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Environmental Aspects of Sustainable Corn Production and its Impact on Grain Quality

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ABSTRACT

In recent years the question about organic cultivation of crops is becoming more popular. It means, that farmers which want to use organic products and grow crops it sustainable way have to follow certain rules. So, the aim of our study was to estimate effect of seed inoculation and foliar fertilization of corn by special fertilizer products with microorganisms that certified Organic standard. Therefore, corn seeds were treated by biofertilizers in liquid (Leanum) and powdered (Vitamin O7) forms and then sown in the field conditions. During summer period, plants were treated by liquid fertilizer one or two times. Also, impact of the soil tillage was studied. Research was conducted on the effects of cultivation at depths of 15–18 and 5–8 cm, as well as plowing and flat–cutting cultivation at depths of 25–28 cm. It was found that fertilization impacted on corn yield and grain quality – protein, ash and starch content. Usage of seed inoculants and foliar fertilization in generally leads to increase yield but at different levels. Protein and oil content had a weak positive correlation with applied fertilizers on the background of flat–cut tillage.

Keywords: biofertilizer, organic farming, microbial inoculation, foliar application, grain quality, soil tillage.

INTRODUCTION

In modern agricultural practices the usage of fertilizer products has become indispensable to enhance crop productivity and meet the ever–growing global food demand [Mishchenko et al., 2022]. Corn (*Zea mays*) among the various agricultural crops is very important both in economical and nutritional roles [Radchenko et al., 2024a]. The quality of corn is determined by its starch, oil, protein, and ash content. It`s not only influences its nutritional value but also affects its applicability in various industrial processes [de Matos Nascimento et al., 2020].

Fertilizer application plays a pivotal role in optimizing crop yield and quality by providing essential nutrients necessary for plant growth and development [Ramírez–Silva et al., 2022; Zakharchenko et al., 2024; Radchenko et al., 2024b]. The characteristics of corn's quality are crucial to both industry and human life. For example, starch content affects its use in food and ethanol production [Hoang and Nghiem, 2021; Pylypchenko et al., 2023]. Oil content relevant for cooking oil and biodiesel production [Wang et al., 2023; Kolisnyk et al., 2024]. Ash content indicative of mineral and nutrient buildup and protein content necessary for animal feed [Loy and Lundy, 2019] together define the overall usefulness of a substance. However, the influence of biofertilizer on these attributes is complex, affected by factors such as soil type, climate, hybrid or variety, and application rates [Hryhoriv et al., 2021; Radchenko and Pshychenko, 2022; Lopushniak et al., 2022; Shelest et al., 2023].

The goal of this paper is to explore the impact of biological fertilizer products Leanum (L) and Vitamin O7 (V) on the quality of corn grain under different soil tillage.

MATERIAL AND METHODS

Research conditions

The study was carried out between 2020 and 2022 in the Sumy National Agrarian University's experimental field. The research plots' soil was a typical chernozem, which is described as low-humus, medium-loam soil with a medium-content, high P and K-content, pH (H_2O) – 6.23. Figure 1 depicts the weather patterns for the three vegetative seasons. Each year's previous crop was winter wheat. The soil was prepared before the sowing by cultivating it to a depth of 10 to 12 cm. Corn hybrid – Harmonium (FAO 380) from Euralis.

Experiment factors

The study that was carried out was a two-factor experiment. Factor A involves the soil tillage: (1) Traditional (reversible tillage) – plowing to a depth of 25–28 cm (R 25–28) as a control; (2) Irreversible tillage to a depth of 25–28 cm (IR 25–28) – using flat–cutting technique; (3) Irreversible tillage to a depth of 15–18 cm (IR 15–18) – disking method; (4) Irreversible tillage to a depth of 5–8 cm (IR 5–8) – using disking approach. Factor B – Inoculation with fertilizer products L and V and foliar treatment using L during critical growth stages V5 and V12. Therefore, the variations are: (C) – no treatment; (C+1L) – with a single foliar application of L; (C+2L) – with two foliar applications of L; (L) – L inoculation before sowing; (L+1L) – inoculation with L and a single foliar application of L; (L+2L) – inoculation with L and two foliar applications of L; (V) – V inoculation before sowing; (V+1L) – inoculation with V and a single foliar application of L; (V+2L) – inoculation with V and two foliar applications of L.

