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PLANT GROWTH STIMULANTS INFLUENCE ON *Miscanthus x giganteus* BIOMASS INDEXES IN FOREST - STEPPE ZONE OF UKRAINE

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Abstract

Miscanthus (Miscanthus x giganteus) forms the largest number of stems in the first year of the life cycle. It was found that the height of the main shoot increased with the number of sprayings. Active growth and development of miscanthus plants begins from the tillering phase, which occurs after the appearance of the first true leaves (from May to September) immediately. It was found that the number of shoots increased (from 8 to 12 units per bush) after each foliar sprayings with plant growth stimulants. The largest leave-stem biomass in the first year of vegetation was obtained in the trial of double foliar treatment soaking in a Quantum gold solution. It was found that the yield of the miscanthus rhizome was slightly higher in 2016-2017 than in 2018-2019. Excessive rainfall of 150 mm in May in 2016 gave a significant impetus to the formation of the underground part of the miscanthus. The highest yield of miscanthus 4.6 t ha^{-1} and energy yield-80 GJ ha^{-1} was obtained in the trial when soaking in a solution of Quantum gold with two-time treatment of plants during the growing season.

Key words*: miscanthus, growth stimulator, biomass, indexes.*

INTRODUCTION

Miscanthus (*Miscanthus x giganteus*) has a very good potential in terms of biomass yield compared with other varieties (Da Borso et al., 2018; Brosse et al., 2012). High adaptation potential make this cultivar very suitable for marginal lands (Heaton et al., 2004; Milovanovic et al., 2012). Giant miscanthus is a C-4 photosynthetic plant. It is characterised by greater carbon dioxide (CO_2) absorption (Kazimierowicz & Dzienis, 2015). Environmental limitations and the greenhouse gas balance of the miscanthus plantations have been estimated. During the combustion of the biomass of *Miscanthus giganteus*, less carbon dioxide is released than was absorbed by plants during photosynthesis. It was established that *Miscanthus* genotypes are able to reduce emissions and emit 40-99% less N_2O compared to annual conventional crops (Di Vita et al., 2017). Miscanthus can be grown on different well drained soil types with pH in the range from 5.5 to 7.5 and with a medium and high fertility level (Heaton et al., 2004; Kharytonov et al., 2019). It was established that *Miscanthus x giganteus* crops achieve full potential yield, regardless of the soil, from the third year of vegetation (Matyka & Kus, 2016; Alexopoulou et al., 2015). It was shown also that miscanthus biomass parameters can be positively influenced with two plant growth regulators (PGRs) when the plant was grown in soil with good agricultural characteristics (Nebeská et al., 2019). Almost all studies on nutrition management of miscanthus *(Miscanthus x giganteus)* to date have focused on three fertilizer elements. Joint N, P, K fertilization increased yield during fourth and fifth year of development on marginal lands (Drazic et al., 2017). It was established, that any nutrient response is highly dependent on the soil on soil physiochemical properties, climatic conditions, and planting location (Souri, 2016; Souri et al., 2017; Hatamian et al., 2019) and planting location (Anderson et al., 2011). The need to develop innovative technological approaches for second generation crops arises in connection with the increase in the area of miscanthus plantations in Ukraine.

The main objective of research was to study plant growth stimulants influence on

miscanthus (*Miscanthus x giganteus*) biomass parameters in forest - steppe zone of Ukraine.

MATERIALS AND METHODS

These studies were conducted on experimental fields of Veselopodilsky experimental station of the Institute of bioenergy crops and sugar beet NAAS of Ukraine for 2016-2019. The subzone of the left bank of the forest-Steppe of Ukraine is marked by a moderate continental climate with warm summers and mild winters and insufficient moisture in some dry years. Most of the precipitation fell in early spring (mainly in May 2016 and 2019). Lack of rain was observed in Spring of 2017 and 2018, which negatively affected the growth and development of plants later (Figure 1).

