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## The yield of Jerusalem artichoke plant *Helianthus tuberosus* L. grown in various combinations of fertilisation – preliminary research

### Introduction

Jerusalem artichoke – *Helianthus tuberosus* L. is commonly known in Poland as ‘topinambur’. It is a plant whose history goes back to the pre-Columbian times, when in the eastern and southern parts of North America, topinambur was cultivated by indigenous peoples. The Jerusalem artichoke was brought to Europe in the early 17<sup>th</sup> century (Jasińska, Kotecki, 2003). Despite the many advantages of tubers, both in nutritional aspects (content of inulin, high content of vitamins and minerals) and the ability to use it in the human diet (tubers can be fried, cooked, marinated, pickled), until now, this plant has not found a widespread use and the area of cultivation is still small (Cieślik, 1998; Cieślik, Filipiak-Florkiewicz, 2000). In Poland, it is cultivated on a small scale, mostly for feed and consumer purposes and as an energy crop and decorative plant. The plant can be used for energy purposes in a twofold way: harvesting green fodder for biogas production or harvesting tubers for bioethanol production. Assuming a triple cut of green fodder and yield within 100 t·ha<sup>-1</sup>, biogas production can reach a level of 53.500 m<sup>3</sup>. In the case of straw (50 t·ha<sup>-1</sup>), it is possible to generate 900 GJ during combustion, and as far as the use of tubers is concerned, it has been calculated that, from 25 t·ha<sup>-1</sup>, 2.600 dm<sup>3</sup> of ethanol can be obtained (Piskier, 2004). This plant is successfully planted around the forest as bait for forestry quarry (mainly wild boars) to minimize losses in root crops in adjacent crop fields.

The Latin name *Helianthus tuberosus* was proposed by Carl Linnaeus in 1753; however, the popular name is topinambur and, in English literature, the Jerusalem artichoke. The origin of this first nomenclature is related to the Indian tribe Topinamba in South America, from where this native plant was taken over by the natives of the North American continent. One of the theories that explain the English name of this plant is derived from the organoleptic properties of this plant. Namely, the cooked

tubers are similar in taste and texture to the receptacle of the globe artichoke (*Cynara scolymus* L.). On the other hand, the reference to Jerusalem artichoke may just be a phonetic simplification of the Italian word (*girasole*) in the 17<sup>th</sup> century, in response to the difficulty of pronunciation (Kays, Nottingham, 2008).

In Poland, there are mainly two cultivar varieties: cv. Albik, elongated, white tubers and cv. Rubik, oval tubers with purple and red skin. Other foreign varieties such as 'Boston Red', 'Fuseau', or 'Golden Nugget' are also available (Makowski, 2014). This species belongs to the Compositae family (now Asteraceae). These plants produce raised stems of about 3–4 m height and underground stolons, at the ends of which are formed tubers of various shapes and different colours, depending on the variety (Forkiewicz et al., 2007).

This species is extremely tolerant to the environment. It does not require intensive cultivation, and stands poor sites in nutrients and water quite well. It reproduces by seeds (but it is quite easy to create hybrids in a natural state and as a short-day plant, in our latitude, it will not be able to develop mature seeds before frosts) as well as vegetatively by tubers (Jasińska, Kotecki, 2003).

Tubers winter in the soil and start growing quite fast in spring. The plant shading the ground dynamically is much better at dealing with weeds, which gives it an advantage over other root crops, especially in relation to the potato. There is no need to plant tubers every year, as the inulin content helps them resist the frosts up to -30°C. Nowadays, the plant is also used to establish energy crops from which biomass is obtained for further processing, achieving an average energy of 96.2 MJ per hectare of plantation in Poland (average yield of dry matter obtained in experiment multiplied by accepted calorific value for this species 15.93 MJ·kg<sup>-1</sup>) (Podlaski et al., 2010).

One of the many positive impacts on the environment is the low demand for phosphorus in the aboveground parts of plants (0.05–0.15% DM), which reduces the risk of water eutrophication in its environment (Kays, Nottingham, 2008). In addition, Antonkiewicz and Jasiewicz (2003) found that the plant exhibited heavy metal accumulation along with soil contamination level (respectively in decreasing order: Cd, Zn, Ni, Cu and Pb), which could be used in phytoremediation of degraded areas. This plant, thanks to its similarity to the sunflower, acts as a reservoir of pollen and nectar for beneficial insects in the wild, especially in the late summer when there is no other source of food for them. Decorative, yellow flowers are used in bouquets and garden design.

