

BIOMASS PRODUCTIVITY OF THREE CORN HYBRIDS AFTER OPTIMIZING THE NUTRIENT AND IRRIGATION REGIME

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Abstract

A field experiment was conducted with three maize hybrids: DKC4416, LG 31.390 and Premeo under irrigated and non-irrigated conditions. The experiment was carried out during the period 2022-2024 at the Academic Technological Complex (ATC) of Trakia University, Stara Zagora, Bulgaria. The productivity of the green mass of the three maize hybrids was determined. After foliar fertilization with a complex of fertilizers Aminosol, Lebosol B, Lebosol Zn and Nutriplant 36, an increase of 22.8% (for LG 31.390), 24.4% (for DKC 4416) and 31.8% (for Premeo) was determined, on average for the three-year study period. The parameters of the additional yield of green mass have been calculated. Optimization of nutrients and irrigation regime contributes to increasing the values of additional yield by 276.8% (Premeo) to 353.5% (DKC 4416). An increase was also reported after applying the organic fertilizer Kinsidro Grow and the nitrogen stimulator N-Lock of 338.3% in DKC 4416, 318.6% in LG 31.390 and 276.8% in Premeo. The efficiency coefficient of irrigation water use has been established. The highest values were recorded for variant 3 with the highest coefficient calculated for DKC 4416 (40.0).

Key words: corn, irrigation, fertilization, yield, efficiency.

INTRODUCTION

Maize is one of the most widely grown and widely cultivated cereals in the world. According to data on world grain production in 2022/2023, maize has become the third most important cereal crop in the world after wheat and rice (Shahbandeh, 2024). The crop is ecologically plastic, but its responsiveness to optimizing available moisture has been proven. (Ivanova et al., 2021; Sharifnasab et al., 2023; Stoyanova A. et al. 2024b). Ecological plasticity and a short growing season are prerequisites for high productivity and versatile use (Popova et al., 2008; Stoyanova A. et al. 2024a). Nyirenda et al. (2021) add that for newly created hybrids, their higher yield and constant adaptability to changing environmental conditions are of high importance.

The impact of climate change trends can be predicted after studying the influence of these climate trends on crop yields. By developing statistical and mathematical models, the relationship between productivity and climate change can be found. Global climate change is associated with fluctuations in the amount and distribution of precipitation, which affects the

balance between plant needs for available moisture and moisture supply (Simić et al., 2023). Determining crop water consumption and irrigation water productivity is an important step towards developing more efficient systems for allocating limited water resources (Wang et al., 2022; Rank et al., 2023; Dimitrov, 2023). Research and updating technologies and policies can have a significant impact on more efficient use of water resources (Žarski et al., 2023). Against the backdrop of global warming and drought, Rank et al. (2023) believe that it is necessary to seek and implement water-saving technologies in agriculture, combined with fertilization, mulching and other approaches to reduce the water footprint of crops.

Managing plant nutrition technologies and optimizing the water regime is an important approach that is fundamental to every agricultural crop. Therefore, updating the irrigation and nutrient regime, aiming at a balance between the volume of irrigation water and the number of fertilizers applied, is a key factor in the use of these resources (Camp et al., 2003; Guo et al., 2022; Žarski et al., 2023). Drip irrigation can effectively improve the growth, yield, water use efficiency, leaf area index and

economic benefit of maize in northwest China reported Liu et al. (2023).

Foliar fertilization is an effective way to treat nutrient deficiencies, improve plant nutritional status, and help plants overcome periods of stress. Foliar biostimulants are an important factor in providing the opportunity to stimulate plant metabolism and improve plant defense mechanisms. Combined root and foliar application and fertigation methods significantly improve corn growth and yield (Khalafi et al., 2021; Fan et al., 2023; Stoyanov et al., 2024; Stoyanov, 2025; Stoyanov et al., 2025). Several researchers have reported on the positive effect of applying foliar nutrition to crops, analyzing the increase in biometric parameters in the three corn hybrids (Bagrintseva et al., 2023; Kovalenko et al., 2023). According to studies by Weisany et al. (2021) foliar application of Zn-Ch and Zn-NCh significantly reduces the adverse effects of drought stress. Other authors also support the thesis that micronutrient fertilization is an effective strategy for reducing the harmful effects of water stress in plants (Solanki, 2021; Umar et al., 2022).