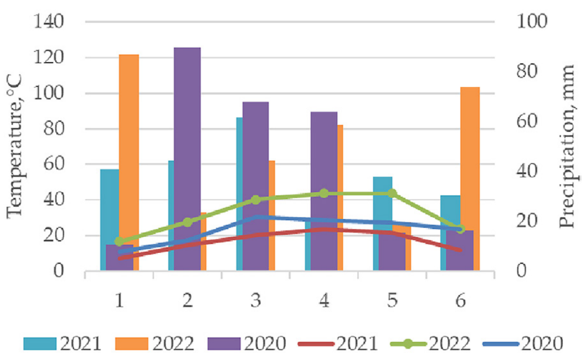

Figure 1. Climatic conditions during the corn planting period in 2020–2022, with columns for temperature and lines for precipitation (Datsko and Zakharchenko, 2023)

Sample selection and analyzing

Ten cobs were chosen from each variant in three replicates for the examination of maize grain using qualitative indicators. The samples were then examined using SupNIR–270 for protein, oil, starch, ash, and cellulose content after the cobs had been peeled.

Statistical analysis

To perform the statistical analysis, Statistica 10.0 (StatSoft Inc., Tulsa, USA) software was used for MANOVA.

RESULTS AND DISCUSSION

According to the findings of the three–year study, plowing to a depth of 25–28 cm and applying the treatment C+2L improved the protein content of Harmonium cultivation (Table 1). On the other hand, after disking to a depth of 5–8 cm and treating it with C+1L and V inoculation, its content increased. Other variations either kept the protein content within normal ranges or had much lower protein contents than the control. Only with disking to a depth of 5–8 cm and the combination treatment L+1L did the oil content of maize grain rise. Under plowing to a depth of 25–28 cm, with the combined treatments V+2L and L+1L, the maximum starch concentration in maize grain was discovered. The combination treatment L+2L demonstrated this effect in the flat–cutting treatment at a depth of 25–28 cm. Other variants either had content that was significantly less than the control variant or that was on the same level with it, with no discernible change. Simultaneously, variants C+2L, L, and L+2L showed an increase in ash content as a result of plowing to a depth of 25–28 cm. Notably, even with the disking treatment at a depth of 5–8 cm, the combination treatment L+ 2L also caused an increase in ash content. However, no variety showed an increase in cellulose content; instead, the only apparent trends were large decreases.

There have already been some researchers investigating into how biofertilizers and soil tillage affect the yield quality of maize. For example, Niu et al. [2023] at Ali–Perudic Argosols soil investigated that the use of traditional tillage (plowing) has a positive effect on the moisture content of the soil, and this, in turn, is positively correlated with the protein content of corn grains. Similar results were also obtained by Resul et al. [2022]. In response, researchers from Romania found that chisel cultivation to a depth of 18–20 cm had the greatest impact on the quality of the yield on chernozem soils [Partal et al., 2023].

The effects of fertilizer products on the yield quality of maize have already been studied. For

Table 1. Qualitative indicators of the Harmonium hybrid in 2020–2022, (x±SD)

