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RESEARCH ON THE NUTRITION SYSTEM FOR *Jerusalem artichoke* GROWN ON SANDY SOILS

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Abstract

From the agronomic point of view, Jerusalem artichoke is considered a drought-resistant species and can be grown in non-irrigated conditions, by capitalizing on poor soils. Research conducted at RDSPCS Dabuleni in the period 2018-2020 under irrigation conditions showed that Jerusalem artichoke is a species that has performed well in cultivation on sandy soils. The experiment was placed on a soil with a low nitrogen content, normal phosphorus, low potassium and organic matter, and the soil reaction was weakly acidic. The research results in the period 2018-2020 show that the highest production of above-ground biomass (stems + leaves) of 64779 kg/ha was obtained on the agrofund of $N_{160}P_{160}$ K_{80} *and the planting distance of 40 cm between plants in a row.*

Key words*: sandy soil, production, density, fertilization.*

INTRODUCTION

Jerusalem artichoke is appreciated for its characteristic, sweet taste, rich in minerals (Ca, Mg, K, P), vitamins (β-carotene, thiamine, lactoflavin, niacin, biotin, ascorbic acid), amino acids (lysine, arginine, histidine ,cystine, tryptophan, aspartic acid), specific amino acids (choline, betaine, saponin, quercitrin) and enzymes (inulinase, proteinase, invertase, phosphorylase and phenolase). The biochemical composition of tubers depends mainly on the genetic structure, environmental factors and genotype (Soare et al., 2017). Over time, Jerusalem artichoke has been used successfully to treat a wide range of conditions, from diabetes, colds, atherosclerosis, colorectal cancer, cholesterol, to digestive candidiasis, constipation, lack of calcium or obesity. Jerusalem artichoke is also recommended in asthenia, as a tonic, antiseptic, gout, dyspepsia, rheumatism. Tubers are used as a raw material in the alcohol industry, but also in the manufacture of sweets. From 100 kg of Jerusalem artichoke tubers can be obtained 7-10 liters of alcohol. The alcohol fermented from the tubers is of a better quality than that of sugar beet.

From an agronomic point of view, Jerusalem artichoke is considered a drought-resistant species and can be grown in non-irrigated conditions, by capitalizing on poor soils (Monti et al., 2005). It has a very high adaptability to the extremes of unfavorable factors, resistance to extremely high temperatures (35-45°C plants and 30-45°C in the case of tubers), resistance to high concentrations of salts, heavy metals, nitrates. Studies in this species have shown that irrigation is necessary when water is insufficient and exacerbates drought. Jerusalem artichoke is also a very valuable crop for biomass that is considered a rich source of ethanol (Denoroy, 1996). Jerusalem artichoke biogas production is much higher compared to other energy crops (Emmerling, 2007). In a semi-arid region of China, Zu Xin Liu (2012) conducted a study of twenty-six Jerusalem artichoke clones to evaluate their potential as a biomass feedstock for ethanol production and demonstrated that the biomass obtained can be a feedstock, first promising material for cellulosic ethanol.

Despite the great interest in this Jerusalem artichoke crop, there are few studies showing the spread of this species in the crop, especially in terms of the behavior of different genotypes. Planting density has been little studied and there is no important research for the regions of southern Europe. In fact, in the literature, planting density varies from case to case in the

range of 2 plants/m^2 to 7 plants/m^2 (Zu XL et al., 2012, Mecella G. et al., 1996, Monti A. et al., 2005, Puangbut et al., 2012). Fertilization is the most important factor influencing the quantity and quality of Jerusalem artichoke production, but research conducted by Pomares et al., 2004, Feleafel, 2005, shows that soil, climatic conditions, genotype and cultivation technology contribute to the increase in Jerusalem artichoke production. Lombardo et al. (2017) showed that nitrogen fertilization significantly influenced the quality and shelf life of fresh Jerusalem artichoke tubers in terms of nutritional and microbiological properties.
The aim of the research was to evaluate the effect of planting density and the response to nitrogen, phosphorus and potassium fertilization of Jerusalem artichoke species with energy and food potential in the conditions of sandy soils from Research Development Station for Plant Culture on Sandy Soils (RDSPCS Dabuleni).

