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INFLUENCE OF TRITICALE STRUCTURAL ELEMENTS ON THE GREEN MASS YIELD IN DEPENDENCY ON THE NITROGEN RATE AND THE HARVESTING PHASE

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Abstract

During the period 2013/2016, at the experimental field of Crop science department at Agricultural University - Plovdiv a field experiment was conducted, using a block method in 4 repetitions and size of the experimental plot 20 m^2. Two triticale varieties - Musala and Attila were tested. The two varieties were grown at fertilization levels, N_0, N_{120}, N_{160}, N_{200}, N_{240} kg/ha. The green mass yield value was reported in heading and milk maturity phases. Plant height and the yield structural elements have been determined. This research aimed to determine the influence of triticale structural elements on green mass yield, as a source of renewable energy, depending on nitrogen fertilizers and the phase of harvesting. The obtained results show that the structural elements have highest influence on the green mass yield. In milk maturity phase, the structural elements values increase, compared to heading phase. Increasing nitrogen fertilizers, leads to increasing in yield values, and highest yield was reported at N_{200} variant. Attila variety is characterized by higher stems and longer spikes than Musala variety. The differences in leaves number and stem thickness between the two varieties are negligible.

Key words*: triticale, green biomass yield, structural elements, harvesting phases and nitrogen fertilization.*

INTRODUCTION

Throughout the last few years, interest in green biomass as one of the renewable energy sources has been continuously growing.

The most important indicator when selecting energy crops is the net energy yield from area unit, which is determined primarily by the biomass yield and said biomass convertibility to methane. Nevertheless, crops used for bio-energy are rarely assessed in terms of biomass yields obtained from those crops.

It has been found based on materials published so far on this issue that when using various crops for energy purposes greater attention is paid to the quantity of methane released than to the biomass quantity obtained while the decisive challenge when building biogas plants is the procurement of sufficient quantities of biomass.

According to the studies of Bassu et al., 2013; Bartocci et al., 2020; Cantale et al., 2016; Csikós et al., 2020; Dekić et al., 2013; De Lucia et al., 2013; D'Imporzano et al. 2018; Luca et al., 2016; Lalević et al., 2013; Pathak et al., 2018; Strauß et al., 2019, triticale is one of the crops with proved reputation both in terms of green mass yield and in terms of dry substance of the crop far exceeding the other cereal crops.

That is why our research is focused on establishing the manners of increasing the quantity of green biomass through testing of various nitrogen fertilizer rates and phases of harvesting of two varieties of triticale grown under the conditions in South Bulgaria.

MATERIALS AND METHODS

The research was conducted in the period 2013/2016 at the experimental field of the Crop Science Department of the Agrarian University of Plovdiv by the block method with size of the experimental plot of 20 m^2 in 4 repetitions. Two triticale varieties were tested, Musala, and Attila, selected in two climatically different regions. The first one was at the Institute of Plant and Genetic Resources - town of Sadovo located in the drier and warmer region of South Bulgaria and the second one was at the Wheat and Sunflower Institute in the town of General Toshevo located in the more humid, cooler and windier region of North Bulgaria.

The crop was planted after rape predecessor. The varieties were grown at the following fertilization levels: N_0, N_{120}, N_{160}, N_{200}, N_{240} kg/ha. The nitrogen fertilizers were introduced in two sessions, one in the autumn during pre-sowing preparation of the soil and another in the spring as nourishment at the earliest opportunity.

The green mass yield was reported in the heading and milk maturity phases by determining the parameters of plant height (cm); spike length (cm); number of leaves per plant (pcs.) and thickness of the stems (cm).

The statistical processing of the data was performed using a SPSS -16.0 software package and the reliability of the differences was determined by Student's t-test.

The soil on which the experiment was conducted is former meadow-swamp soil, slightly saline, sandy clay with power of the humus horizon "A" 25-28 cm. According to its mechanical nature it is a clayish, heavy soil (Popova et al., 2012).

