmelak et al., 2012). Concerns about healthy food reaching the next generation led us to use a combination of biological, chemical, and organic fertilizers to reduce the use of chemical fertilizers and replace it with biofertilizers while maintaining the existing yield to increase the quality of corn kernels; also, selection of proper fertilizer composition can reduce the amount of harmful nitrate in corn kernels.

Materials and Methods

Treatements tested include nitrogen-based fertilizer[1] as the main treatemtn in three levels of 0 kg (control), 150 kg, and 300 kg based on soil test in twice-split plots, vermicompost in three levels of zero (control), 6 tons and 12 tons in split plots and sub-sub-factor of the mycorrhizal fungus in two levels of without application (control) and with application. The study was done in large split plots, in the form of randomized complete block design, with four repetitions, and in two consecutive years of 2018 and 2019 in Nahavand city. The city has a temperate climate, is located in the southwest of Hamadan province, on the slope of Garin mountain range in the western Zagros mountain range with a latitude of 3791114.37 meters east and 243392.60 meters south and an altitude of 1506 above sea level. The mycorrhizal fungus used in this study, *Glomus mosseae*, which was provided by Turan Biotech Company, included a mixture of sterile sand, gravel, soil, fungal hyphae, and 20 fungal spores per gram. 555 kg/ha and 5 g of mycorrhiza mixed with soil were placed in planting holes under the seeds and at a distance of 12 cm in a row and seeds were placed on mycorrhizal fungi. Soft soil was poured on them and the field was irrigated. Nitrogen was used as 46% urea fertilizer and calculated as 0 kg, 150 kg (326 kg of 46% urea), and 300 kg (653 kg of 46% urea) pure nitrogen at the beginning of cultivation and used as thoroughly mixed with soil. Vermicompost fertilizer was poured in the furrows previously created by the tractor based on the division of plots, and by re-grooving on the ridges, the required amount of soil was poured on the vermicomposts to get ready for digging holes and planting. In the laboratory to determine the percentage of nitrogen in the seed by the Kjeldahl method, the ground seed sample was first digested with sulfuric acid and catalyst and then the amount of nitrogen was determined in the extract, which was measured by multiplying it by 5.7 (Bremner et al., 1965; Nelson & Sommers, 1973). The amount of protein was obtained by multiplying the percentage of nitrogen by 5.25. The amount of nitrate in the seeds was calculated by the standard solution of nitrate and spectrophotometer model GBC Cintra101. After assessing normality, data were analyzed in SAS 9.1 software, and the means were compared with Duncan's multiple range test at a probability level of five percent. EXCEL 2013 software was used to draw the graphs and tables.

Results and discussion

Number of seeds per row

The result of the combined analysis of data revealed that the effect of vermicompost at the level of five percent and nitrogen at the level of one percent on seeds per row was significant (Table 1). Based on the table of comparison of means in the use of vermicompost, the highest number of seeds per row was 31.97 seeds per row in the application of 12 tons of vermicompost per hectare (Table 2; Figure 1). Based on the table of comparison of means in the use of nitrogen, the highest number of grains per row was 32.23 grains per row in the application of 300 kg nitrogen per ha (Table 3; Figure 2). According to the table of comparison of the means in the interaction of mycorrhiza × vermicompost × nitrogen, the highest number of seeds per row was 32.95 grains per row in mycorrhiza application and 12 tons of vermicompost and 300 kg nitrogen per hectare, and the lowest amount was in non-application of mycorrhiza, vermicompost, and nitrogen which was 29.56 grains per row. The

[1] Urea 46% per hectare

reason for the decrease in the number of seeds per row in the control plot without nitrogen application can be attributed to more infertility and increased abortion and lack of seed development, that in the plot with nitrogen application, the number of seeds in the row increases due to proper nutrition and reduced flower competition in the stage of determining the number of ovules. It also seems that the use of higher amounts of nitrogen has increased the vegetative and reproductive growth of maize and the plant has been able to create more reproductive units per ear, performed better in the transfer of photosynthetic material and optimal allocation of carbohydrates to reproductive organs and ultimately lead to an increased number of seeds per row. Mycelial outgrowths of mycorrhizal fungi can enter soils and areas that are not accessible to the roots and root hair of the plant, thus using more volume of soil. By providing additional surface area for absorption, these microorganisms increase the absorption of nutrients, especially phosphorus and nitrogen, and thus increase the production of assimilates in the plant (Heidari and Karimi, 2014). Ebadi et al. (2016) by examining the effect of mycorrhizal fungus on maize reported that the application of mycorrhizal fungus increased the number of seeds per row, which is consistent with the results of the current study. Shamoradi et al. (2019) showed that the effect of biological and nitrogen fertilizers on the number of seeds per row was significant at the level of one percent but their interaction was not effective, which is in line with the results of the current research. It is stated that nitrogen increases the efficiency of photosynthesis and ultimately increases the number of grains in the row (Fereyduni et al., 2017). The number of grains in the row is one of the main components of grain yield. The positive effect of adding nutrients in improving grain yield is mostly through increasing the number of grains per row. The number of grains per ear depends on the genetic potential of the plant and the availability of necessary nutrients in the conversion stage of vegetative meristem to reproductive meristem and after. Nitrogen deficiency in maize causes the ends of the ears to be seedless, and seeds can be easily separated (Rafiei, 2014). Rafiei and Konani (2019) showed that nitrogen fertilizer increases the number of grains in the row, which is consistent with the results of the current study. Payandeh et al. (2019) in an experiment on maize showed the application of mycorrhiza increases the number of seeds in the row, which is consistent with the results of this study.

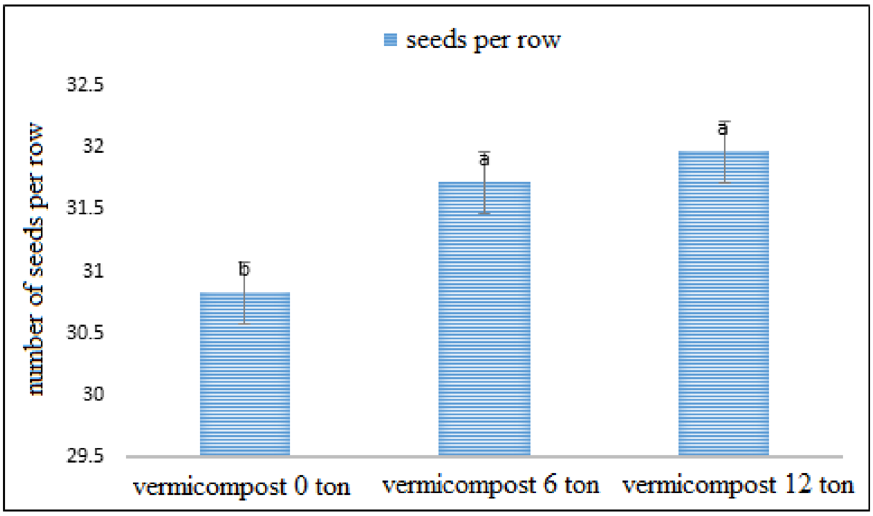

Figure 1. Comparison of the average effect of vermicompost on the number of grains per ear row.