MATERIALS AND METHODS

The research was conducted at RDSPCS Dabuleni, in the period 2018-2020, in the conditions of a sandy soil with a low nitrogen content, normal phosphorus, low potassium and organic material, and the soil reaction was weakly acidic. The experience was bifactorial, placed according to the method of subdivided plots, in three repetitions.
FACTOR A: Fertilization system
a_1– Unfertilized
a_2 – $N_{40}P_{40}K_{40}$
a_3 – $N_{80}P_{80}$ K 80
a_4 – $N_{120}P_{120}K_{80}$
a_5 - $N_{160}P_{160}K_{80}$
FACTOR B: The distance between plants in a row
b_1 - 40 cm
b_2 - 50 cm
The biological material used for planting was the Rustic variety. The preparation of the land was done by plowing at a depth of 28-30 cm, fertilization with complex fertilizer 15-15-15 at the level of N, P, K established for the variants studied, disking + worked with milling cutter. Planting was done manually on April 3 in 2018, on March 20 in 2019 and on March 13 in 2020, at a distance of 70 cm between rows and 40 cm, respectively 50 cm between tubers per row.
In order to determine the nutrient supply status of the soil from the Jerusalem artichoke culture, soil samples were collected at a depth of 0-40 cm. The samples were recorded and conditioned in the laboratory, from which the following determinations were made:
- total nitrogen - Kjeldahl method;
- extractable phosphorus (P-AL) - Egner method - Riem Domingo, by which phosphates are extracted from the soil sample with a solution of acetate - ammonium lactate at pH - 5.75, and the extracted phosphate anion is determined colorimetrically as - blue of molybdenum;
-changeable potassium (K-AL) - Egner - Riem Domingo method by which the hydrogen and ammonium ions of the extraction solution replace by exchange the potassium ions in exchangeable form from the soil sample which are passed into the solution. The potassium is determined in the solution obtained by flame emission photometry.
-organic carbon - wet oxidation method and titrimetric dosing (after Walkley - Blak in the Gogoasa modification);
- pH- of the soil, potentiometric method.
During the vegetation period, observations and determinations were made regarding: plant height, average number of shoots/plant, average number of leaves/plant, stem base diameter, leaf area. At the beginning of flowering, because the initiation of flowers is a signal of accumulation of assimilates in tubers (M.D. Curt et al., 2006) the number of tubers/plant, the weight of tubers/plant, the production of aerial and underground biomass were determined. Biomass production (stems and tubers) was expressed in kg/ha. The nutritional quality of the potato tubers was determined in the laboratory regarding:
- water and total dry matter (%) - gravimetric method;
- soluble dry matter (%) - refractometric method;
- vitamin C (mg/100 g s.p) - iodometric method;
- starch (%) - gravimetric method;
The calculation and interpretation of the results was performed in comparison with the unfertilized control, using the method of analysis of variance.

RESULTS AND DISCUSSIONS

Laboratory analyzes on the chemical composition of the soil show the existence of a soil with (Table 1) a low content of nitrogen, normal phosphorus, low to medium potassium and organic material and the soil reaction was moderately acidic to neutral.

Table 1. Chemical composition of soil in Jerusalem artichoke culture (2018-2020)

Fertilization dose	Total nitrogen (%)	Extractable phosphorus (ppm)	Exchangeable potassium (ppm)	Organic carbon (%)	pH in water
a_1- Unfertilized	0.07	45	61	0.98	6.99
a_2 - $N_{40}P_{40}K_{40}$	0.06	56	59	0.90	7.30
a_3 – $N_{80}P_{80}K_{80}$	0.04	47	58	0.69	7.25
a_4 – $N_{120}P_{120}K_{80}$	0.07	93	93	0.97	6.72
a_5--$N_{160}P_{160}K_{80}$	0.05	80	78	0.61	6.40
poorly stocked	<0.10	8.1-18	<66	<0.58	5.01-5.80 Weak acid
Middle stocked	0.11-0.15	18.1-36	66.1-132	0.59-1.16	5.81-6.8 Moderate acid
Well stocked	0.16-0.20	36.1-72	132.1-200	1.17-2.32	6.81-7.20 Neutral

Biometric measurements made during the vegetation period on the height of the plant, no. of stems/plant, no. of lateral shoots/plant are presented in Table 2.

