Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 1, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

POTENTIAL OF JERUSALEM ARTICHOKE (*Helianthus tuberosus* L.) AS A BIOMASS CROP

Gheorghe MATEI[1], Valentin VLĂDUȚ[2], Simona ISTICIOAIA[3], Radu Lucian PÂNZARU[1], Diana POPA[3]

[1]University of Craiova, 13 A.I. Cuza Street, Craiova, Dolj County, Romania
[2]National Institute of Research, Development for Machines and Installations Designed to Agriculture and Food Industry - INMA Bucharest, 6 Ion Ionescu de la Brad Blvd, District 1, Bucharest, Romania
[3]Research Development Agricultural Station Secuieni, 377 Principala Street, Secuieni, Neamț County, Romania

Corresponding author email: simonapochi@yahoo.com

Abstract

Jerusalem artichoke is a species with high production potential, resistance to diseases and pests, with a good tolerance to the variations of climatic factors. The upper part of the Jerusalem artichoke can be used for the production of biofuel, for the manufacture of briquettes and pellets. In addition to the above-ground biomass yield, Jerusalem artichoke also produces a high yield of tubers. The research carried out by us in the climatic conditions from ARDS Caracal showed that both the applied fertilization level and the nutrition space influenced the quantity of biomass generated by the Jerusalem artichoke, with values that ranged between 36.2 t/ha in the unfertilized variant, with planting at 40 cm between plants/row and 60.1 t/ha at the variant with the fertilization dose of $N_{160}P_{160}K_{80}$ *at the planting distance of 50 cm between plants/row.*

Key words: *Jerusalem artichoke, biomass yields, fertilization, density.*

INTRODUCTION

The Jerusalem artichoke is a perennial plant that has a grassy stem that can reach a height of over 3 m, the vegetative part of the plant drying in autumn (Matei et. al., 2018). In next spring emerges again from the underground tubers. It has a high nutritional value due to the presence of almost all essential amino acids (Rakhimov et al., 2003), is used as feed in animal feed (Seiler and Campbell, 2004), and biomass is considered as a rich source of ethanol (Denoroy, 1996). The biogas production in the Jerusalem artichoke is much higher compared to other energy crops (Emmerling, 2007).
According to Cabral et al. (2018), Jerusalem artichoke stems are an alternative raw material for cement composites being suitable to be used to produce cement-bonded boards for construction applications.
In the literature, there are reports on the feed value of Jerusalem artichokes, the effect of fertilization, variety and date of harvest on the yield of production and the chemical composition of the tubers (Sawicka, 1998; Prośba-Białczyk 2007). However, there are fewer information on optimal plant density (Tabin and Pawłowski, 1956). Research studies have shown that plant density increases the yield of tubers and the upper part. The production of fresh tubers ranged from 40 to 100 t/ha in the researches mentioned by Ibarguren et al. (2013). Liu et al. (2015), obtained yields between 20 and 60 t/ha for different Jerusalem artichokes clones in the semi-arid region of China. As a non-grain crop, Jerusalem artichoke possesses a number of desirable characteristics that make it a valuable feedstock, for bio refinery, such as inulin content, rapid growth, strong adaptability, and high yields. Qiu et al. (2018), provides a comprehensive introduction to renewable Jerusalem artichoke-based biomass resources and recent advances in bio-based product conversion.
From the agronomic point of view, the Jerusalem artichokes is considered drought-resistant and can be cultivated at low cost without irrigation by harnessing poor soils (Monti et al., 2005), exhibits very high

adaptability at the extremes of the unfavourable factors - drought resistance at extremely high temperatures.

MATERIALS AND METHODS

The research was carried out at Agricultural Research and Development Station Caracal (ARDS), during the 2018 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 - $N_{160}P_{160}K_{80}$;

The collected data in the field were analysed using statistical ANOVA program.

