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CORN RESPONSE TO FOLIAR FERTILIZER APPLICATION

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Abstract

A field experiment was conducted with five maize hybrids during the period 2022-2024. The parameters of the yield of green mass, of the additional yield formed under the influence of foliar fertilization, have been established. The application of the organic liquid fertilizer Aminosol, the single-component inorganic fertilizers Boron, Zinc and Nutriplant 36 contributed to an increase in biomass by 20608.4 to 26799.0 kg/ha, on average over the study period. After treatment with the organo-mineral fertilizer Kinsidro Grow and the nitrogen stabilizer N-Lock, an increase in the productivity of the hybrids was again established. The greatest increase was registered at LG 31,390, respectively with 26068.8 kg/ha. In total, for hybrids and variants for the period of the field study, an increase of 41.4% was recorded after foliar fertilization with the products of the first technology. A strong correlation was established between the indicators of plant height and green mass yield for Premeo (R^2 = 0.9284) and Pioneer P9889 (R^2 = 0.9043). A positive correlation dependence, with a coefficient of determination R^2 = 0.8998 for DKC 4416.

***Key words**: corn, yield, biomass, foliar fertilization, regressions.*

INTRODUCTION

Global climate change, prolonged droughts, insufficient water resources and last but not least interrupting the growing population of the planet raises the question of the need to produce more output per unit of area. An increase in average temperature leads to variability in the productivity of all agricultural crops, Tigchelaar et al. (2018) prove in their research. This is a serious challenge to crop production and agricultural science.

Management and adaptation can greatly reduce the potential impacts of climate change and climate variability on crop yields and farmers' incomes (Mineva, 2020; Popova et al., 2022). It is necessary to study the changes induced by the elements of climate on the growing seasons and yields of agricultural crops (Cojocaru, 2022; Song et al., 2023; Bijnens et al., 2024).

According to world grain production data in 2022/2023, maize has become the third most important grain crop in the world after wheat and rice (Shahbandeh, 2024).

For optimal nutrient supply, ecological, sustainable and innovative strategies need to be developed to be implemented as effective tools to maintain productivity and increase the tolerance of maize to drought stress (Ghiyasi et al., 2023; Moitazedi et al., 2023; Zarea et al., 2023).

The assimilation of nutrients throughout the growing season is linked in a number of agronomic practices that contribute to optimizing the process and guaranteeing high yields. These practices include structuring the soil, having enough readily available moisture for plants, combating water deficit and nutrient deficiency. Balanced fertilization is a key factor in the development and productivity of plants. Mineral fertilizers are crucial for increasing yields, but their unrestricted use leads to deterioration of the quality of plant production and environmental pollution (Yan et al., 2012; Zhao et al., 2013; Mu et al., 2015; Mustafa et al., 2021; Harish et al., 2022). According to research by Marschner (2012), after nitrogen fertilization, an increase in plant biomass was observed. The effect of nitrogen sources on the biomass and quality of silage maize has been the focus of a number of studies (Amin, 2011; Safdarian et al., 2014). An increase in the photosynthesizing surface of the leaves was also reported by Leghari et al. (2022).

Application of foliar fertilizers after soil fertilization is an effective method for increasing crop micronutrient content and crop yield and improving soil environment (Niu et al., 2021;

Stoyanov et al., 2024). According to Ramesh et al. (2018) foliar fertilization with organic fertilizers had a positive effect on growth and yield of maize (*Zea mays* L.). The authors reported increases in plant height, leaf area index, dry matter production, cob length and diameter, number of cob kernels, and grain yield. Asare et al. (2023) also reported an increase in leaf area and productivity in maize after foliar application of micronutrient-rich fertilizers.

Additionally, micronutrient fertilization is an effective strategy to reduce the harmful effects of water stress in plants (Solanki, 2021; Umar et al., 2022; Stoyanova et al., 2024). Foliar nutrition of plants, including application of the main nutrients (N, P and K) alone and in different combinations, leads to increased yields even under water stress conditions, reported Kakar et al. (2014). The authors found taller plants (221 cm), heavier grains (229 g/1000 grains) and prolongation of physiological maturity after foliar fertilization. Grain yield increased (2896 ha^{-1}) and harvest index (28.2%) compared to the control plots (no foliar nutrients were applied).