Table 2. Biometric determinations of Jerusalem artichoke during the growing season (2018-2020)

Fertilization dose	Planting density	The average size of the plant (cm)	Average number of stems/plant	Average number of lateral shoots/plant
a_1- Unfertilized	b_1-40 cm	205.2	5.9	4.9
	b_2- 50 cm	216.5	4.6	2.5
a_2 - $N_{40}P_{40}K_{40}$	b_1-40 cm	215.8	4.1	2.8
	b_2- 50 cm	231.3	3.0	2.6
a_3 -$N_{80}P_{80}K_{80}$	b_1-40 cm	250.3	3.9	2.8
	b_2- 50 cm	271.3	2.5	3.6
a_4 -$N_{120}P_{120}K_{80}$	b_1-40 cm	224.3	1.4	3.0
	b_2- 50 cm	255.2	2.8	3.4
a_5- $N_{160}P_{160}K_{80}$	b_1-40 cm	240.3	3.3	4.5
	b_2- 50 cm	227.3	3.9	5.0

Biometric determinations performed on the waist of Jerusalem artichoke plants show an average plant height with values between 205.2 cm in the unfertilized version which can reach up to 271.3 cm in the fertilized version with a dose of $N_{80}P_{80}K_{80}$ where the distance between plants in a row was 50 cm. Compared to the unfertilized control variant the plant size increased with the increase of fertilizer doses to $N_{120}P_{120}K_{80}$, followed by a decrease of the plant size with the increase of fertilizer doses to $N_{160}P_{160}K_{80}$ (Table 2).

It is observed that depending on the planting density, the height of the plants had higher values in the variants where the distance between plants in a row was 50 cm (Figure1).

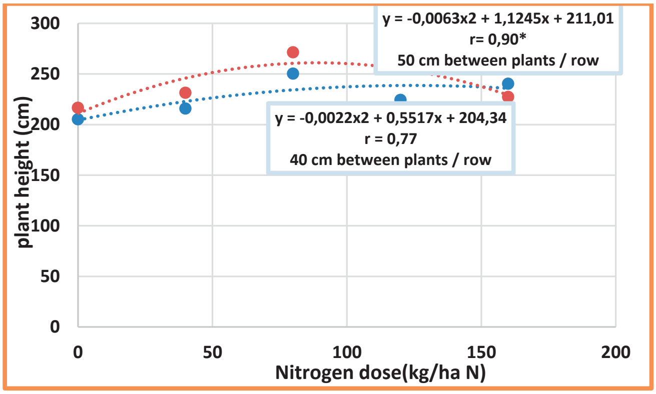

Figure1. The influence of planting density depending on the dose of nitrogen on the size of the plant

Table 3. Biometric determinations of Jerusalem artichoke during the growing season (2018-2020)

Fertilization dose	Planting density	Number of leaves/plant	Leaf area (m^2/ha)	Aboveground biomass weight (stems + leaves)(kg/ha)
a_1- Unfertilized	b_1-40 cm	444	103594.3	34250
	b_2- 50 cm	426	78933	34050
a_2 - $N_{40}P_{40}K_{40}$	b_1-40 cm	470.3	119015.3	42502
	b_2- 50 cm	454.3	96696	36589
a_3 - $N_{80}P_{80}K_{80}$	b_1-40 cm	517.3	115530.7	57487
	b_2- 50 cm	660.3	143960	46166
a_4- $N_{120}P_{120}K_{80}$	b_1-40 cm	486.6	124030	52173
	b_2- 50 cm	649.6	147810.7	54080
a_5 - $N_{160}P_{160}K_{80}$	b_1-40 cm	651.3	163860	64779
	b_2- 50 cm	512.6	105468.7	45881
LSD 5%=			67369	20960
LSD 1%=			95766	29800
LSD 0.1%=			138665	43150

The number of leaves per plant is an important component of biomass. The average results from 2018-2020 show that the average number of leaves per plant increased significantly with increasing fertilization doses, from 426 in the non-fertilized version to 660.3 in the version where the dose of $N_{80}P_{80}K_{80}$ was used (Figure 2) .

