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ORIGINAL ARTICLE

Influence of fertilization and foliar feeding on maize grain qualitative indicators

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The article presents the research results on studying the impact of fertilizer rates and foliar feeding on the qualitative indicators of maize grains. The rise in fertilizer rates fostered the increase in crude protein content in maize grains, but there was a decrease in starch and crude fat content. Foliar feeding had the most significant effect in the complex application (Maize boost+Rexolin ABC+urea 5%+magnesium sulfate 5%) in the phase of ejection of panicles at all levels of NPK fertilizers. One has defined that increasing the rate of fertilizers to $N_{160}P_{80}K_{140}$ and foliar feeding using Maize boost+Rexolin ABC+urea 5%+magnesium sulfate 5% in maize tassels of phase received the highest content of crude protein in the grain-11.10%. The starch and fat content were highest in the control variant with $N_{80}P_{40}K_{60}$ fertilizer-74.20% and 4.33%, respectively.

Keywords: Maize, fertilizers, microfertilizers, grain quality.

Introduction

Maize is the third most essential crop in the world, after wheat and rice. It is used for nutritional, food, feed, and technical purposes. One kilogram of maize grain contains 1.34 fodder units, which prevails oats, barley, and rye. One obtains bioethanol from maize grain, which causes the expansion of the area under this crop. A lower protein content characterizes the chemical composition of maize grain compared to other cereals but has a higher fat content. In addition to the yielding capacity, the qualitative indicators of maize grain are essential-the content of protein, starch, and fat, which affect the cost of the obtained yielding capacity (Petrychenko & Lykhochvor, 2020; Kylymniuk, 2013; Shpaar, 2012). Plenty of factors, such as hybrid (Poliakov, 2020; Hlushko & Voitashenko, 2013), sowing date (Vozheohva, Drobit & Drobitko, 2020), crop density (Vlashchuk, Kolpakova & Konashchuk, 2017, Krasnienkov and others, 2015), growing conditions, application of fertilizers (Wang et al., 2020, Szulc et al., 2013), cultivation technology (Petrychenko & Tomashuk, 2019) and other factors influence the quality of maize grain.

One of the most important aspects is the supply of nutrients. Fertilizer application increases the protein content in maize grain (Holou & Kindomihou, 2011; Wang et al., 2008), but the starch and fat content slightly reduces (Illés et al., 2020; Miao et al., 2006). Studies confirm that increasing the rate of NPK, the yield of protein, starch, and fat from 1 ha, as well as the estimated yield of bioethanol increase (Kaminskyi & Asanishvili, 2020, Biswas & Bao-LuoMa, 2016, Yermakova & Svystunov, 2016, Asanishvili, Korsun & Shliakhturov, 2014).

Microelements, which plants in relatively small quantities need, are vital as most of them are catalysts of chemical reactions and are part of enzymes that increase plant immunity. Sufficient content of microelements promotes better taking of macronutrients (Hospodarenko, 2013). One has established that foliar feeding of maize plants with microfertilizers positively affects the content and yield of starch in maize grain (Palamarchuk, 2020, Krestyaninov, Yermakova & Antal, 2019, Mazur & Shevchenko, 2017).

The research aims to study the influence of diverse norms of mineral fertilizers and different terms of foliar feeding on the formation of quality indicators of maize grain.

Materials and Methods

The research was carried out in the experimental field of the Research and Production Center 'Podillia" of State Agrarian and Engineering University in Podilia during 2018-2020. The soil of the experimental site is typical black soil; the humus content is 3.27%, the content of easily hydrolyzed nitrogen is 116 mg/kg of soil (Cornfield method), mobile phosphorus compounds (Chirikov method)-95 mg/kg of soil, potassium-87 mg/kg of soil (Chirikov method), pH of the salt extract-6.5. The total area of the plot was 60 m^2, registration-50 m^2. The frequency is triple, the placement of plots is systematic. Hybrid LG 3258 (FAO 250). In a three-factor field experiment, we studied: 1) fertilizer rates: $N_{80}P_{40}K_{60,}$ $N_{120}P_{60}K_{100,}$ $N_{160}P_{80}K_{140}$. 2) foliar feeding: Rexolin ABC+Maize boost l/ha; Rexolin ABC+Maize boost l/ha+urea 5% solution; Rexolin ABC+Maize boost l/ha+urea 5% solution+$MgSO_4$-5% solution.

Concerning nitrogen fertilizers, we used urea (content N 46.2%) and ammonium nitrate (content N 34.4%) in a ratio of 50:50, phosphorus-ammophos (content P 52%), potassium-potassium chloride (content K 60%). Phosphorus and potassium fertilizers were applied for fall plowing, nitrogen-for pre-sowing cultivation. The composition of product used for foliar feeding: Rexolin ABC (9%-MgO, 7%-SO_2, 4%-Fe, 0.5%-B, 0.1%-Mo, 4.0%-Cu, 1.5%-Zn, 0.03%-Co)-2.0 l/ha+Maize boost (29.5%-P_2O_5, 5%-K_2O, 4.5%-MgO, 3.1%-Zn) at the rate of 0.2 kg/ha. One carried out harvesting and registration in the full ripeness of grain with the Haldrup C-85 combine harvester. We researched according to generally accepted methods and State Standards of Ukraine. The content of crude fat (oil) was determined by extraction in the Soxhlet apparatus (according to S. Rushkovskyi, State Standards of Ukraine 13496.15-97), crude protein-by the amount of total nitrogen (Kjeldahl method, State Standards of Ukraine 13496.4-93), starch according to State Standards of Ukraine 10845-91. The yielding capacity was brought to 100% purity and 14% moisture. We performed mathematical processing of the experimental results using the program Statistica 6.0.