Improving nutrient use efficiency and crop yield through improved nutrient and water management practices is an important approach to resource optimization (Noulas et al., 2023; Qin, 2024). Improving strategies for more effective and efficient use of irrigation water in agriculture is important for alleviating water scarcity and related environmental problems. According to Li et al. (2020) spatiotemporal review of agricultural water use provides guidance for improving irrigation water utilization ratio in China.

The aim of this study is to analyze the influence of irrigation and corn nutrition on the green mass productivity of three corn hybrids, as well as to establish the efficiency of irrigation and the productivity of irrigation water.

MATERIALS AND METHODS

To achieve the set goal, a field trial was conducted with the following corn hybrids: DKC4416 is a Bayer hybrid, from the FieldShield hybrids group; LG 31.390 is a hybrid from Limagrain, a representative of Hydraneo technology, and Premeo is a hybrid from Syngenta, from Artesian technology.

The field experiment was carried out at the Academic Technological Complex (ATC) of Trakia University, Stara Zagora, Bulgaria during the period 2022-2024. The study was conducted on a soil type typical of meadow-cinnamon soil in a fertilizer experiment under irrigated and non-irrigated conditions. The experiment was conducted using the fractional plot method, in 4 replications, with a crop plot size of 15 m².

After sowing, before the seed germinates, soil fertilization was carried out with N₁₄ (Ammonium nitrate). Nutrition during the growing season of the studied corn hybrids was carried out with organic multicomponent and single-component fertilizers. The influence of the foliar fertilizers Aminosol (AS), Lebosol B and Lebosol Zn, Nutriplant 36 (N36), Kinsidro Grow (KG) and N-Lock were tested. The field trial options include: 1. Control - fertilization with N₁₄ and no irrigation; 2. Fertilization with N₁₄ + irrigation; 3. Fertilization with N₁₄ + foliar feeding (Aminosol, Lebozol B and Lebosol Zn, Nutriplant 36) + with irrigation; 4. Fertilizing with N₁₄ + foliar feeding (Kinsidro Grow and N-Lock) + with irrigation. In case of lime. 3 feeding with Aminosol, Lebozol B and Lebosol Zn is applied in the 4-6 leaf phase, and with Nutriplant 36 it is treated in the 8-10 leaf phenophase. In lime. 4 the biostimulator Kinsidro Grow is applied in the phenophase 2-8th leaf, and the nitrogen stimulator N-Lock in the phenophase 3-6th leaf.

Irrigation was carried out with a drip irrigation system. In the first year, 4 irrigations were carried out, with an irrigation rate of 30 mm, and in the second and third, 6 and 5 irrigations were carried out, respectively, to maintain 75-80% FC (Field Capacity) in the soil layer 0- 0.80 m.

The irrigation water efficiency coefficient was calculated. The productivity of irrigation water in the studied hybrids was established. Irrigation water productivity is defined as the ratio between yield and irrigation rate.

Statistical analysis was performed with ANOVA.

RESULTS AND DISCUSSIONS

Climatic Conditions

The region in which the experimental field is located belongs to the European-continental climate zone. The years of the field study, in

terms of average daily temperatures, are characterized by significant differences from the measured temperatures compared to multi-year periods (Figure 1).