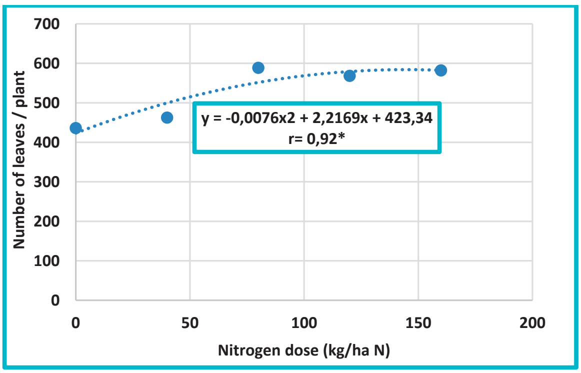

Figure 2. The influence of nitrogen dose on the number of leaves/plant

The leaf surface is a physiological indicator directly related to the amount of light that can be intercepted by plants.
Knowledge of the leaf area is a particular importance. Knowing this parameter we can approximate the primary photosynthetic production. evapotranspiration and can be used as a reference tool for crop growth. having an essential role in the ecology of theoretical production.
The leaf area/ha increased with increasing number of plants/ha by reducing the distance to 40 cm between plants/row leading to the interception of a larger amount of photosynthetically active radiation due to the higher number of plants/ha (Figure 3).

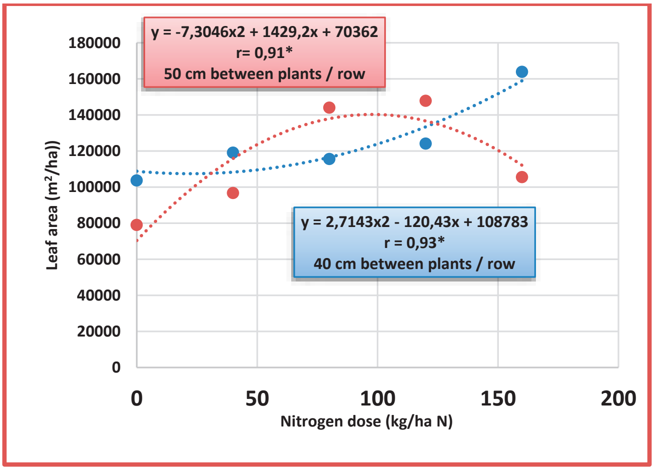

Figure 3. Influence of planting density depending on the dose of nitrogen on the leaf area

Also, the increase of fertilizer doses per unit area led to an increase in the production of stems and leaves. Increasing the amount of biomass obtained. There is a distinctly significant correlation between the leaf area and the amount of biomass obtained given by the polynomial equation of degree 2 (r = 0.99**)(Figure 4).

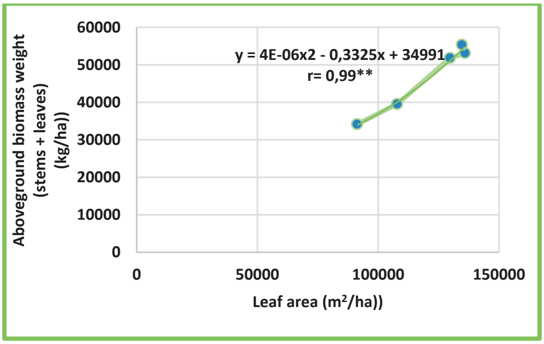

Figure 4. Correlation between leaf area and biomass production depending on nitrogen dose

From our research in the period 2018-2020 it is observed that the highest biomass production of 64779 kg/ha was obtained on the agrofund of$N_{160}P_{160}$ K_{80} and the planting distance of 40 cm between plants in a row. The functional link between the fertilization variant with N_{160} and the density of 40 cm between plants in a row is given by the polynomial function of degree 2 which shows a significant correlation (r = 0.93*) (Figure 5). In order to determine the production of tubers/ha, the number of tubers/plant, the weight of tubers/plant were determined at harvest (Table 6).