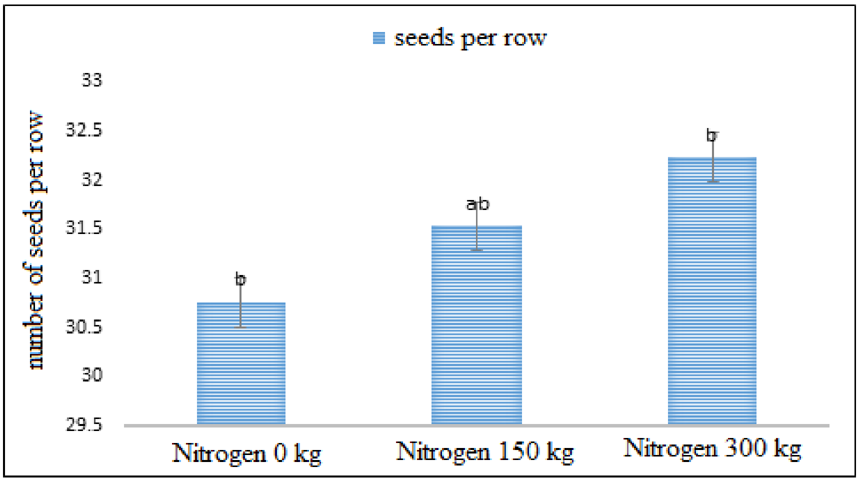

Figure 2. Comparison of the average effect of nitrogen on the number of grains per ear row.

Table 1: Analysis of variance of traits caused by interaction of year, mycorrhiza, vermicompost and nitrogen in maize.

Variables	Degrees of freedom (df)	Mean Squares (MS)				
		Seed rows per ear	Seeds in a row	100-grain weight (gr)	Total grain yield (ton)	Nitrate (mg/kg grain)
year	1	0.54^{ns}	0.51^{ns}	0.24^{ns}	0.55^{ns}	0.01**
error	6	0.45	0.490	0.50	0.69	0.37
Mycorrhiza (M)	1	0.30^{ns}	0.15^{ns}	0.01**	0.01**	0.05*
Year × mycorrhiza	1	0.27^{ns}	0.37^{ns}	0.01**	0.06^{ns}	0.01**
Main factor error	6	0.29	0.54	0.87	0.83	0.50
Vermicompost (V)	2	0.02**	0.02*	0.01**	0.007**	0.02*
Mycorrhiza × vermicompost	2	0.57^{ns}	0.98^{ns}	0.86^{ns}	0.27^{ns}	0.01**
Year × vermicompost	2	0.78^{ns}	0.38^{ns}	0.94^{ns}	0.98^{ns}	0.01**
Year × mycorrhiza × vermicompost	2	0.24^{ns}	0.93^{ns}	0.55^{ns}	0.07^{ns}	0.01**
Sub-factor error	24	0.80	0.46	0.78	0.98	0.48
Nitrogen (N)	2	0.002**	0.01**	0.01**	0.003**	0.01**
mycorrhiza × nitrogen	2	0.31^{ns}	0.59^{ns}	0.06^{ns}	0.18^{ns}	0.01**
vermicompost × nitrogen	4	0.89^{ns}	0.76^{ns}	0.85^{ns}	0.16^{ns}	0.01**
Year × nitrogen	2	0.95^{ns}	0.92^{ns}	0.32^{ns}	0.35^{ns}	0.01**
Year × mycorrhiza × nitrogen	2	0.66^{ns}	0.50^{ns}	0.12 ^{ns}	0.01**	0.01**
Year × vermicompost × nitrogen	4	0.47^{ns}	0.98^{ns}	0.94^{ns}	0.26^{ns}	0.01**
mycorrhiza × vermicompost × nitrogen	4	0.77^{ns}	0.98^{ns}	0.93^{ns}	0.13^{ns}	0.01**
Year × mycorrhiza × vermicompost × nitrogen	4	0.31^{ns}	0.96^{ns}	0.89^{ns}	0.97 ^{ns}	0.01**
Sub-sub-factor error	72	1.37	0.92	3.33	2.31	20.37
Coefficient of variation		8.54	6.29	6.13	11.54	7.99

*, ** and ns indicate significance at the levels of five percent, one percent, and non-significance, respectively.

Table 2: Comparison of the effect of Mycorrhiza on Mean Yield and Yield Components of Qualitative Traits of Single-Cross Simon Maize

Mycorrhiza	Seed rows	Seeds in a row	100-grain weight (gr)	Total grain yield (ton)	Nitrate (mg/kg grain)
Non-Application	13.61^{a}	31.27^{a}	29.10^{b}	12.68^{b}	55.72^{a}
Application	13.81^{a}	31.75^{a}	30.41^{a}	13.67^{a}	57.21^{a}

Table 3: Comparison of the effect of Vermicompost on Mean Yield and Yield Components of Qualitative Traits of Single-Cross Simon Maize

vermicompost	Seed rows	Seeds in a row	100-grain weight (gr)	Total grain yield (ton)	Nitrate (mg/kg grain)
0 ton	13.27[b]	30.83[b]	28.87[b]	12.46[b]	56.92[a]
6 ton	14.14[a]	30.72[a]	29.88[a]	13.44[a]	59.95[b]
12 ton	13.71[c]	31.97[a]	30.52[a]	13.63[a]	57.53[a]

Number of rows per ear

The result of the combined analysis of data showed that the effect of vermicompost and nitrogen on the grain row was significant at the level of one percent (Table 1). Based on the table of comparison of the average effect of the application of vermicompost, the highest number of grain rows per ear was 14.14 in the application of 6 tons of vermicompost per hectare (Table 3; Figure 3). Based on the table of comparison of the means, the highest number of grain rows per ear was 14.89 in the application of 300 kg nitrogen per hectare (Table 4; Figure 4). According to the table of comparison of the average effect of the interaction of mycorrhiza × vermicompost × nitrogen, the highest number of grain rows per ear was 15.24 in the application of mycorrhiza, 6 tons of vermicompost, and 300 kg nitrogen per hectare. The highest number of grain row per ear was 16.61 rows of seeds per ear in the interaction of application of mycorrhiza, 6 tons vermicompost, and 300 kg nitrogen per hectare, and the lowest number of grain rows per ear was in non-application of mycorrhiza, vermicompost, and nitrogen with 12.13 rows of seeds per ear. The decrease in the number of seed rows per ear in non-application of nitrogen fertilizer is due to nitrogen deficiency stress, which is due to reduced leaf area development, photosynthesis, number of ear buds, increased leaf aging, and seed miscarriage. Shamradi et al. (2017) reported that nitrogen and biological fertilizers increase the number of grains per ear, but their interaction did not have a significant effect on the number of grains per ear, which is consistent with the current results. Other researchers also stated the increased number of grain rows per ear in the application of biofertilizer and attributed this to the increase in nitrogen fixation, increase in phosphorus solubility in soil and also a significant increase in growth regulator (Fathi et al., 2017).