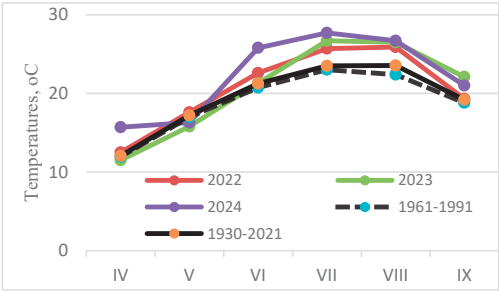


Figure 1. Dynamics of average daily temperatures for the period 2022-2024

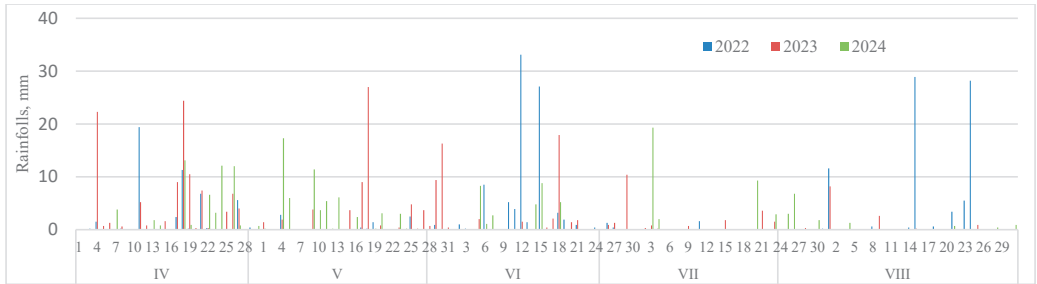


Figure 2. Amount and distribution of rainfall during the growing season of maize 2022-2024, the Stara Zagora region

In terms of precipitation, with a precipitation rate of 302.3 mm (1961-1991), 15.7% less precipitation was recorded in the first year, and 8.91% in the second year.

Table 1. Amount of precipitation for the growing season period

Years	IV	V	VI	VII	VIII	IX
2022	48.3	8.3	88.5	1.8	79.2	28.8
2023	98.6	83.6	39.7	9.2	11.9	32.5
2024	55.8	59.4	30.9	45.1	3.3	98.5
1961-1991	58.5	65.9	50.1	49.0	31.4	47.3
1930-2021	45.7	60.5	66.9	48.2	41.2	34.7

In 2024, the amount is close to the climate norm, only 3.1% less than the same for the period 1961-1991. The period of the field study is characterized by an uneven distribution of precipitation. In the first and second years, precipitation of 1.8 mm (2022) and 9.2 mm (2023) was recorded in July (Figure 2). The

The graph shows that the values during both applied multi-year periods are characterized by lower values. In the analysis, we apply two periods - one covers a multi-year period from 1930 to 2021, and the other period 1961-1991 is considered a representative climate norm by the National Institute of Meteorology and Hydrology (NIMH) - Bulgaria. The dynamics of the average daily temperature values by month for the corn growing period shows a permanent increase in temperatures compared to previous periods. On average for the study period, the average daily temperatures were higher by 12.1% (June), 16.1% (July) and 17.9% (August) compared to the average daily temperature for the period 1961-1991.

uneven distribution is characteristic, which provides insufficient moisture for crop development. For normal growth and development of corn, moisture characteristics are optimized through irrigation.

Productivity of corn hybrids

The yields of the studied corn hybrids vary by year and treatment options under the influence of different moisture and nutrient availability. Experimental results for green mass yield show an increase in values after application of irrigation and foliar fertilization. Under conditions of natural moisture supply and without fertilization during the growing season, yields ranged from 18100.0 (DKC 4416) to 20166.7 kg/ha (Premeo), on average for the study period (Table 2). In the variants without foliar fertilization, but under irrigation conditions, during the vegetation period, yields of 37133.0 kg/ha (LG 31.390), 39866.7 kg/ha (Premeo) and 43466.7 kg/ha (DKC 4416) were obtained in the first

experimental year. After foliar fertilization with the organic and mineral products Aminosol + Lebosol B + Lebosol Zn, Nutriplant 36, an increase in yields was found in the hybrids by 21.1% to 50.9%, respectively in Premeo and LG 31.390. In the second year, an increase in the productivity of the hybrids was observed after

the application of organic fertilizers and nitrogen stimulators Kinsidro Grow, N-Lock. The increase was 33.3% (Premeo), 38.6% (DKC 4416) and 43.7% (LG 31.390). The hybrid LG 31.390 stands out as the most responsive to foliar fertilization and to both fertilization technologies during the growing season.