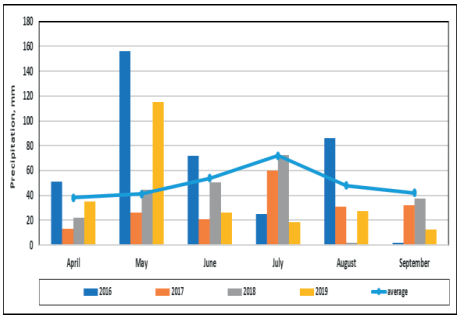

Figure 1. The precipitation (2016-2019)

The average annual precipitation was 511 mm with large variations from 306 to 500 mm. 326 mm of precipitation fell during the growing season (4-10 months). The average long-term air temperature data for the last four years are shown in Figure 2.

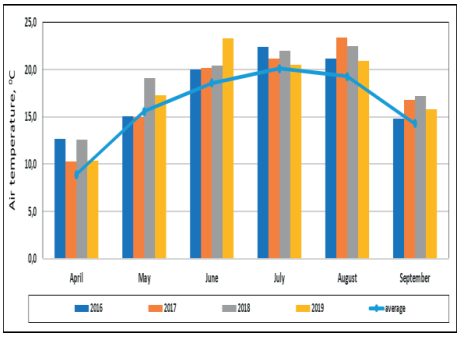

Figure 2. Air temperature data (2016-2019)

The average sum of the effective temperatures during vegetation period was 2200°C-2400°C. High air temperatures (above 25^0C) and soil surfaces (up to 60^0C) accompanied by winds (between May and August) were a negative prerequisite for restraining the growth and development of miscanthus plants. Local soils are represented by typical chernozem, slightly saline, low-humus, mid-loam. The depth of the humus horizon varies from 35 to 45 cm, the humus content from 3.6 to 4.2%. The reaction of the soil solution of the arable layer is weakly alkaline (pH 7.2-7.4).

The field experiment was conducted according to a two-factor scheme, which involved soaking with rhizomes and subsequent foliar treatment. Water as a control was selected to determine the effectiveness of two growth stimulators (Quantum gold and Vympel-K) to treat miscanthus rhizomes before planting. Quantum gold is a universal micronutrient containing a large number of macro and microelements, as well as a complex of biologically active substances, in particular a highly effective non-toxic phytohormone auxin type. The composition of the PGRs Vympel – K includes polyatomic alcohols - up to 300 g l^{-1}, humic acids - 30 g $l^{-1}$and carboxylic acids of natural origin - 3 g l^{-1}. Foliar feeding of plants of miscanthus with growth stimulators was carried out in the phase 3-4 of real leaves and with the density of standing 90% of plants in the area. The first and second treatment was done at the end of the day. The total area of each plot is 50 m^2, the total area is 10 m^2. The number of repetitions - 4. Planting was done during the first half of April.

RESULTS AND DISCUSSIONS

The study of growth and development rates of miscanthus plants during the growing season allowed us to reveal the most important dependencies of the process of formation of high productivity of miscanthus. The height of the plant and the number of shoots are the most important signs of the plants organogenesis phases. It was found that the height of the main shoot increased with the number of foliar treatments from 125 to 135 cm on average (Table 1).

Table 1. Height of miscanthus plants in the first year of vegetation, cm

Factor A	Factor B	Height of the main shoot				Average
		2016	2017	2018	2019	
Water	Water	182	90	100	140	128
	Quantum Gold[1]	182	107	100	120	127
	Quantum Gold[2]	190	86	100	120	124
	Vympel - K[1]	188	92	100	130	128
	Vympel - K[2]	190	100	100	120	128
Quantum gold	Water	210	76	100	110	124
	Quantum Gold[1]	180	80	90	110	115
	Quantum Gold[2]	202	100	90	130	131
	Vympel - K[1]	194	78	80	120	118
	Vympel - K[2]	210	65	80	120	119
Vympel-K	Water	190	102	100	120	128
	Quantum Gold[1]	200	94	100	140	134
	Quantum Gold[2]	196	84	100	130	128
	Vympel - K[1]	196	88	80	130	124
	Vympel - K[2]	187	100	80	130	124
$LSD_{0.05}$		9.7	4,5	4.7	6.2	6.3

[1]single foliar spraying; [2]two time foliar spraying

It was established that the number of shoots increased after each foliar treatment with the PGRs from 8 to 12 units. The largest number of stems of miscanthus forms in the first year of the life cycle (Table 2).