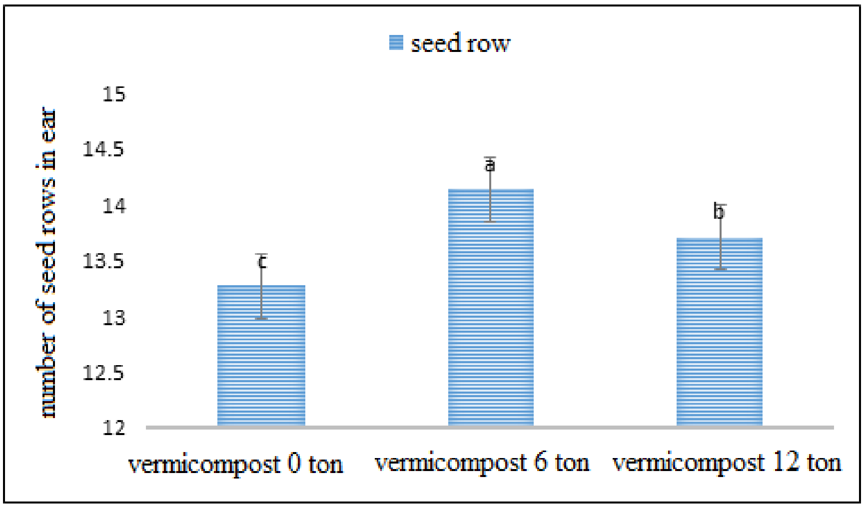

Figure 3. Comparison of the average effect of vermicompost on the number of grains rows per ear.

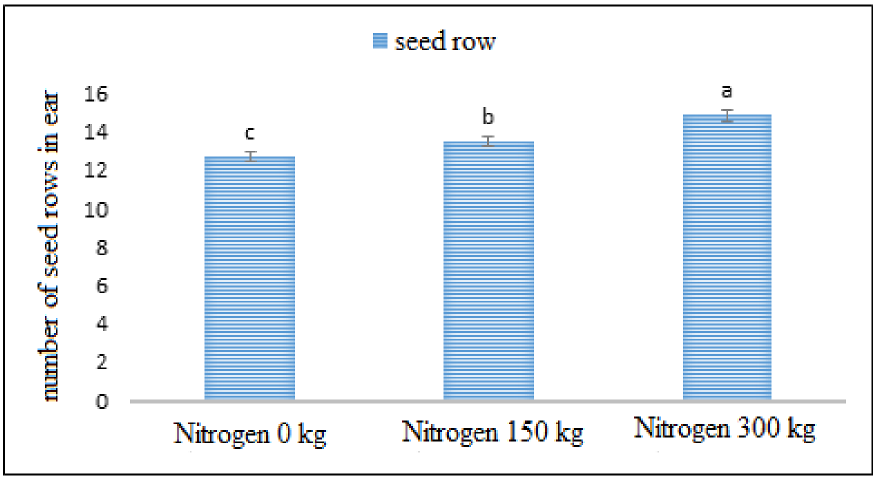

Figure 4. Comparison of the average effect of nitrogen on the number of grains rows per ear.

Table 4: Comparison of the effect of Nitrogen on Mean Yield and Yield Components of Qualitative Traits of Single-Cross Simon Maize

Nitrogen	Seed rows	Seeds in a row	100-grain weight (gr)	Total grain yield (ton)	Nitrate (mg/kg grain)
0 kg	12.73^{c}	30.76^{b}	26.64^{c}	9.79^{c}	6.10^{c}
150 kg	13.51^{b}	31.53a^{b}	30.38^{b}	13.90^{b}	42.88^{b}
300 kg	14.89^{a}	32.23^{a}	32.23^{a}	15.84^{a}	119.43^{a}

100-grain weight of maize

The result of combined analysis of the data showed that the effect of mycorrhiza, vermicompost, and nitrogen on 100-grain weight was significant at the probability level of one percent (Table 1). Based on the table of comparison of mean effect of the application of mycorrhiza, the maximum 100-grain weight was 30.41 g in the application of mycorrhiza (Table 2; Figure 5). Based on the table of comparison of mean effect of the application of vermicompost, the maximum 100-grain weight was 30.52 gr in the application of 12 tons of vermicompost per hectare (Table 3; Figure 6). Based on the table of comparison of mean effect of the application of nitrogen, the maximum 100-grain weight was 32.23 g in the application of 300 kg of nitrogen per hectare (Table 4; Figure 7). According to the comparison of means table in the the effect of interaction of mycorrhiza × vermicompost × nitrogen, the maximum 100-grain weight was 33.53 g in application of mycorrhiza, 12 tons of vermicompost, and 300 kg of nitrogen per hectare. The lowest 100-grain weight was in non-application of mycorrhiza, vermicompost, and nitrogen with 25.05 gr. Due to the use of nitrogen fertilizer, suitable nutritional conditions have been created for the plant, which has increased photosynthesis and vegetative growth and transferred more carbohydrates to the grain, which increased the 100-grain weight in corn. In this regard, there are reports of improved corn grain protein yield in case of using adequate amounts of nitrogen (Fatemi et al., 2011). Mirzakhani and Ali Bakhshi (1399) in an experiment showed that 1000-grain weight is largely dependant on the genetic characteristics of the plant and environmental conditions and fluctuations do not have much effect on 1000-grain weight. For example, the fertilizer range of 0 to 225 kg nitrogen per hectare could not have a significant effect on the 1000-grain weight, which is not consistent with the results of this study.

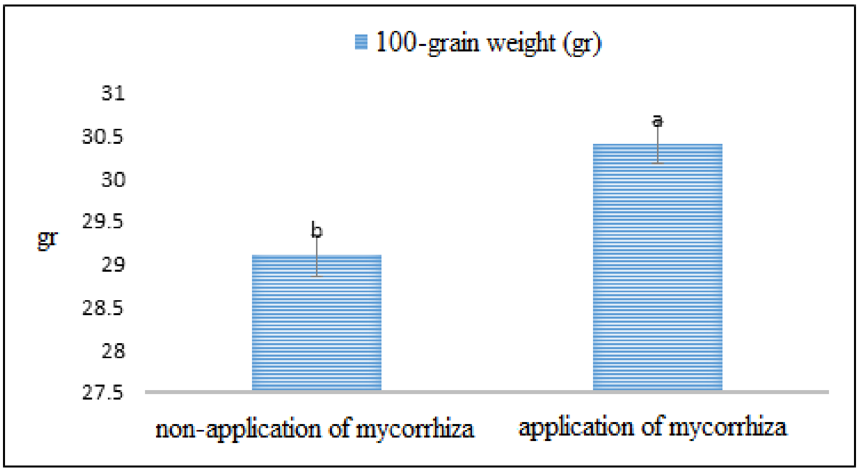

Figure 5. Comparison of the average effect of mycorrhiza on the 100-grain weight (gr).

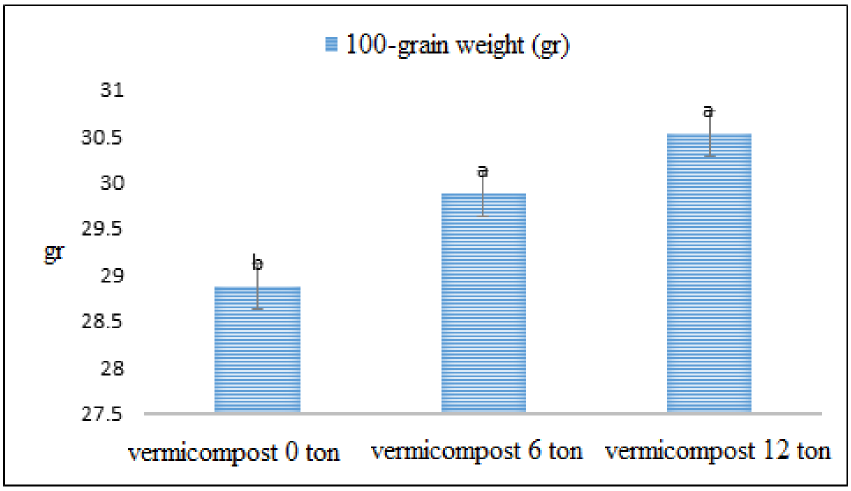

Figure 6. Comparison of the average effect of vermicompost on the 100-grain weight (gr).

