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THE MANAGEMENT OF APPLIED FERTILIZERS AND NUTRITIONAL SPACE ON THE YIELD'S CAPACITY ON JERUSALEM ARTICHOKE

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ABSTRACT

The literature is relatively poor in data on the fertilization of Jerusalem artichoke and especially the optimization of this technological stage which is not always correlated with the nutritional space of plants in order to obtain higher amount of fresh biomass or tubers.

Although Jerusalem artichoke is promoted as a crop with low requirements for soil fertility, it reacts very well to both types of mineral fertilization and especially on applied organic fertilizer.

In this paper we highlight the main levels of mineral fertilization corelated with plant's density which show us that in the tested conditions of argic chernozem from ARDS Caracal we obtained the most valuable yields of fresh biomass at variant where we applied $N_{120}P_{120}K_{80}$ in the conditions of 50 cm between plants/row. The highest level of fresh biomass was 55.1 t/ha and the underground tubers production was almost 28 t/ha.

INTRODUCTION

Helianthus tuberosus L. belongs to the type Helianthus, which belongs to the family Asteraceae, order Asterales, genomic formula 2n = 102. There are 10 species of Helianthus type, but due to the large number of natural hybrids, some authors have classified more than 70 species.

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. 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 background of $N_{160}P_{160}K_{80}$ and the planting distance of 40 cm between plants in a row. (Dima Milica et. Al., 2021).

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 (MateiGh., et. al, 2020). Liava, Vasiliki et al., 2021, in a study focused on the effects of the main cultivation practices (e.g., the planting density and pattern, weed management, fertilization, irrigation, genotypes and harvest) on tuber yield and quality conclude that the Jerusalem artichoke yield and quality depend on several factors, and this plant, due to its high productivity, constitutes a promising crop with multiple uses.

Numerous other researchesplaces Jerusalem artichokes in the *sphere of environmental protection*. Studies about Carbon sequestration in Jerusalem artichoke biomass under nitrogen applications were conducted by Li Niu et al., 2016. Carbon sequestration in Jerusalem artichoke was higher in treatments with nitrogen fertilization compared to the CK treatment. Soil carbon content was higher in the 0-10 cm than 10-20 cm layer, with nitrogen fertilization increasing carbon content in both soil layers. Carbon sequestration in both soil and Jerusalem artichoke residue was increased by nitrogen fertilization depending on the rates in the area studied.

Also, two varieties of Jerusalem artichoke weretested to assess the effectiveness of phytoextraction of heavy metals from sewage sludge (Antonkiewicz, Jacek et al., 2018).

The highest heavy metal uptake with the yield of the Jerusalem artichoke varieties was observed at a dose of 60 Mg DM.ha(-1). Among the tested varieties of Jerusalem artichoke, Albik had higher yield, higher content and uptake of heavy metals, and greater recovery of these elements as compared to Rubik. Therefore, based on the obtained research results, Albik can be recommended for phytosequestration of heavy metals from sewage sludge amended soil.

Taking in account all those possibilities of Jerusalem artichoke to be validified we start a study in order to improve the crop technology.

MATERIAL AND METHOD

The experiment was carried out at Agricultural Research and Development Station Caracal (ARDS), during the 2020 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.