In terms of weather conditions during the years of the experiment, no significant deviations were observed in the values of average 24-hour temperature in the region of Central South Bulgaria compared to the multiannual period. The absolutely minimal temperatures are short-term and do not cause freezing.

The greatest amount of rainfall was registered in 2014/2015 (579.1 mm). The rainfall sum was lower in 2013/2014 (395.5 mm), and lowest in 2015/2016 (336.8 mm).

Regardless of the lowest amount of rainfall compared to the other two years the third year was characterized by the comparatively more regular distribution of such rainfall throughout vegetation and supply of sufficient amount of moisture in the critical phases of the crop's development.

During all three experimental years, the amount of rainfall in the experiment region (Central South Bulgaria) exceeded the rainfall amounts of the multiannual period (321 mm).

RESULTS AND DISCUSSIONS

The results of the experiment regarding the value of green biomass yield indicated that yield changed depending on the meteorological conditions during the years of experiment and depending on the harvesting phases.

The data in Table 1 illustrating the development of the Musala variety indicate that in the heading maturity stage the greatest green biomass yield was obtained during the third year (2016) of the experiment (from 37,400 kg/ha to 47,460 kg/ha).

The relatively lower amounts of rainfall (336.8 mm) and higher temperatures typical for 2016 were favourable for the better development of the Musala variety selected in the region of South Bulgaria.

Yield received throughout the second year of research was 6,890 kg/ha to 9,820 kg/ha lower compared to that from the third year and takes the intermediary place.

The lowest green biomass yield obtained from Musala variety at that stage was during the first experimental year, from 20,420 kg/ha to 30,200 kg/ha.

The reasons include the greater amounts of rainfall (121.5 mm) during the variety heading period accompanied by strong winds of 6-8 m/s by the Beaufort's wind force scale, which led to bending of the plants lowering of yield. The registered degree of bending of the crops by the Eucarpia scale (from 1 to 9) is one or 100%.

With the advance of the development phases of triticale its productivity increased significantly and the green biomass yield obtained in the milk maturity phase considerably exceeded that in the heading phase.

The yield obtained at this stage by years follows the same trend as that in the heading maturity phase. The highest yield was obtained during the third year of the experiment (from 39,200 kg/ha to 51,300 kg/ha), followed by the second year (37,300 kg/ha to 46,300 kg/ha) and the lowest yield was during the first year (from 35,000 kg/ha to 38,840 kg/ha).

In contrast to the Musala variety, the green biomass yield of the Attila variety throughout the years of research followed exactly the opposite trend (Table 2).

The years of the experiment characterized by lower rainfall amounts and higher temperatures (2015 and 2016), which favoured the development of the Musala variety, were less favourable for the development of Attila variety.

That is why with this variety in both phases of harvesting the highest green biomass yield was obtained during the first year of experiment - 2014, the second year by yield was the second year of the experiment - 2015 and the lowest yield was reported in 2016 - the third year of research.

The greater amounts of rainfall and more wind during the first experimental year that had a negative influence on the development of Musala variety did not influence the Attila variety's yield so much.

One of the reasons thereof was its earlier entering into heading maturity phase (15.04.2014) and its thicker and more resistant to bending stem distinguished by its conic shape compared to the Musala variety with typically thinner and easily bending stem.

That is why bending of the plants of Attila variety was significantly weaker (by the Eucarpia scale the crop bending level was 7 (30^0 slope of the stems).

During the first experimental year the green biomass yield obtained from Attila variety exceeded the yield from Musala variety and it varied from 29,280 kg/ha to 39,150 kg/ha at the heading maturity phase and from 38,110 kg/ha to 46,980 kg/ha at the milk maturity phase.