Table 2. The number of miscanthus shoots in the first year of vegetation

Factor A	Factor B	The number of shoots, units				Average
		2016	2017	2018	2019	
Water	Water	9	8	8	7	8
	Quantum Gold[1]	19	6	10	5	10
	Quantum Gold[2]	14	4	8	5	8
	Vympel - K[1]	22	7	12	7	12
	Vympel - K[2]	20	10	13	5	12
Quantum gold	Water	16	5	9	7	9
	Quantum Gold[1]	14	2	8	5	7
	Quantum Gold[2]	20	5	11	12	12
	Vympel - K[1]	21	5	11	5	11
	Vympel - K[2]	19	3	10	6	9
Vympel-K	Water	16	6	10	7	10
	Quantum Gold[1]	16	4	9	6	9
	Quantum Gold[2]	15	6	9	8	9
	Vympel - K[1]	18	6	11	5	10
	Vympel - K[2]	24	7	14	7	11
$LSD_{0.05}$		0.9	0.3	0.5	0.3	0.5

Active growth and development of miscanthus plants begins from the tillering phase, which occurs immediately after the appearance of the first true leaves (from May to September).

The formation of new shoots depends on foliar treatment directly. Due to soaking rhizome in Quantum gold solution and subsequent single treatment received 8 shoots per bush. The number of stems increased to 12 units after the second treatment. The number of stems in the bush varied from 10 to 11 after the use of the PGRs Vympel K (after soaking and one time foliar treatment) compared with double treatment.

The largest leave-stem biomass in the first year of vegetation was obtained in the trial of double foliar treatment soaking in a Quantum gold solution (Table 3).

Table 3. Productivity of aboveground miscanthus biomass in the first year of vegetation, t ha^{-1}

Factor A	Factor B	Productivity of aboveground miscanthus biomass				Average
		2016	2017	2018	2019	
Water	Water	5.9	2.8	3.5	3.1	3.8
	Quantum Gold[1]	7.3	2.8	3.9	1.5	3.9
	Quantum Gold[2]	7.1	4.6	2.6	1.6	4.0
	Vympel - K[1]	6.0	4.2	1.6	2.3	3.5
	Vympel - K[2]	8.0	2.3	1.3	1.5	3.3
Quantum gold	Water	6.4	4.2	1.6	1.5	3.4
	Quantum Gold[1]	6.9	2.3	2.6	1.2	3.3
	Quantum Gold[2]	11.2	1.4	2.9	2.7	4.6
	Vympel - K[1]	6.8	1.4	1.2	1.3	2.7
	Vympel - K[2]	10.0	2.8	1.7	1.3	3.9
Vympel-K	Water	4.3	3.7	3.6	2.0	3.4
	Quantum Gold[1]	6.7	4.6	2.2	2.5	4.0
	Quantum Gold[2]	6.1	4.6	3.5	1.7	4.0
	Vympel - K[1]	8.7	3.7	3.5	2.0	4.5
	Vympel - K[2]	8.2	2.8	2.3	2.0	3.8
$LSD_{0.05}$		0.4	0.2	0.1	0.1	0.2

The yield of miscanthus was 2.7 t ha^{-1} when combined with two stimulating drugs (soaking in Quantum gold and one time foliar spraying with Vympel K). The branched root system of miscanthus plants in the first year of vegetation deepens to a depth of 40-60 cm, and underground stems (rhizomes) are placed at a depth of 5 to 30 cm.

The best underground yield of miscanthus 7.9 t ha^{-1} was recorded after double treatment with Quantum gold solution (Table 4). It was found that the yield of the rhizome of miscanthus in 2016-2017 was slightly higher than in 2018-2019. Excessive rainfall of 150 mm in May in 2016 gave a significant impetus to the formation of the underground part of the miscanthus. The largest yield of solid biofuel 5 t ha^{-1} was obtained when using the Quantum gold by soaking rhizome before planting in the soil and two time treatment of miscanthus plants during the growing season. Similar data were obtained after treatment of miscanthus with two plant growth stimulators Stimpo and

Regoplant (Malinská et al, 2020). The results of energy output calculation with miscanthus biomass are shown in Table 5.