The objective of the present study was to investigate the effect of foliar fertilizers on biomass productivity in five maize hybrids.

MATERIALS AND METHODS

The study was conducted in the Stara Zagora region, Bulgaria during the period 2022-2024. The field experiment involved five maize hybrids from the FAO early and medium-early group. The hybrids tested were DKC 4416, Pioneer P9889, LG 31.390, Premeo and Knezha-461. They are of a different genetic background. LG 31.390 (FAO 390) is a representative of Hydraneo technology. This is a new generation of hybrids for managing drought risk DKC4416 (FAO 330) is a hybrid of the FieldShield hybrids and is characterized by high resistance to abiotic stress.

Pioneer P9889 (FAO 360) is a hybrid of the Optimum® AQUAmax® product line, a selection of hybrids adapted to drought. Premeo (FAO 400) is an Artesian technology representative. Knezha-461 (FAO 400-500) is a representative of the Bulgarian selection of hybrids. The study was carried out using the method of fractional plots, in 4 replications, with the size of the experimental area of 15 m^2. Variations of the experience are the following: 1. Control - Soil fertilization with N_{14} (without irrigation); 2. Soil fertilization with N_{14}; 3. Soil fertilizing + foliar fertilizing with Aminosol + Lebozol B + Lebosol Zn, Nutriplant 36; 4. Soil fertilization + Kinsidro Grow, N-Lock.

In the control variant, soil fertilization of the crop was carried out. In variants 2-4, irrigation was carried out using a drip irrigation system. The distance between the drippers was 0.15 m, in order to create a continuous moistened strip in the soil horizon. With the artificial supply of irrigation, conditions are created for optimizing the water regime in the soil and increasing the moisture in the ground air layer. The realized irrigation rate is 30 mm when the soil moisture reaches below 75-80% marginal field moisture capacity (FMC).

The tested hybrids were fed with foliar fertilizers during the growing season. The first technology included the organic liquid fertilizer Aminosol (2.0 l/ha), the single-component inorganic fertilizers Lebozol B (2.0 l/ha), Lebosol Zn (1.0 l/ha), and Nutriplant 36 (10.0 l/ha). According to the second technology, foliar fertilizing was carried out with the organo-mineral fertilizer Kinsidro Grow (150 g/ha), in the form of granules and is the nitrogen stabilizer N-Lock (2.50 l/ha).

RESULTS AND DISCUSSIONS

In the development of the crop, the soil-climatic features of the region where the experimental field is located are important. Of the elements of climate, temperature and rainfall are the factors that most influence the growth and development of agricultural crops.

Figure 1 presents the dynamics of the monthly average daily temperature for the three-year study period. Significant differences in temperature values have been reported when compared to the multi-year norm (for the period 1930-2024).

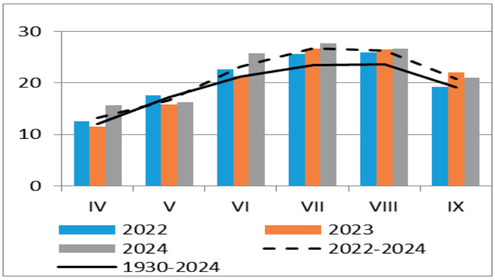

Figure 1. Dynamics of average daytime temperatures, by months, for the period 2022-2024

The analysis of the values shows that the average day-night temperature is above the norm in the three years, by 5.7%, 6.0% and 13.9%, respectively, and on average for the period by 8.5%. The extremely high temperatures registered in the second ten-day period of July 2024 make an impression. The increase in this month is 4.2ºC, or 13.4% compared to the climate norm. On average for the period, positive differences have been established compared to the temperatures for a multi-year period. According to Wang (2021) higher temperatures accelerate plant development, which shortens the length of reproductive phases.