Table1. Yields green mass in phase heading maturity stage and milk maturity stage at variety Musala, kg/ha

Variants of fertilization kg/ha N	Heading maturity stage					Milk maturity stage				
	Years			Mean	%	Years			Mean	%
	2014	2015	2016			2014	2015	2016		
N_0	20420c	27580e	37400d	28470	100,0	35000d	37300e	39200e	37170	100,0
N_{120}	26720b	33010d	40920b	33550	117,8	35760c	43780c	46060c	41870	112,6
N_{160}	26880b	37710b	45280a	36620	128,6	38260b	44580b	47780b	43540	117,1
N_{200}	30200a	38150a	47460c	38600	135,6	38840a	46300a	51300a	45480	122,4
N_{240}	26800b	36330c	43220e	35450	124,5	38230b	42950d	45060d	42080	113,2

*Values with the same letters do not differ significantly

Table 2. Yields green mass in phase heading maturity stage and milk maturity stage at variety Attila, kg/ha

Variants of fertilization kg/ha	Heading maturity stage					Milk maturity stage				
	Years			Mean	%	Years			Mean	%
	2014	2015	2016			2014	2015	2016		
N_0	29280d	24780e	23100e	25720	100	38110e	33680e	31980e	34590	100
N_{120}	34340c	31850d	30170d	32120	124.9	41040d	40710d	39910d	40550	117,2
N_{160}	37040b	35550b	34250a	35610	138,4	43420b	41600b	40560b	41860	121,0
N_{200}	39150a	36760a	35130b	37010	143,8	46980a	45720a	42000a	44900	129,8
N_{240}	36900b	35400c	34020c	35440	137,8	42220c	40990c	40100c	41100	118,8

*Values with the same letters do not differ significantly

For the Attila variety as well, the yield obtained at the milk maturity phase exceeded the yield from the heading phase.

In view of the reasons specified above, during the second and third year of all tested variants and harvesting phases the Attila variety was less productive than the Musala variety.

The productivity of Attila variety during the second experimental year varied from 24,780 kg/ha to 36,760 kg/ha in the heading maturity phase and from 33,680 kg/ha to 45,720 kg/ha, at the milk maturity phase, while during the third year the yield at the heading maturity phase dropped to 23,100 kg/ha, for non-fertilized variants and to 35,130 kg/ha, for the variant fertilized with (N_{200}) and respectively from 31,980 kg/ha to 42,000 kg/ha, at the phase of milk maturity.

Upon monitoring the effect of nitrogen fertilization on the green biomass yield it is evident that both during the years of research and average for the period, for the two varieties and harvesting phases, the lowest yield was obtained in the variant without nitrogen fertilization.

For the Musala variety, it was 28,470 kg/ha at the heading maturity phase and 37,170 kg/ha at the milk maturity phase, while for the Attila variety yield was respectively 25,720 kg/ha; 34,590 kg/ha.

For both varieties and in both phases of harvesting, all fertilized variants exceeded the non-fertilized variants by green biomass yield.
For the Musala variety, average for the research period fertilized variants exceeded the control variant with 17.8% to 35.6% at the heading maturity phase and with 12.6% to 22.4% at the milk maturity phase.
For the Attila variety, a stronger impact was observed of the fertilized variant as to the control variant. All fertilized variants of the variety compared to the control variant in both harvesting phases exceeded by yield the control variant with a higher percentage than that for the Musala variety.
In the Attila variety, the average green biomass yield of the fertilized variants increased compared to the control variant with 24.9% to 43.8%, at the heading maturity phase and with 17.2% to 29.8%, at the milk maturity phase.
With the increase of nitrogen fertilization rates, both during the three years of research and at the two harvesting stages, yield of green biomass increased to the variant fertilized with 200 kg/ha a.s. nitrogen.
For this variant, the average yield obtained for the period at the heading maturity phase with Musala variety was 38,600 kg/ha green biomass and with Attila variety it was 37,010 kg/ha, and at the milk maturity phase yield was respectively 45,480 and 44,900 kg/ha.
For the variants fertilized with the highest nitrogen norm, N_{240}, a drop of yield was observed compared to the previous variant.
The parameters influencing the green biomass yield are the crops' height and the yield-forming structural elements (Figures 1 and 2).
The data in the chart reflect the average values of researched parameters throughout the experimental period.
They indicate that the plant height of Attila variety at the heading maturity phase exceeded the height of Musala variety plants with 10 to 12.9 cm.
The plant height for the variants without nitrogen fertilization was the lowest (108.2 for Musala variety and 118.2 for Attila variety).
With the versions with included nitrogen fertilization the plants of the crops cultivated reacted with different growing intensity for the grown varieties.
The data indicate that with the increase of the nitrogen fertilization norms, the plant height also increased and the highest plants were formed at the nitrogen norm of 200 kg/ha a.s. For this variant, the plants of Musala variety reached a height of 125.5 cm, and the Attila variety reached 138.2 cm.