RESULTS AND DISCUSSIONS

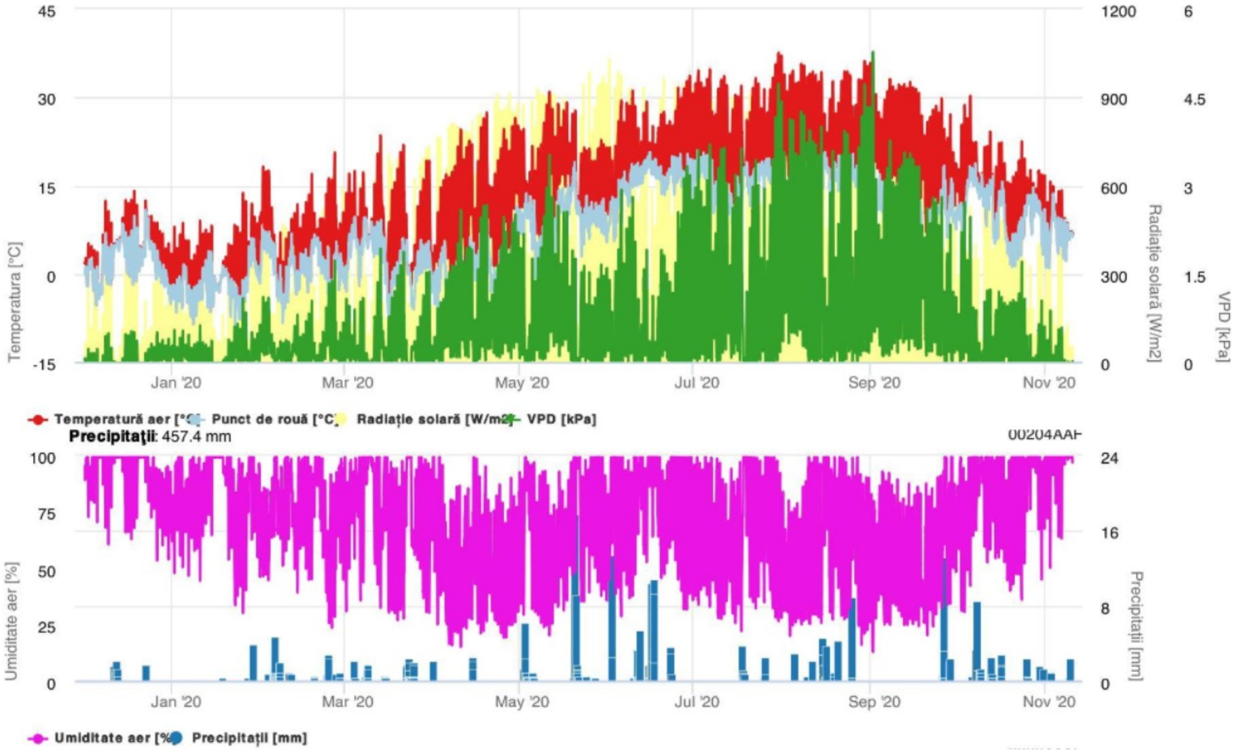
Climatic conditions of the experiment were presented in the figure 1. Regarding the temperature, the collected data in the Meteorological station from experimental field certifies that the agricultural year 2019 - 2020 was an excessively hot year that continued the period with high thermal values from the previous year. Compared to the normal regime, an average temperature of 12.7^{o}C was achieved, with + 2.7^{o}C higher than the normal regime, which is 10.6^{o}C.

Regarding the months of the cold period of this agricultural year (October 2019 - March 2020), it is found that all the months were much warmer than average regime for the area, highlighting especially the months of November and February, with a thermal surplus of +5.0^{o}Crespectively +6.2^{o}C. January, which is the coldest month of the cold season, was very warm this year, exceeding the monthly average by +3.8^{o}C. October, December and March also recorded higher values compared to the multiannual average between 2.3 - 3.7^{o}C.

Regarding the thermal regime of the months during the warm period of the year (April – September2020) we find that in the interval of months of April-August there were no lower temperatures than the multiannual average. The deviations was positive, ranging from +0.2 to 3.5^{o}C.

The rainfall regime in this agricultural year, between October and September, totaled 529.0 mm, being with 8.4 mm lower than the multiannual average, which is 537.4 mm. In these conditions where the level of precipitation was lower, the important element to be taken into account was the non-uniformity of their distribution during the vegetation period of Jerusalem artichoke.

During the cold period of the year, the months of October, December and January were marked as dry, when there was a deficit of precipitation of 19.6 mm, 14.0 mm and respectively 24.9 mm in comparison with the multiannual regime. The month with a high rainfall regime during this period was November, which exceeded the multiannual amount by 62.1 mm.



Year 2020	Air temperature [°C]			Solar radiation [W/m2]	VPD [kPa]		Air humidity [%]			Precipitations [mm]	Wind speed [m/s]		Maximum wind speed	Daily ETO
Month	average	max	min	average	average	min	average	max	min	sum	average	max	[m/s] max	(ET0) [mm]
January	0,82	14,17	-8,65	55	0,13	0	83,45	99,28	29,16	8,4	1,3	7	12	21,6
February	5,58	20,97	-6,2	89	0,26	0	76,5	99,26	21,69	47,4	2,2	11,4	20,7	42,5
March	7,46	23,84	-6,36	124	0,34	0	75,43	99,28	24,85	49,4	1,7	6,9	13	54,2
April	11,92	28,35	-3,58	210	0,84	0	52,94	99,26	12,84	12,8	1,5	7,3	13,2	102,1
May	16,81	31,71	5,02	215	0,78	0	67,28	99,24	18,04	61,6	1,7	7,5	14,6	121,2
June	20,77	35,73	4,86	217	0,73	0	76,96	99,28	23,47	108	1	4,5	10,2	117,1
July	23,74	37,98	11,26	233	1,29	0,01	65,6	99,26	20,53	22,6	0,8	5,1	11,7	138
August	24,72	36,97	12,32	220	1,55	0,01	60,31	99,25	14,01	44,8	0,8	5,7	10,1	129,4
September	21,17	37,1	6,63	173	1,34	0	56,44	99,26	11,78	25,4	1	6,7	15,9	95,4
Octomber	13,9	31,22	1,3	95	0,34	0	83,63	99,29	28,53	46,2	1	6,4	11,8	43,8
November	7,92	15,96	0,67	47	0,07	0	94,77	99,29	48,47	5,4	0,6	2,6	5,1	6,2
Artichoke Mar - Oct 2020	17,56		-6,36							370,8 mm				801,2