In terms of the amount and distribution of precipitation, Figure 2 shows that the humidity conditions are different in the three years. In 2022, the amount of precipitation recorded during the vegetation period was 254.9 mm, which is 14.1% less than the norm for the period. In the second year, precipitation was 7.1% less, while in 2024 a decrease of 1.2% was found. It should be noted that in the last year of the field experiment, 98.5 mm were measured in September, when corn had completed its vegetation and was in the process of harvesting. The reported amount and distribution of precipitation during the corn growing season is extremely uneven. As a result, there is a deficiency of sufficiently readily available moisture, necessary for the growth and development processes of the studied corn hybrids.

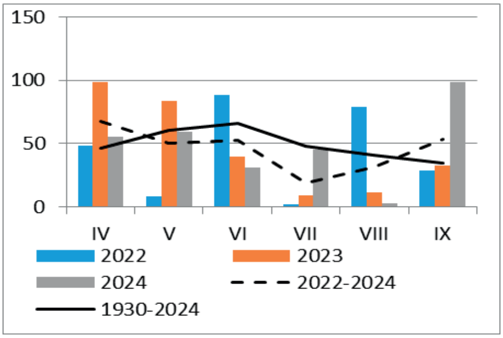

Figure 2. Amount and distribution of rainfall, during the period 2022-2024

The productivity of the culture and the stability of the yields depend not only on the level of agricultural technology, but also on the biological potential and adaptability of the respective hybrids. In the present study, the productivity of five maize hybrids of different genetic origins was examined. In natural, non-irrigated conditions, and under optimization of humidity conditions, the productivity under the influence of foliar nutrition of plants was established (Figure 3).

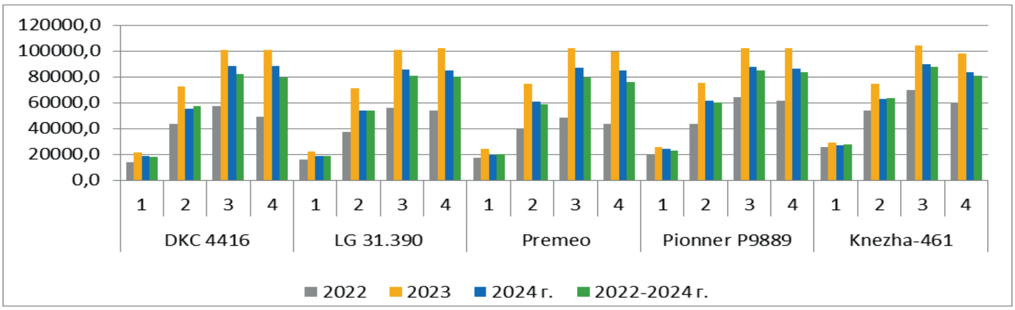

Figure 3. Green mass yield, for the period 2022-2024, kg/ha

The experimental results show that with natural moisture supply, yields in the range of 18100.0 kg/ha (for DKC 4416) to 27500.0 kg/ha (for Knezha-461) were established in all three years (Table 1). When optimizing the water factor, yields increased by 131.7% (Knezha-461), 159.9% (Pionner P9889), 182.4% (LG 31.390), 190.2% (Premeo) to 216% (DKC 4416). During the study, the nature of the dependence between yield and irrigation rate, the productivity of irrigation water and the additional yield was established (Stoyanova, 2018).