RESULTS AND DISCUSSIONS

Climatic conditions (Figure 2) show that the 2018 agricultural year was one excessively warm and these conditions were strongly influenced the main evolutions of the rhythm of plant's development and their capacity for production. Compared to the multiannual registrations, an average temperature of 12.6°C was achieved, with 2.0°C, higher than the multiannual average of 10.6°C. Regarding the months of the warm period of the year (April - September), we find that in no month were recorded temperatures lower than the multiannual average. The deviations were positive, ranging from 0 to +5.2°C. April was remarkably hot, recording a thermal surge of +5.2°C, the highest temperature ever recorded in April from this area. Daily average temperatures exceeded 32°C in the middle of the month. Also in May were exceptional temperatures, with monthly deviation of + 3°C, all of which led to a record: the warmest spring since there were meteorological records in the area. It is also remarkably hot in August and September, with a thermal surplus of +2.4°C and respectively +2.0°C related to multiannual average.
From the point of view of precipitations, the 2018 year was on with a high level of rainfall, especially in the second part of plant's vegetation. The precipitation in this agricultural year reach totals of 843.6 mm, with 306.2 mm higher than the multiannual average for the Caracal Plain area, of 537.4 mm.
The lack of precipitations at the beginning of stage vegetation of plants had negatively influenced the emergence of plants, which made the period with high temperatures in the summer overlap with the period when the requirements of the plants for water were maximum, that fact going to a decrease of the potential of plants to ensure large amount of biomass. These conditions lead to another negative situation for emerge of plants - crust on the soil surface (Figure 1).

Figure 1. Crust on the soil surface in spring of 2018 at ARDS Caracal

Jerusalem artichoke is a plant that ideally suits for efficient biomass production and can be grown on very weak, also degraded, soils which are not used for the cultivation of crops for consumption. In a study who aims to evaluate the energy efficiency of Jerusalem artichoke in various processing technologies in terms of use in biogas plants: green mass silage, straw and bulbs fermentation, and then comparison of energy efficiency and profitability in the biogas plants with the most popular type of substrate used in European biogas plants - maize silage - Kowalczyk-Jusko et al. (2017), showed that the total energy value of the aerial parts of dried Jerusalem artichoke was 4.472 kWh/kg DM, which represents approx. 65% of energy value of typical coal.

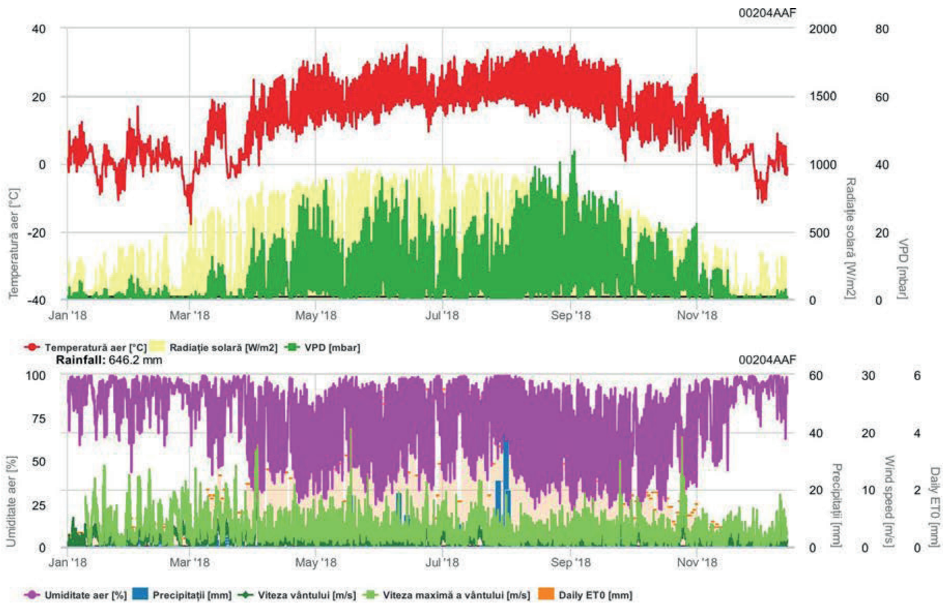


Figure 2. Climatic conditions in 2018 at ARDS Caracal

The yield formation on Jerusalem artichoke was studied by Lv et al. (2019), in order to describe the mechanism based on its growth and photosynthetic characteristics and to identify reliable criteria for high yield cultivar screening, and to guide the breeding of new high yield cultivars. High yield group (MH) cultivars exhibited vigorous above-ground and root growth, higher photosynthetic capacities (especially in terms of their ability to utilize weak light and minimize dark respiration) and lower rates of sexual reproduction than low yield group (ML) cultivars.

