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Impact of Foliar Fertilization and of Irrigation Regime on Dry Biomass Production in *Miscanthus Giganteus* L.

Ricuţa Vasilica Dobrinoiu
Faculty of Biotechnology
University of Agriculture and Veterinary Medicine Bucharest
Maraşti Bvd, no. 59, zip code 011464, Bucharest, Romania
ricuta_dobrinoiu@yahoo.com

Luminiţa Vişan
Faculty of Biotechnology
University of Agriculture & Veterinary Medicine Bucharest
Maraşti Bvd, no. 59, zip code 011464, Bucharest, Romania
l_visan@yahoo.com

Silvana Dănăilă-Guidea
Faculty of Biotechnology
University of Agriculture and Veterinary Medicine Bucharest
Maraşti Bvd, no. 59, zip code 011464, Bucharest, Romania

Marin Dumbravă
Faculty of Agriculture
University of Agriculture and Veterinary Medicine Bucharest
Maraşti Bvd, no. 59, zip code 011464, Bucharest, Romania

Abstract **– Gradual depletion of fossil fuel resources together with the global warming process, linked to the increased emissions of greenhouse gases, caused the onset and the stimulation of researches aiming to find other energy resources of renewable type, to which belongs the biomass obtained from energy crops.**

The researchers conducted in the field of management of using energy crops for producing energy from solid biomass in general and of bio-fuels in particular, showed that it is a topical issue for Romania and in this context we decided to test the combined effect of foliar fertilization with Bonus K-Energy in differentiated doses and of the irrigation regime both on total biomass production and differentially on the plant components, respectively on stems and leaves of the perennial species *Miscanthus giganteus* L.

Keywords **- Biomass, Bonus K-Energy, Dry Matter, Foliar Fertilizer, Bio-Fuel.**

I. Introduction

Miscanthus comes from Eastern Asia and it was brought to Europe in 1930s as an ornamental plant. It is a perennial plant with a rhizome. It belongs to C_4 group, leading to a more efficient assimilation of light, water and nitrogen fact which mirrors into the high content of biomass till 32 t DM/ha (DM = Dry mass) on the year in unfavourable climate conditions.

The first *Mischantus* cropping trials in energetic purposes were achieved in Denmark at the end of 1960s. In 1989, it was launched JOULE European research programme. There were established control fields in Denmark and in other countries too.

Recent research made in Romania shows that, averagely, natural and anthropic ecosystems may offer per yearly about 190 million tons extractable, renewable biomass, without causing disorders in ecosystems.

Although the whole biomass may be turned in energy, present technologies request their arrangement and the use of those which request low costs for bio-energy production. From DLG DLG (Deutsche Landwirschaft) point of view, special crops, their rests and wood wastes including the sawdust, constitute the most adequate resources of biomass which are proper to the energy production. If we wish to cultivate specific plants for energy achievement it is necessary to know the area necessary in order to obtain a GJ. In this situation, the most profitable crop is *Mischantus*.

II. Materials and Methods

Experimental parameters

The experimental plot was established by planting the rhizomes in the spring of 2010, to achieve the uniform density of 10.000 plants/ha.

The planted area was of 100 m^2, out of which 50 m^2 in non-irrigation conditions and the other 50 m^2 in irrigation conditions, at 50% of AHI (active humidity interval).

Harvested area for each experimental variant was of 5 m^2; for this were settled since the onset of vegetation in the spring of 2010, 5 control points on the diagonal of each experimental variant, each control point having an area of 1 m^2. Plant density on 1 m^2 was of 4 plants in both irrigation and non-irrigation conditions. The space between the plant rows was established since the onset of the experimental plot in 2010, being of 70 cm, with a space between plants in the row of 50 cm.

