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EFFECT OF FOLIAR FERTILIZATION ON PROTEIN LEVELS AND NUTRITIONAL VALUE OF THREE HYBRID MAIZE BIOMASS

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Abstract

Foliar fertilization is a widely used practice for correcting nutrient deficiencies in plants. The object of the present study are three corn hybrids (DKC 4416, LG 31.390 and Premeo), with different genetic origins. Variants of the field experience are 1. Control without irrigation, with soil fertilization with N14 in the form of ammonium nitrate; 2. Soil fertilization with N14 in the form of ammonium nitrate; 3. Fertilization with N14 + foliar fertilization with Aminosol +Lebozol B + Lebosol Zn, Nutriplant 36; 4. Fertilization with nitrogen N14 + Kinsidro Grow, N-Lock. In variants 2, 3 and 4, irrigation was carried out, with a drip irrigation system. The parameters of yield of green mass and yield of dry matter were determined. The content of crude protein, KEM, KER and PSC in green mass was calculated. Linear regression equations were developed, which show that there is a strong positive correlation between green mass yield and crude protein content. The correlation coefficients for the three hybrids r = 0.99 (DKC 4416), r = 0.96 (LG 31.390) - r = 0.93 (Premeo) were established.

Key words*: corn, green mass, foliar fertilization, nutritional value.*

INTRODUCTION

Practice has shown that one of the most powerful agrotechnical factors for increasing yields from a unit of area is fertilization (Mineva et al., 2016; Meng et al., 2018; Ray et al., 2019; Stoyanova et al., 2019a; Stoyanova et al., 2019b). That is why, in order to avoid unfavorable changes in the soil as a result of fertilization, approaches are sought for balanced and tailored to the specific requirements of each crop, variety and hybrid, with the phenophase of development and the level of applied agronomic plant nutrition. Climatic conditions, especially the length of the growing season directly affect the selection of maize hybrids (Zhao et al., 2017; Ileri et al., 2018; Bonea et al., 2019).

Green fodder is considered to be one of the most important factors for successful dairy farming. Maize is one of the most studied crops because of its high genetic diversity and is gaining increasing popularity and market demand, as grain, animal feed and other industrial purposes (López-Reyes et al., 2015). Maize is a valuable forage because it grows rapidly, forms rich biomass and helps increase body weight and milk quality in cattle due to its higher nutritional value (Iqbal et al., 2006; Chaudhary et al., 2016; Ferraretto et al., 2018).

According to Wadhwa et al. (2010) crop contained, in corn forage, the highest organic matter (OM) and crude protein (CP) content and the lowest neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose and hemicellulose content compared to other forages. In addition, maize harvested at milk maturity phenophase frees up areas for subsequent crops (Brar et al., 2017).

In recent years, selection has focused on the creation of high-yielding, ecologically plastic and high-nutritional forage corn hybrids (Hundal et al., 2019). The existing rich genetic diversity makes it possible to correctly select the appropriate hybrids (Keskin et al., 2017; Zaragoza et al., 2019). Newly created hybrids should show consistent performance and adaptability under different environmental conditions. (Nyirenda et al., 2021 opined).

The one-sided application of mineral fertilizers leads to a disturbance of the ecological balance and a decrease in the quality of production (Wei et al., 2020). The need to add micronutrients is a problem that has been recognized for a long time (Enakiev et al., 2018).

Foliar fertilization is a widely used practice to correct nutrient deficiencies in plants caused by improper or insufficient nutrient supply to the roots. Nutritional management influences crop performance. Adequate supply of nutrients during the growing season greatly affects the quantity and quality of yields (Subrahmanya et al., 2017; Lato et al., 2012; Niu et al., 2021).
As per Kumar et al. (2016) soil and foliar applied zinc sulfate had significant effects on dry matter yield and quality of maize forage. Djurdjic et al. (2017) reported an increase in yield, organic matter and crude protein after the combination of classical fertilization and foliar fertilization of maize with the organo-mineral fertilizer "Synergon 2000".
To increase plant height, leaf area index, fresh matter by more than 40%, and leaf area, Brankov et al. (2020), after foliar application. A positive effect on the accumulation of crude protein was established by Semina et al. (2020) after foliar application of the complex fertilizers with macroelements in a chelated form (Azosol 36 Extra and Aquarin 5).
Through foliar fertilizing, the nutritional regime of the plants is optimized and they can develop their productive potential. Breeders could help develop cultivars and hybrids that respond well to foliar feeding, Kannan (2010) believes.
The aim of the present study was to evaluate the energy and protein nutritional value of the biomass of three maize hybrids of different genetic origins, fed with foliar fertilizers during the growing season.