Table 2. Green mass yield (kg ha⁻¹), for the three hybrids, for the period 2022-2024

Corn Hybrids	Variants	2022	2023	2024	2022-2024
DKC 4416	1. N ₁₄ , non-irrigation	14000.0	21800.0	18500.0	18100.0
	2. N ₁₄ with irrigation	43466.7	72648.9	55648.9	57254.8
	3. AS, B, Zn, N36	57267.0	100545.7	88455.4	82089.4
	4. N-Lock, KG	49133.3	100675.7	88172.9	79327.3
LG 31.390	1. N ₁₄ , non-irrigation	16400.0	22300.0	18700.0	19133.3
	2. N ₁₄ with irrigation	37133.0	70978.4	53974.2	54028.5
	3. AS, B, Zn, N36	56033.0	101137.5	85312.0	80827.5
	4. N-Lock, KG	53633.0	101976.5	84682.3	80097.3
Premeo	1. N ₁₄ , no- irrigation	17200.0	24100.0	19200.0	20166.7
	2. N ₁₄ with irrigation	39866.7	74774.2	60954.3	58531.7
	3. AS, B, Zn, N36	48273.3	102320.9	86826.0	79140.1
	4. N-Lock, KG	43533.3	99668.3	84785.5	75995.7
LSD. P <0.05		14620.9	4617.2	5088.7	7634.7
LSD. P <0.01		11850.53	7656.6	8438.5	10414.0
LSD. P <0.001		45342.4	14318.9	15781.1	14089.4
VC, %		0.393	0.449	0.468	0.440

After applying the first technology (variant 3), the increase in 2024 was 42.4% for Premeo, 58.15 for LG 31.390 and 59.0% for DKC 4416. Treatment with the products Kinsidro Grow, N-Lock (variant 4) contributed to an increase in yields by 39.1% for Premeo, 56.9% for LG 31.390 and 58.4% for DKC 4416. In the last year of the field study, a positive trend towards an increase in biomass yield parameters after treatment with foliar fertilization products was again established. Higher results were reported for variant 3, in which feeding during the growing season contributes to an increase in productivity of 42.5 (Premeo) to 58.9% (DKC 4416). The rates of increase in biomass yield after application of the foliar fertilizers Kinsidro Grow and N-Lock range from 39.1% (Premeo) to 58.5% (DKC 4416). The hybrid DKC 4416 proved to be extremely responsive to foliar fertilization in the last year.

The analysis of the results shows an increase in biomass productivity in the three corn hybrids studied. Yields when optimizing moisture in the soil horizon lead to an increase in the indicator. The most responsive, on average for the period, was the hybrid DKC 4416, which recorded an

increase of 216.3% compared to the non-irrigated variant. In the hybrids LG 31.390 and Premeo, an increase of 182.3% and 190.2% was recorded. After optimizing the nutritional and irrigation regime, a trend towards an increase in the productivity of the hybrids was reported after

The highest yield was found in DKC 4416 (82089.4 kg/ha), followed by LG 31.390 and Premeo. The application of the organic and mineral products Aminosol + Lebosol B + Lebosol Zn, Nutriplant 36 contributes to increasing productivity by 292.4% in Premeo, by 322.4% in LG 31.390 and by 353.5% in DKC 4416 compared to the non-irrigated and non-fertilized variant. The results after applying the organic fertilizer Kinsidro Grow and the nitrogen stimulator N-Lock are also high. An increase of 338.3% was recorded for DKC 4416, 318.6% for LG 31.390 and 276.8% for Premeo.