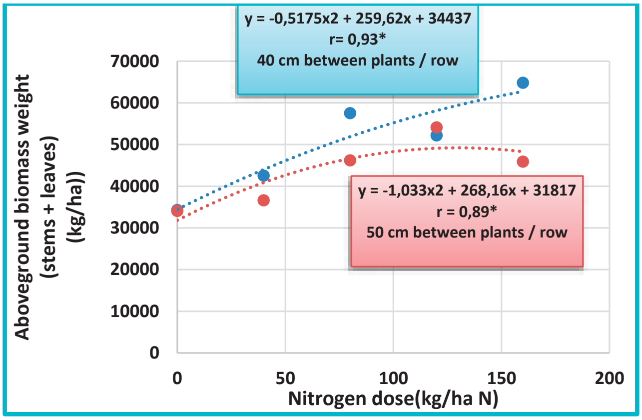

Fig. 5. Influence of planting density and nitrogen dose on aboveground biomass production (stems + leaves)

The average results of 2018-2020 on the influence of nitrogen dose on tuber production/ha show that it increased with increasing nitrogen doses to the dose of N_{120}, a significant increase compared to the unfertilized control variant. Also, there is a significant correlation (r = 0.88*) between the leaf area and the tuber production obtained/ha depending on the applied nitrogen dose (Figure 6).

Table 6. Production of Jerusalem artichoke tubers depending on fertilization and planting density (2018-2020)

Fertilization dose	Planting density	Number of tubers/ plant	Weight of tubers/ plant (kg)	Average production of tubers (kg/ha)
a_1-Unfertilized	b_1-40 cm	50.4	0.658	23036
	b_2- 50 cm	45.5	0.848	23756
a_2 - $N_{40}P_{40}K_{40}$	b_1-40 cm	46.8	0.908	31785
	b_2- 50 cm	43.5	0.913	25570
a_3 - $N_{80}P_{80}K_{80}$	b_1-40 cm	40.4	0.839	29376
	b_2- 50 cm	47.6	1.1	31039
a_4 -$N_{120}P_{120}K_{80}$	b_1-40 cm	38.7	1.19	41671
	b_2- 50 cm	55.7	1.39	39127
a_{5-} $N_{160}P_{160}K_{80}$	b_1-40 cm	37.5	1.08	37807
	b_2- 50 cm	38.0	1.069	29947

LSD 5%=	11200
LSD 1%=	16000
LSD 0.1%=	23200

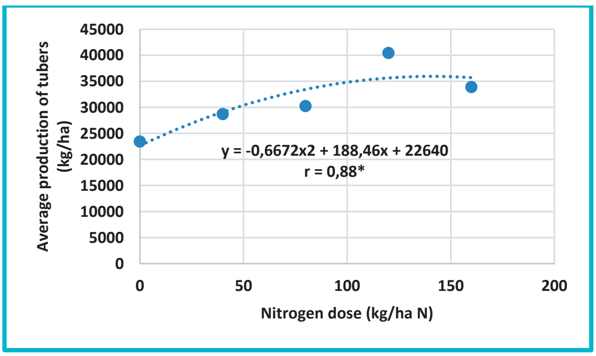

Figure 6. The influence of nitrogen dose on the production of Jerusalem artichoke tubers

Analyzing the interaction between the studied factors (planting density x fertilization doses) on the production of fresh tubers, it is found that the distance of 40 cm between plants/row and the level of fertilization of $N_{120}P_{120}K_{80}$ ensured the highest production of 41671 kg/ha fresh tubers/ha, not statistically insured (Figure 7).

