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Impact of Harvesting the Aerial Part of Jerusalem Artichoke (*Helianthus tuberosus* L.) as Forage on Tuber Yield

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ABSTRACT

This study aimed to determine the effect of cutting the aerial part of Jerusalem artichoke at different growth stages, as forage, on tuber yield. Tubers were planted in a randomized complete block design in 16 plots with dimensions of 3 m × 4 m (4 plots in 4 blocks). Treatments with different dates of the harvest of the aerial part were: 1) first cut at stem elongation stage, BBCH-39 and second cut at inflorescence emergence stage, BBCH-59 (66 and 138 days after planting, respectively), 2) first and second cuts at stem elongation stage, BBCH-39 (100 and 173 days after planting, respectively), 3) one cut at inflorescence emergence stage, BBCH-59 (132 days after planting) with no regrowth of the aerial part, and 4) no aerial part cut. Tubers were harvested with approaching the cold season when the aerial part stopped growing. Treatment 1 and 2 resulted in lower total fresh and dry matter yield than treatment 3. The amount of water-soluble carbohydrates and crude protein in second cuts were numerically higher and fiber fractions lower than the first cuts. The highest fresh and dry tuber yield in treatment 4 was 63.3 and 14.8 t/ha, respectively, which was significantly higher than the mean of fresh (25.4-29.5 t/ha) and dry (4.6-6.1 t/ha) tuber yield in the other treatments. An increase in tuber organic matter was observed in treatment 4 with a significant increase in soluble carbohydrate contents. The results showed that an extra cut of the aerial part of Jerusalem artichoke during the vegetative stage did not increase the aboveground biomass yield compared to the treatment in which the only harvest was made just before the flowering stage. Yield of tubers was also negatively affected by regrowth of the aerial part.

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1. Introduction

Jerusalem artichoke (*Helianthus tuberosus* L.; also known as sunchoke) is a perennial plant belonging to the *Asteraceae* family. It has resistance to most pests and diseases, tolerance to drought and salt stresses, and can be grown with minimal fertilization and irrigation (Rossini *et al*, 2019). Jerusalem artichoke has many advantages over traditional crops (e.g., maize and wheat), including high ecological adaptability, rapid growth, large biomass, low management cost, and high energy conversion efficiency making it suitable for cultivation on marginal land without reducing food security (Kou *et al.*, 2014). Another important feature of this plant is producing two products: tubers and green fodder.

The yield of the tuber has been reported up to 75 t/ha which consists of 75 to 79% water, 2-3% protein, and 15-16% carbohydrate (Long *et al.*, 2016; Diederichsen, 2010). It is an excellent biomass crop resource for renewable bioenergy production, such as bioethanol, methane from anaerobic digestion, and biogas from pyrolysis (Panchev *et al*., 2011; Gunnarsson *et al.*, 2014).

The aboveground parts of the plant can grow up to 3 m tall (Kays and Nottingham, 2007). A fresh biomass yield of over 100 t/ha per year has been reported (Stauffer *et al.*, 1980). Although its fiber and lignin content are higher than those of corn, it is still palatable to ruminants and can be used as a source of coarse feed or silage production and even biogas production in

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industrial (Ciccoli *et al*., 2018; Papi *et al*., 2017; Papi *et al*., 2019).

These two products (tuber and forage) of Jerusalem artichoke are not independent, as damage to one organ can affect the growth and development of plants (Gao *et al*., 2019). To the best of our knowledge, no study is available comparing the yield and chemical composition of tuber and forage (leaf, stem and total) when the aerial part is cut at different growth stage. Therefore, the present study aimed to investigate the effect of harvesting the aerial part of the Jerusalem artichoke plant in one or two cuts during growth stages on tuber and forage yield.

2. Materials and methods

The experiment was set up in mid-April 2020 at the Razi University Agricultural Research Station in Kermanshah (34°21′ N, 45°9′ E). On 27 April, Jerusalem artichoke tubers with 2-3 buds planted by hand in sixteen 3m × 4m plots arranged in 4 blocks (4 plots/block) at a depth of 7-10 cm. Plant spacing was 0.5 m between rows and 0.25 m within rows, giving a density of 80,000 plants per hectare. Weeds were removed manually, and no pesticides were used. On 11 June and 3 July, foliar application NPK (20: 20: 20) was completed according to the company recommendation. All temperature and precipitation data (Table 1) were accumulated based on measurements conducted at Kermanshah meteorological organization.