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Table 1. Production of green mass and additional production, average for the period 2022-2024, kg/ha

Corn hybrids	Variant	Average yield for the period 2022-2024	Additional yield	%
DKC 4416	1	18100,0	0,0	100,0
	2	57254,8	39154,8	316,3
	3	82089,4	63989,4	453,5
	4	79327,3	61227,3	438,3
LG 31.390	1	19133,3	0,0	100,0
	2	54028,5	34895,2	282,4
	3	80827,5	61694,2	422,4
	4	80097,3	60963,9	418,6
Premeo	1	20166,7	0,0	100,0
	2	58531,7	38365,1	290,2
	3	79140,1	58973,4	392,4
	4	75995,7	55829,0	376,8
Pionner P9889	1	23100,0	0,0	100,0
	2	60037,8	36937,8	259,9
	3	84690,7	61590,7	366,6
	4	83350,2	60250,2	360,8
Knezha -461	1	27500,0	0,0	100,0
	2	63708,1	36208,1	231,7
	3	87816,0	60316,0	319,3
	4	80545,7	53045,7	292,9

The analysis of the results reports an increase in green mass yield under the influence of foliar application of fertilizers during the vegetation of the corn hybrids. The obtained data are based on the optimization of the water reserve in the soil horizon.

Foliar fertilization of plants with the organic liquid fertilizer Aminosol, single-component inorganic fertilizers Boron, Zinc and Nutriplant 36 contributed to increase the biomass by 20608.4 to 26799.0 kg/ha, on average over the study period. The increase over unfertilized variants was 35.2% for Premeo, 37.8% for Knezha-461, 41.1% for Pionner P9889, 43.4% for DKC 4416 and 49.6% for LG 31.390. After treatment with the organo-mineral fertilizer Kinsidro Grow and the nitrogen stabilizer N-Lock, an increase in the productivity of the hybrids was found again. The greatest increase was registered at LG 31,390, respectively with 26068.8 kg/ha.

In total, across hybrids and variants for the field study period, an increase of 41.4% was reported after foliar fertilization with the products from the first technology. After applying the second technology, the average increase over the period was 36.4% for the five hybrids. Therefore, Zhuk (2022) also recommends that when growing corn for green table, foliar treatment is applied to increase yields.

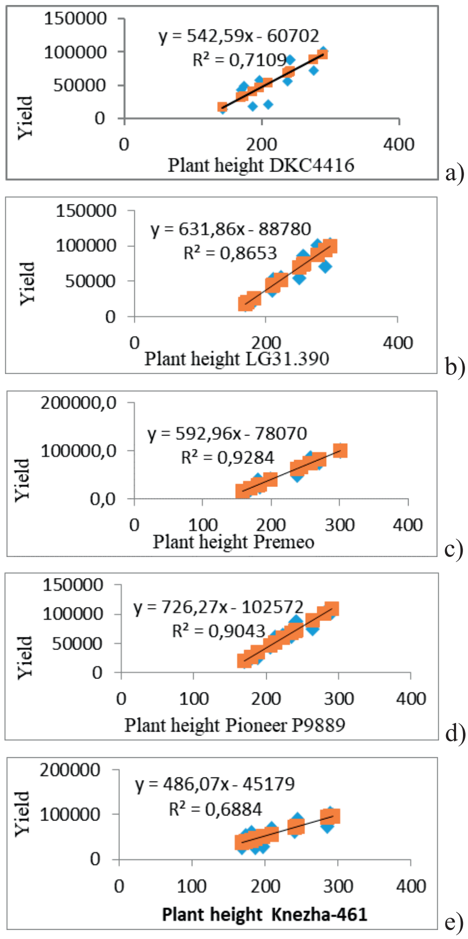

Figure 4. Linear regression model between plant height and yield of green mass

On average over the three-year test period, LG 31.390 stood out as the most responsive to foliar fertilizers. The application of the organic fertilizers Aminosol + Lebozol B + Lebosol Zn and Nutriplant 36 help to increase productivity by 49.6%, and after treatment with the products Kinsidro Grow and N-Lock, an increase of 48.2 5 was found. In the other hybrids, productivity increased by 35.2% (Premeo), by 37.8% (Knezha-461), by 41.1% (Pioneer P9889) and by 43.4 (Pioneer P9889) after application of Aminosol + Lebozol B + Lebosol Zn and Nutriplant 36. The increase was by 26.4 %, 29.8 %, 38.6 %, 38.8 %, respectively, in Knezha-461, Premeo, DKC 4416 and Pioneer P9889.