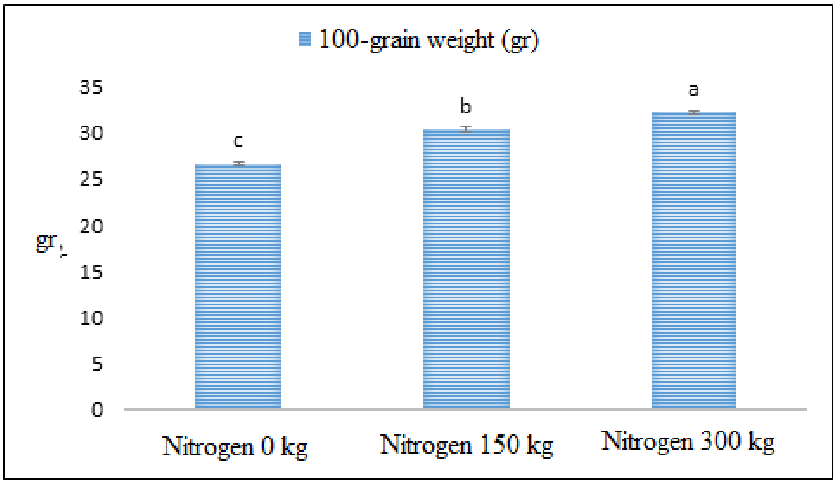

Figure 7. Comparison of the average effect of nitrogen on the 100-grain weight (gr).

Nitrate content in grain dry weight:

The result of combined analysis of data showed that the effect of year on grain nitrate was significant at the level of one percent. Also, the effect of mycorrhiza and vermicompost at the level of five percent and the effect of the year × mycorrhiza, mycorrhiza × vermicompost, year × vermicompost, year × mycorrhiza × vermicompost, nitrogen, mycorrhiza × nitrogen, vermicompost × nitrogen, year × nitrogen, year × mycorrhiza × nitrogen, year × vermicompost × nitrogen, mycorrhiza × vermicompost × nitrogen, and year × mycorrhiza × vermicompost × nitrogen were significant at the level of one percent (Table 1). Based on the mean comparison table based on mycorrhiza use, the highest amount of cumulative nitrate in the grain was in the application of mycorrhiza with the amount of 57.21 mg/kg of grain (Table 2; Figure 8). Based the mean comparison table based on vermicompost application, the highest amount of cumulative nitrate in the grain was obtained in the application of 12 tons of vermicompost per hectare with the amount of 57.53 mg/kg of grain (Table 3; Figure 9). According to the mean comparison table based on the average nitrogen use, the highest amount of cumulative nitrate per grain (119.43 mg/kg) was obtained at 300 kg nitrogen per ha, and the lowest amount was 6.10 mg/kg grain at no nitrogen use. (Table 4; Figure 10). Based on the mean comparison table based on the interaction of mycorrhiza × vermicompost, the highest amount of cumulative nitrate in the grain as a result of mycorrhiza use was obtained in 12 tons of vermicompost (63.51 mg/kg of grain) (Table 5; Figure 11). Based on the mean comparison table based on the interaction of mycorrhiza × nitrogen, the highest amount of cumulative nitrate in the grain was obtained as a result of mycorrhiza use × 300 kg of nitrogen (119.35 mg/kg of grain), and the lowest value was obtained from the interaction of not using mycorrhiza and zero kg of nitrogen per hectare (7.08 mg/ha) (Table 6; Figure 12). Based on the mean comparison table based on the interaction of vermicompost × nitrogen, the highest amount of cumulative nitrate in grain was obtained by the interaction of 0 ton vermicompost and 300 kg of nitrogen (128.13 mg/kg of grain), and the lowest amount was obtained in 0 ton vermicompost at and 0 kg per hectare nitrogen (1.78 mg/kg of grain) (Table 7; Figure 13). Based on the mean comparison table based on the interaction of mycorrhiza × vermicompost × nitrogen, the highest amount of cumulative nitrate in the grain was obtained by not using mycorrhiza, 0 ton vermicompost, and 300 kg nitrogen (142.77 mg/kg of grain). The lowest amount was obtained by non-application of mycorrhiza, vermicompost, and nitrogen at the rate of 1.02 mg/kg of grain. Among the levels of vermicompost fertilizers, the increase of nitrate accumulation has been accompanied by the increase of fertilizer application with a gentler slope than the nitrogen fertilizer levels. It seems that the gradual release of elements in vermicompost can be the reason that nitrogen uptake and release is more coordinated with plant growth and yield components and more nitrogen is used to make amino acids, compounds, and proteins. So it is clear that, at high levels of application and absorption of nitrogen, reduction of all absorbed nitrate and its entry into plant metabolism is not possible, and most of it is accumulated as a mineral in the plant. Rostami et al. (2014) showed that with increasing nitrogen consumption at planting time the amount of nitrate in the grain is increased.

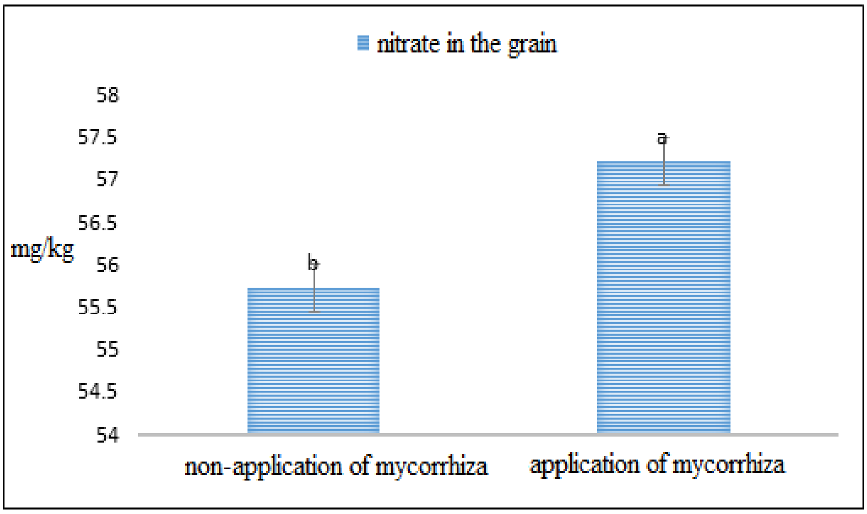

Figure 8. Comparison of the mean effect of mycorrhiza on the amount of grain nitrate (mg/kg).