Table 1. Climate conditions during the growth stages of Jerusalem artichoke[1].

Month	Mean monthly temperature (°C)	Precipitation (mm)
April	11.5	88.1
May	17.7	38.8
June	25.2	0.0
July	28.8	0.0
August	29.6	0.0
September	26.0	0.0
October	19.1	0.7
November	13.1	44.2
December	6.3	132.0

[1] Kermanshah meteorological organization

To investigate the effect of harvesting the aerial part of the Jerusalem artichoke plant in one or two cuts during growth stages on tuber yield, each block was assigned with 4 plots to 1 of 4 harvest dates as an experimental treatment. Treatments with different dates of the harvest of the aerial part were: 1) first cut at stem elongation stage, BBCH-39 and second cut at inflorescence emergence stage, BBCH-59 (66 and 138 days after planting, respectively), 2) first and second cut at stem elongation stage, BBCH-39 (100 and 173 days after planting, respectively), 3) one cut at inflorescence emergence stage, BBCH-59 (132 days after planting) with no regrowth of the aerial part, and 4) no aerial part cut. Tubers were harvested with approaching the cold season when the aerial part stopped growing. When plants of each plot were harvested from 10 cm above ground, 4 plants were randomly selected to determine the aerial part fractions (leaf and stem). The tubers of 12 and 6 plants from each plot were also examined for biomass determination and chemical analysis, respectively.

Dried whole-plant, leaf, and stem forages and tuber were ground (Willey mill) to pass through a 1-mm sieve for chemical analysis. Organic matter and crude protein were analyzed according to standard procedures detailed by the Association of Official Analytical Chemists (AOAC, 2000). Samples were analyzed sequentially for neutral detergent fiber and acid detergent fiber by the method of Van Soest et al. (1991). Water-soluble carbohydrates were determined using anthrone reaction as described by Dubois et al. (1956).

Data were analyzed using SAS statistical software (version 9.4) through the GLM procedure. Comparison of mean data was performed using Duncan's multiple range test at a probability level of five percent.

3. Results

Climate conditions during the growth stages of Jerusalem artichoke are presented in Table 1. The yield of the aerial part of the Jerusalem artichoke plant from each cut and total fresh and dry yield are shown in Table 2 and Fig. 1, respectively. In the first and second cut, the aerial part yield increased with plant growth. A significant increase in the total fresh and dry yield of the aerial part was observed in treatment 3 compared to the other treatments. Total fresh biomass produced from treatments 1, 2, and 3 were 74.2, 77.6, and 92.8 t/ha, respectively. The corresponding values for dry matter production were 17.1, 18.6, and 28.0 t/ha, respectively. Reduction of leaf to stem ratio (on DM basis) was observed with increasing plant age.

A significant increase in water-soluble carbohydrates of the aerial part was associated with a significant increase in water-soluble carbohydrates content of stem (P<0.01; Table 3). The crude protein content showed a significant decrease with increasing plant age and being higher in the leaf (P<0.01). Therefore, the highest organic matter and soluble carbohydrates and lowest crude protein contents of the aerial part in the first harvest observed in treatment 3, were 890.3, 223.4, and 96.3 g/kg DM, respectively. Neutral detergent fiber and acid detergent fiber were also 410.3 and 346.1 g/kg DM, respectively. In the second cut, the amount of neutral detergent fiber and water-soluble carbohydrates at different growth stages were in the range of 303.3-362.4 g/kg DM and 188.6-246.8 g/kg DM, respectively. The amount of water-soluble carbohydrates and crude protein in second cuts were numerically more and fiber fractions lower elevated than the first cuts.

Table 2. The yield of the aerial part of Jerusalem artichoke harvested from the first and second cut.