A bi-factorial experiment was established in the experimental field, according to the method of subdivided parcels, into 4 repetitions [6], the tested factors being the followings:

Factor A - *irrigation system with 2 gradations:*
- a_1 – *unirrigated;*
- a_2 - *irrigated at 50% AHI.*

Factor B - *foliar fertilization system with Bonus K-Energy, with 4 gradations:*
- b_1 - *unfertilized;*
- b_2 - *fertilized with 5 kg/ha* – at the stage of 8 formed leaves;
- b_3 - *fertilized with 10 kg/ha* - the first fertilization at the 8 formed leaves stage and the second to the phase of intensive stem growth, respectively the phase of 12 developed leaves;
- b_4 - *fertilized with 15 kg/ha* - the first fertilization to the phase of 8 developed leaves, the second to the phase of intensive growth of stems, respectively the phase with 12 developed leaves and the last fertilization to the pre-phase of panicle emergence.

Phenological observations and measurements performed in the experiment

Sprouting time: it was noted the day when it was estimated that 90% of plants have sprung, this phenophase being recorded on March 27, 2011.

Flowering time: it was recorded when 50% of plants had a flowered panicle, namely on 17 October 2011.

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Technical maturity: it was recorded the date when the plants have reached the stage of technical maturity, respectively on November 26, 2011. At this stage the plants were completely dry and the harvesting campaign of the crop could have been started, but this operation was postponed until March 2012, in order to improve the quality of the biomass used for energy conversion processes.

Observations and measurements on morphological and physiological plant traits

Plant height: was determined at the time of harvesting, by measuring 10 plants in each repetition, separately for each experimental variant. Measurements, expressed in meters, were made starting from the plant base up to the top of the panicle.

Average number of leaves per plant: it was determined at the date of technical maturity on 10 plants from each repetition and experimental variant, making an average which was recorded on the observations sheet.

Resistance to falling: it was evaluated after the occurrence of appropriate climatic conditions (winds accompanied by heavy rains), by determining as percentage the number of fallen plants/m^2. In this regard *Miscanthus giganteus* has an excellent resistance to falling, due to the well developed mechanical tissue in the stem, so that it was not recorded any fallen plant in our experiment.

Resistance to breaking: it was determined as the number of broken plants from the inter-node 2/m^2, but from this point of view no broken plants were recorded.

Observations and collection of production data in the phase of harvesting the experimental variants

Harvesting

After each harvest, the production of green mass of each experimental variant was weighed with an accuracy of one decimal, then the production of green mass as tons g.m/ha was calculated for each experimental variant and each repetition. From each variant repetition, a sample of 1 kg green mass was extracted which was dried in an oven at a temperature of 80^0 C for 24 hours and then reweighed. The resulting amount from the second weighing represents the dry matter content, which was expressed as a percentage.
The measurement of the of dry matter content (t/ha) was performed according to the formula:

$$t/ha = \frac{g.m.(t/ha)x\,d.m.\%}{100}$$

Chemical analysis:

The content of crude protein, cellulose and soluble sugars was determined in laboratory, being expressed as percentages of dry matter. For this, samples of 100 g finely crumbled dry matter were sent to ISTIS.

III. Results and Discussions

Biometric measurements on plants of Miscanthus giganteus L.

The most sensitive parameter to irrigation regime and to foliar fertilization was the number of stems formed on the rhizome. In this regard, the number of formed stems for the variants where the combined effect of the two technological factors was tested has increased very significantly compared to variants that have not benefited from the contribution of the two factors. Thus, in the third year from planting the rhizomes their ability to sprout greatly increases and hence the number of developed shoots. Great differences were noticed between unfertilized variants, where the number of stems per plant was of 21 under the natural hydrological regime, specific to the growing area and 29 stems per plant under irrigated conditions, the fertilized experimental variants recording between 64 and 152 developed stems per plant (table 1). The total solubility and the rapid absorption of macro and micronutrients contained in the tested fertilizer has a direct and visible impact on the growth and further development of the culture, impact which can be found later on in the quantity and quality of the phytomass obtained when the crop is harvested. [2].

Miscanthus plants grown under irrigation regime and foliar fertilization had a height significantly distinct greater than the plants cultivated under natural hydrological regime. If during the setting up year of the experimental plot (2010) plants have reached an average height of 1.12 m at technical maturity, in the third year of culture, when the installation phase is complete, the plants clearly exceeded this value. Thus, there were recorded plant height values of over 2.53 m in the phase of technical maturity, the maximum values, stabilized at 3.45 m height, being registered in the variants which received three foliar treatments with Bonus K-Energy (table 1).