The developed linear regression equations show the nature of the relationship between the studied biometric indicators and yield of green mass. A strong positive correlation (R^2) was found. The determination coefficients were calculated for the five hybrids. A strong correlation was found between the parameters of plant height and green mass yield in Premeo (R^2 = 0.9284) and Pioneer P9889 (R^2 = 0.9043) (Figure 4).

In the remaining three hybrids, the relationship is a little less pronounced, respectively, in LG 31.390 the coefficient of determination is R^2 = 0.8653, in DKC 4416 it is R^2 = 0.7109 and in Knezha-461 R^2 = 0.6884. The coefficient of determination shows what percentage of the variance in the outcome variable is explained by the action of the factor variable. In the calculated values of for the five hybrids means that from 69 to 93 % of the yield depends on the plant height.

When investigating the nature of the interrelationships between the number of leaves per plant and green mass yield, the regression equations developed show that there are strong correlational dependencies in them as well (Figure 5).

A strong positive correlation was found between the indicators number of leaves and yield of green mass, with a coefficient of determination R^2 = 0.8998 for DKC 4416. A strong positive relationship was also found for Knezha-461 (R^2 = 0.8867), Premeo (R^2 = 0.7768), Pioneer P9889 (R^2 = 0.7607) and LG 31.390 (R^2=0.7106). The results show that from 71 to 89% green mass yield depends on the number of leaves per plant.

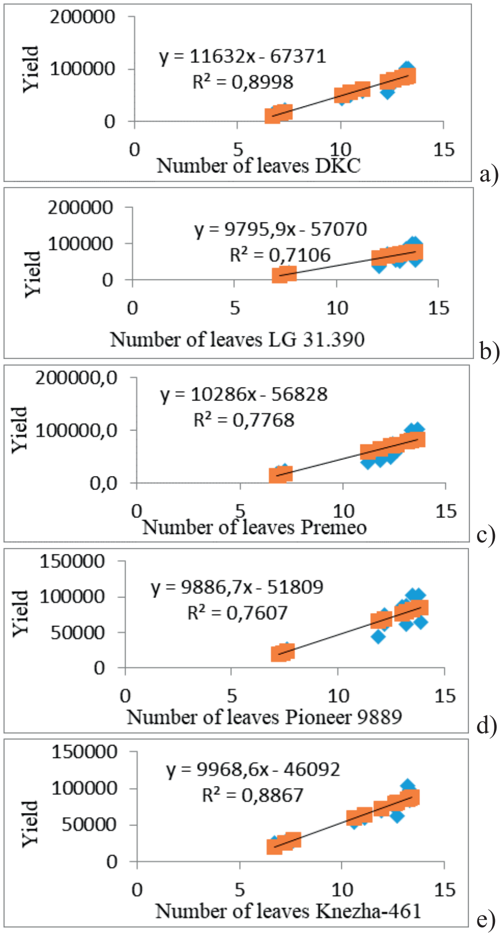

Figure 5. Linear regression model between number of leaves per plant and yield of green mass

CONCLUSIONS

Based on the field experience, several main conclusions were made.

A positive trend towards an increase in green mass yield after foliar fertilization was established. The application of the organic liquid fertilizer Aminosol, the single-component inorganic fertilizers Boron, Zinc and Nutriplant 36 contributed to an increase in biomass by 20608.4 to 26799.0 kg/ha, on average for the study period. The increase compared to the unfertilized variants was highest in LG 31.390, by 49.6%. After treatment with the organo-mineral fertilizer Kinsidro Grow and the nitrogen stabilizer N-Lock, an increase in the productivity of the hybrids has also been found.