Soil tillage	Biofertilizer	Protein, %	Oil, %	Starch, %	Ash, %	Cellulose, %
R 25–28	C	7.71±0.23a	4.00±0.13a	73.65±1.70a	1.94±0.08a	3.59±0.08a
	C+1L	8.17±0.19a	4.15±0.10a	74.82±3.48a	2.01±0.06a	3.68±0.16a
	C+2L	8.29±0.14c	4.00±0.07a	75.02±1.95a	2.07±0.13c	3.71±0.07a
	V	6.38±0.11b	3.64±0.19b	76.39±2.67a	1.63±0.03b	3.85±0.12a
	V+1L	7.22±0.58a	3.69±0.17b	74.81±1.43a	1.75±0.09b	3.73±0.10a
	V+2L	7.15±0.27b	4.14±0.18a	78.22±4.16c	1.85±0.18a	3.75±0.26a
	L	7.69±0.27a	3.95±0.22a	69.92±1.86b	2.08±0.08c	3.54±0.13a
	L+1L	7.63±0.29a	4.05±0.25a	76.53±4.89c	1.93±0.26a	3.69±0.19a
	L+2L	7.74±0.23a	4.10±0.30a	75.80±2.75a	2.16±0.12c	3.78±0.17a
IR 25–28	C	6.87±0.36b	3.75±0.11b	73.08±2.23a	1.67±0.10b	3.23±0.33b
	C+1L	7.58±0.26a	3.81±0.14a	76.37±1.76a	1.69±0.06b	3.24±0.23b
	C+2L	7.87±0.33a	3.73±0.25b	76.14±3.28a	1.69±0.06b	3.41±0.33a
	V	8.42±0.28c	3.38±0.23b	69.78±3.32b	1.94±0.06a	3.26±0.16b
	V+1L	7.54±0.55a	3.97±0.25a	75.98±5.29a	1.71±0.07b	3.46±0.45a
	V+2L	7.66±0.27a	4.08±0.16a	75.21±1.89a	1.75±0.03b	3.63±0.44a
	L	7.55±0.64a	3.70±0.34b	72.37±2.49a	2.01±0.39a	3.43±0.09a
	L+1L	7.31±0.32a	3.94±0.16a	74.41±2.48a	1.80±0.09b	3.25±0.22b
	L+2L	7.60±0.20a	4.09±0.10a	77.47±3.72c	1.87±0.05a	3.39±0.29a
IR 15–18	C	7.36±1.30a	3.36±0.09b	68.52±3.15b	1.65±0.06b	2.99±0.23b
	C+1L	7.63±0.54a	3.38±0.09b	70.12±2.01b	1.57±0.03b	2.94±0.19b
	C+2L	7.52±0.64a	3.32±0.19b	71.12±2.02a	1.41±0.07b	3.00±0.34b
	V	7.82±0.31a	3.46±0.56b	65.86±5.25b	1.65±0.08b	2.90±0.17b
	V+1L	6.89±0.58b	3.49±0.17b	72.60±2.79a	1.33±0.14b	3.13±0.39b
	V+2L	7.44±0.30a	3.64±0.13b	71.06±2.25a	1.55±0.03b	3.18±0.47b
	L	6.98±0.73b	3.65±0.58b	70.06±2.67b	1.57±0.15b	3.05±0.06b
	L+1L	6.81±0.47b	3.73±0.30b	70.86±2.16b	1.51±0.03b	2.95±0.17b
	L+2L	7.66±0.85a	3.99±0.33a	72.92±1.42a	1.79±0.13b	3.30±0.07b
IR 5–8	C	7.34±0.29a	3.73±0.08b	73.40±2.01a	1.69±0.03b	3.37±0.54a
	C+1L	8.25±0.41c	3.82±0.07a	72.92±2.53a	1.89±0.07a	3.09±0.26b
	C+2L	7.70±0.64a	4.13±0.57a	75.37±3.12a	1.83±0.12a	3.65±0.08a
	V	8.50±1.36c	3.48±0.07b	73.38±3.14a	1.96±0.19a	3.14±0.24b
	V+1L	7.99±0.95a	3.27±0.06b	71.51±5.03a	1.73±0.28b	3.15±0.40b
	V+2L	6.97±0.18b	3.82±0.16a	75.53±3.38a	1.39±0.15b	3.08±0.31b
	L	7.52±0.30a	4.02±0.22a	74.67±2.09a	1.55±0.03b	3.33±0.39a
	L+1L	7.96±0.57a	4.28±0.28c	74.60±2.16a	1.99±0.09a	3.67±0.50a
	L+2L	7.69±0.36a	4.19±0.21a	74.26±2.12a	2.14±0.06c	3.72±0.44a
		$p_{tillage} < 0.05$ $p_{biofertilizer} < 0.05$ $p_{tillage+biofertilizer} < 0.05$	$p_{tillage} < 0.05$ $p_{biofertilizer} < 0.05$ $p_{tillage+biofertilizer} < 0.05$	$p_{tillage} < 0.05$ $p_{biofertilizer} < 0.05$ $p_{tillage+biofertilizer} < 0.05$	$p_{tillage} < 0.05$ $p_{biofertilizer} < 0.05$ $p_{tillage+biofertilizer} < 0.05$	$p_{tillage} < 0.05$ $p_{biofertilizer} < 0.05$ $p_{tillage+biofertilizer} < 0.05$

Note: *x* – mean value; SD – standard deviation; *p* – confidence level of the criterion; abc – LSD_{05} of the studied variants compared to the control according to Fisher's criterion instance, research has shown that Rhizobium leguminosarum has a considerable impact on the starch and protein content of grains [Santoyo et al., 2021]. Other researches, like Pereira et al. [2023] and Mondal et al. [2020], have also confirmed that the inoculation causes an increase in the content of the grain quality components.

CONCLUSIONS

The results of the data analysis show that, with only a few exceptions where multiple indications significantly increase, the content of one indicator reduces as the value of another indicator grows. For instance, the C+2L treatment's raw material protein and ash contents significantly increased when the plowing was done to a depth of 25–28 cm. However, after disking to a depth of 5–8 cm and inoculating with V the protein content significantly raised but the oil content fell.

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