Information from the literature is discussed to define guidelines for a model of the growth and development of *Helianthus tuberosus* (L.) in non-limiting conditions. Dynamics of the leaf area index and the distribution of growth between structural growth and reserves (in stem, stolons and tubers) are the most crucial processes (Denoroy, 1996). The potential as feedstock and tuber yield was investigated by Gao K. et al. (2019), using different leaf removal treatments in 2013 and 2014 in Inner Mongolia, China. Tuber yield was significantly higher in plants from which the lower 1/3 and 1/4 of the leaves were removed than that in control plants.

In our case, the main morphological features of Jerusalem artichoke under the influence of the density and fertilization levels were presented in Table 1. The plant's height was directly correlated with the fertilization and increase simultaneous with levels on both tested distances between plants/row. On the variant with 40 cm between plants/row the height varied from 247.6 cm on the unfertilized variant to 298.6 cm registered at the highest level of fertilization of $N_{160}P_{160}K_{80}$, with an average of 273.2 cm. A similar situation we recorded on the second tested density where the plants height ranged from 287.1 cm on the variant with no fertilizers applied to 308.1 cm on the $N_{160}P_{160}K_{80}$ variant. The height plant's average on the second density was 295.3 cm. The value of the length of the plants from both densities tested in the experiment for the 2018 year was 284.3 cm.

One of the main aerial biomass components are leafs. The numbers and their dimensions had a very large influence to the amount of biomass on Jerusalem artichoke. Related to this aspect, we can observe that *on the variant with 40 cm between plants/row*, the average dimensions of the leafs were 15.7 cm length and 9.5 cm wide, with a minimum of 10 cm registered in case of length and a maximum of 23 cm for the same parameter. Related the wide of leafs, those had a minimum values of 4.8 cm and a maximum registered of 15.5 cm. *On the variant* where we test the density *with 50 cm between plants/row*, the average dimensions of leafs had 16.9 cm of length and 9.4 cm of wide. Easy can be observed that the large space of nutrition for each plant lead to modify the leaf geometry, forming longer and narrower leaves. Also, on this density we found a large variations of leaf dimensions, from 8.5 cm to 26 cm for length of leafs and starting from 4 cm to 16 cm in case of leaf's wide.

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

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	247.6	273.2	Av.: 15.7	Av.: 9.5	39.0
	$N_{40}P_{40}K_{40}$	262.8				
	$N_{80}P_{80}K_{80}$	270.1		Min: 10.0	Min: 4.8	
	$N_{120}P_{120}K_{80}$	286.8		Max: 23.0	Max: 15.5	
	$N_{160}P_{160}K_{80}$	298.6				
50 cm	Unfertilized	287.1	295.3	Av.: 16.9	Av.: 9.4	45.0
	$N_{40}P_{40}K_{40}$	290.0				
	$N_{80}P_{80}K_{80}$	292.6		Min: 8.5	Min: 4.0	
	$N_{120}P_{120}K_{80}$	298.8		Max: 26.0	Max: 16.0	
	$N_{160}P_{160}K_{80}$	308.1				
Av./experiment		**284.3**				

Not only the dimensions of the leafs were influenced by the nutritional space of the plant, but entire architecture of the plant. Thus, the number of ramifications of the plant's stem had a large variation due this factor and varied, in average on each tested distance between plants/row, between 39 ramifications in case of 40 cm and 45 ramifications on the second variant with 50 cm. One example of the recorded characters is exemplified in Figure 3.

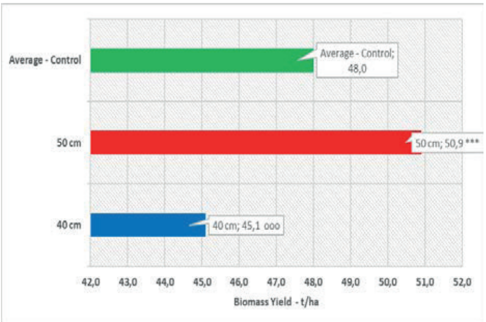
All this presented morphological features of the Jerusalem artichoke were finally influenced the biomass yield: underground and upper ground ones.