The greatest increase was registered at LG 31,390, respectively with 26068.8 kg/ha.
In total, across hybrids and variants for the Polish study period, an increase of 41.4% was reported after foliar fertilization with the products from the first technology. After applying the second technology, the average increase over the period was 36.4% for the five hybrids.
A strong correlation was found between the parameters of plant height and green mass yield in Premeo (R2 = 0.9284) and Pioneer P9889 (R^2 = 0.9043).
A positive correlation dependence, with a coefficient of determination R^2 = 0.8998 in DKC 4416. A strong positive relationship was also established in Knezha-461 (R^2 = 0.8867).

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REFERENCES

Asare, G., Avornyo, V. K., Gyamfi, R. A., Bindraban, P. S., & Attakora, W. K. (2023). Effect of Foliar Application of some Macro and Micronutrients on the Growth and Yield of Maize. International Journal for Research in Applied Science and Engineering Technology (IJRASET), 11, 56655.

Amin, M. E. M. H. (2011). Effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.). Journal of the Saudi Society of Agricultural Sciences, 10(1), 17-23.

Bijnens, G., Anyfantaki, S., Colciago, A., De Mulder, J., Falck, E., Labhard, V., Strobel, J. (2024). The impact of climate change and policies on productivity. ECB Occasional Paper, (2024/340).

Cojocaru, O. (2022). Trends of significant variability of climate change in the village of Negrea in the last 120 years. *Scientific Papers. Series A. Agronomy, 65*(1), 61-70.

Ghiyasi, M., Danesh, R.Y., Amirnia, R., Najafi, S., Mulet, J.M., Porcel, R. (2023). Foliar Applications of ZnO and its nanoparticles increase safflower (*Carthamus tinctorius* L.) growth and yield under water stress. *Agronomy, 13* (1), 192. https://doi. org/10.3390/agronomy13010192.

Harish, M. N., Choudhary, A. K., Kumar, S., Dass, A., Singh, V. K., Sharma, V.K., & George, S. (2022). Double zero tillage and foliar phosphorus fertilization coupled with microbial inoculants enhance maize productivity and quality in a maize–wheat rotation. Scientific Reports, 12(1), 3161.

Kakar, K. M., Khan, A., Khan, I., Shah, Z., & Hussain, Z. (2014). Growth and yield response of maize (*Zea mays* L.) to foliar NPK-fertilizers under moisture stress condition. Soil & Environment, 33(2).

Leghari, S.J., Wahocho, N.A., Laghari, G.M., Laghari, A.H., Bhaban, G.M., Talpur, K.H., Bhutto, T.A., Wahocho, S.A. and. Lashari, A.A. (2022). Role of nitrogen for plant growth and development: A review. *Adv. Environ. Biol., 10*(9): 209-218.

Mineva, R. (2020). Study of the effect of foliar fertilizer containing macro and micronutrients" Panacea Space" on productivity of oil bearing rose (*Rosa damascena* Mill). Journal of Mountain Agriculture on the Balkans, 23 (5), 218-228.

Moitazedi, S., Sayfzadeh, S., Haghparast, R., Zakerin, H.R., Jabari, H. (2023). Mitigation of drought stress effects on wheat yield via the foliar application of boron, zinc, and manganese nano-chelates and supplementary irrigation. *J. Plant Nutr. 46*(9), 1988–2002.
https://doi.org/10.1080/01904167.2022.2105719

Mu, X., Chen, F., Qiuping, Wu, Chen, Q., Wang, J., Yuan, L., Mi, G. (2015). Genetic improvement of root growth increases maize yield via enhanced post-silking nitrogen uptake. *European Journal of Agronomy, Volume 63*, 55-61.

Mustafa, A., Hu, X., Abrar, M.M., Shah, S.A., Nan, S., Saeed, Q., Kamran, M., Naveed, M., Conde-Cid, M., Hongjun, G., Ping, Z., Minggang, X. (2021). Long-term fertilization enhanced carbon mineralization and maize biomass through physical protection of organic carbon in fractions under continuous maize cropping. *Applied Soil Ecology. Volume 165*.

Marschner, H. (2012). Mineral nutrition of higher plants. Academic press, USA.

