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JERUSALEM ARTICHOKE - SOURCE OF BIOMASS IN THE CONDITIONS OF SUSTAINABLE AGRICULTURE

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Abstract: In order to establish the optimal nutritional space of Jerusalem artichoke plants and the density of the variant with the best productivity of this less known and cultivated species in Romania, experiments were set up at ARDS Caracal in order to determine the effects of density and response to nitrogen. Phosphorus and potassium fertilization on the Jerusalem artichoke species, a species with energy and food potential. The experiment had in study 2 factors: planting distance (with 2 graduations: at 40 cm and at 50 cm between plants / row) and the level of fertilization (with 5 variants: unfertilized, $N_{40}P_{40}K_{40}$, $N_{80}P_{80}K_{80}$, $N_{120}P_{120}K_{80}$, $N_{160}P_{160}K_{80}$). It was found that the density of plants is an important agronomic factor that affects the growth, development and yield of the crop. The biometrics data of the recorded Jerusalem artichoke plants show that, in the climatic conditions of experimented area, the Jerusalem artichoke has the capacity to capitalize very well the agro-productive potential of the experimental conditions, the plant height of the Rareș variety ranged between 207 cm in non-fertilization conditions at a distance of 40 cm at planting and 244 cm in the variant with fertilization of $N_{160}P_{160}K_{80}$ on the variant with 50 cm between plants. The value of biomass production reached the highest value, of over 58 t / ha, in the variant with $N_{160}P_{160}K_{80}$.
Keywords: Jerusalem artichoke, density, fertilization level, fresh biomass

1. INTRODUCTION

In a broad sense, biomass is represented by plant organic matter, metabolic residues of animal origin (garbage) as well as microorganisms. Strictly speaking, agricultural biomass includes by-products of cultivated plants such as: straw, ham, stems (sunflower, soybeans), leaves (beets), pods (soybeans, beans), shells (nuts, hazelnuts), seeds (plums, peaches, apricot) and animal manure. Biomass is biodegradable and renewable. Biomass production is a booming field due to growing interest in alternative energy sources.

On a large-scale plant biomass production involves the cultivation of many plant species, the most important being: elephant grass (Miscanthus giganteus), hemp (Canabis sativa), maize (Zea mays), (Salix sp.), sorghum (Sorghum sp.) and sugar cane (Saccharum officinarum) *(Gazeta de Agricultura, 2011)*.

Other species with a real biomass potential is Jerusalem artichoke (*Helianthus tuberosus L.*). The main uses are for many purposes, such as human nutrition, feed and the production of bioenergy and biochemicals *(Li L., et al., 2013; Popescu C., et al., 2018; Vlăduț V., et al., 2018; Vlăduț V., et al., 2019a; Vlăduț V., et al., 2019b)*.

Jerusalem artichoke is a species with high production value, with potential and extensive use (Sawicka 1999, 2004), with high tolerance to climatic conditions *(Baldini et al. 2006, Lingyun et al. 2007)*. The above-ground part of Jerusalem artichoke can be used for biomethane production, for the manufacture of briquettes and pellets *(Stolarski 2004, Stolarski et al., 2008; Sawicka 2009)*. In addition to the yield of above-ground biomass, Jerusalem artichoke also produces a high yield of tubers *(Sawicka, 1999; Góral, 2000)* that can have various uses.

There are lots of reports in the literature about the forage value of Jerusalem artichoke, also to the effect of fertilization, variety and date of harvest on production yield and chemical composition of tubers *(Sawicka 1998, Prośba-Białczyk 2007, Matei et al.; 2018, 2020)*. However, there is little information on optimal plant density *(Tabin and Pawłowski 1956)* and many contradictory results in the studies conducted.

2. MATERIALS AND METHODS

Our experiment was carried out at Agricultural Research and Development Station Caracal (ARDS), during the 2019 year in the conditions of a chermozem soil, medium rich in nutrient and with a humus content which varied between 3% to 4%. The soil in the arable layer (0-20 cm) has a lutearic texture with a clay content (particles below 0.002 mm) of 36.2%, an apparent density of 1.42 g/cm^3, a total porosity of 47% and one medium penetration rate (penetration resistance of 42 kg/cm^2).