Results and Discussion

Considering the research results, we established that the application of fertilizers and foliar feeding contributed to an increase in crude protein content in maize grain (Table 1).

Growth phase	**Feeding**	**$N_{80}P_{40}K_{60}$**			**$N_{120}P_{60}K_{100}$**			**$N_{160}P_{80}K_{140}$**		
		Protein	**Starch**	**Fat**	**Protein**	**Starch**	**Fat**	**Protein**	**Starch**	**Fat**
without feeding		9.12	74.20	4.33	9.56	73.02	4.16	9.85	72.96	3.89
10 leaves	1*	9.94	73.51	4.31	10.25	72.61	4.09	10.53	72.27	3.88
	2*	10.09	73.43	4.3	10.38	72.42	4.08	10.73	72.66	3.87
	3*	10.27	73.36	4.29	10.45	72.34	4.08	10.79	72.57	3.86
Tasseling of maize	1*	10.51	73.28	4.29	10.75	71.81	4.06	10.90	72.04	3.84
	2*	10.54	73.19	4.28	10.80	71.77	4.05	11.03	71.99	3.83
	3*	10.63	73.15	4.28	10.90	71.75	4.03	11.10	71.80	3.82
After flowering time	1*	10.31	73.48	4.29	10.35	72.29	4.04	10.85	72.10	3.82
	2*	10.37	73.44	4.28	10.68	72.24	4.03	10.93	72.06	3.79
	3*	10.43	73.27	4.24	10.71	71.22	4.02	11.06	72.02	3.76

Note: 1*-feeding using Rexolin ABC+Maize boost; 2*-feeding using Rexolin ABC+Maize boost+urea 5%; 3*-feeding using Rexolin ABC+Maize boost+urea 5%+magnesium sulfate 5%.

Table 1. The impact of fertilizers on the quality of maize grain, 2018-2020.

Rising in the rate of fertilizers from $N_{80}P_{40}K_{60}$ to $N_{120}P_{60}K_{100}$ increased the crude protein content in the grain by 0.44%, and using the fertilizer at the rate of $N_{160}P_{80}K_{140}$ crude protein content was 9.85%.

The starch content in the maize grain was the highest in the control variant at the lowest fertilization level. Increasing fertilizer rates, the content of starch and fat in the grain decreased.

Carrying out foliar feeding in diverse ways affected the qualitative indicators of maize grain. The most significant influence on the content of crude protein was contemplated in the maize tassel phase. Considering the background of fertilizers $N_{160}P_{80}K_{140}$ due to complex fertilization, this figure was 11.10%, the increase in control-1.25%, using fertilization $N_{120}P_{60}K_{100}$ it was 10.90%, an increase-1.34%, and concerning fertilization $N_{80}P_{40}K_{60}$ it was10.63%, an increase of -1.51%.

The application of foliar fertilizers fostered a slight reduction in starch and fat content, despite used fertilizers. Feeding with 10 leaves had the most negligible negative impact on the content of these indicators.

As a result of correlation and regression analysis, we revealed a strong relationship between protein content, feeding and fertilization. The correlation coefficient was r=0.74 and r=0.43, respectively. There was a weak direct relationship between protein content and growth phase (r = 0.14). This dependence is described by the regression equation:

$$У = -28,4 +0,06X_1 + 0,04X_2 +0,002\ X_3 \text{ ……..(1)}$$

Where: У-protein, %
X_1-growth phase
X_2-feeding
X_3-fertilization
The multiple correlation coefficient is R=0.87, which indicates a close relationship between the result and the argument. The coefficient of determination is equal to R^2=0,75.
We revealed a strong inverse relationship between starch content, feeding, and fertilization concerning correlation and regression analysis. The correlation coefficient was r=-0.46 and r=-0.66, respectively. A weak inverse relationship was between the starch content and the growth phase (r=-0.14). This dependence is described by the regression equation:

$$У = 105.6-0.13X_1-0,3X_2-0,01\ X_3 \text{ ……..(2)}$$

Where: У-starch, %
X_1-growth phase
X_2-feeding
X_3-fertilization
The multiple correlation coefficient is R=0.82, which indicates a close relationship between the result and the argument. The coefficient of determination is equal to R^2=0.67.
Considering correlation and regression analysis, we revealed a strong inverse relationship between fat content and fertilization. The correlation coefficient was respectively r=-0.98. There was a weak inverse relationship between fat content, growth phase, and feeding, -r=-0.09 and -0.16, respectively. This dependence is described by the regression equation:

$$У = 7,49 - 0,02\ X_1 - 0,03X_2 -0,01\ X_3 \text{ ……..(3)}$$

Where: У-fat, %
X_1-growth phase
X_2-feeding
X_3-fertilization
The multiple correlation coefficient is R=0.99, which indicates a close relationship between the result and the argument. The coefficient of determination is similar to -R^2=0.99.

Conclusion

The application of mineral fertilizers and feeding have various effects on the qualitative indicators of maize grain. Due to the increase of the fertilizer rate to $N_{160}P_{80}K_{140}$, one obtained the highest content of crude protein in maize grain-11.10%, at the same time, one observed a decrease in the content of starch and fat. Conducting foliar feeding also impacted qualitative indicators depending on the composition and growth phase of maize grains. The most significant effect on crude protein content was contemplated when feeding Rexolin ABC+Maize boost+urea 5%+magnesium sulfate 5% in 10 maize leaves on the background of fertilizers $N_{160}P_{80}K_{14.}$

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