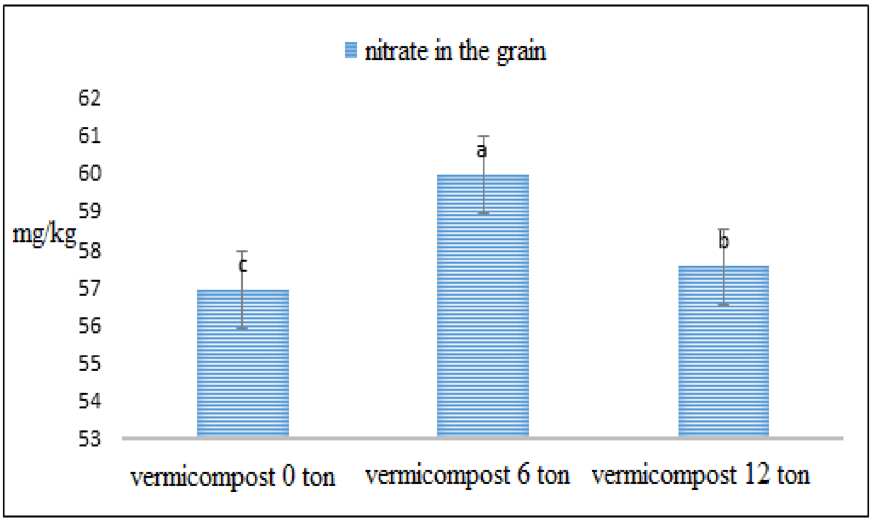

Figure 9. Comparison of the mean effect of vermicompost on the amount of grain nitrate (mg/kg).

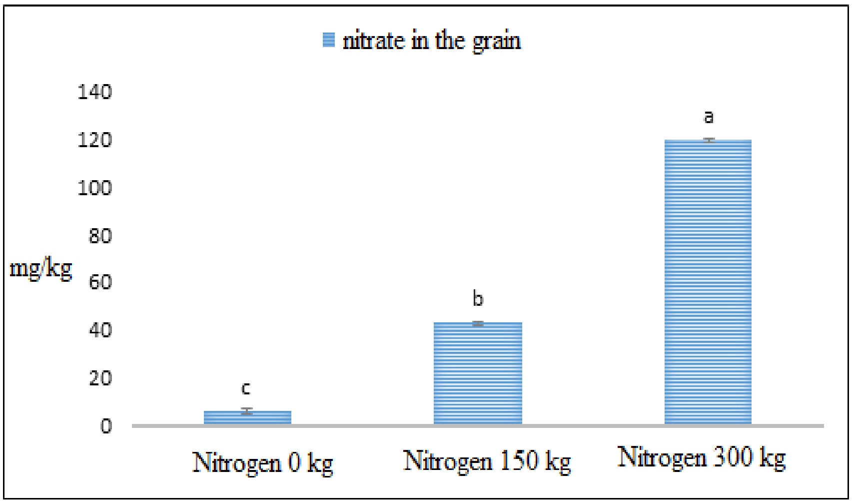

Figure 10. Comparison of the mean effect of nitrogen on the amount of grain nitrate (mg/kg).

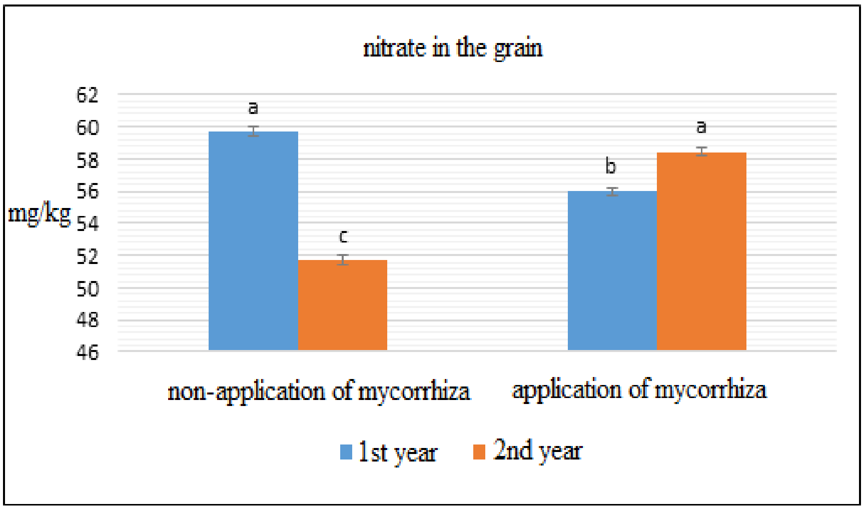

Figure 11. Comparison of the mean effect of mycorrhiza × year on the amount of grain nitrate (mg/kg).

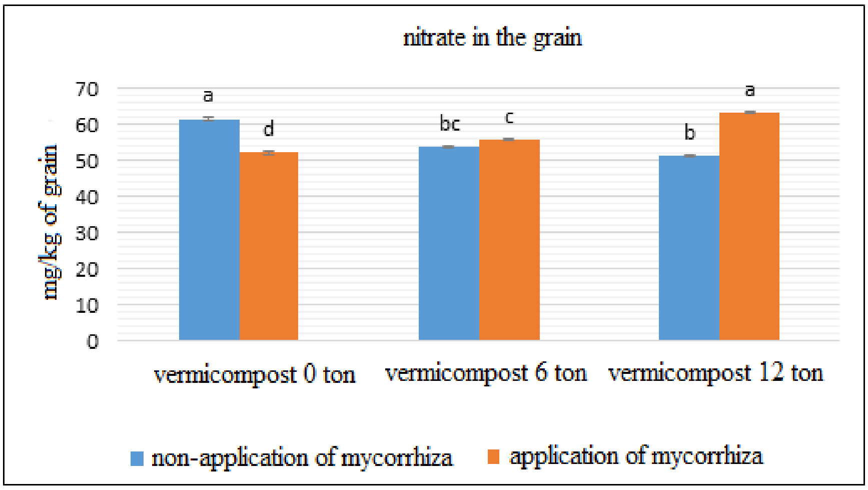

Figure 12. Comparison of the mean effect of mycorrhiza × vermicompost on the amount of grain nitrate (mg/kg).

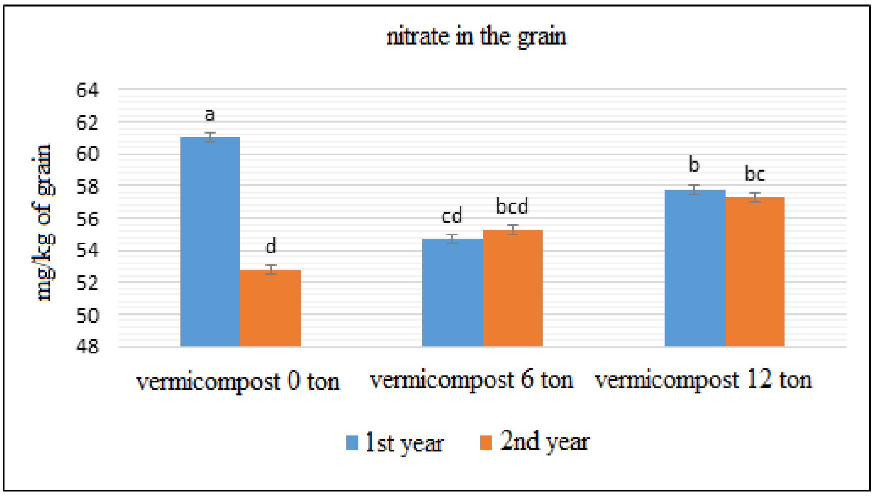

Figure 13. Comparison of the mean effect of vermicompost × year on the amount of grain nitrate (mg/kg).