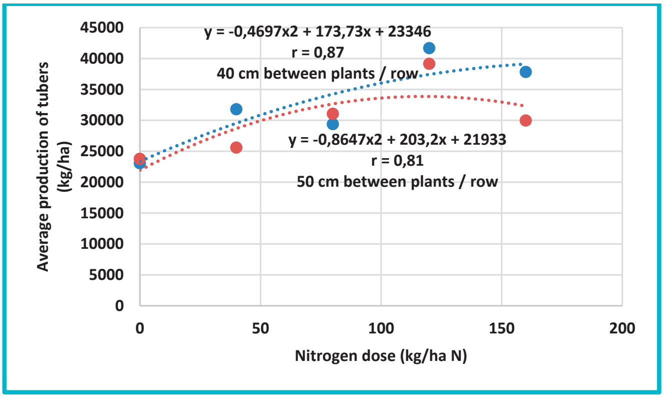

Figure 7. Influence of planting density and nitrogen dose on the production of Jerusalem artichoke tubers

The chemical composition of Jerusalem artichoke tubers depends on the cultivation technology and to a large extent on the nutritional level.The chemical composition of the tubers is also highly dependent on the type of soil, its productivity, the genetic potential of the variety and the growth stage (Meijer & Mathijssen, 1991; Mclaurin et al.,1999; Sawicka & Kalembasa, 2013), which are largely related to harvest maturity (Saengthobpinit & Sajjaanantakul, 2005). Jerusalem artichoke tubers usually contain about 80% water. They can play an important role in human nutrition as sources of protein (1-2%), carbohydrates (15%), vitamins,inulin (up to 20%) and minerals, especially iron (0.4 to 3.7 mg/100 g), calcium (14 to 37 mg/100 g) and potassium (420-657 mg/100 g) (Whitney &Rolfes, 1999).

The results obtained regarding the nutritional quality of Jerusalem artichoke tubers depending on fertilization and planting density are presented in Tables 7 and 8.

Table 7. Biochemical composition of Jerusalem artichoke tubers depending on the fertilization system

Fertilization dose	Total dry matter (%)	Water (%)	Soluble dry matter (%)	Inulin (%)	Carbohydrate content (%)	C vitamin (mg/100 g s.p)	Average tubers production (kg/ha)
a_1-Unfertilized	22.72	77.28	22.16	11.91	18.29	8.37	23396
a_2 - $N_{40}P_{40}K_{40}$	23.25	76.75	21.32	13.10	18.07	8.52	28678
a_3- $N_{80}P_{80}K_{80}$	23.64	76.36	21.22	12.38	17.99	9.12	30208
a_4 - $N_{120}P_{120}K_{80}$	23.28	76.72	20.15	12.78	17.12	8.22	40399
a_5- $N_{160}P_{160}K_{80}$	22.81	77.19	20.68	12.41	17.56	8.51	33878

Depending on the fertilization dose, in the Jerusalem artichoke tubers was determined a total dry matter between 22.72% in the unfertilized version and 23.64% in the version fertilized with $N_{80}P_{80}K_{40}$. The amount of water in the tubers that was between 76.72% and 77.28% decreases with the accumulation of dry matter.

D. De Santis, M. & Teresa Frangipane, 2017,determined in the Jerusalem artichoke tubers a water content of 79.76-81.25%. Sandra Žaldarienė et al., 2012, in a study conducted on a farm in Lithuania determined a dry matter content of 23.21%. and the average weight of the tubers was 26.1g.

Vînatoru C.. 2017, highlights the importance of water from Jerusalem artichoke tubers for the human body. Belgian chemist Aldenne B. C. together with the team of researchers from the U. B. Brussels have shown that the water present in fruits (cellular water) has other properties than that from direct sources:rivers, precipitation. The water present in Jerusalem artichoke tubers is totally different from the usual one. This cellular water synthesized and metabolized by Jerusalem artichoke has the ability to rejuvenate some cells due to its special physical properties. Studies have recently been taken up by cardiologists in the UK. And they say that there is a possibility and they think that the common Jerusalem artichoke has the ability to maintain the heart muscle.

The soluble dry matter was between 20.15% in the fertilized version with the dose of $N_{120}P_{120}K_{80}$ and 22.16% in the unfertilized version. The carbohydrate content was between 17.12% and 18.29% in the same variants.