From the point of view of the hydric features in the superficial layer, the wilting coefficient records the value of 12.3%, the field capacity 24.5% and the hydraulic conductivity is 9.2 mm/h.

The main aim of the research was to establish the most valuable variant of fertilization on the best density on Jerusalem artichokes. As experimented genotype we use a rustic variety - Rares, with provenience from ARDS Bacau, Romania. The crop was planted in early of March and the experiment had two factors:

A factor – distance between plants/row:

- a1 – 40 cm;
- a2 – 50 cm.

B factor - fertilization - with five graduations:

- b1 – unfertilized variant;
- b2 – $N_{40}P_{40}K_{40}$;
- b3 – $N_{80}P_{80}K_{80}$;
- b4 – $N_{120}P_{120}K_{80}$;
- b5 – $N_{160}P_{160}K_{80}$;

All collected data in the field were analyzed using statistical ANOVA program.

3. RESULTS

CLIMATIC CONDITIONS (figure 1) – during the experiment, the climatic conditions had an important influence on the evolution of grain sorghum crop.

Regarding the evolution of temperature, we can say that the agricultural year of 2019 was an excessively hot year. Compared to the normal values of area, an average temperature of 12.7°C was achieved, with +2.1°C higher than the normal zone, which is 10.6°C. Regarding the months of the warm period of the year (April - September) we find that in no month were temperatures lower than the multiannual average. The deviations were positive, between + 0.4°C to +3.1°C. It is noted that the months of June, August and September were extremely hot, with a thermal surplus between +2.3°C and respectively +3.1°C.

The rainfall in this agricultural year totaled 647.8 mm, being with 110.4 mm higher than the multiannual average, which for this area is 537.4 mm. During the warm period of the year, the months of August and September are highlighted as very poor in precipitation, when the precipitation deficit was between -49.7 mm and -37.6 mm.

During the vegetation of Jerusalem artichoke, May - September, the total of 508.2 mm, although close to the average value of the area, was not evenly distributed, with the highest distribution in the first part of vegetation, when plant consumption is not significant, and the temperatures were lower, so that the rainwater was mostly unused by Jerusalem artichoke plants. With the onset of the drought, after mid-July and continuing with the lack of rainfall in August and September, amid average daily temperatures that exceeded the average in these months by 3.1°C and respectively 2.4°C, Jerusalem artichoke plants suffered greatly, and that lead to losing a large part of leaves by drying at the end of August.

Figure 1 - Climatic condition on 2019 year registered at ARDS Caracal

The results obtained at SCDA Caracal, during the year 2019, related the height of the plants (*table 1*), showed us that plant's height had different values on the tested density, between 207 cm at unfertilized variant on the 40 cm between plants/row and 239 cm at the highest level of fertilization, of $N_{160}P_{160}K_{80}$, on the same density where we recorded an average of 228 cm for the plants.

Table 1. The influence of fertilization and distance between plant/row on development of Jerusalem artichoke in 2019

A Factor	B Factor	Plant's height	Height average	Leaf dimensions		Average number of ramification
Distance between plants/row	Fertilization	cm	cm	Length cm	Wide cm	
40 cm	Unfertilized	207	228	Av.: 13.4	Av.: 8.3	32.0
	$N_{40}P_{40}K_{40}$	227				
	$N_{80}P_{80}K_{80}$	231		Min: 8.0	Min: 4.5	
	$N_{120}P_{120}K_{80}$	236		Max: 21.0	Max: 11.7	
	$N_{160}P_{160}K_{80}$	239				
50 cm	Unfertilized	208	232	Av.: 14.1	Av.: 8.5	37.0
	$N_{40}P_{40}K_{40}$	230				
	$N_{80}P_{80}K_{80}$	237		Min: 8.3	Min: 4.3	
	$N_{120}P_{120}K_{80}$	240		Max: 22.5	Max: 12.1	
	$N_{160}P_{160}K_{80}$	244				
Av./experiment		230				

A larger nutritional space for plants - in case of the second density with 50 cm between plants/row - led to a better development of the plants of the tested variety, Rares, and in this case we observed higher values that the previous presented ones, starting to 208 cm on the unfertilized variant and reaching 244 cm for the levels of $N_{160}P_{160}K_{80}$. The average height of plants recorded for this density was 232 cm.