Gao K. et al. (2019), showed that fresh and dry weights of tubers and underground biomass were higher when harvested after freezing; the dry yields of leaves and stems decreased with harvest time. In addition, irrigation signify-cantly enhanced the yields of underground biomass, aboveground biomass and tubers, compared with non-irrigation conditions ($p < 0.05$). The results obtained from the data recorded on the experimented variety - Rares - and presented in the Figure 4, conduct us to conclude that, for the climatic conditions of 2018 year, the most valuable density generate by the distance between plants/row was 50 cm, with a total fresh biomass of 50.9 t/ha and an increase of 2.9 t/ha, statistically ensured as distinct significant related to the average, used as Control. On the second distance between plants/row of 40 cm we recorded a smaller yield of fresh biomass, of 45.1 t/ha.

Even though it is considered by many to be a rustic species, Jerusalem artichoke has a powerful reaction to the applied fertilizers, a fact we registered and presented in Figure 5. The total fresh biomass had an increasing trend from the unfertilized variant, where we record a value of 40.7 t/ha, to highest level of fertilization where we obtained 55.5 t/ha aboveground fresh biomass.

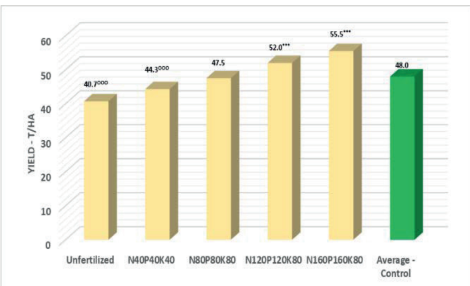
50 cm/row 40 cm/row

Figure 3. Influence of distance of plants/row on the branches degree



LSD 5% - 1.3 t/ha; LSD 1% - 1.7 t/ha; LSD 0.1% - 2.3 t/ha

Figure 4. Influence of the A factor - distance of plants/row - on the Jerusalem artichoke biomass yields



LSD 5% - 1.6 t/ha; LSD 1% - 2.3 t/ha; LSD 0.1% - 3.1 t/ha

Figure 5. Influence of the B factor – fertilization - on the Jerusalem artichoke biomass yields

Due the climatic conditions of this year, mostly related the rainfall regime, the unfertilized variant had a large amount of biomass. Comparing its value with other fertilized variants we can easy see that the increases were statistically ensured as very significant. Taking in account this particularly situation we used as Control the average of fresh biomass on the entire experiment. Related to this mark the most valuable variants prove to be $N_{120}P_{120}K_{80}$ and $N_{160}P_{160}K_{80}$ with values of 52.0 t/ha fresh biomass and respectively 55.5 t/ha fresh biomass.

Regarding fertilization, *the results obtained can be ambiguous* (Denoroy, 1996). However, Kays and Nottingham (2008), recommend for fertilization 70-100 kg/ha of N, about 80 to 100 kg/ha of P and 150-250 kg/ha of K. These authors point out that nitrogen fertilizers can cause overgrowth of the aerial part to the detriment of tuber yield when there is a high level of nitrate in the soil.

Rebora et al. (2011), obtained a different answer, where the increase of density by decrease the distance between plants conduct in a decrease of the weight of the tubers and a compensation of the yield by increasing the number of tubers.

In our experiment the response of the Jerusalem artichoke to the *combined interaction of the two factors - plant density and fertilization* - is presented in Table 2. Thus, on the smallest distance between plants/row, of 40 cm, the average of the tested density was 45.1 t/ha fresh biomass, with limits that falls between 36.2 t/ha on the unfertilized variant and 50.9 t/ha on the level of $N_{160}P_{160}K_{80}$. Compared these values with Control – the average/experiment, who's production of fresh biomass was of 48.0 t/ha, very significant increases of 4.7% and 6% were observed on variants of $N_{120}P_{120}K_{80}$ and respectively of $N_{160}P_{160}K_{80}$. Negative differences, statistically ensured as very significant related to the Control, has been recorded to the first two variants: unfertilized (with a diminution of fresh biomass yield of 11.8 t/ha) and $N_{40}P_{40}K_{40}$ (with a diminution of fresh biomass yield of 6.0 t/ha).