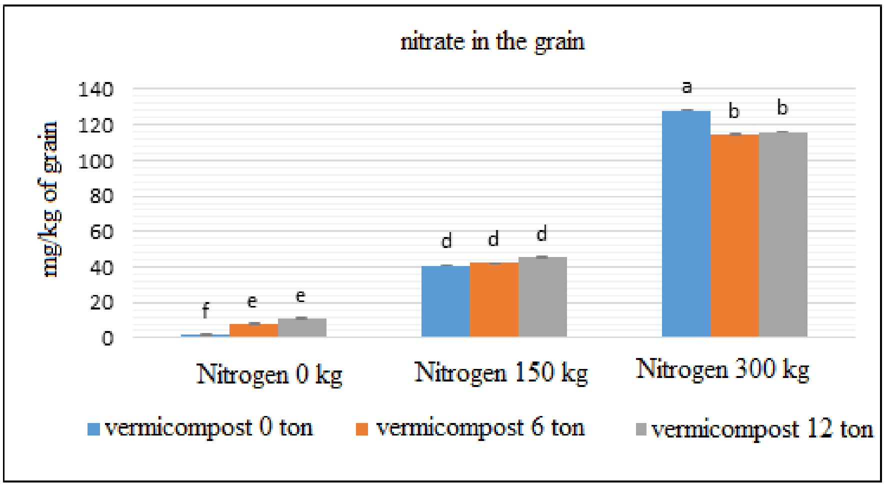

Figure 14. Comparison of the mean effect of vermicompost × nitrogen on the amount of grain nitrate (mg/kg).

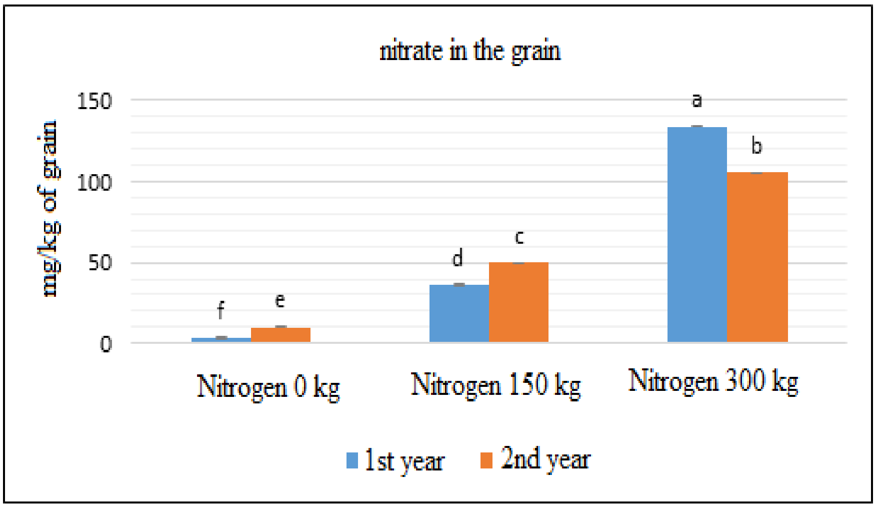

Figure 15. Comparison of the mean effect of nitrogen × year on the amount of grain nitrate (mg/kg).

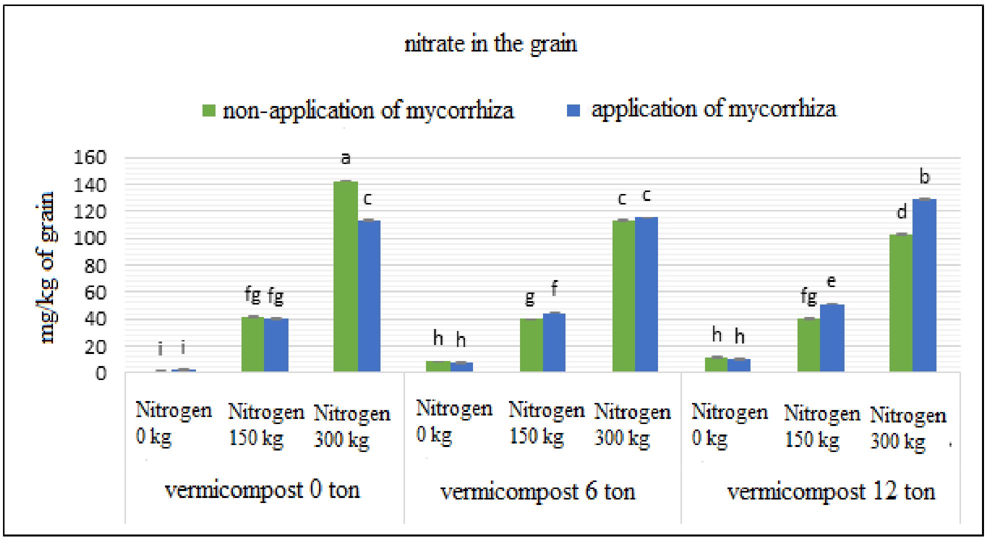

Figure 16. Comparison of the mean effect of mycorrhiza × vermicompost × nitrogen on the amount of grain nitrate (mg/kg).

Table 5: Comparison of Effect of Mycorrhiza × Vermicompost Interaction on Mean Yield and Yield Components of Maize Qualitative Traits

Mycorrhiza	vermicompost	Seed rows	Seeds in a row	100-grain weight (gr)	Total grain yield (ton)	Nitrate (mg/kg grain)
Non-Application	0 ton	13.13^{d}	30.57^{b}	28.30^{d}	11.87^{d}	61.68^{a}
Non-Application	6 ton	18.14^{a}	31.47^{ab}	29.24^{cd}	13.23^{bc}	53.94^{bc}
Non-Application	12 ton	13.51^{bcd}	31.77^{a}	29.75^{bc}	12.95^{c}	51.45^{c}
Application	0 ton	13.42^{cd}	31.10^{ab}	29.43^{c}	13.06^{bc}	52.16^{c}
Application	6 ton	14.11^{ab}	31.98^{a}	30.51^{ab}	13.64^{b}	55.97^{b}
Application	12 ton	13.92^{abc}	32.17^{a}	31.28^{a}	14.31^{a}	63.51^{a}

Table 6: Comparison of Effect of Mycorrhiza × Nitrogen Interaction on Mean Yield and Yield Components of Maize Qualitative Traits

Mycorrhiza	Nitrogen	Seed rows	Seeds in a row	100-grain weight (gr)	Total grain yield (ton)	Nitrate (mg/kg grain)
Non-Application	0 kg	12.76^{c}	30.67^{b}	25.76^{d}	9.14^{e}	7.08^{d}
Non-Application	150 kg	13.49^{b}	31.37^{b}	29.44^{b}	13.22^{c}	40.37^{c}

Non-Application	300 kg	14.57[a]	31.75[ab]	32.09[a]	15.68[a]	119.71[a]
Application	0 kg	12.70[c]	30.85[b]	27.52[c]	10.43[d]	6.88[d]
Application	150 kg	13.54[b]	31.69[ab]	31.32[a]	14.59[b]	45.40[b]
Application	300 kg	15.20[a]	32.70[a]	32.37[a]	16.00[a]	119.35[a]