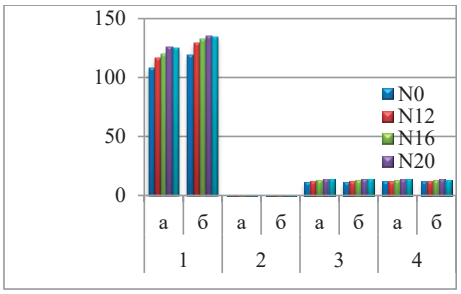

Figure 1. Structural analysis of yield element, mean for the period 2013-2016 at variety Musala
1 - height/plants (cm); 2 - thickness of stems (cm); 3 - number of leaves/plants; 4 - spike length (cm); а - heading maturity stage; б - milk maturity stage

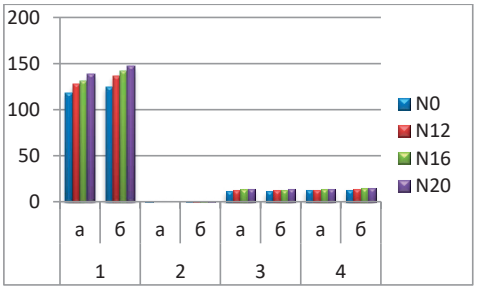

Figure 2. Structural analysis of yield element, mean for the period 2013-2016 at variety Atila:
1 - height/plants (cm); 2 - thickness of stems (cm); 3 - number of leaves/plants; 4 - spike length (cm); а - heading maturity stage; б - milk maturity stage

The Musala variety plants exceeded the control ones with 17.3 cm, while those of Attila variety exceeded the control ones with 20.0 cm, which indicates the greater responsibility of Attila to higher fertilization levels.
For fertilization performed with the highest nitrogen fertilization norms (N_{240}), the height of plants of various varieties was too close to the one reported for the previous variant N_{200}. Most frequently, the values of the two fertilization norms were almost the same.
At the milk maturity phase, the plants developed more vigorously and grew higher. The trend with respect to the plant height and

the activity of different nitrogen norms was preserved.

At this phase, similarly, the plant height values were higher for the Attila variety and exceeded the height of Musala variety plants with 5.6 to 11.6 cm.

Again, the greatest difference in terms of plant height is demonstrated between the control variant and the variant fertilized with N_{200}, 16.6 cm for the Musala variety and 22.6 cm for Attila variety. Analogously, at this phase the lowest plants were those of the variant with no fertilization, 118.7 cm, for Musala variety and 124.3 cm for the Attila variety.

At both harvesting phases, average throughout the research period, the difference in the stem thickness was negligible between the two varieties, with slight prevalence of Attila.

At the milk maturity stage, the plants formed a little thicker stems compared to those at the heading phase.

Stem thickness of the Attila variety varied from 0.49 cm to 0.52 cm at the heading maturity phase and from 0.51 cm to 0.54 cm at the milk maturity phase. The stem of Musala variety was thinner and its thickness varied from 0.47 cm to 0.51 cm at the heading maturity phase and from 0.49 cm to 0.53 cm at the milk maturity phase.