MATERIALS AND METHODS

To achieve the goal, a field experiment with three corn hybrids was conducted. The region in which the experiment was carried out belongs to the European-continental climate zone, the Stara Zagora region, Bulgaria. The object of the study are three corn hybrids: DKC 4416 (FAO 330), which is a representative of the FieldShield technology. The hybrids are characterized by high resistance to abiotic stress. LG 31.390 (FAO 390) is a representative of Limagrain's Hydraneo technology. These are a new generation of hybrids for drought risk management. Premeo is the representative of Syngenta's Artesian technology. The advantages of the technology are yield stability in the event of a deficiency of rainfall and soil moisture. The hybrid is moderately early with FAO 400.
During the vegetation period of the corn hybrids, foliar fertilization was carried out with fertilizers rich in macro and microelements. Foliar fertilization, with organic and inorganic foliar fertilizers, was carried out with the recommended doses for each of them. According to the first technology, including the organic liquid fertilizer Aminosol and the single-component fertilizers Boron, Zinc and Nutriplant (var. 3), fertilization was carried out in a dose of Aminosol (2.0 l/ha), Lebosol B (2.0 l/ha), Lebosol Zn (1.0 l/ha) and Nutriplant 36 (10.0 l/ha). According to the second technology (var. 4), the applied products are the organic fertilizer Kinsidro Grow (150 g/ha), in the form of granules, and the nitrogen stabilizer N-Lock (2.50 l/ha).
The experiment was conducted under irrigated and non-irrigated conditions. Variants of the study are as follows:1. Control - without irrigation, with soil fertilization with N14 in the form of ammonium nitrate; 2. Soil fertilization with N14 in the form of ammonium nitrate; 3. Fertilization with N14 + foliar fertilization with Aminosol +Lebozol B + Lebosol Zn, Nutriplant 36; 4. Fertilization with nitrogen N14 + Kinsidro Grow, N-Lock. In options 2, 3 and 4, irrigation was carried out, with a drip irrigation system, to maintain a sufficient amount of readily available moisture for the 0-50 cm soil layer.
By the formulas of Todorov et al. (2007) the FUM, FUG, PDI and RDP content for ruminants were calculated.

$$GE = 0 .0242\ CP + 0.0366\ EE + 0.0209\ CF + 0.017\ NFE$$

$$ME = 0.0152\ DP + 0.0342\ DEE + 0.0128\ DCF + 0.0159\ DNFE$$

$$q = ME / GE$$

$$FUM = ME\ (0.075 + 0.039q)$$

$$FUG = ME\ (0.04 + 0.1q)$$

$$PDI = 1.11CP\ (1 - Deg)\ Dsi + 0.093\ FOM$$

$$FOM = DOM - DEE - FP - CP\ (1 - Deg)$$

$$FP = 250 – 0.5\ DM$$

$$RDP = CP\ (Deg – 0.1) – 0.145\ FOM$$

where: CF - crude fibre, CP - crude protein, DEE - digestible ether extract, Deg - degradability of dietary protein in the rumen, DF - digestible fibre, DNFE - digestible nitrogen free extract, DOM - digestible organic matter, DP - digestible protein, Dsi - digestibility in small intestine, EE

- ether extract, FOM - fermentable organic matter, FP - silage fermentable products, FUG - feed unit for growth (= 6 MJ net energy for growth), FUM - feed unit for milk (= 6 M J net energy for lactation), GE - gross energy, ME - metabolizable energy, NFE - nitrogen free extract, PDI - protein digestible in (small) intestine, RDP - rumen degradable protein.