The entire above ground biomass contains leaves, which can participate in a large amount to the total biomass with their features: number and dimensions. At Jerusalem artichoke, the leaf is simple, lanceolate or ovate, having dimensions of 10-20 cm long and 5-10 cm wide, serrated, pubescent on the underside. The number of leaves per plant varies greatly between varieties grown under same conditions, for example, from 372 to 953 *(Swanton, 1986, McLaurin et al., 1999)*.

In our research, the result recorded clearly show us that both factors had a powerful influence to the dimensions of the leaves, with limits which ranges between 8 cm to 21 cm for length on the first density, and an average of 13.4 cm. Related the wide of leaves, the dimensions were situated between 4.5 cm to 11.7 cm, with an average of 8.3 cm.

On the second density, due the higher space between plants, the recorded dimensions of leaves were higher than the previous density, with limits in this year from 8.3 cm to 22.5 cm and an average of 14.1 cm for length and 4.3 cm to 12.1 cm, with 8.5 cm as average for leaves wide.

As majority of cultivated plants, Jerusalem artichoke had a better development in the situation when the space between plans was larger, increasing not only the leaves dimensions but also the number of the branches.

The collected data put us in a position to conclude that feature was, in average on the density with 40 cm between plants/row of 32, smaller than the second one, of 50 cm between plants/row, where we obtained a mean of 37 ramifications.

Regarding the fresh biomass production obtained under the influence of A factor - density of plants - we can synthetize the results presented in figure 2 and conclude that the Jerusalem artichoke had a higher production on the variant with 50 cm between plant/row, of 48.5 t/ha, than those registered on the variant with 40 cm between plants/row, where we note a yield of 42.7 t/ha.

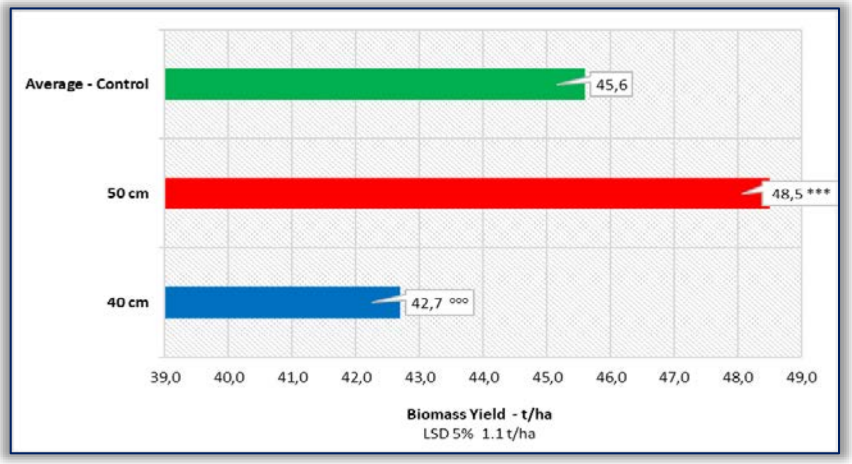

Figure 2. Influence of the A factor – distance of plants/row - on the Jerusalem artichoke biomass yields

The differences between those two densities and Control variant, of 2.9 t/ha, were statistically point of view ensured as very significant, with an increases of 6.4% in case of highest density tested.

Under the applied fertilizers (B factor), Jerusalem artichoke gave a very good response in comparison with the variants used as Control (unfertilized ones) and in conditions of the experimented area the results show that this species has a very high potential to generate fresh biomass (*figure 3*).

The level of yields maintained an ascendant trend starting from Control to the highest level of fertilization, even in the situation of climatic conditions with high thermic stress for the second part of plant vegetation.