Harvest	Treatments*	Aerial part yield (kg/ha)			Yield percentage (on DM basis)		Leaf to stem ratio (on DM basis)
		Fresh	Dry matter	% DM	Leaf (%)	Stem (%)	
First cut	1	17200^{c}	2680^{c}	15.5^{c}	64.2^{a}	35.8^{c}	1.79^{a}
	2	54060^{b}	12856^{b}	23.7^{b}	49.6^{b}	50.4^{b}	0.98^{b}
	3	92824^{a}	26090^{a}	28.1^{a}	35.3^{c}	64.7^{a}	0.54^{c}
SEM		2746	902	0.77	1.85	1.85	0.08
P-value							
Treatment		<.01	<.01	<.01	<.01	<.01	<.01
Block		0.34	0.53	0.85	0.32	0.32	0.27
Second cut	1	57060^{a}	14460^{a}	25.3	46.1^{b}	53.9^{a}	0.85^{b}
	2	23608^{b}	5803^{b}	24.5	61.7^{a}	38.3^{b}	1.61^{a}
SEM		4130	1179	0.74	0.68	0.68	0.03
P-value							
Treatment		0.01	0.01	0.60	<.01	<.01	<.01
Block		0.85	0.84	0.47	0.22	0.22	0.24

* Treatments: 1) first cut at stem elongation stage, BBCH-39 and second cut at inflorescence emergence stage, BBCH-59 (66 and 138 days after planting, respectively), 2) first and second cut at stem elongation stage, BBCH-39 (100 and 173 days after planting, respectively), and 3) one cut at inflorescence emergence stage, BBCH-59 (132 days after planting) with no regrowth of the aerial part.
Numbers with the same letters for each column for each cut are not significantly different (P<0.05).

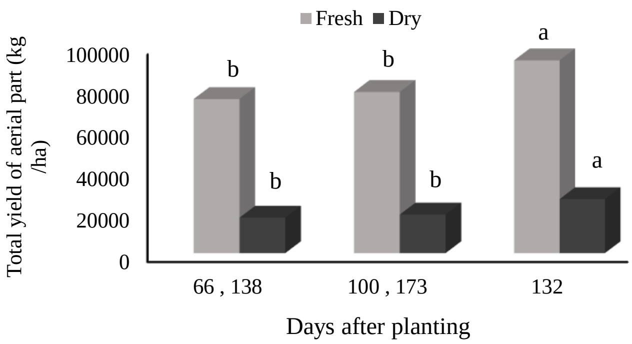

Figure 1. Total yield (kg/ha) of the aerial part of Jerusalem artichoke harvested once or twice at different growth stages (days after planting). The same letters on each bar are not significantly different (P<0.05).

The results related to harvesting the aerial part of the Jerusalem artichoke plant at different growth stages on tuber yield are presented in Table 4. The highest fresh and dry tuber yield in treatment 4 (at death and drying stage) was 63.3 and 14.8 t/ha, respectively, which was significantly higher compared to fresh (25.4-29.5 t/ha) and dry (4.6-6.1 t/ha) tuber yield in the other treatments. The dry matter percentage of tubers ranged from 18.4 to 23.4%, and the lowest dry matter content was observed in treatment 1 (P<0.05).

Table 3. Chemical composition of the aerial part of Jerusalem artichoke harvested from the first and second cut.