In both varieties, the stems of the plants are a little thicker for the variants without fertilization than those for the variants with fertilization. Depending on the harvesting phase, thickness of 0.51 and 0.53 cm was reported to Musala and for Attila the reported thickness was 0.52 and 0.54 cm.

The stem thickness gradually decreased with the increase of the nitrogen fertilization norm and the stems were thinnest for the highest norm (N_{240}), 0.47; 0.49 cm for the Musala variety and 0.49; 0.51 cm for the Attila variety.

The leaf mass of cereal crops is ultimately formed at the heading phase.

With respect to the leaf number, greater differences were observed between the years of research but between the two varieties studied they were almost none. The plant height is proportional to the leaf number. Plants with higher stems also form a greater number of leaves. That is why, the leaf number is greater for the Attila variety both throughout the years and average for the period of research.

At the heading maturity phase Musal variety formed from 11.39 to 14.21 leaves while Attila formed from 11.54 to 14.38 leaves.

At the milk maturity phase some of the leaves began to dry and their number slightly decreased. At this phase, for Musala variety from 11.30 to 14.12 leaves were reported and from 11.42 to 14.25 leaves for Attila variety.

For both tested varieties and harvesting phases, the least number of leaves was formed in non-fertilized variants. At the heading maturity phase they reached up to 11.39 pieces for Musala variety and up to 11.54 pieces for Attila variety while at the milk maturity phase their number was respectively, 11.30; 11.42 leaves.

With the increase of the nitrogen fertilization norms the number of leaves gradually increased to that of the variant fertilized with N_{200}, where also the highest number of leaves was reported (14.21; 14.12 leaves for Musala and 14.38; 14.25 leaves for Attila variety), which also correlates with the plant height.

For the variant with highest fertilization norm N_{240} the number of leaves for both varieties dropped insignificantly compared to that of the previous variant.

Regardless of the fact that the length of the spike is a genetically determined value, it is at the same time influenced by the climatic conditions and the agricultural technical machinery applied.

It is evident from the figures that in both phases of harvesting, a little longer spikes were formed by the Attila variety. The length of its spikes at the heading maturity phase varied from 12.60 to 13.90 pieces and for Musala it varied from 11.68 to 13.76 pieces.

For both varieties and for both phases the lowest values of length were reported for the non-fertilized variants. At the heading maturity phase the length of the spikes of Attila was with 0.92 cm greater than that of the Musala variety.

The inclusion of fertilization in the following variants had a positive impact on the spike length.

With the increase of the nitrogen fertilization norm, the spike length gradually increased. For both tested varieties the spike length parameter was most distinguished for the variant fertilized N_{200}. In this variant, at the heading maturity

phase Musala variety formed spikes of length - 13.76 cm, and Attila variety - 13.90 cm.
In the variant with the highest nitrogen norm (N_{240}) the spike length for both varieties dropped compared to that of the previous variant.
At the milk maturity phase the spike length increased slightly as the spikes were almost completely developed.
At this phase, similarly longer spikes were formed in the Attila variety, from 13.03 cm to 14.80 cm, while in the Musala they were from 11.84 cm to 14.01 cm. In terms of fertilization, the spike length followed the same trend as for the heading phase.
The shortest spikes were those of the variants without nitrogen fertilization - 11.84 cm for Musala and 13.03 cm, for Attila.
With the increase of the fertilizer norms, the spike length also increases as the longest spikes were measured for the variant with nitrogen fertilization norm of N_{200}, 14.01 cm - for Musala and 14.80 cm, for Attila variety.
At this phase as well, for the highest fertilization norm of N_{240} the spike length of both varieties dropped insignificantly than that of the previous variant.