Irrigation water productivity

During the period of the field study, a different number of irrigations were carried out in different years. In 2022, 4 irrigations were carried out to maintain moisture in the soil

horizon. In 2023, 6 irrigations were implemented and 5 irrigations in 2024. The amount of the implemented irrigation rate varied over the years of the field study from 1200 mm to 1800 mm.

Table 3 presents the parameters of the additional green mass yield, which is formed under the influence of irrigation. Productivity values increased after irrigation in all three corn hybrids. The increase in green mass yield under the influence of the optimized irrigation regime is in the range of 34895.2 (LG 31.390) to 39154.8 kg/ha (DKC 4416). There is a trend towards an increase in additional yield after optimizing the irrigation and nutrient regime. The analysis of the results shows that after feeding with the organic fertilizers Aminosol, boron, zinc and N36, productivity is higher. The influence of complex fertilization with the products Kinsidro Grow and the nitrogen stimulator N-Lock is very well manifested in LG 31.390 and gives results similar to fertilization with the complex of fertilizers in variant 3. The

difference between the yield of green mass is only 730.2 kg/ha. More responsive to fertilization with the organic fertilizer Aminosol and the single-component boron and zinc and Nutriplant 36 are the hybrids DKC 4416 and Premeo.

Irrigation water productivity is an important factor in modern conditions, when water resources are limited and of high value. In the present study, the productivity of water was calculated for different fertilization and irrigation options (Table 3). Irrigation water productivity is defined as the ratio between yield and irrigation rate. Irrigation water productivity ranges from 33.8 to 54.9 kg/mm, on average over the study period. In the first year, it was found that the productivity of irrigation water had the lowest values, with an average for all variants of 43.4 kg/mm. The highest values were found in the variants fed with the complex of foliar fertilizers, the organic fertilizer Aminosol and the single-component boron and zinc and Nutriplant 36, in all three hybrids.

Table 3. Additional green mass yield, irrigation water productivity and effect of 100 m³ of irrigation water for the period 2022-2024

Corn Hybrids	Variant	Additional yield (AY), kg/ha				Irrigation water productivity (IWP), kg/mm				Effect of 100 m ³ of irrigation water, kg/ha			
		2022	2023	2024	2022-2024	2022	2023	2024	2022-2024	2022	2023	2024	2022-2024
DKC 4416	2	29466.7	50848.9	37148.9	39154.83	36.2	40.4	37.1	35.8	3622.2	4036.1	3709.9	3578.4
	3	43267	78745.7	69955.4	63989.37	47.7	55.9	59.0	51.3	4772.3	5585.9	5897.0	5130.6
	4	35133.3	78875.7	69672.9	61227.3	40.9	55.9	58.8	49.6	4094.4	5593.1	5878.2	4958.0
LG 31.390	2	20733	48678.4	35274.2	34895.2	30.9	39.4	36.0	33.8	3094.4	3943.2	3598.3	3376.8
	3	39633	78837.5	66612	61694.17	46.7	56.2	56.9	50.5	4669.4	5618.8	5687.5	5051.7
	4	37233	79676.5	65982.3	60963.93	44.7	56.7	56.5	50.1	4469.4	5665.4	5645.5	5006.1
Premeo	2	22666.7	50674.2	41754.3	38365.07	33.2	41.5	40.6	36.6	3322.2	4154.1	4063.6	3658.2
	3	31073.3	78220.9	67626	58973.40	40.2	56.8	57.9	49.5	4022.8	5684.5	5788.4	4946.3
	4	26333.3	75568.3	65585.5	55829.03	36.3	55.4	56.5	47.5	3627.8	5537.1	5652.4	4749.7