Harvest	Treatments*	Neutral detergent fiber (g/kg DM)			Acid detergent fiber (g/kg DM)			Water-soluble carbohydrate (g/kg DM)			Crude protein (g/kg DM)			Organic matter (g/kg DM)		
		Total aerial part	Leaf	Stem	Total aerial part	Leaf	Stem	Total aerial part	Leaf	Stem	Total aerial part	Leaf	Stem	Total aerial part	Leaf	Stem
First cut	1	424.1	374.8	432.0	301.3^{b}	260.8^{b}	306.5^{b}	85.5^{c}	87.2^{b}	98.9^{c}	144.8^{a}	194.6	92.1^{a}	813.9^{c}	811.3	846.7^{c}
	2	420.1	359.8	441.5	329.1^{a}	298.7^{a}	352.5^{a}	176.9^{b}	115.6^{a}	206.2^{b}	113.6^{b}	183.0	80.6^{ab}	846.2^{b}	809.8	879.0^{b}
	3	410.3	379.5	434.2	346.1^{a}	308.0^{a}	361.1^{a}	223.4^{a}	128.6^{a}	267.6^{a}	96.3^{c}	164.5	61.3^{b}	890.9^{a}	796.8	942.5^{a}
SEM		7.2	8.7	6.12	6.8	5.40	6.02	7.5	2.21	9.8	5.2	10.7	4.31	1.3	7.6	3.5
P-value																
Treatment		0.15	0.32	0.55	0.01	<.01	<.01	<.01	<.01	<.01	<.01	0.20	0.06	<.01	0.66	<.01
Block		0.39	0.24	0.79	0.68	0.42	0.61	0.90	0. 01	0.95	0.44	0.76	0.95	0.16	0.39	0.57
Second cut	1	387.3^{a}	362.4	444.6	238.0	181.4^{a}	282.5	246.8^{a}	152.2	312.0	109.3^{b}	175.2	77.4	859.5^{a}	765.4	924.3
	2	339.5^{b}	330.3	403.1	218.8	112.3^{b}	230.7	188.6^{b}	110.8	273.9	160.7^{a}	198.5	86.1	826.3^{b}	771.2	913.2
SEM		3.0	6.1	5.8	2.4	0.7	2.3	1.3	4.2	6.3	2.4	5.8	7.1	1.4	6.8	3.9
P-value																
Treatment		0.02	0.43	0.32	0.13	0.01	0.05	<.01	0.06	0.18	0.04	0.21	0.30	<.01	0.15	0.06
Block		0.99	0.88	0.95	0.16	0.06	0.13	0.03	0.21	0.86	0.19	0.38	0.64	0.26	0.07	0.31

* Treatments: 1) first cut at stem elongation stage, BBCH-39 and second cut at inflorescence emergence stage, BBCH-59 (66 and 138 days after planting, respectively), 2) first and second cut at stem elongation stage, BBCH-39 (100 and 173 days after planting, respectively), and 3) one cut at inflorescence emergence stage, BBCH-59 (132 days after planting) with no regrowth of the aerial part.

Numbers with the same letters for each column for each cut are not significantly different (P<0.05).

Neutral detergent fiber contents of the tuber in different treatments varied from 83 to 115 g/kg DM, and the lowest value was found in treatment 1 (P<0.05; Table 5). However, the acid detergent fiber and hemicellulose contents of tubers were not affected by treatment (P>0.05). Water-soluble carbohydrates and organic matter in tubers from treatment 4 were significantly higher than the other treatments (P<0.01).

Table 4. The effect of the aerial part harvest of Jerusalem artichoke plant on yield of tuber

Treatments*	Tuber yield (kg/ha)		% DM
	Fresh	Dry matter	
1	25430[b]	4688[b]	18.4[b]
2	29549[b]	6174[b]	20.8[ab]
3	27014[b]	5796[b]	21.4[a]
4	63361[a]	14870[a]	23.4[a]
SEM	2558	540	0.79
P-value			
Treatment	<.01	<.01	0.01
Block	0.90	0.35	0.12

*Treatments: 1) first cut at stem elongation stage, BBCH-39 and second cut at inflorescence emergence stage, BBCH-59 (66 and 138 days after planting, respectively), 2) first and second cuts at stem elongation stage, BBCH-39 (100 and 173 days after planting, respectively), 3) one cut at inflorescence emergence stage, BBCH-59 (132 days after planting) with no regrowth of the aerial part, and 4) no aerial part cut.
Numbers with the same letters are not significantly different (P<0.05).