CONCLUSIONS

Due to the selection of tested varieties in different climatic regions, strong variety reaction was observed between them in terms of yield. In 2015 and 2016 the higher yields were obtained from the Musala variety and in 2014 - from Attila.
The higher yield of green biomass was obtained from triticale harvesting at the milk maturity phase.
The lowest yield for both varieties in both phases of harvesting was obtained from the non-fertilized variants and the highest in the variant fertilized with N_{200}, which also correlates with the higher levels of tested parameters.
Attila variety is characterized with a little higher stems and longer spikes compared to Musala variety. The differences in the leaf number and stem thickness between the two varieties are negligible.
At the milk maturity phase, the values of structural elements increased compared to the heading phase, except the number of leaves.
The variants without nitrogen fertilization were with lower values compared to the fertilized variants.
With the increase of nitrogen fertilization norms, parameter values increased up to the variant fertilized with N_{200}. With the highest fertilization norm of $N_{240,}$ the parameter values dropped insignificantly.

REFERENCES

Bassu, S., Asseng, S., Giunta, F., Motzo, R. (2013). Optimizing triticale sowing densities across the Mediterranean Basin. *Field Crops Research*, *144*, 167–178.

Bartocci, P., Zampilli, M., Liberti, F., Pistolesi, V., Massoli, S., Bidini, G., Fantozzi, F. (2020). LCA analysis of food waste co-digestion. *Science of the Total Environment*, *709*, 136187.

Cantale, C., Petrazzuolo, F., Correnti, A., Farneti, A., Felici, F., Latini, A., Galeffi, P. (2016). Triticale for Bioenergy production. *Agriculture and Agricultural Science Procedia, 8*, 609–616.

Csikós, N., Szilassi, P. (2020). Impact of Energy Landscapes on the Abundance of Eurasian Skylark (*Alauda arvensis*), an Example from North Germany. *Sustainability*, *12*(2), 664.

Đekić, V., Staletić, M., Milovanović, M., Đurić, N., Popović, V. (2013). Study on productivity and quality of the kg winter triticale varieties. *Zbornik naučnih radova Instituta PKB Agroekonomik*, *19*(1-2), 53–60.

De Lucia, C., Vecchione, V., Conto, F., Pazienza, P. (2013). The effect of agricultural and energy prices on biomass production: the case of triticale in the OECD area. *Intellectual Economics*, *7*(4), 439–452.

D'Imporzano, R., Pilu., L. Corno., F. Adani (2018). *Arundo donax* L. can substitute traditional energy crops for more efficient, environmentally-friendly production of biogas: A Life Cycle Assessment approach. *Bioresource Technology*, *267*, 249–256.

Lalević, D., Biberdžić, M., Jelić, M., Barać, S. (2012). The characteristics of triticale cultivated in rural areas. *Agriculture & Forestry/Poljoprivreda i Sumarstvo*, *58*(2), 27–34.

Luca, C., Pilu, R., Cantaluppi, E., Adani, F. (2016). Giant cane (*Arundo donax* L.) for biogas production: The effect of two ensilage methods on biomass characteristics and biogas potential. *Biomass and Bioenergy*, *93*, 131–136.

Pathak, V., Gedam., S. Bhagat., A. Chahande (2018). Biorefineries: A Sustainable Approach for High Value-Added Products in Rural India. *Techno-Societal*, 585–593.

Popova, R., Zhalnov, I., Valcheva, E., Zorovski, P., Dimitrova, M. (2012). Assessment of the Ecological Status of Soils in the Plovdiv Region with Application of New Herbicides for Weed Control in Main Field Crops. *Journal of Central European Agriculture*, *13*(3), 604–609.

Strauß, Ch., Herrmann, Ch., Weiser, Ch., Kornatz, P., Heiermann, M., Aurbacher, J., Müller, J., Vetter, A. (2019). Can Energy Cropping for Biogas Production Diversify Crop Rotations? Findingsfrom a Multi-Site Experiment in Germany. *BioEnergy Research*, *12*(1), 123–136.