RESULTS AND DISCUSSIONS

During the three farming years, the field experiment was based on the optimal sowing dates. During the crop's vegetation, biometric measurements and phenological observations were carried out. Corn hybrids with different genetic origins and with different resistance to environmental conditions have been tested in the field study, especially with regard to adaptability to soil moisture deficits. The results show the parameters of productivity in the three studied hybrids of corn (Table 1).
The values of the green mass presented in the table show that in conditions of natural moisture and supply, the yield of green mass varies over the years from 14000.0 kg (at DKC 4416) to 22300.0 kg (at LG 31.390). On average for the study period it was found that the hybrid DKC 4416 forms a green mass of 18100.00 kg/ha, followed by LG 31.390, with 19133.33 kg/ha. For the three-year period, under non-irrigated conditions, the highest yield of green mass was registered at Premeo - 20166.67 kg/ha. In the variants with irrigation, without foliar fertilization, an increase in the productivity of the hybrids was established.
When optimizing the moisture in the soil horizon, a tendency towards an increase in the obtained biomass was recorded for all hybrids. The increase in the productivity of the green mass was respectively 182.4% for Premeo, 19.2% for LG 31.390 and 216.3% for DKC 4416. The data analysis shows the parameters of the influence of readily available moisture in the soil. Yields increased to 57,254.8 kg/ha for DKC 4416, to 58,531.7 kg/ha for Premeo, and to 54,028.5 kg/ha for LG 31,390.
The treatment with foliar fertilizers in var. 3 and 4 leads to an increase in the productivity of maize hybrids at different rates over the years. In the first year after the application of the organic fertilizer Kinsidro Grow and the nitrogen stabilizer N-Lock, 100,675.7 kg/ha of green mass was registered at DKC 4416, and 101,976.5 kg/ha at LG 31.390, while the hybrid Premeo (102,320.9 kg/ha) was more responsive to foliar fertilization with the organic fertilizer Aminosol and the single-component fertilizers Boron, Zinc and NutriPlant. In the year 2023 a tendency to increase the yield of green mass after treatment with Aminosol, Boron, Zinc and Nutriplant (var. 3) was reported. An increase was also reported in var. 4, but with a smaller growth in yield. In the last year of the study, the trend towards increasing green mass yield values after applying foliar fertilization products was maintained, with var. 3, higher yield values were again registered.
On average for the three-year period, an increase of 29.8% (for Premeo), 38.6% (DKC 4416) to 48.3% (for LG 31.390) was found after application of the organic fertilizer Kinsidro Grow and N-Lock. 43.4% (at DKC 4416) and by 49.6% (at LG 31.390). The results indicate that the improvement of the nutritional regime during the vegetation of the crop helps to increase the green mass yield.
Optimizing the water and food regimes create conditions for unfolding the productive potential of the culture. In addition to yields, humidity and nutritional conditions also affect the parameters of dry matter and crude protein content. Figure 1 shows how the values of crude protein increase after irrigation to optimize the moisture factor, as well as after the application of foliar fertilizers rich in macro and microelements. The diagram shows the positive trend towards an increase in crude protein content in the green mass. The lowest values of the indicator were found at var. 1.
In the three studied hybrids, an increase in crude protein content under the influence of the artificially applied irrigation water was reported. In DKC 4416, the increase in the values of the indicator was 182.3% compared to the non-irrigated variant, on average for the period of the study. The LG 31.390 hybrid responded with a 109.7% increase and Premeo with 98.6% after optimizing the soil moisture.