Table 1: Biometric Measurements on *Miscanthus giganteus* L.

Irrigation Regime	Bonus K-Energy Doses (kg s.a./ha)	Number of Stems per Plant	Plant Height (m)	Number of Leaves per Plant
a_1–unirrigated	b_1 - 0	21	1,84	9
	b_2 - 5	64	2,53	12
	b_3 - 10	97	2,94	15
	b_4 - 15	117	3,26	18
a_2 – irrigated	b_1 - 0	29	1,90	11
	b_2 - 5	72	2,85	16
	b_3 - 10	111	3,17	20
	b_4 - 15	152	3,45	22

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Influence of irrigation regime and foliar fertilization on whole plant production in Miscanthus giganteus L.

In order to determine the total biomass, destructive plant samples were taken, the harvesting being done by shaving the stems at the ground surface, binding the stems in bundles and labeling each sample according to the experimental variant to which it belonged. The crop harvesting is recommended to be performed every year in autumn, winter or spring. It should be mentioned that choosing the optimal timing for harvesting significantly influences the quantity and the combustion quality of the harvested biomass [1]. The largest amount of biomass is obtained when the harvesting takes place in autumn, but in the same time this biomass is of low quality due to the high content of moisture and minerals. In winter, the stems lose part of their leaves and the remaining ones are dehydrated, leading to a decrease in biomass yield. Some of the nutrients are released into the rhizomes and others are drained from the stems on the soil or lost with the fallen leaves [3]. Overall, this results in improving the quality of biomass for the energy conversion processes. Therefore, a later harvesting is a very reasonable step to gain a high quality combustible.

From the above-made considerations, the harvesting of the biomass was performed in March 2012. The collected samples were dried until a constant humidity was achieved, after which they were reweighed, the results being recorded in tons DM/ha, after previously being statistically analyzed according to the method of experiment establishment in subdivided parcels.

Making an analysis of the experimental results recorded in unirrigated conditions, it is evident that the smallest value of whole plant biomass production, of 9.21 t DM/ha, was recorded in the control variant a_1b_1 [2]. The rest of the experimental variants clearly exceeded the unfertilized and un-irrigated control, the yield differences being highly significant statistically (***). Yield increases ranging from 3.54 t DM/ha by applying 5 kg/ha of Bonus K-Energy and 5.09 t DM/ha in the variant a_1b_4 were achieved, the increase in production being due exclusively to the three foliar treatments administered in the key phases of vegetation, with the final dose of 15 kg/ha Bonus K-Energy (table 2).

A similar situation was recorded in irrigation conditions, the highest production of dry biomass, of 15.32 tons DM/ha, being recorded in the experimental variant a_2b_4. The results obtained with this experimental variant are due to the combined effect of the two studied technological factors, as the total dry biomass production increased proportionally with increasing the dose of foliar fertilizer and by applying a system of irrigation at 50% of AHI.

Therefore, from the experimental data ensued that both the irrigation regime and the fertilization scheme used for the crop represent restrictive factors in achieving the biomass production in *Miscanthus giganteus L.,* because on the correct management of these factors depend both the quantity and the combustion quality of biomass bound for being used as biofuel.

Influence of irrigation regime and of foliar fertilization on stem production in Miscanthus giganteus L.

Research has continued with the separation in some plant components, respectively stems and leaves. Subsequent to the separation, the two components were weighed separately, according to each experimental variant and the results were statistically analyzed by the method of setting up in subdivided plots.

The production of stems under natural hydrological conditions was thus between 9.53 t/ha for fertilization with 5 kg/ha Bonus K-Energy and 10.98 t/ha for fertilization with 15 kg/ha Bonus K-Energy, the yield increases ranging between 2.71 and 4.16 t DM/ha in the experimental variant a_1b_4; this increases are statistically very significant (***) compared with the control variant a_1b_1.