Niu, J., Liu, C., Huang, M., Liu, K. & Yan, D. (2021). Effects of Foliar Fertilization: A review of Current Status and Future Perspectives. *J Soil Sci Plant Nutr 21*, 104–118. https://doi.org/10.1007/s42729-020-00346-3

Popova, A., Kuneva, V., Dintchev, I., Ivanov, V. (2022). Mathematical approach to evaluation of the influence of climate indicators on quality of grapes in syrah clones. *Scientific Papers. Series B, Horticulture*. Vol. LXVI, No. 1, 335-340.

Ramesh, S., Sudhakar, P., & Elankavi, S. (2018). Effect of organic foliar nutrition on growth and yield of maize (*Zea mays* L.). *International Journal of Research and Analytical Reviews, 5*(3), 64-67.

Stoyanova, A. (2018). Relationships between the irrigation norm and production of maize (*Zea mays*). In Agronomie şi agroecologie (Vol. 52, pp. 88-93).

Stoyanova, A., Petrovska, N., Dinev, T., Velichkova, K., & Sirakov, I. (2024). Irrigation water productivity under drip irrigation of two corn hybrids. *Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 2*, 392-399.

Stoyanov, G., & Kuneva, V. (2024). Mathematical approach for assessing the impact of foliar nutrition on the main indicators in maize hybrids. *Scientific Papers. Series A. Agronomy, 67*(1), 683-690.

Safdarian, M., Razmjoo, J., & Dehnavi, M. M. (2014). Effect of nitrogen sources and rates on yield and quality of silage corn. *Journal of Plant Nutrition, 37*(4), 611-617.

Song, Y., Wang, C., & Wang, Z. (2023). Climate risk, institutional quality, and total factor productivity. Technological Forecasting and Social Change, 189, 122365.

Shahbandeh, M., 2024. Worldwide production of grain in 2023/24.

https://www.statista.com/statistics/263977/world-grain-production-by-type/.

Solanki, M. (2021). The Zn as a vital micronutrient in plants. *J. Microbiol. Biotechnol. Food Sci. 11*, e4026 https://doi.org/10.15414/jmbfs.4026

Tigchelaar, M., Battisti, D. S., Naylor, R. L., & Ray, D. K. (2018). Future warming increases probability of globally synchronized maize production shocks. *Proceedings of the National Academy of Sciences, 115*(26), 6644-6649.

Umar, U.d., Ahmed, N., Zafar, M.Z., Rehman, A., Naqvi, S.A.H., Zulfiqar, M.A., Malik, M. T., Ali, B., Saleem, M.H., Marc, R.A. (2022). Micronutrients foliar and drench application mitigate mango sudden decline disorder and impact fruit yield. *Agronomy 12*, 2449. https://doi.org/10.3390/agronomy12102449

Wang, Y., Sheng, D., Zhang, P., Dong, X., Yan, Y., Hou, X., Huang, S. (2021). High temperature sensitivity of kernel formation in different short periods around silking in maize. *Environmental and Experimental Botany, 183*, 104343.

Yan, P., Yue, S., Qiu, M., Chen, X., Cui, Z., Chen, F. (2012). Using maize hybrids and in-season nitrogen management to improve grain yield and grain nitrogen concentrations. *Field Crops Research. Volume 166*, 38-45

Zhao, B., Chen, J., Zhang, J., Xin, X., & Hao, X. (2013). How different long-term fertilization strategies influence crop yield and soil properties in a maize field in the North China Plain. *Journal of Plant Nutrition and Soil Science, 176*(1), 99-109.

Zhuk, E.A. (2022). Effect of nitrogen fertilizer life force humic n on the yield and quality of the green mass of corn in the conditions of the Republic of Belarus. Fodder Production. Collection of scientific papers, 21, 138.

Zarea, M.J., Karimi, N. (2023). Grain yield and quality of wheat are improved through post-flowering foliar application of zinc and 6-benzylaminopurine under water deficit conditions. *Front. Plant Sci., 13*, 1068649 https://doi.org/10.3389/fpls.2022.1068649