Figure 1 – Climatic condition of the agricultural year of 2020 registered at ARDS Caracal

During the warm period of the year, the months of April, July, August and September are highlighted as very poor in precipitation, when the deficit was situated between 5.9 mm and 30.8 mm. Also in June, when the rainfall exceeded the multiannual average by 41.0 mm, but the water that fell from the rainfall was inefficiently used by plants due to high temperatures, associated with heat and monthly evapotranspiration(ETO) of 117.1 mm.

In conclusion, during the vegetation period of the Jerusalem artichoke, the months of March - October, the total of 370.8 mm precipitations, was below the average value of the area, and the element that had a significant influence in the registration of the biomass and tubers productions was uneven distribution of those, with the highest distribution in the first and middle part of the vegetation (June), a period associated with high temperatures, followed by periods of water and heat stress (July and August) when the need for water increases and evapotranspiration exceeds 130 mm.

The biometrical results obtained at SCDA Caracal, during the year 2020, **related the height of the Jerusalem artichoke plants** (*table 1*), showed us that plant's height had different values on the tested density, between 192.2 cm at unfertilized variant on the 40 cm between plants/row and 239 cm at the highest level of fertilization, of $N_{120}P_{120}K_{80}$, on the same density where we recorded an average of 205.2 cm for the plants.

Table 1

The influence of fertilization and distance between plant/row on development of Jerusalem artichoke in 2020

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	192.2	198.1	Av.: 11.7	Av.: 7.1	**45.1**
	$N_{40}P_{40}K_{40}$	193.6				
	$N_{80}P_{80}K_{80}$	195.0		Min: 6.4	Min: 4.1	
	$N_{120}P_{120}K_{80}$	205.2		Max: 18.1	Max: 10.2	
	$N_{160}P_{160}K_{80}$	204.3				
50 cm	Unfertilized	193.5	201.7	Av.: 12.8	Av.: 8.1	**49.0**
	$N_{40}P_{40}K_{40}$	195.1				
	$N_{80}P_{80}K_{80}$	205.0		Min: 7.2	Min: 4.2	
	$N_{120}P_{120}K_{80}$	208.6		Max: 19.5	Max: 11.5	
	$N_{160}P_{160}K_{80}$	206.5				
Av./experiment		**199.9**				

When the plants had a larger nutritional space - the second density with 50 cm between plants/row –conducted 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 193.5 cm on the unfertilized variant and reaching 208.6 cm for the levels of $N_{120}P_{120}K_{80}$. The average height of plants recorded for this density was almost 200 cm.

Beside stalks, the leaves contribute to the above ground fresh biomass and those leaves 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 yields recorded clearly show that both tested factors had a powerful influence to the dimensions of the leaves, with limits which ranges between 6.4 cm to 18.1 cm for length on the first density, and an average of 11.1 cm. Related the wide of leaves, the determinate dimensions range between 4.1 cm to 10.2 cm, with an average of 7.1 cm.

The second density tested, on 50 cm between plants/row, due the higher space between plants, the dimensions of leaves were higher than the previous density, with limits for the climatic features of 2020 year from 7.2 cm to 19.5 cm and an average of 12.8 cm for length and 4.2 cm to 11.5 cm, with 8.1 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 45.1 smaller than the second one, of 50 cm between plants/row, where we obtained a mean of 49 ramifications.

Swanton, C.J. (1986) cited by Zu Xin et al., (2015), confirm that Jerusalem artichoke produces a very large amount of green biomass and tubers.