For this year, the best production of fresh biomass had recorded on the variant of $N_{160}P_{160}K_{80}$, of 53.9 t/ha, with 18.1% higher than the Control, which realize 37.1 t/ha.
Closer values were recorded at variant with lower level of fertilizers with nitrogen and phosphorus, of $N_{120}P_{120}K_{80}$, where the increases were also very significant in comparison with the unfertilized variant and the yield was higher with 8.9%.
The average/experiment from the second factor - level of applied fertilizers - was 45.6 t/ha fresh biomass, determinate in flowering stage of development of Jerusalem artichoke plants.

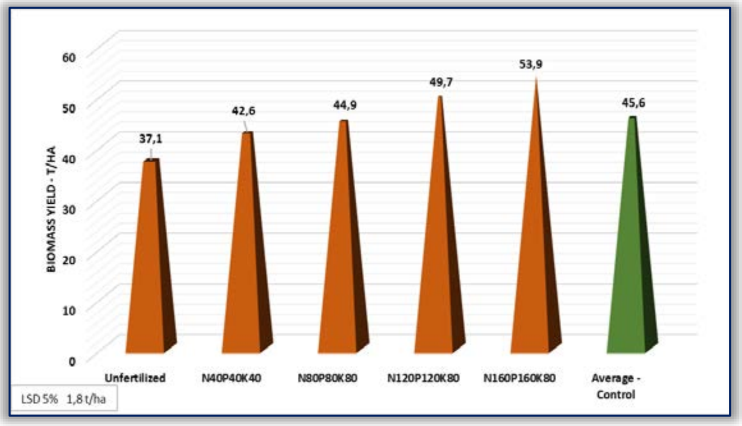

Figure 3. Influence of the B factor – fertilization - on the Jerusalem artichoke biomass yields

In the described above climatic conditions, when the lack of precipitations or lower regime of them, in the second part of vegetation of Jerusalem artichoke plants, the applied fertilizers were better capitalized by plants on variants with moderate levels, without any supplementary stress for plants amplified by lower humidity and high thermal regime.
The response of the Jerusalem artichoke crop to the combined influence of the two factors - density and fertilizers level - was one very well quantified in the values of the fresh biomass recorded (*table 2*). The average of the entire experiment was 45.6 t/ha. In comparison with this Control, the situation can be described, as we present in the next paragraphs.
On the first density, of 40 cm between plants/row, the level of fresh biomass production ranges between 33.8 t/ha on the unfertilized variant to 49.8 t/ha fresh biomass recorded at variant with $N_{160}P_{160}K_{80}$. Positive differences in comparison with the Control were observed on last two levels of fertilization, at variants of $N_{160}P_{160}K_{80}$ and $N_{120}P_{120}K_{80}$, with plus productions of 2.65 t/ha and respectively 4.14 t/ha.

Table 2. The influence of interaction of density (A) and fertilization (B) on Jerusalem artichoke biomass yield in 2019

A Factor	B Factor	Yield		Differences	Signification
Distance between plants/row	Fertilization	t/ha	%	t/ha	
40 cm	Unfertilized	33.8	74,1	-11,82	OOO
	$N_{40}P_{40}K_{40}$	40.3	88,4	-5,30	OO
	$N_{80}P_{80}K_{80}$	41.8	91,6	-3,84	OO
	$N_{120}P_{120}K_{80}$	48.3	105,8	2,65	*
	$N_{160}P_{160}K_{80}$	49.8	109,1	4,14	**
Average		42.8			
50 cm	Unfertilized	40.3	88,3	-5,32	OO
	$N_{40}P_{40}K_{40}$	44.8	98,2	-0,80	
	$N_{80}P_{80}K_{80}$	47.9	105,1	2,32	*
	$N_{120}P_{120}K_{80}$	51.2	112,1	5,54	**
	$N_{160}P_{160}K_{80}$	58.1	127,3	12,44	***
Average		48.5			
Average/experiment		45.6	100,0	CONTROL	CONTROL