The same situation is also found in irrigation conditions, where all experimental variants exceeded very significantly (***) the unfertilized control variant which had a stem production of 8.32 t DM/ha (table 3). Thus, it was found an increase of the stem production directly proportional with the increase of the foliar fertilizer dose, the maximum value being obtained with testing the fertilizing scheme consisting in 15 kg/ha Bonus K-Energy, in conditions of a water supply of 50% from AHI (a_2b_4) [3].

Table 2: Influence of Irrigation Regime and of foliar Fertilization on the Whole Plant Production in Miscanthus giganteus L.

Irrigation Regime	a_1 - UNIRRIGATED			a_2 - IRIGATED		
	Whole Plant Production			Whole Plant Production		
Bonus K-Energy Doses (kg s.a./ha)	Dry matter (tons/ha)	Difference dry matter (tons/ha)	Semnification	Dry matter (tons/ha)	Difference dry matter (tons/ha)	Semnification
b_1 - 0	9,21	-	-	10,78	-	-
b_2 - 5	12,75	3,54	***	13,01	2,23	***
b_3 - 10	13,77	4,56	***	14,93	4,15	***
b_4 - 15	14,30	5,09	***	15,32	4,54	***

Dl 5%=0,36 t s.u./ha *Dl 1%=0,49 t s.u./ha* *Dl 0,1%=0,67 t s.u./ha*

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The effect of irrigation regime and of foliar fertilization on the production of leaves in Miscanthus giganteus L.

The number and the weight of leaves formed on the stems directly affects the amount of biomass produced at the end of the crop vegetation. It was noted that in the year of data collecting the leaf production is superior to that of the year of setting up the experimental plot (2010). In conditions of crop non-fertilization, the obtained leaves production was of 2.39 t DM/ha, which increased with the number of foliar treatments applied during the growing phase.

The maximum value of leaf production was determined when three foliar treatments with Bonus K-Energy were administered, which was of 3.33 t DM/ha under non-irrigation and of 3.57 t DM/ha under irrigation conditions, at a level of 50% from AHI (table 4). All other experimental variants exceeded the unfertilized control with production increases that were statistically very significant (***) [4].

Thus it was ascertained the ability of this species to acquire its complete establishment in field conditions after at least two years from the planting of rhizomes, when the requirements for water and nutrients are growing, the effect being encountered in obtaining constant production of biomass every year, that can easily exceed 15 tons DM/ha from the third year of culture (table 5). These yields are comparable or even superior to other annual plant species used as sources of biomass, such as corn or sorghum.

Thus, it can be certainly asserted that *Miscanthus giganteus L.* is a highly efficient plant species in economic terms due to low inputs, which since the third year after having settled the culture consist only in expenses derived from managing the irrigation water, foliar fertilization and biomass harvesting.

Given the small quantities of fertilizer that are recommended to be applied during the vegetation period (max. 15 kg a.s./ha), their low cost (1 EUR/kg commercial product) and the possibility of their administration together with the necessary treatments against diseases that eventually occur during the crop growing season, this new technologic element makes the cultivation of this species a highly profitable activity.

Table 3: Influence of Irrigation Regime and of foliar Fertilization on Stem Production in *Miscanthus giganteus* L.

Irrigation Regime	a_1 - UNIRRIGATED			a_2 - IRRIGATED		
	Stem Production			Stem Production		
Bonus K-Energy Doses (kg s.a./ha)	Dry matter (tons /ha)	Difference dry matter (tons/ha)	Semnification	Dry matter (tons/ha)	Difference dry matter (tons/ha)	Semnification
b_1 - 0	6,82	-	-	8,32	-	-
b_2 - 5	9,53	2,71	***	9,59	1,27	***
b_3 - 10	10,51	3,69	***	11,49	3,17	***
b_4 - 15	10,98	4,16	***	11,75	3,43	***

Dl 5%=0,15 t s.u./ha *Dl 1%=0,21 t s.u./ha* *Dl 0,1%=0,29 t s.u./ha*

Table 4: The Effect of Irrigation Regime and of foliar Fertilization on the Production of Leaves in *Miscanthus giganteus* L.