The fresh biomass production obtained under theinfluence of A factor - density of plants - the results presented in table 2 show that the more developed plants lead to the high fresh biomass production. That is obvious in the conditions of the 50 cm between plants/row where we observe a fresh biomass production of 46.0 t/ha, with an increase in production of 6.2% related to Control – the average of densities.

Table 2

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

A Factor Distance between plants/row	Fresh biomass		Difference t/ha	Signification
	t/ha	%		
40 cm	40.7	94.0	-2.6	OO
50 cm	46.0	106.2	2.6	**
Average	**43.3**	**100.0**	**Control**	**Control**

LSD 5%=1.3 t/ha; LSD 1%=2.5t/ha; LSD 0,1%=7.2t/ha

Under the applied different fertilizer's dose (B factor), Jerusalem artichoke gave a very good response in comparison with the variants used as Control (unfertilized variant) and the results obtained show that this species has a very high potential to generate fresh biomass (*table 3*).

Table 3

Influence of the B factor – fertilization - on the Jerusalem artichoke fresh biomass yields

B Factor Fertilization	Fresh biomass		Difference t/ha	Signification
	t/ha	%		
Unfertilized	35.0	80.8	-8.34	OOO
$N_{40}P_{40}K_{40}$	39.7	91.6	-3.64	OO
$N_{80}P_{80}K_{80}$	43.4	100.1	0.06	-
$N_{120}P_{120}K_{80}$	51.6	119.1	8.26	***
$N_{160}P_{160}K_{80}$	47.0	108.4	3.66	**
Average	**43.3**	**100.0**	**Control**	**Control**

LDS 5%=1.2 t/ha; LSD 1%=2.9t/ha; LSD 0,1%=5.7t/ha

Even under the conditions of which the precipitations were unevenly distributed the Jerusalem artichoke gave a very powerful reaction to the mineral fertilization and starting to the low level of applied fertilizers register a trend of increasing their quantity of fresh biomass.The values of yields grown from 35.0 t/ha on the unfertilized variant to the one with $N_{120}P_{120}K_{80}$ which reach the highest level of this experiment.

Increasing the level of fertilizers at $N_{160}P_{160}K_{80}$ we observe a decrease of fresh biomass production due the lack of precipitation and a high termohydric stress create to the Jerusalem artichoke plants.

The main Control - average/experiment from the second factor - level of applied fertilizers - was 43.3 t/ha fresh biomass, determinate in flowering stage of development of Jerusalem artichoke plants and related to that value only two above mentioned variants had statistical increases in production: very significant for $N_{120}P_{120}K_{80}$ variant and distinct significant for $N_{160}P_{160}K_{80}$.

The combined influence of the two factors - density and fertilizers levelon the production capacity of Jerusalem artichoke crop was one very well quantified in the values of the fresh biomass recorded (*table 4*). The average of the entire experiment was 43.3 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 range between 32.9 t/ha on the unfertilized variant to 48.1 t/ha fresh biomass recorded at variant with $N_{120}P_{120}K_{80}$, with a significative difference of 11.0 % related to Control. Also, positive differences in comparison with the Control were observed on variant of $N_{160}P_{160}K_{80}$ and with plus productions of 2.1 t/ha, but unsignificant from statistically point of view.

Table 4

The influence of interaction of density (A) and fertilization (B) on Jerusalem artichoke fresh biomass yield in 2020

A Factor	B Factor	Fresh biomass yield		Differences	Signification
Distance between plants/row	**Fertilization**	**t/ha**	**%**	**t/ha**	
40 cm	Unfertilized	32.9	75.9	-10.4	OOO
	$N_{40}P_{40}K_{40}$	37.5	86.6	-5.8	OO
	$N_{80}P_{80}K_{80}$	39.6	91.3	-3.8	O
	$N_{120}P_{120}K_{80}$	48.1	111.0	4.8	*
	$N_{160}P_{160}K_{80}$	45.4	104.7	2.1	-
Average		*40.7*			
50 cm	Unfertilized	37.1	85.6	-6.2	OO
	$N_{40}P_{40}K_{40}$	41.8	96.5	-1.5	-
	$N_{80}P_{80}K_{80}$	47.3	109.1	4.0	*
	$N_{120}P_{120}K_{80}$	55.1	127.1	11.8	***
	$N_{160}P_{160}K_{80}$	48.6	112.1	5.3	**
Average		*46.0*			
Average/experiment		***43.3***	***100.0***	***CONTROL***	***CONTROL***
LSD 5%		2.7			
LSD 1%		4.8			
LSD 0.1 %		7.1			

On the density 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 fresh biomass yields varied between 37.1 t/ha to 55.1 t/ha. 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 +4.0 t/ha on the $N_{80}P_{80}K_{80}$ variant, +11.8 t/ha on the $N_{120}P_{120}K_{80}$ variant and + 5.3 t/ha fresh biomass for highest level of fertilizers of $N_{160}P_{160}K_{80}$.