Table 1. Energy and protein nutritional content of the green mas

Hybrids of maize	Variants	Green matter, kg	DM, kg	FUM	FUG	CP, kg	PDI, kg
2022							
DKC 4416	1	14000,00	6171,55	6917,13	7201,50	501,15	537,80
	2	43466,70	15730,69	18306,70	19179,40	1347,86	1400,85
	3	57267,00	21140,28	24314,26	25429,42	1888,51	1893,80
	4	49133,30	17458,97	19411,26	20214,52	1538,95	1524,50
LG 31.390	1	16400,00	7607,96	8434,45	8707,92	701,45	685,34
	2	37133,00	12918,88	14524,94	15111,31	1182,08	1154,72
	3	56033,00	19333,47	21478,88	22362,13	1869,55	1743,48
	4	53633,00	18758,25	21607,71	22596,86	1800,79	1718,20
Premeo	1	17200,00	6710,57	7358,01	7594,80	614,20	599,11
	2	39866,70	13863,41	16094,65	16845,85	1296,53	1263,67
	3	48273,30	16942,63	19584,09	20448,48	1681,11	1574,49
	4	43533,30	14773,88	16115,58	16693,95	1509,23	1346,36
2023							
DKC 4416	1	21800,00	7303,59	7925,76	8193,13	687,14	639,92
	2	72648,90	15857,25	16723,21	17104,28	1972,04	1506,90
	3	100545,70	22602,46	23672,67	24159,29	2763,22	2133,70
	4	100675,70	22668,72	24076,96	24678,70	2669,19	2109,81
LG 31.390	1	22300,00	7959,35	8729,23	9058,88	682,91	686,11
	2	70978,40	15353,40	16455,17	16900,63	1578,33	1386,79
	3	101137,50	25894,18	28305,07	29243,90	2703,35	2354,88
	4	101976,50	24198,50	26016,49	26814,89	2415,01	2159,91
Premeo	1	24100,00	8245,54	8848,78	9116,39	705,71	704,10
	2	74774,20	16256,70	17266,86	17740,16	1416,27	1398,84
	3	102320,90	23559,69	24755,08	25193,89	2681,57	2179,97
	4	99668,30	20599,93	21729,10	22277,03	2228,81	1859,61
2024							
DKC 4416	1	18500,00	5868,89	6271,50	6427,03	530,45	511,48
	2	55648,90	14852,66	16265,05	16820,41	1532,16	1346,75
	3	88455,40	21977,00	24097,06	24897,54	2472,29	2040,15
	4	88172,90	21118,26	23165,92	23919,70	2302,73	1949,19
LG 31.390	1	18700,00	5853,23	6166,95	6301,07	587,78	522,56
	2	53974,20	12597,30	13530,19	13886,81	1374,67	1158,08
	3	85312,00	21788,58	23347,21	23984,99	2423,81	2006,82
	4	84682,30	22727,18	25035,66	25918,21	2242,38	2046,73
Premeo	1	19200,00	6633,19	7040,15	7186,97	822,62	630,36
	2	60954,30	13803,57	15295,27	15786,25	1541,48	1285,04
	3	86826,00	23016,06	25461,91	26294,93	2346,80	2087,77
	4	84785,50	17695,53	18931,84	19367,11	1941,99	1633,43
Average 2022-2024							
DKC 4416	1	18100,00	64489,01	7038,13	7273,89	572,91	563,07
	2	57254,83	15480,20	17098,32	17701,36	1617,35	1418,17
	3	82089,37	21906,58	24028,00	24828,75	2374,67	2022,55
	4	79327,30	20415,32	22218,05	22937,64	2170,29	1861,17
LG 31.390	1	19133,33	7140,18	7776,88	8022,62	657,38	631,34
	2	54028,53	13623,19	14836,77	15299,58	1378,36	1233,20
	3	80827,50	22338,74	24377,05	25197,01	2332,24	2035,06
	4	80097,27	21894,64	24219,95	25109,99	2152,73	1974,95
Premeo	1	20166,67	7196,43	7748,98	7966,05	714,18	644,52
	2	58531,73	14641,23	16218,93	16790,75	1418,09	1315,85
	3	79140,07	21172,79	23267,03	23979,10	2236,49	1947,41
	4	75995,70	17689,78	18925,51	19446,03	1893,34	1613,13

Feeding with foliar fertilizers leads to an increase in the crude protein index values. After treatment with the products Aminosol, Boron, Zinc and Nutriplant, an increase of 213.2%, 254.8% and 314.5% was found, respectively, in the hybrids Premeo, LG 31.390 and DKC 4416. The increase in the index after fertilization with Kinsidro Grow and N-Lock was 165.1%, 227.5% and 278.8%, respectively, in Premeo, LG 31.390 and DKC 4416.