Table 7: Comparison of Effect of Vermicompost × Nitrogen Interaction on Mean Yield and Yield Components of Maize Qualitative Traits

vermicompost	Nitrogen	Seed rows	Seeds in a row	100-grain weight (gr)	Total grain yield (ton)	Nitrate (mg/kg grain)
0 ton	0 kg	12.32[f]	29.67[c]	25.88[f]	9.23[e]	1.78[f]
0 ton	150 kg	13.06[def]	30.95[bc]	29.18[d]	12.57[d]	40.84[d]
0 ton	300 kg	14.43[bc]	31.87[ab]	31.54[bc]	12.59[ab]	128.13[a]
6 ton	0 kg	13.30[de]	31.10[b]	26.81[ef]	10.00[e]	8.15[e]
6 ton	150 kg	13.81[cd]	31.77[ab]	30.65[c]	14.35[c]	42.16[d]
6 ton	300 kg	15.33[a]	32.30[ab]	32.16[ab]	15.96[a]	114.55[b]
12 ton	0 kg	12.56[ef]	31.52[ab]	27.23[e]	10.13[e]	11.01[e]
12 ton	150 kg	13.68[cd]	31.87[ab]	31.32[bc]	14.79[bc]	45.65[c]
1 ton	300 kg	14.90[ab]	32.51[a]	33.00[a]	15.95[a]	115.92[b]

Final grain yield per hectare:

The result of combined analysis of data showed that the effect of mycorrhiza, vermicompost, nitrogen, and the interaction of year × mycorrhiza × nitrogen at the level of one percent on grain yield per hectare (ton) was significant (Table 1). Based on the mean comparison table based on mycorrhiza use, the highest grain yield of 13.67 tons has been obtained in the application of mycorrhiza (Table 2; Figure 17). Hamzei and Babaei (2014) also obtained similar results. Based on the mean comparison table based on vermicompost application, the highest grain yield of 13.63 tons was obtained in the application of 12 tons of vermicompost per hectare (Table 3; Figure 18). Based on the mean comparison table based on nitrogen application, the highest grain yield of 15.84 tons have been obtained in the application of 300 kg nitrogen per ha (Table 4; Figure 19). Accordingly, in the interaction of mycorrhiza × vermicompost × nitrogen, the highest grain yield per hectare was 16.96 tons in the application of mycorrhiza and 12 tons of vermicompost and 300 kg of nitrogen per hectare and the lowest yield was in non-application of mycorrhiza and no use of vermicompost and no use of nitrogen with the amount of 8.53 tons. It seems that integrated fertilizer, by a timely and balanced supply of nutrients, increases the plant's access to high-consumption elements and improves the physical condition and vital processes in the soil and creates a suitable environment for root growth, and also through positive physiological effects such as the effect on plant cell metabolism increases shoot growth and yield. Combined application of vermicompost with other organic fertilizers seems to compensate for the weaknesses in each of the two types of fertilizers[2] by providing better nutrients, and along with improving soil properties, conditions for nutrient uptake, improving production and supply, provides the nutrients to the ear and ultimately increase the grain yield per unit area. Ebadi et al. (2016) reported mycorrhizal fungi increased corn grain yield, which is consistent with the results of this study. Davaran Hagh et al. (2016) in a study on corn showed that vermicompost increases corn grain yield by 17% compared to the control (non-application), which is consistent with the research of Mohammad Khani and Roozbehani (2013). Namazi et al. (2015) reported that by using 75% of chemical fertilizer based on soil tests and five tons per hectare of vermicompost, maximum grain yield in corn is obtained. Nasrollahzadeh et al. (2016) showed that vermicompost and nitrogen fertilizer has a significant effect on grain yield. Similar to the results of this study, the study of other researchers has shown that the use of vermicompost by 5 tons per hectare increased the yield and yield components of corn. This increase in yield is probably due to higher amounts of nitrogen available, which is essential for the production of structural proteins (Yadav et al., 2016). In addition to nutrients and organic matter, vermicompost contains large amounts of humic substances that increase plant growth and yield by improving the bioavailability of certain nutrients, especially iron and zinc and directly affecting plant metabolism (Tartura, 2010). Shirkhani et al. (2019) showed that chemical fertilizer had a significant effect on grain yield and with the application of chemical fertilizers from zero to 100% of plant fertilizer requirements based on soil test, the average grain yield increased from 4.5 to 7.8 tons per hectare. On the other hand,

[2] Including lack of organic matter, the presence of growth stimulants or differences in the content of elements

the use of vermicompost had a significant effect on grain yield and with increasing vermicompost application from zero to six tons per hectare, the average grain yield increased from 5.5 to 7.2 tons per hectare. Mahbubul Alam et al. (2015) reported that with increasing the amount of nitrogen from zero to 90 kg of pure nitrogen per hectare grain yield increased per unit area. These results show that the use of chemical fertilizers along with biofertilizers increases the efficiency of biofertilizers. It seems that in this experiment nitrogen affected the number of seeds produced per ear by increasing the growth rate of the plant. Besides, nitrogen provided nutrients for the ear through photosynthetic durability, and due to reduced grain competition for nutrients, the number of grains per ear and 1000-grain weight increased. Thus, with increasing yield components, grain yield also increased. Rahimi Gavdaneh Godari et al. (2016) in an experiment on sweet corn showed that the use of nitrogen (urea fertilizer) has increased grain yield in corn, which is consistent with the results of the present study. Rostami and Mahmoudi (2016) in an experiment on corn found that grain yield was affected by nitrogen fertilizer application. They obtained the highest grain yield (194 g/plant) by applying 150% fertilizer requirement (225 kg nitrogen per ha) which was significantly different from the control treatment and 50% fertilizer requirement. Poorabrahimi et al. (2017) showed that increasing the application of nitrogen fertilizer from 80 to 160 kg/ha, significantly increased grain yield. Increasing the yield components of corn including the number of grain rows per ear, the number of seeds per row and the weight of 1000 grains under the influence of experimental treatments increase the yield of corn (Akbari et al., 2019; Ahmadi et al., 2020), which is consistent with the current research results.

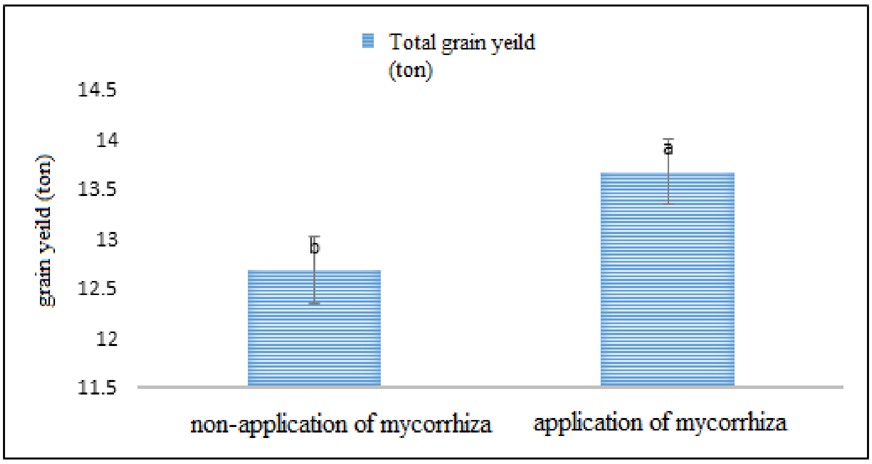

Figure 17. Comparison of the mean effect of mycorrhiza on grain yield per hectare (ton).