Kays and Nottingham, 2007, in a Canadian study determined in different groups of varieties a carbohydrate content between 8.2% and 20.7%. The root of this plant stores a polymer of fructose, inulin. Compared to other plants it has been found that the inulin in Jerusalem artichoke has the lowest percentage of glucose and sucrose, thus helping patients with diabetes, helping to normalize blood sugar.

The highest inulin content (13.10%) was determined in the variant fertilized with $N_{40}P_{40}K_{40}$.

The inulin content of artichoke tubers in Jerusalem varies from 7 to 30% of its fresh weight (Kays & Nottingham, 2008; Saengthongpinit, 2005).

The highest values of vitamin C (9.12 mg) were recorded in the version fertilized with $N_{80}P_{80}K_{80}$. Jerusalem artichoke tubers are a source of vitamin C (4.1 mg/100 g) (Scollo et al., 2011). Ermosh et al., 2020, determined in the Jerusalem artichoke tubers an amount of vitamin C between 17 mg and 18.64 mg/100g s.p. Also, Yue Wang et al., 2015 found in Jerusalem artichoke tubers a vitamin C content between 7 and 26 mg/100 g s.p.

Analyzing the influence of fertilizer doses, the best quality results were obtained in the variants fertilized with $N_{40}P_{40}K_{40}$ and $N_{80}P_{80}K_{80}$ (Table 7) and the highest production (40399 kg/ha) was recorded in the variant fertilized with $N_{120}P_{120}K_{80}$.

Regarding the influence of planting density on the production of tubers. as well as on their quality, the results obtained and presented in Table 8, showed an increase in the production of tubers planted at 50 cm between plants in a row compared to the distance of 40 cm by 5962 kg/ Ha. Jerusalem artichoke tubers in this variant recorded a higher content of total dry matter (23.25%), a higher amount of inulin (13.10%), as well as a higher amount of vitamin C (8.52 mg).

Table 8. Biochemical composition of Jerusalem artichoke tubers depending on the distance between plants

Varianta	Total dry matter (%)	Water (%)	Soluble dry matter (%)	Inulin (%)	Carbohydrate content (%)	C vitamin (mg/100 g s.p)	Average tubers production (kg/ha)
b_1 – 40 cm	22.72	77.28	22.16	11.91	18.29	8.37	32735
b_2 - 50 cm	23.25	76.75	21.32	13.10	18.07	8.52	29888

Multiple studies have described the effect of fertilizers on Jerusalem artichoke. For example, lack of phosphorus or potassium alters the morphogenesis, growth and yield of tubers, more pronounced compared to aerial growth. However, the influence of nitrogen on yield is stronger than that of potassium, due to differences in their original soil content; nitrogen determines the photosynthesis potential and somewhat increases the efficiency of water use (Soja and Haunold, 1991). Therefore, drought and fertilizers with nitrogen.

phosphorus and potassium can strongly affect the weight of dry matter (Monti et al., 2005). At harvest tuber production can reach up to 62 t/ha (Zhong et al., 2007).

CONCLUSIONS

Jerusalem artichoke is a species that has performed well in cultivation on sandy soils in climatic conditions from 2018-2020.

From the research carried out in 2018-2020 it is observed that the highest biomass production of 64779 kg/ha was obtained on the agrofund of $N_{160}P_{160}$ K_{80} and the planting distance of 40 cm between plants in a row.

Analyzing the interaction between the studied factors (planting density x fertilization doses) on the production of fresh tubers. it is found that the distance of 40 cm between plants/row and the level of fertilization of $N_{120}P_{120}K_{80}$ ensured the highest production of 41671 kg/ha fresh tubers / ha. not statistically insured.

The results obtained on the nutritional quality of Jerusalem artichoke tubers highlight the low requirements of the species for fertilizers.

The studied biochemical components showed a higher content at low doses of fertilizers as well as in the unfertilized version.

The planting density of the tubers did not significantly influence the quality of the Jerusalem artichoke tubers.

Jerusalem artichoke, due to the low requirements for environmental factors,but also for technological ones, can be part of the category of food safety species.

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