However, the cultivation of the Jerusalem artichoke also exhibits negative aspects. As a result of plants density and susceptibility to the fungal disease caused by *Sclerotinia sclerotiorum* (Lib.) de Bary, there is a risk of a high volatility of dry matter yields. As Podlaski et al. (2010) pointed out, this variability can range from 2.7 to 9.7 t·ha<sup>-1</sup>. It is a plant classified according to Tokarska-Guzik et al. (2011, 2012) as an

alien species with the status of invasive taxa. Rapidly spreading, and being stable in the environment by producing large amounts resistant to adverse environmental conditions with tubers that are deeply embedded in the soil.

## Material and methods

The study was based on a field experiment in 2016 at Experimental Station of Department of Agrotechnology and Agricultural Ecology at the University of Agriculture in Kraków, 50°05'08.5"N; 19°51'08.3"E. The experimental area was on sandy soil with a pH of 6.36, the contain of total C-org 1.14% of DM (biochar was derived from coniferous wood wastes, which contains: total C (77%), ash (5%) and volatile matter (18%); this fertiliser is attested by National Institute of Public Health-National Institute of Hygiene, No PZH/HT-3146/2016), N 0.13%, P<sub>2</sub>O<sub>5</sub> 31.00 and K<sub>2</sub>O 7.67 and Mg 8.10 mg 100g soil. Total precipitation between April and November was 55.3 mm, according to the long-period total precipitation on a level of 68.2 mm (1961–1990). The average daily temperature was 13.5°C compared to the long-period mean temperature of 12°C (1961–1990). The experiment was established as a factorial design with two factors (varieties and fertilisation) in a randomised complete block design with three replications.

The cv. Albik and cv. Rubik were cultivated in 5 combinations of fertilisation in 5 replications: (1) control object – without mineral fertilisation and biochar, (2) mineral fertilisation NPK: 100:80:100 kg·ha<sup>-1</sup>, (3) biochar 10 t·ha<sup>-1</sup>, (4) biochar 10 t·ha<sup>-1</sup> and NPK 100:80:100 kg·ha<sup>-1</sup>, and (5) biochar 5 t·ha<sup>-1</sup> and NPK 50:40:50 kg·ha<sup>-1</sup>. Fertilisation was applied early in the spring prior to establishing the cultivation. Tubers were planted at 1 m spacing and at 0.5 m spacing between plants in a row. No pesticides were used in the crop. Tubers harvest was made at the end of November when the plant stems were already dried. For the measurement of morphological features, tubers of 2 randomly selected plants were taken from one row. This is equivalent to 4 square meters per row. The yield was obtained from 6 plants which were grown in the row. The area of the plot was 18 square meters.

Data was subjected to the analysis of variance (ANOVA). Means (n = 5) were separated using HSD Tukey range test at the 0.05 significance level.

The results discussed in this paper are a part of the long-term field experiment.

## Results and discussion

The applied various kinds of fertilisation in Jerusalem artichokes cultivation differentiated tubers yield (Tab. 1). Significant differences in tuber yield between varieties were found. Higher yields were noted for the cv. Rubik. Significant differences were also ob-

**Tab. 1.** Average tubers yield and the biomass of a single tuber of *Helianthus tuberosus* L. 'Albik' and 'Rubik'

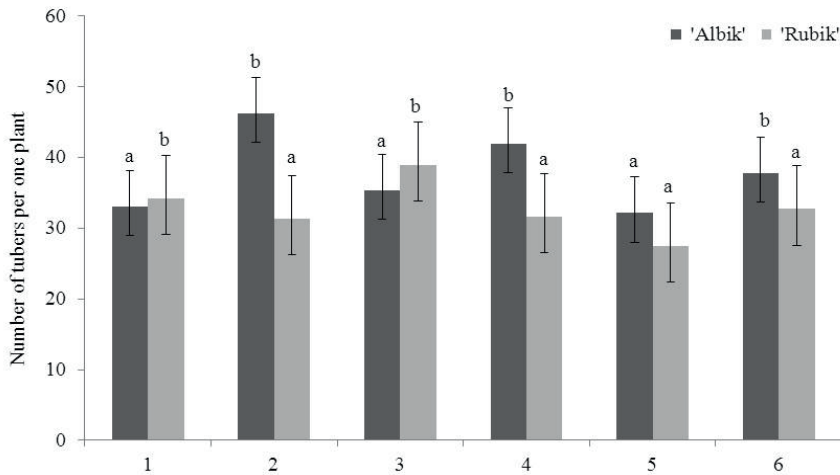
Objects	Average tubers yield [t·ha <sup>-1</sup> ]		The biomass of a single tuber [g]	
	'Albik'	'Rubik'	'Albik'	'Rubik'
1	19.35 a	34.27 b	37.31 a	49.14 a
	17.45–20.30	30.35–36.35	32.00–52.00	33.66–58.46
2	28.45 b	32.07 b	43.68 a	53.22 a
	24.35–34.45	23.35–40.15	34.67–56.00	20.40–65.60
3	22.32 a	34.13 b	44.31 a	54.74 a
	19.05–25.70	33.95–34.25	13.16–62.11	30.24–83.48
4	27.85 b	35.68 b	44.61 a	51.49 a
	19.20–33.60	27.85–40.45	17.46–65.93	33.71–72.50
5	22.57 a	29.75 b	43.94 a	55.48 a
	15.95–26.95	25.45–32.40	19.46–56.36	34.50–75.50
S	24.11 a	33.18 b	42.77 a	52.81 b