Table 5. The effect of the aerial part harvest of Jerusalem artichoke plant on the chemical composition of tuber

Treatments*	Fiber fractions (g/kg DM)			Water-soluble carbohydrate (g/kg DM)	Organic matter (g/kg DM)
	Neutral detergent fiber	Acid detergent fiber	Hemicellulose		
1	83.3[b]	54.0	29.9	575.9[c]	912.5[c]
2	115.2[a]	68.3	47.0	618.0[b]	927.4[b]
3	92.6[b]	60.7	31.8	622.8[b]	926.7[b]
4	95.8[ab]	57.4	44.6	653.7[a]	948.2[a]
SEM	6.39	5.35	0.96	10.70	3.29
P-value					
Treatment	0.03	0.33	0.39	<.01	<.01
Block	0.31	0.09	0.48	0.86	0.91

* Treatments: 1) first cut at stem elongation stage, BBCH-39 and second cut at inflorescence emergence stage, BBCH-59 (66 and 138 days after planting, respectively), 2) first and second cuts at stem elongation stage, BBCH-39 (100 and 173 days after planting, respectively), 3) one cut at inflorescence emergence stage, BBCH-59 (132 days after planting) with no regrowth of the aerial part, and 4) no aerial part cut.
Numbers with the same letters are not significantly different (P<0.05).

4. Discussion

In the present study, the effect of harvesting the aerial part of the Jerusalem artichoke plant in one or two cuts during growth stages on tuber yield and forage production were investigated. The results showed that cutting the aerial part during the vegetative stage compared to cutting at the inflorescence emergence stage (just before flowering) reduced the total (first and second cut) fresh and dry yield per hectare. Above-ground biomass production in treatment 3 was inconsistent with the results from our previous study in 2018 (unpublished) and studies of Swanton et al. (1992) and Li et al. (2017) with a forage yield of more than 90 tons per hectare. It appears that the first cut has imposed external stress to reduce the regrowth of the aerial part of the plant. This stress reduced the yield of the second cut in treatment 2 further by due to reduction in the temperature in October.

In both cuts, the distribution of dry matter between leaves and stems indicated that more photosynthetic material is allocated to the stem with advancing plant age. This phenomenon has been attributed to the more strength needed with increasing the plant height. Thus, in the early stages of growth, when the amounts of dry matter are lower, a larger share is assigned to the leaf (Kays and Nottingham, 2007).

The chemical composition of the plant varies due to the high transport of nutrients such as proteins, carbohydrates, and minerals during the growth period and with maturity between different parts (Gunnarsson *et al.,* 2014). These changes during the growth period are affected by various environmental factors such as temperature, light, and other factors such as the frequency and time of irrigation and fertilization (Rossini *et al.,* 2019). The increase in organic matter with increasing plant age in the present study was due to increased stem yield along with an increase in its organic matter. This indicates the transfer and storage of more photosynthetic organic matter from the leaf to the stem. Similar to the results of the present study, Malmberg and Theander (1986) reported higher amounts of ash in the leaves than in the stem of the Jerusalem artichoke plant.

Different results have been reported regarding the changes in the fiber fractions of the aerial part of the Jerusalem artichoke plant during the growing season (Hay and Offer, 1992; Gunnarsson *et al.,* 2014). However, these differences are due to the transfer of nutrients between different plant parts and their conversion to other substances during the growing season (Gao *et al.,* 2020).

In the second cut, the reduction of fiber fractions and the increase of water-soluble carbohydrates compared to the first cut, especially in the first treatment, were associated with a higher proportion of leaf dry matter. An increase in leaf biomass can lead to an increase in photosynthesis and eventually leads to more carbohydrates being produced for distribution to all organs (Krober *et al.,* 2015).

Cutting of the aerial part of the plant not only did not show any advantages for tuber yield but also, regardless of the time of cutting, reduced tuber yield. After the beginning of tubers formation, which occurs from 11 to 17 weeks after emergence, redistribution of dry matter from the aerial part to and accumulation in tubers is a continuous process up to 20 to 25 weeks after emergence, during which dry matter accumulation slows down (Mclaurin *et al.,* 1999). In other words, nutrients are initially stored in the aerial part and later reallocated into the tubers (Wang *et al.,* 2020). Therefore, it could be expected that harvesting the above-ground organs have some negative effect on the accumulation of dry matter in tuber and tuber yield. However, results of tuber yield from the present study are in contrast with those of Gao et al. (2020), who found cutting of the aerial part of Jerusalem artichoke before flowering resulted in comparable tuber yield with not cutting. Similar tuber production, 14 t/ha dry matter, has also been reported by Kays and Nottingham (2007) and Denoroy (1996) when the aerial part cut.