Table 4. Roots biomass yield in the first year of vegetation, t ha^{-1}

Factor A	Factor B	Roots biomass yield				Average
		2016	2017	2018	2019	
Water	Water	5.8	7.4	4.0	4.1	5.3
	Quantum Gold[1]	18.5	5.5	5.4	1.5	7.7
	Quantum Gold[2]	13.5	10.2	5.6	2.2	7.9
	Vympel - K[1]	9.3	6.0	2.1	3.5	5.2
	Vympel - K[2]	19.9	3.2	1.4	2.2	6.7
Quantum gold	Water	11.6	3.2	2.,0	2.5	4.9
	Quantum Gold[1]	5.1	4.6	5.2	2.2	4.3
	Quantum Gold[2]	15.9	3.7	5.4	5.7	7.7
	Vympel - K[1]	7.8	2.8	1.9	2.1	3.6
	Vympel - K[2]	14.5	5.5	2.6	3.2	6.5
Vympel-K	Water	6.5	6.0	5.0	2.0	4.9
	Quantum Gold[1]	9.6	7.4	2.6	4.9	6.1
	Quantum Gold[2]	15.0	4.6	4.7	3.3	7.7
	Vympel - K[1]	9.4	6.0	6.6	4.8	6.7
	Vympel - K[2]	7.5	5.1	3.2	4.5	5.1
$LSD_{0.05}$		0.6	0.3	0.2	0.2	0.3

Table 5. The energy output with miscanthus biomass in the trials

Factor A	Factor B	Yield, ha^{-1}	Solid biofuel, t ha^{-1}	Energy output, GJ ha^{-1}
Water	Water	3.8	4.2	67.1
	Quantum Gold[1]	3.9	4.2	67.8
	Quantum Gold[2]	4.0	4.4	70.4
	Vympel - K[1]	3.5	3.9	61.7
	Vympel - K[2]	3.3	3.6	57.6
Quantum gold	Water	3.4	3.8	60.2
	Quantum Gold[1]	3.3	3.6	57.6
	Quantum Gold[2]	4.6	5.0	80.3
	Vympel - K[1]	2.7	3.0	47.3
	Vympel - K[2]	3.9	4.3	69.4
Vympel-K	Water	3.4	3.7	59.8
	Quantum Gold[1]	4.0	4.4	70.4
	Quantum Gold[2]	4.0	4.4	69.8
	Vympel - K[1]	4.5	4.9	78.4
	Vympel - K[2]	3.8	4.2	67.3
$LSD_{0.05}$		0.2		

All PGRs contain various compounds and extracts which were expected to stimulate plant growth (Schmidt et al., 2017; Verma et al, 2016). The influence of PGRs "Regoplant" was higher and the best results were obtained with combined treatment: application to rhizomes before planting and spraying on the biomass during vegetation (Nebeská et al., 2019).

It is known that both Regoplant and Quantum gold contains synthetic analogue of plant auxin (1-NAA).

The maximum energy yield per unit area was achieved by soaking in growth stimulators with one-time and two-time treatment, as following: 80 GJ ha^{-1} in Quantum gold, and 78 GJ ha^{-1} - in Vympel K. Slightly lower volume of solid biofuel at 0.1 t ha^{-1} was obtained by soaking rhizome in the preparation Vympel K.

CONCLUSIONS

Miscanthus forms the largest number of stems in the first years of the life cycle. The yield of miscanthus roots differs from the above-ground mass, since the formation of shoots in plants occurs throughout its growing season. First of all, the plant forms an underground part of the biomass. It was found that the number of shoots increased (from 8 to 12 units per bush) after each foliar treatment with growth stimulants. The highest yield of miscanthus 4.6 t ha^{-1} and energy yield - 80 GJ ha^{-1} was obtained in the trial when soaking in a solution of Quantum gold with two time treatment of plants during the growing season.

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