The increase in the index after fertilization with Kinsidro Grow and N-Lock was 165.1%, 227.5% and 278.8%, respectively, in Premeo, LG 31.390 and DKC 4416. The maize hybrid DKC 4416 is the most responsive to the optimized feeding regime.

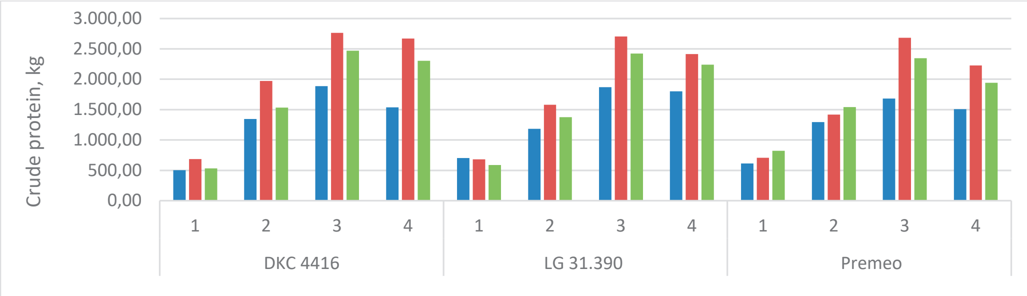

Figure 1. Content of crude protein (kg), by hybrids maize and years

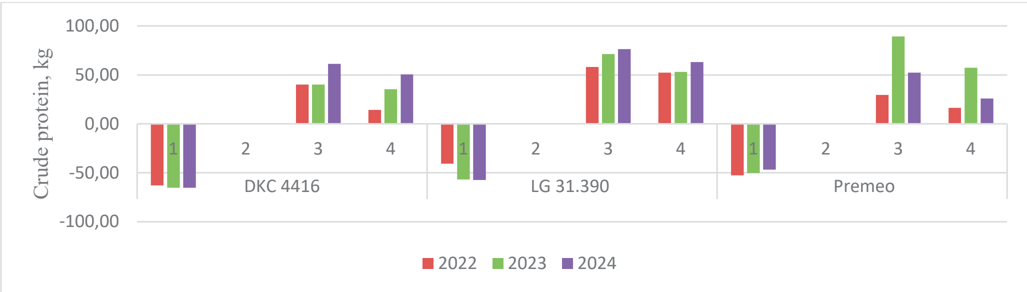

Figure 2. Content of crude protein (kg), compared to var. 2, by hybrids maize and years

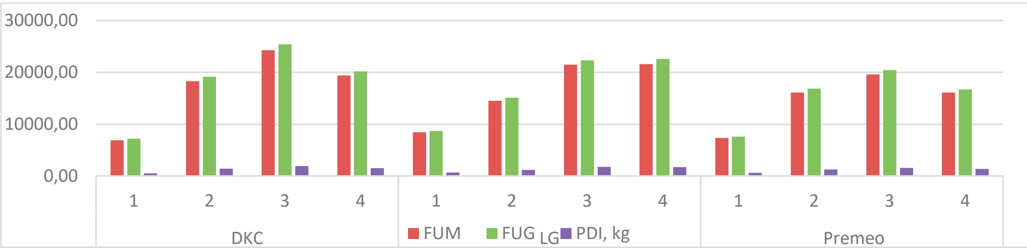

Figure 3. Content of FUM, FUG and PDI in kg, by hybrids and variants, on average for the 2022-2024 period

If, however, the data from var. 2 are accepted as control and a comparison was made with the results of the other options, it can be seen that when soil nutrition is implemented, but without irrigation, how the crude protein content in the green mass decreases. The reduction in crude protein was 49.6% (at Premeo), 52.3% (at LG 31.390) and by 64.6% (at LG 31.390). On the other hand, taking var. 2 for the control, the values of the indicator immediately stand out, increased thanks to the macro and micro elements brought in during the vegetation, through the foliar fertilizers (Figure 2). The increase in crude protein content under the influence of foliar fertilization was 46.8%, 57.7% and 69.2%, respectively, for DKC 4416, Premeo and LG 31.390, and was under the influence of feeding with the organic fertilizer Aminosol and the monocomponent Boron, Zinc and Nutriplant. The treatment with the organic fertilizer Kinsidro Grow and the nitrogen stimulator N-Lock contributed to an increase in the content of the indicator by 33.5%, 34.2% and 56.2%, respectively, in Premeo, DKC 4416 and LG 31.390.