The chemical composition of Jerusalem artichoke tubers is affected by planting and harvesting time, fertilization, and other environmental factors. Tubers contain about 80% water, 15% carbohydrates, and 1-2% protein (Li *et al.,* 2017). The amount of moisture in the tuber depends on the amount of soil moisture and its absorption by the tuber. It has been reported that Jerusalem artichoke tuber ash is about 4% of its dry weight. However, the ash of the aerial part is two to three times as much as the ash of the tuber (Gunnarsson *et al.,* 2014). The results of the present study showed a higher concentration of organic matter and soluble carbohydrates in the tubers harvested from treatment 4, in which no aerial part was cut. Most of the tuber organic matter and soluble carbohydrates in tubers are affected by the transfer of nutrients and soluble carbohydrates from the aerial part to fill the tuber (Slimestad *et al.,* 2010).

5. Conclusion

The results showed that an extra cut of the aerial part of Jerusalem artichoke during the vegetative stage did not increase the aboveground biomass yield compared to the treatment in which the only harvest was made just before the flowering stage. Yield of tubers was also negatively affected by the cutting and regrowth of the aerial part.

Conflict of Interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

All authors had an equal role in study design, work, statistical analysis and manuscript writing.

Informed Consent

The authors declare not to use any patients in this research.

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References

AOAC. 2000. Official methods of analysis, 15th Edition. Association of Official Analytical Chemists, Washington, DC, USA.

Ciccoli R., Sperandei M., Petrazzuolo F., Broglia M., Chiarini L., Correnti A., Tabacchioni S. 2018. Anaerobic digestion of the above ground biomass of Jerusalem Artichoke in a pilot plant: Impact of the preservation method on the biogas yield and microbial community. Biomass and Bioenergy 108: 190-197. https://doi.org/10.1016/j.biombioe.2017.11.003

Denoroy P. 1996. The crop physiology of *Helianthus tuberosus* L.: a model oriented view. Biomass and bioenergy 11(1):11-32. https://doi.org/10.1016/0961-9534(96)00006-2

Diederichsen A. 2010. Phenotypic diversity of Jerusalem artichoke (*Helianthus tuberosus* L.) germplasm preserved by the Canadian gene bank. Hellia 33 (53): 1-16. https://doi.org/10.2298/HEL1053001D

Dubois M., Gilles K.A., Hamilton J.K., Rebers P.T., Smith F. 1956. Colorimetric method for determination of sugars and related substances. Analytical Chemistry 28 (3): 350-356. https://doi.org/10.1021/ac60111a017

Gao K., Zhang Z., Zhu T., Tian X., Gao Y., Zhao L., Li T. 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. https://doi.org/10.1016/j.indcrop.2019.01.024

Gao K., Zhang Z., Zhu T., Coulter, J.A. 2020. The influence of flower removal on tuber yield and biomass characteristics of *Helianthus tuberosus* L. in a semi-arid area. Industrial Crops and Products 150:112374-112380. https://doi.org/10.1016/j.indcrop.2020.112374

Gunnarsson I.B., Svensson S.E., Johansson E., Karakashev D., Angelidaki I. 2014. Potential of Jerusalem artichoke (*Helianthus tuberosus* L.) as a biorefinery crop. Industrial Crops and Products 56: 231-240. https://doi.org/10.1016/j.indcrop.2014.03.010

Hay R.K.M., Offer N.W. 1992. *Helianthus tuberosus* as an alternative forage crop for cool maritime regions: a preliminary study of the yield and nutritional quality of shoot tissues from perennial stands. Science of Food and Agriculture 60 (2): 213-221. https://doi.org/10.1002/jsfa.2740600209

Kays S.J., Nottingham, S.F. 2007. Biology and chemistry of Jerusalem artichoke: *Helianthus tuberosus* L. CRC press. https://doi.org/10.1201/9781420044966

Kou Y.X., Zeng J., Liu J.Q., Zhao C.M. 2014. Germplasm diversity and differentiation of *Helianthus tuberosus* L. revealed by AFLP marker and phenotypic traits. The Journal of Agricultural Science 152 (5): 779-789. https://doi.org/10.1017/S0021859613000476