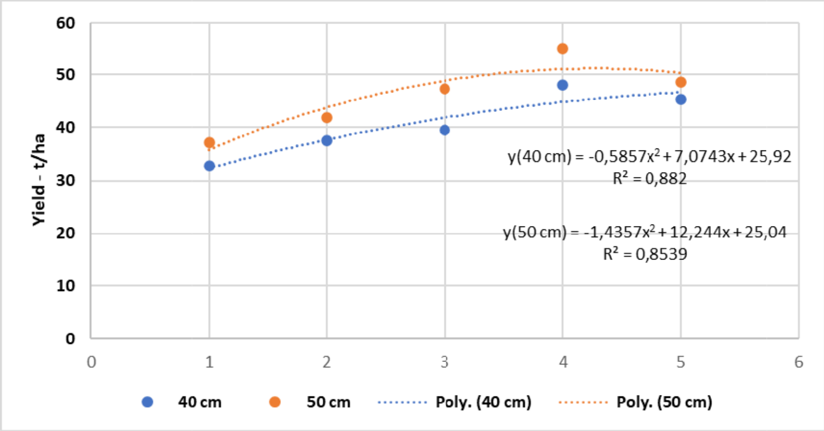


Figure 2 - Trend line of the Polynomial equation, second degree, regarded the influenceof the A x B factors on the Jerusalem artichoke biomass yields

In literature we found several studies which have been conducted to determine the effects nutritional space on fresh biomass and tuber yield at Jerusalem artichokebut the results are contradictory, some genotypes reacted better to a higher density / ha, and others to a higher nutritional space (Ciuciuc et al., 2019; Matei et al., 2018, 2020).

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 2)* 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.

Other researches 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 our experiment the evolution of the tuber's yields recorded was as follow in the next paragraphs.

The tuber yields had a similar evolution as the fresh biomass production registered under the influence of the two tested factors: distance of plants/row and level of applied fertilizers.

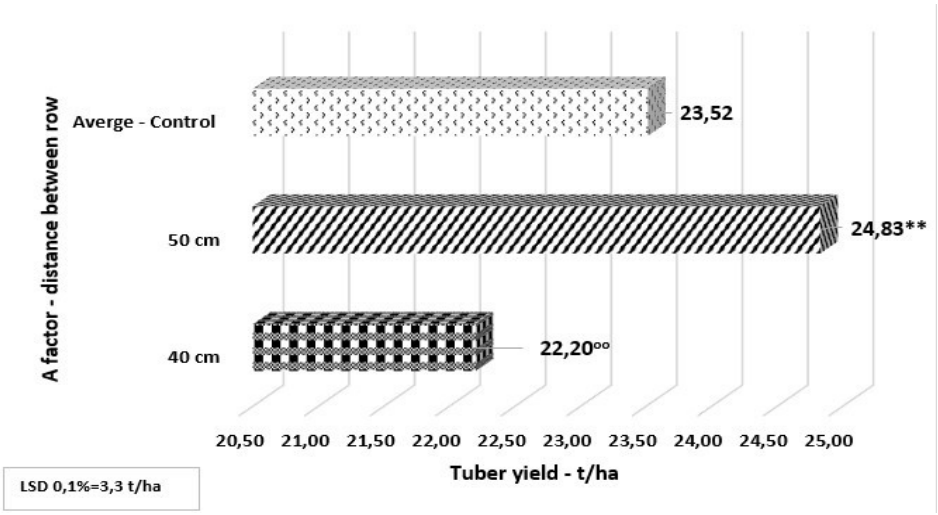


Figure 3 – Influence of the A factor – distance of plants/row - on the Jerusalem artichoke tuber yields

The most valuable distance between plant/row (*figure 3*) proves to be that with 50 cm, where the tuber yield reach 24.83 t/ha, with a difference related to the control statistically ensured as distinct significant.

Jerusalem artichoke is able to accumulate a large amount of fresh biomass and tubers, for which large amounts of nutrients are needed. However, the crop has a good efficiency in the use of nutrients, as shown by Raso E, (1990), which recorded the highest yield of tubers (34 t · ha-1) on fertile sandy soil with 50 kg · ha- 1 N, while the application of a larger amount of N (100, 150, 200 kg · ha-1) led to a slight decrease in yield. Fertilization with K (100, 200 kg · ha-1) had no influence on yield and no N × K interaction was observed.