On the second distance between plants/row of 50 cm, the average of fresh biomass yield recorded was of 50.9 t/ha. The most valuable levels of fertilization for that second graduation of A factor proved to be the same as those from the first graduation: $N_{120}P_{120}K_{80}$ and respectively of $N_{160}P_{160}K_{80}$ with yields of 53.7 t/ha and respectively 60.1 t/ha. Their increases of 5.7 t/ha and 12.1 t/ha were statistically ensured as very significant in comparison with the Control - the average/experiment. From the results that we recorded is obviously that on the second distance tested we obtained increases starting from the third level of fertilization of $N_{80}P_{80}K_{80}$.

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

A Factor Distance between plants/row	B Factor Fertilization	Yield t/ha	Yield %	Differences t/ha	Signification
40 cm	Unfertilized	36.2	75.4	-11.8	OOO
	$N_{40}P_{40}K_{40}$	42.0	87.5	-6.0	OOO
	$N_{80}P_{80}K_{80}$	46.0	95.9	-2.0	
	$N_{120}P_{120}K_{80}$	50.3	104.7	2.3	**
	$N_{160}P_{160}K_{80}$	50.9	106.0	2.9	**
Average		*45.1*			
50 cm	Unfertilized	45.2	94.2	-2.8	O
	$N_{40}P_{40}K_{40}$	46.6	97.2	-1.3	
	$N_{80}P_{80}K_{80}$	48.9	102.0	0.9	
	$N_{120}P_{120}K_{80}$	53.7	111.9	5.7	***
	$N_{160}P_{160}K_{80}$	60.1	125.3	12.1	***
Average		*50.9*			
Average/experiment		***48.0***	***100.0***	***CONTROL***	***CONTROL***
LSD 5%		2.1			
LSD 1%		2.8			
LSD 0.1 %		3.7			

That situations conduct us to believe that on the higher density (with small distance between plants/row), is not justified to apply higher levels of nutrients of N_{160} or P_{160} due the feedback of yield increases. On the other part, the increases registered on the second density of factor A of 11.9% or 25.3% fully justifies the increases of nutrients amount.

CONCLUSIONS

From the above presented data, we can highlight, the follow important conclusions:

- climatic conditions of 2018 year from ARDS Caracal allow to the Jerusalem artichoke plants to express their productive potential;
- the main morphological features of plants were strongly influenced by the density of plant and fertilization regime, height of plants reaching over 3 meters in the situation of large nutritional space on the smallest density, with 50 cm between plants/row;
- the number of branches and leafs form were also modified in the variants, with impact on the total aboveground fresh biomass yields recorded;
- the best density of Jerusalem plants, not only from the point of view of morphological features, but from the fresh biomass yields also, proved to be the distance of 50 cm between plants/row, with an average of 50.9 t/ha in the experiment;
- the fresh biomass yield, in average/experiment, had a value of 48 t/ha;
- from the fertilization factor the most valuable variants prove to be $N_{120}P_{120}K_{80}$ and $N_{160}P_{160}K_{80}$ with values of 52.0 t/ha fresh biomass and respectively 55.5 t/ha fresh biomass;
- if we take in account the *combined interaction of the two factors – plant density and fertilization* of the Jerusalem artichoke, very significant increases of 4.7% and 6% were observed on variants of $N_{120}P_{120}K_{80}$ and respectively of $N_{160}P_{160}K_{80}$ which proved to be the most valuable in the conditions of density with 50 cm between plants/row.

ACKNOWLEDGEMENTS

The research was done in the activities of the Project no. 9/PCCDI/2018 VALINTEGR supported by Ministry of National Education UEFISCDI, Program PN III 2017- 2020.

REFERENCES

Cabral R., Nakanushi, M. E. Y., Marmol, G., Palacios, J., Godbout, S., Lagace, R., Savastano Junior H., Fiorelli, J. (2018). Potențial of Jerusalem artichoke (*Helianthus tuberosus* L.) stalks to produce cement-bonded particleboards. *Industrial Crops & Products*, *122*, 214–222;

Denoroy. P. (1996). The crop physiology of *Helianthus tuberosus* L.: A model oriented view. *Biomass and Bioenergy, 11*(1), 11–32.

Emmerling, C., Barton, J. (2007). Anaerobic co-digestion of topinambour (*Helianthus tuberosus* L.) and properties of the remaining biogas manure. *Archives of Agronomy and Soil Science*, *53*(6), 683–690.