The energy and protein nutritional content of the green mass was calculated.

The parameters of FUM, FUG and PDI were established for hybrids and variants. Figure 3 shows the positive trend towards increasing values of milk feed units (FUM) in lactating animals, feed growth units (FUG) in growing animals and digestible protein in the small intestine of ruminants PDI. The positive trend towards growth with optimization of conditions – moisture and nutrients, confirms the influence of both factors in the three corn hybrids. Higher values were calculated for DKC 4416, followed by LG 31.390 and Premeo.
The conducted regression analysis establishes a high positive correlation between green mass yield and the content of crude protein, in kg per ha. The correlation coefficients for the corn hybrids studied were established – r = 0.99 (DKC 4416), r = 0.96 (LG 31.390) – r = 0.93 (Premeo). Linear regression models were developed and the coefficients of determination determined. R2 = 0.8733 Premeo, R2 = 0.929 LG 31.390, R2 = 0.9823 at DKC 4416 (Figure 4).

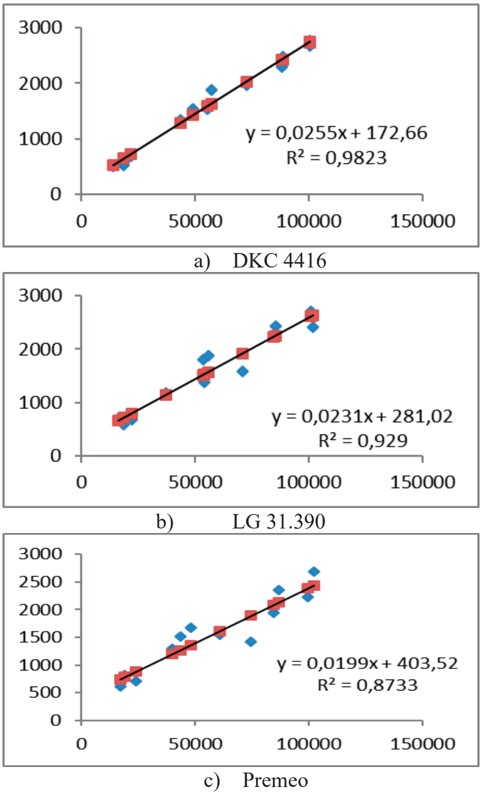

Figure 4. Linear regression models between yield of green mass and the content of crude protein, in kg/ha, at a) DKC 4416, b) LG 31.390 and c) Premeo

The coefficient of determination indicates the percentages of variation in crude protein content, i.e. they express the influence of green mass yield on the crude protein content of that mass.

CONCLUSIONS

As a result of the conducted field study, several main conclusions can be drawn:
Fertilization with foliar fertilizers leads to an increase in the values of the crude protein indicator. After treatment with the products Aminosol, Boron, Zinc and Nutriplant, an increase of 213.2%, 254.8% and 314.5% was found, respectively, in the hybrids Premeo, LG 31.390 and DKC 4416. The increase in the index after fertilization with Kinsidro Grow and N-Lock was 165.1%, 227.5% and 278.8%, respectively, in Premeo, LG 31.390 & DKC 4416.
A positive trend towards an increase in FUM, FUG and PDI indicators was established with the optimization of the water and nutrition regime of hybrid corn.
A high positive correlation between green mass yield and crude protein content was found, correlation coefficients r = 0.99 (DKC 4416), r = 0.96 (LG 31.390) – r = 0.93 (Premeo).
Linear regression models were developed and the coefficients of determination were determined for the three corn hybrids - R^2 = 0.87 (Premeo), R^2 = 0.93 (LG 31.390), R^2 = 0.98 for DKC 4416.

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