From the point of view of **reaction to the mineral fertilizers** (figure 4), the tuber yields had fluctuated a lot, since 20.8 t/ha recorded at unfertilized variant to the highest value, of 26.5 t/ha, noted on the $N_{120}P_{120}K_{80}$ variant. Significant differences were observed at the last two variant of $N_{120}P_{120}K_{80}$, and $N_{160}P_{160}K_{80}$ with increases of 3.0 t/ha and respectively 1.9 t/ha.

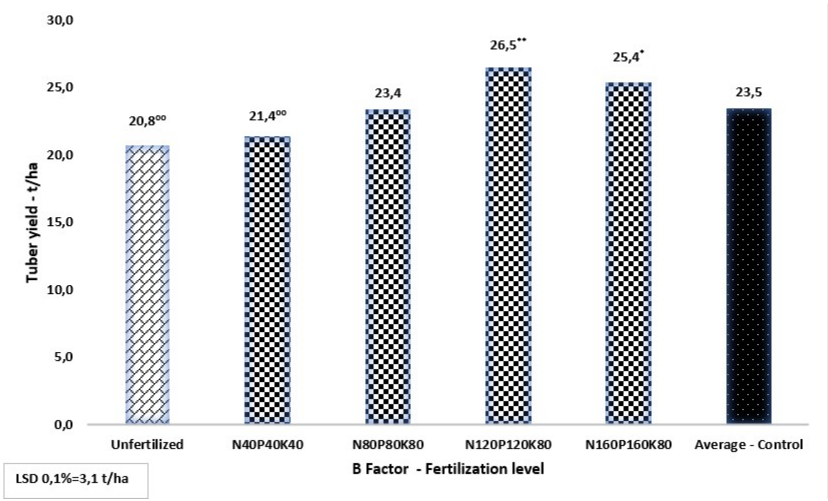


Figure 4 – Influence of the B factor – fertilization - on the Jerusalem artichoke tuber yields

However, the most obvious variations in tuber production were recorded in the combined influence of the experimented factors (table 5). On the first tested of nutritional space the tuber yields range from 19.0 t/ha at unfertilized variant to 25.16 t/ha, a value recorded on the $N_{120}P_{120}K_{80}$ variant.

Table 5

The influence of interaction of density (A) and fertilization (B) on Jerusalem artichoke tuber yield in 2020

A Factor	B Factor	Tuber yield		Differences	Signification
Distance between plants/row	Fertilization	t/ha	%	t/ha	
40 cm	Unfertilized	19.00	80.8	-4.53	OOO
	$N_{40}P_{40}K_{40}$	20.18	85.8	-3.35	OO
	$N_{80}P_{80}K_{80}$	23.07	98.0	-0.46	-
	$N_{120}P_{120}K_{80}$	25.16	106.9	1.63	*
	$N_{160}P_{160}K_{80}$	23.64	100.5	0.11	-
Average		*22.20*			
50 cm	Unfertilized	22.71	96.5	-0.82	-
	$N_{40}P_{40}K_{40}$	22.62	96.2	-0.91	-
	$N_{80}P_{80}K_{80}$	23.80	101.2	0.27	-

	$N_{120}P_{120}K_{80}$	27.83	118.3	4.30	***
	$N_{160}P_{160}K_{80}$	27.27	115.9	3.74	**
Average		*24.83*			
Average/experiment		***23.52***	***100.0***	***CONTROL***	***CONTROL***

LSD 5%=1.2 t/ha; LSD 1%=2.6 t/ha; LSD 0.1 %=4.2 t/ha

The same mentioned variant proves to be most valuable on the second distance tested and the yield recorded in this case was of 27.83 t/ha tubers. Taking in account the positive differences related to the Control – the average/experiment of 23.52 t/ha, on the 40 cm between plant/row were noted only last two variants wit increases and on the second nutritional space of 50 cm between plants/row the positive differences range from 0.27 t/ha to 4.30 t/ha tubers.

CONCLUSIONS

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

- The climatic conditions of 2020 year lead allowed to the Jerusalem artichoke plants to have a good development and capitalize the mineral fertilizers applied 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 branches/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;
- Under the conditions of the influence of both tested factors, the recorded yield of fresh biomass and tubers reach good values for fresh biomass and moderate values for tubers, levels 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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