In the second year of the field experiment, the values ranged from 40.4 to 57.8 kg/mm, with an average for the year of 51.1 kg/mm. Again, the trend for higher values is observed for lime. 3. In 2024, the highest productivity results (60.0 kg/mm) of irrigation water were recorded for Premeo, variant 3. On average for all variants, the analyses show 51.6 kg/mm is the water productivity. Summarizing the results obtained, an average productivity of 46.1 kg/mm was established for the three hybrids over the three-

year study period. Establishing the productivity parameters of irrigation water is important in the construction of hydro-reclamation systems, Wang et al. (2022). The effect of 100 m³ of irrigation water is another important indicator by which the role of irrigation is determined. It is defined as the ratio between the additional yield and the irrigation rate. The conducted data analysis shows that the effect is highest in 2024. The average across variants was 5160.9 kg/ha. In the second year, 5113.6 kg/ha were

established, and in the first year 4335.8 kg/ha. In terms of fertilization options, a trend towards increasing the effect after foliar fertilizer application was observed in the three hybrids. After applying the second technology with foliar fertilization, the data show that this leads to a

higher effect than 100 m³ of irrigation water. After applying the organo-mineral fertilizer Kinsidro Grow and the nitrogen stimulator N-Lock, the effect is again high compared to lime. 2, in which no feeding was carried out during the vegetation period.

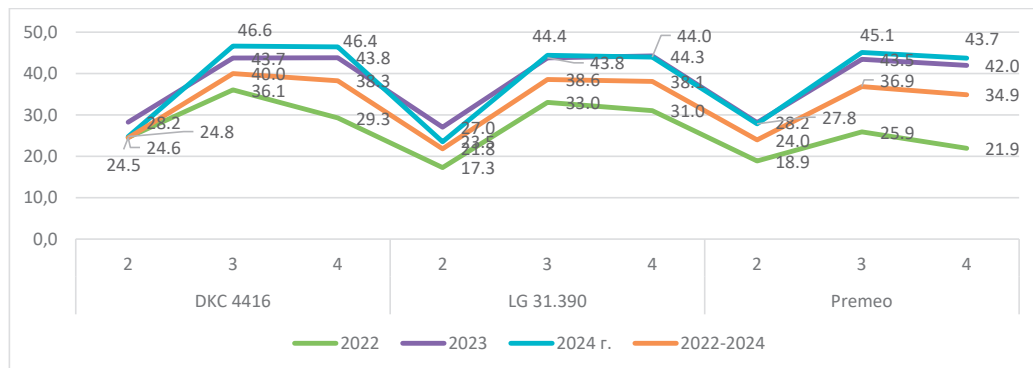


Figure 3. The irrigation efficiency coefficient for three corn hybrids for the period 2022-2024

Figure 3 presents the results of the calculated irrigation water efficiency coefficient (IWE). The irrigation efficiency coefficient is defined as the ratio between the additional green mass yield and the amount of irrigation rate. The diagram shows that in the second and third years, more efficient use of irrigation water was registered, which generated higher additional yield, with indicator values, on average for the year, of 37.4 and 37.2, respectively. In the first year, lower indicator values were established, ranging from 17.3 to 36.3, with an average of 27.9 across variants. The IWE values vary by variant, with a trend for the highest values in the three hybrids for variant 3 and all three hybrids.

CONCLUSIONS

The parameters of green mass productivity growth in three corn hybrids have been established. After foliar fertilization with the complex of fertilizers Aminosol, Lebosol B, Lebosol Zn and Nutriplant 36, an increase of 22.8% (for LG 31.390), 24.4% (for DKC 4416) and 31.8% (for Premeo) was found, on average for the three-year study period.

The parameters of the additional yield of green mass were calculated. Optimizing the nutrient and irrigation regime contributes to increasing the additional yield values by 276.8% (Premeo) to 353.5% (DKC 4416).

The efficiency coefficient of irrigation water use has been established. The highest values were registered for variant 3, with the highest coefficient calculated for DKC 4416 (40.0).

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