1 – control object without mineral fertilisation and biochar, 2 – mineral fertilisation NPK: 100-80-100 kg·ha<sup>-1</sup>, 3 – biochar 10 t·ha<sup>-1</sup>, 4 – biochar 10 t·ha<sup>-1</sup> and NPK, 5 – biochar (5 t·ha<sup>-1</sup>) and NPK 50-40-50 kg·ha<sup>-1</sup>, S – mean values; a, b – different letters relate to the significant differences according to Tukey test, n = 5, p = 0.05

served between the fertilisation objects, but only for the 'Albik' (Tab. 1). The highest effect of increasing yield was obtained using mineral fertilisation (Object 2) and biochar with a full dose of mineral fertilisers (Object 4). The difference between the smallest and the largest yield was over 9 t (cv. Albik) and about 6 t (cv. Rubik). In case of the 'Rubik', there were no significant differences in the yield of tubers between the kind of fertilisation. The application of biochar (Objects 3 and 4) also significantly affected the yield of tubers. The cv. Albik also yielded worse under control conditions than the cv. Rubik. The average yield of tubers for the cv. Albik was (regardless of fertilisation objects) 24.11 t·ha<sup>-1</sup> and for cv. Rubik 33.18 t·ha<sup>-1</sup>. According to Prośba-Białczyk (2007), the yield of tubers of these varieties of Jerusalem artichoke in favourable weather conditions without fertilisation and chemical protection can be about 40 t·ha<sup>-1</sup>. In that paper, one can also notice that cv. Albik yields better than cv. Rubik. This is in contrast to the results obtained in this study, because the control object (without fertilisation) was 19.35 t·ha<sup>-1</sup> for 'Albik' and 34.27 t·ha<sup>-1</sup> for 'Rubik' (Tab. 1).

According to applied fertilisation, cv. Albik produced on average smaller and more diversified tubers than cv. Rubik (Tab. 1). Nevertheless, based on the statistical analysis, no significant differences were found between fertilisation objects and varieties. The results show that the most optimum combination of fertilisation, where the largest biomass of tubers 'Albik' were recorded (Objects 3 and 4), and for 'Rubik' (Objects 3 and 5). Similar results according to the reduced doses of mineral fertilisation were obtained in the studies of Kocsis et al. (2007).

During the evaluation of the number of tubers from one plant, significant differences between varieties in the size of this parameter and some combination of fertilis-



**Fig. 1.** Number of tubers per one plant *Helianthus tuberosus* 'Albik' and 'Rubik': 1 – control object without mineral fertilisation and biochar, 2 – mineral fertilisation NPK: 100-80-100 kg·ha<sup>-1</sup>, 3 – biochar 10 t·ha<sup>-1</sup>, 4 – biochar 10 t·ha<sup>-1</sup> and NPK, 5 – biochar (5 t·ha<sup>-1</sup>) and NPK 50-40-50 kg·ha<sup>-1</sup>, 6 – mean values; a, b – different letters relate to the significant differences according to HSD Tukey test, n = 5, p = 0.05

ation were recorded (Fig. 1). In the case of the 'Albik' variety, the most favourable conditions for the development of tubers were the conditions where a full dose of mineral fertilisation (Object 2) and full dose of NPK with the addition of biochar (Object 4) were applied. Under these conditions, one plant produced, on average, from about 42 to more than 46 tubers. On the other objects these values ranged from 32 to about 36 tubers per plant. In turn, the 'Rubik' variety, in this experience, was different from the 'Albik' variety. The highest number of tubers (over 38) was from one plant, where only full biochar was used (Object 3).