Gao, K., Zhang, Z.X., Zhu, T.X., Tian, X., Gao, Y., Zhao, L.X., Li, T.Q. (2019). The influence of leaf removal on tuber yield and fuel characteristics of Helianthus tuberosus L. in a semi-arid area. *Industrial crops and products, 131*, 8–13.

Ibarguren, L., Rebora, C. (2013). El cultivo de topinambur: generalidades sobre su ecofisiología y manejo. *Horticultura Argentina, 32*(77), 35–41.

Kays, S.J., Nottingham, S.F. (2008). Chapter 6: Value in human and animal diets. *Biology and Chemistry of Jerusalem Artichoke Helianthus tuberosus* L.

Kowalczyk-Jusko, A., Kupryaniuk, K., Oniszczuk, T., Wojtowicz, A., Janczak, D., Smurzynska, A., Jozwiakowski, K., Czechlowski, M. (2017). Applicability of Jerusalem artichoke in agricultural biogas plants as maize silage alternative. *Proceedings of the 3rd International Conference on Energy and Environment (ICEE 2017). Book Series: ICEE International Conference on Energy & Environment*, 89–94.

Liu, Z.X., Steinberger, Y., Chen, X., Wang, J.S., & Xie, G.H. (2015). Chemical composition and potential ethanol yield of Jerusalem artichoke in a semi-arid region of China. *Italian Journal of Agronomy*, *10*(1), 34–43.

Lv, S.Q., Wang, R.X., Xiao, Y.M., Li, F.C., et al., (2019). Growth, yield formation, and inulin performance of a non-food energy crop, Jerusalem artichoke (*Helianthus tuberosus* L.), in a semi-arid area of China. *Industrial crops and products, 134*, 71–79.

Matei Gh., Vlăduț V.N., Ștefan M., Constantinescu E., Sălceanu, C. (2018). Variability of some morphological characters to the Jerusalem artichoke crop under the conditions of the ARDS Caracal. *ISB INMA TECH' 2018 Agricultural and mechanical engineering*, 1023–1028.

Monti A., Amaducci M.T., Venturi G., (2005). Growth response and leaf gas exchange and fructans accumulation of Jerusalem artichoke (*Helianthus tuberosus* L.) as affected by different water regimes. *Eur. J. Agron., 23*, 136–145.

Prośba-Białczyk, U. (2007). Produkcyjność topinamburu (*Helianthus tuberosus* L.) uprawianego bez nawożenia. *Fragm. Agron*., *XXIV*, *4*(96), 106–112.

Rakhimov D.A., Arifkhodzhaev A.O., Mezhlumyan L.G., Yuldashev O.M., Rozikova U.A., Aikhodzhaeva N., Vakil M.M. (2003). Carbohydrates and proteins from Helianthus tuberosus. *Chem. Nat. Comp., 39*(3), 312–313.

Rebora, C., Ibarguren, L., Lelio, H., Gomez, L. (2011). Effect of plant population density on tuber yield of Jerusalem artichoke (*Helianthus tuberosus* L.) urban waste water irrigated. *Revista de la Facultad de Ciencias Agrarias*, *43*(2), 83–90.

Sawicka, B. (1998). Wartość pastewna słonecznika bulwiastego (*Helianthus tuberosus* L.) w warunkach nawożenia azotem. *Ann. Univ. Mariae Curie-Skłodowska*, *Sect. E. LII. 11*, 97–108.

Seiler G.J., Campbell L.G. (2004). Genetic variability for mineral element concentrations of wild Jerusalem artichoke forage. *Crop Sci., 44*. 289–292. *Buletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture, 73*(2).

Tabin, S., Pawłowski, F. (1956). Wpływ rozstawy i obsypywania na plon bulwy (*Helianthus tuberosus* L.). *Ann. Univ. Mariae Curie-Skłodowska*, *11*(9), 243–257.

Qiu, Y.B., Lei, P. Zhang, Y.T, Sha, Y.Y., Zhan, Y.J., Xu, Z.Q., Li, S., Xu, H., Ouyang, P.K. (2018). Recent advances in bio-based multi-products of agricultural Jerusalem artichoke resources. *Biotechnology for biofuels, 11*(151).