Irrigation Regime	a_1 - UNIRRIGATED			a_2 - IRRIGATED		
	Leafs Production			Leafs Production		
Bonus K-Energy Doses (kg s.a./ha)	Dry matter (tons /ha)	Difference dry matter (tons/ha)	Semnification	Dry matter (tons /ha)	Difference dry matter (tons/ha)	Semnification
b_1 - 0	2,39	-	-	2,46	-	-
b_2 - 5	3,22	0,83	***	3,42	0,96	***
b_3 - 10	3,26	0,87	***	3,44	0,98	***
b_4 - 15	3,33	0,94	***	3,57	1,11	***

Dl 5%=0,12 t s.u./ha *Dl 1%=0,16 t s.u./ha* *Dl 0,1%=0,22 t s.u./ha*

Table 5: Influence of Irrigation Regime and of foliar Fertilization on the Production of Phytomass in *Miscanthus giganteus* L.

Irrigation Regime	Bonus K-Energy Doses (kg s.a./ha)	Production					
		Whole Plant		Stems		Leafs	
		Tons dry matter/ha	(%)	Tons dry matter/ha	(%)	Tons dry matter/ha	(%)
a_1 - UNIRRIGATED	b_1 - 0	9,21	100,00	6,82	100,00	2,39	100,00
	b_2 - 5	12,75	138,43	9,53	139,73	3,22	134,72
	b_3 - 10	13,77	149,51	10,51	154,10	3,26	136,40
	b_4 - 15	14,30	155,26	10,98	160,99	3,33	139,33

a_2 - IRRIGATED	b_1 - 0	10,78	100,00	8,32	100,00	2,46	100,00
	b_2 - 5	13,01	120,68	9,59	115,26	3,42	139,02
	b_3 - 10	14,93	138,49	11,49	136,53	3,44	139,83
	b_4 - 15	15,32	142,11	11,75	142,78	3,57	145,12

Conclusion

It can be stated that *Miscanthus giganteus* is a highly efficient species in economic terms due to the low inputs, which since the third year of culture consist only of the costs of providing the irrigation water, the foliar treatments and the harvesting of the biomass.

Given the small quantities of fertilizer that are recommended to be applied during the vegetation period (max. 15 kg a.s./ha), its low cost (1 EUR/kg commercial product) and the possibility of its application together with the treatments necessary to fight against some diseases that may occur during the crop growing season, it is obvious that this new technological approach makes the cultivation of *Miscanthus giganteus* a highly cost-effective activity.

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Author's Profile

Ricuta-Vasilica DOBRINOIU, Ph.D.
(42 years old) is an engineer licensed in the field of agriculture since 1995 (with Diploma of Agricultural Engineer obtained at the USAMV Bucharest, in profile specializing - Agriculture). In prezent is an asst. Professor at the USAMV Bucharest, Faculty of Biotechnology, 16 years old (since 1997) with activities in education in Agricultural and Horticulture Biotechnology and Experimental techniques field .

Luminita VISAN, Ph.D.
(49 years old) is an engineer licensed in the field of Horticulture since 1987 (with Diploma of Horticulture Engineer obtained at the USAMV Bucharest, in profile specializing - Horticulture). In prezent is an Lecturer Senior at the USAMV Bucharest, Faculty of Biotechnology, 16 years old (since 1997), with activities in Horticulture and Fermentative Biotechnology field.

Dr. Silvana GUIDEA DANAILA
(45 years old) is an engineer licensed in the field of horticulture since 1993 (with Diploma of Agricultural Engineer obtained at the USAMV Bucharest, in profile specializing -Horticulture).In prezent is an associate professor at the USAMV Bucharest, Faculty of Biotechnology, 14 years old (since 1999) with activities in education in Agricultural and Horticulture Biotechnology field by multiplying plants by biotechnological methods (in vitro culture) to improve plant conventional crops and vegetable species of flower species, plant biodiversity conservation, viticulture and pomiculture.