LSD 5%	2.3
LSD 1%	3.5
LSD 0.1 %	5.9

On the second density tested, of 50 cm between plants/row, it is observed the same tendency of increase of yields from the unfertilized variant in the same time with the increase of fertilizers amount. The yields varied between 40.3 t/ha to 58.1 t/ha fresh biomass. Also, on these conditions we recorded statistical increases in productions, but this time, due the larger nutritional spaces of Jerusalem artichoke plants, the last three variants had this feature with +2.32 t/ha on the $N_{80}P_{80}K_{80}$ variant, +5.54 t/ha on the $N_{120}P_{120}K_{80}$ variant and + 12.44 t/ha fresh biomass for highest level of fertilizers of $N_{160}P_{160}K_{80}$.
In literature we find several studies which have been conducted to determine the effects of water stress on tuber yield and Jerusalem artichoke biomass *(Conde et al., 1991; Schittenhelm, 1999; Monti et al., 2005; Liu et al., 2012)* even for tropical regions *(Ruttanaprasert et al., 2014)*.
In the study, conducted by Conde et al., 1991; Losavio et al., 1997, drought reduced dry tuber weight and biomass, and reductions in dry tuber weight and biomass were greater under severe drought (85.8-98.2%) compared to drought in moderate conditions (49.3-85.2%).

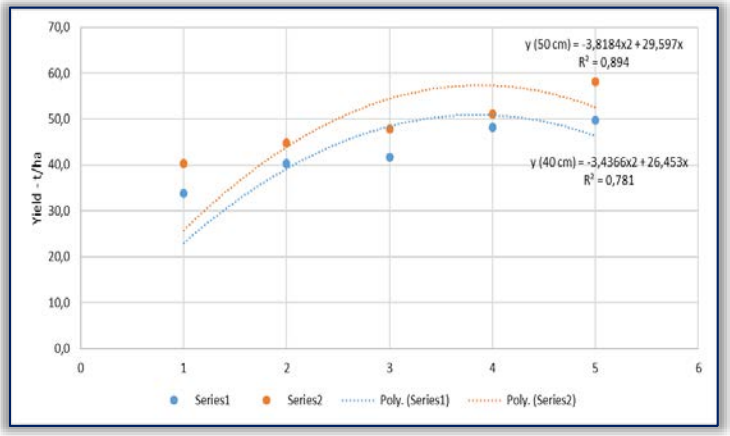

Figure 4. Trend line of the Polynomial equation, second degree, regarded the Influence of the A x B factors on the Jerusalem artichoke biomass yields

The main results of this study clearly indicated that Jerusalem artichoke is generally not a very drought-resistant crop, the fresh biomass yield has been greatly reduced, especially in the tropics conditions, even under mild drought stress. In the temperate region, the drought reduced the dry weight of the tubers by 20%. A loss of tuber yield of over 29% was observed in tropical regions with high temperature *(Ruttanaprasert et al., 2014)*.

In order to have a clear image about the fertilized variants from our experiment we use a Polynomial equation of second degree to obtain a theoretical trend line of the evolution of fresh biomass yields on the two densities used *(figure 4)* and the results certified that on the highest levels of the fertilizers applied of $N_{120}P_{120}K_{80}$ and $N_{160}P_{160}K_{80}$ were better capitalized on the density of 50 cm between plants/row.

4. CONCLUSIONS

From the above presented data, we can highlight, as most important conclusions, the follows:

- Jerusalem artichoke found good climatic conditions for growth and development of the plants in 2019 in the tested area of ARDS Caracal;
- We observe that the main morphological features of Jerusalem artichoke plants were influenced by the tested factors: density of plants and fertilizers applied, with variations of height of plants, leaves dimensions and number of braches/plant, all of these being higher on the 50 cm between plants/row variant;
- From the single point of view of the experimented factors, the recorded result let us to conclude that the most valuable density was one of 50 cm between plants/row;
- In the conditions of the influence of both tested factors, the obtained yield of fresh biomass for the experiment was 48.0 t/ha, a values which is on the range of mentioned literature for this crop in various areas of cultivation;
- The most valuable levels of fertilization proved to be those with $N_{120}P_{120}K_{80}$ and $N_{160}P_{160}K_{80}$ where the nutrients were better capitalized on the density of 50 cm between plants/row than the variant of 40 cm between plants/row.

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