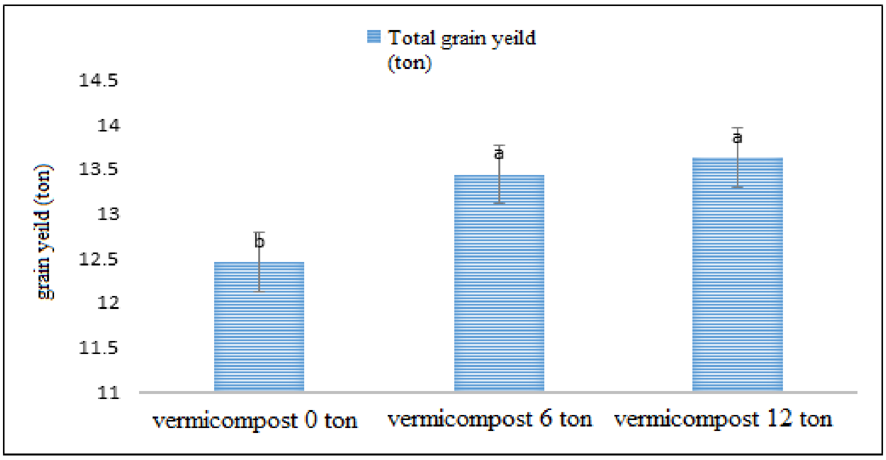

Figure 18. Comparison of the mean effect of vermicompost on grain yield per hectare (ton).

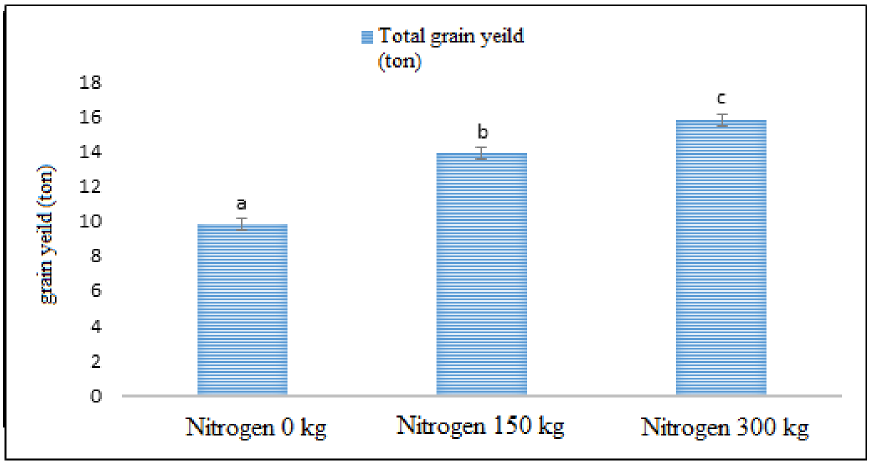

Figure 19. Comparison of the mean effect of nitrogen on grain yield per hectare (ton).

Conclusion and Recommendations

Like many previous studies on corn, the use of chemical fertilizers in this experiment significantly improved the yield of grain protein. Due to the harmful effects that the use of these fertilizers have on nature in the long run and also their influence on the amount of nitrate accumulated in grain, the reduction of their consumption is cost-effective when combined with organic biofertilizers. In this research, the best fertilizer composition recommended was mycorrhiza application, 6 tons of vermicompost, and 150 kg of nitrogen per hectare. The results of this fertilizer combination are 14.85 tons of grain yield per hectare and 44.65 mg/kg nitrate and 9.25% protein and 77.43% carbohydrate in grain, which although we have a 12% reduction in yield compared to complete fertilizer composition, instead the amount of nitrate is reduced by 65%. Due to the up to 50% reduction of cost per hectare in the use of vermicompost per hectare and also 50% in nitrogen in terms of economic justification, this fertilizer combination seems desirable because it has reduced harmful nitrate in the grain by 65%, which has a high value in improving the community health index. In general, in a plant such as corn, which has high nutritional requirements to produce optimal performance, biofertilizers alone can not replace chemical fertilizers, but they can be used as a supplement to chemical fertilizers. This will improve the sustainability of the systems produced and chemical fertilizers will still be considered as necessary, albeit with optimized use, in sustainable agriculture.

Referneces

Ahmadi, F., Pasari B, Javaheri M. 2020. Investigation of the reaction of maize (Zea mays L) under the influence of various chemical, nano, nanobiological and organic extracts of seaweed. Journal of Plant Ecophysiology. 41: 188-203.

Ahmadi, K., Qolizadeh, H. A., Ebadzadeh, H. R., Hosseinpour, R., Abdolshah, H., Kazemian, A., Rafiei. M. 2017. Agricultural statistics of the crop year 2015-16. Crops, first volume. Ministry of Jihad Agriculture. Deputy of Planning and Economics, Information and Communication Technology Center. Page 117.

Ahmadi M, Mendeni, F. Khorami Wafa, M. Mohammadi, Gh. Shirkhani, Sh. 2017. The effect of nitrogen on radiation consumption efficiency and growth indices of different maize cultivars (Zea mays L) under the conditions of Kermanshah, Iranian Journal of Crop Research, Volume 15, Number 4, Winter, 2017 p. 885-900.

Akbari, A., Mousavi, S. Gh, R. Seghatoleslami M. 2018. The effect of foliar application of nano and conventional fertilizers of zinc and silica on the yield and yield components of maize. Journal of Agricultural Research.10 (2): 153-166.

Tabandeh, L. Safarzadeh Shirazi, S. 2018. Investigation of nitrate accumulation and its effective factors in some vegetables in Zanjan region. Journal of Soil Research (Soil and Water Sciences) / A / Volume 32 / Number 2/2018.

Davaran Hagh, Elnaz. Mirshekari, B. Ardakani, M. Farahosh, F., Rejali, F., 2016. Evaluation of quantitative and qualitative characteristics of corn (Zea mays L.) under the influence of vermicompost, Thiobacillus bacteria and foliar application of iron and zinc. Journal of Agricultural

Ecology, Volume 8, Number 3, Fall, 2016. 359 -372.

Rahimi Gavadaneh Godari, M. Modares Sanavi, S., A. Agha Ali Khani, M. Heidarzadeh, A. 2020. Effect of pesticide, vermicompost, and azocompost on some traits of sweet corn cultivars under water stress. Journal of Agricultural Knowledge and Sustainable Production, Vol. 30 No. 1, Spring 2020.

Rostami, M. Ahmadi, A. 2014. Investigating the effect of type and frequency of application of nitrogen fertilizers on yield and grain nitrogen percentage of two maize cultivars. Journal of Agriculture, No. 104, Fall 2014.

Rafiei, M. Konani, Abdolreza. 2019. The effect of application of vermicompost and nitrogen fertilizer on quantitative and qualitative yield of corn (Zea mays L.). Iranian Journal of Crop Science. Volume 50, Number 1, Spring 2019 (pp. 151-159).

Shamoradi, F., Moreshi, S.K., 2019. The effect of biological and chemical nitrogen sources on yield and yield components of corn (Zea mays L). Journal of Applied Agricultural Research Volume 32-Number 4- Winter 2019 Page: 76-90.

Mohammad Khani, A. Roozbehani A. 2015. Management of consumption of vermicompost fertilizer and iron nanofertilizer in improving the yield of corn. Journal of Plant Ecophysiology 23: 123-131.

Mirzakhani, M. Ali Bakhshi A. 2020. The effect of different levels of urea fertilizer and several simultaneous cultivation of some legumes on agronomic characteristics and biomass of whole corn. Journal of Plant Ecophysiology .41: 18-27.

Nasrallahzadeh, S. Shirkhani, A. Zehtab Salmasi, S. Chukan, R. 2016. Effect of biological and chemical fertilizers on grain yield and leaf characteristics of corn under different irrigation conditions. Journal of Applied Agricultural Research, Volume 29, Issue 4, Winter 2016.