## Conclusions

Based on the field experiment, it was found that the addition of biochar derived from coniferous wood biomass could be useful in the fertilisation of the Jerusalem artichoke. The yield of tubers and the morphological features of *Helianthus tuberosus* L. cv. Albik and cv. Rubik were varied and dependent on the fertilisation variants applied. In the studied conditions of the habitat for yields of the Jerusalem artichoke, the most effective were the fertilisation of the soil with a full dose of biochar and mineral fertilisation.

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## Abstract

Jerusalem artichoke is a perennial plant, which originates from North America. Tubers are characterised by high nutritional and energy values and can therefore be a source of food for humans and animals. The interest in tubers of *Helianthus tuberosus* L. in the diet of man is primarily due to the content of inulin and fructooligosaccharides, minerals, vitamins, and amino acids in them. In addition, it is a plant that is not demanding in agrotechnical conditions. Hence, the interest in cultivation this plant has increased. The main objective of the experiment was to evaluate the effect of biochar on the average yield of tubers and some morphological characteristics of plants. The study was conducted in conditions of a field experiment in 2016 at the Experimental Station of the University of Agriculture in Kraków. Two varieties: 'Albik' and 'Rubik', were grown in the experiment with different fertilisation variants. Biochar from the coniferous wood industry and mineral fertilisers were used. The 'Rubik' variety yields better than the 'Albik' variety under tested soil conditions, and the combined use of biochar and the basic dose of mineral fertilisation gives the best yields in the cultivation of Jerusalem artichoke.

**Key words:** Jerusalem artichoke, *Helianthus tuberosus* L. cv. Albik, cv. Rubik, biochar, size and numbers of tubers

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## Plon słonecznika bulwiastego *Helianthus tuberosus* L. uprawianego w różnych kombinacjach nawozowych – badania wstępne

### Streszczenie

Topinambur (słonecznik bulwiasty) *Helianthus tuberosus* L. to wieloletnia roślina, która pochodzi z Ameryki Północnej. Bulwy charakteryzują się wysokimi właściwościami odżywczymi, dlatego mogą być źródłem pożywienia dla człowieka i paszą dla zwierząt. Ponadto wykorzystywane są jako biomasa do produkcji energii i etanolu. Zastosowanie bulw w diecie człowieka wynika przede wszystkim z zawartości w nich inuliny i fruktooligosacharydów, minerałów, witamin oraz aminokwasów. Jest to roślina o małych wymaganiach agrotechnicznych, stąd też w ostatnich latach wzrasta zainteresowanie jej uprawą, zwłaszcza na glebach słabych. Głównym celem eksperymentu była ocena wpływu biowęgla na plon bulw i niektóre cechy morfologiczne topinamburu. Doświadczenie polowe przeprowadzono w 2016 roku w Stacji Doświadczalnej Katedry Agrotechniki i Ekologii Rolniczej Uniwersytetu Rolniczego w Krakowie. Uprawiano dwie odmiany topinambura: 'Albik' i 'Rubik', przy zróżnicowanym nawożeniu: 1 – obiekt kontrolny bez nawożenia mineralnego i biowęgla, 2 – NPK: 100-80-100 kg·ha<sup>-1</sup>, 3 – biowęgiel 10 t·ha<sup>-1</sup>, 4 – biowęgiel 10 t·ha<sup>-1</sup> i NPK, 5 – biowęgiel (5 t·ha<sup>-1</sup>) i NPK 50-40-50 kg·ha<sup>-1</sup>. Na tle porównywanych obiektów nawozowych stwierdzono, że najlepszą kombinacją nawożenia w uprawie słonecznika bulwiastego było zastosowanie biowęgla wraz z nawozami mineralnymi.

**Słowa kluczowe:** słonecznik bulwiasty, *Helianthus tuberosus* L. cv. Albik i cv. Rubik, biowęgiel, wielkość i liczba bulw

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Her research is connected with agrotechnology in plant cultivation and plant ecology. Presently, she is interested in the use of the biomass of plants and other organic fertiliser like biochar in agriculture.

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She is focusing on enhancing the understanding of the influence of different factors on soil structure and fertility. Particularly, she is investigating the interaction of plants with the physical, chemical, and biological properties of the soil. She is also interested in organic methods of plant production and soil-enriching substances.