Krober W., Heklau H., Bruelheide H. 2015. Leaf morphology of 40 evergreen and deciduous broad leaved subtropical tree species and relationships to functional ecophysiological traits. Plant Biology. 17: 373–383. https://doi.org/10.1111/plb.12250

Li L., Shao T., Yang H., Chen M., Gao X., Long X., Rengel Z. 2017. The endogenous plant hormones and ratios regulate sugar and dry matter accumulation in Jerusalem artichoke in salt-soil. Science of the Total Environment 578: 40-46. https://doi.org/10.1016/j.scitotenv.2016.06.075

Long X.H., Shao H.B., Liu L., Liu L.P., Liu Z.P. 2016. Jerusalem artichoke: A sustainable biomass feedstock for biorefinery. Renewable and Sustainable Energy Reviews 54: 1382-1388. https://doi.org/10.1016/j.rser.2015.10.063

Malmberg A., Theander O. 1986. Differences in chemical composition of leaves and stem in Jerusalem artichoke and changes in low-molecular sugar and fructan content with time of harvest. Swedish Journal of Agricultural Research 16 (1): 7-12.

Mclaurin W.J., Somda Z.C., Kays S.J. 1999. Jerusalem artichoke growth, development, and field storage.I. Numerical assessment of plant part development and dry matter acquisition and allocation. Journal of Plant Nutrition 22 (8):1303-1313. https://doi.org/10.1080/01904169909365714.

Panchev I., Delchev N., Kovacheva D., Slavov A. 2011. Physicochemical characteristics of inulins obtained from Jerusalem artichoke (*Helianthus tuberosus* L.). European Food Research and Technology 233 (5): 889-896. https://doi.org/10.1007/s00217-011-1584-8

Papi N., Kafilzadeh F., Fazael, H. 2017. Effects of incremental substitution of maize silage with Jerusalem artichoke silage on performance of fat-tailed lambs. Small Ruminant Research 147: 56-62. https://doi.org/10.1016/j.smallrumres.2016.11.013

Papi N., Kafilzadeh F., Fazaeli H. 2019. Use of Jerusalem artichoke aerial parts as forage in fat-tailed sheep diet. Small Ruminant Research 174: 1-6. https://doi.org/10.1016/j.smallrumres.2019.03.001

Rossini F., Provenzano M.E., Kuzmanović L., Ruggeri R. 2019. Jerusalem artichoke (*Helianthus tuberosus* L.): a versatile and sustainable crop for renewable energy production in Europe. Agronomy 9(9): 528-568. https://doi.org/10.3390/agronomy9090528

Slimestad R., Seljaasen R., Meijer K., Skar S.L. 2010. Norwegian-grown Jerusalem artichoke (*Helianthus tuberosus* L.): morphology and content of sugars and fructo-oligosaccharides in stems and tubers. Science Food Agriculture 90(6): 956-964. https://doi.org/10.1002/jsfa.3903

Stauffer M.D., Chubey B.B., Dorrell D.G. 1980. Growth, yield and compositional characteristics of Jerusalem artichoke as it relates to biomass production. Am. Chem. Soc., Div. Fuel Chem., Prepr; (United States), 25 (CONF-800814-P3).

Swanton C.J., Clements D.R., Moore M.J., Cavers P.B. 1992. The biology of Canadian weeds. 101. *Helianthus tuberosus* L. Canadian Journal of Plant Science 72 (4): 1367-1382. https://doi.org/10.4141/cjps92-169

Van Soest P.Y., Robertson J., Lewis B. 1991. Methods for dietary fiber, neutral detergent fiber, and no starch polysaccharides in relation to animal nutrition. Dairy Science 74: 3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Wang Y., Zhao Y., Xue F., Nan X., Wang H., Hua D., Liu J., Yang L., Jiang L., Xiong B. 2020. Nutritional value, bioactivity, and application potential of Jerusalem artichoke (*Helianthus tuberosus* L.) as a neotype feed resource. Animal Nutrition 6 (4): 429-437. https://doi.org/10.1016/j.aninu.2020.09.001

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