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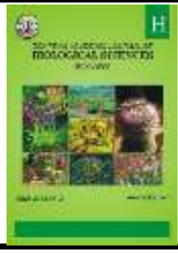

Horticultural Performance, Yield Components and Sugar Content of Jerusalem Artichoke Cultivated Under the Middle Egypt Conditions

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ABSTRACT

Jerusalem artichoke is a hardy plant with high photosynthetic efficiency. It is used for many purposes such as human food and animal feedstock. Currently, it is important as a source of inulin, which is considered a functional food ingredient. Inulin or fructan depends on many factors such as photosynthesis and temperature. This study was conducted to investigate the horticultural characteristics, the yield of tubers and inulin content of Egyptian Jerusalem artichoke under Middle Egypt growing conditions. Results showed that there were differences in the shape and size of tubers. The morphological parameters; plant height was (201.0 and 204.33 cm) in the first and second seasons, respectively and the number of branches/plant, it was 42.67 and 41.67 in the first and second seasons, respectively. This study proved that tubers contain a high percentage of inulin which is widely found in nature as a storage carbohydrate, especially in the plants of the family of Asteraceae. So it is important to cultivate these plants in Egypt to bridge the gap of sugar needed to feed diabetics. Also, these plants grow under drought conditions and therefore suitable for cultivation in new lands in Egypt for local marketing or for export to increase the national income of Egypt from hard currency.

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus* L.) is native to North America and is a perennial of the Asteraceae (Compositae) family, which includes lettuces, sunflowers and globe artichokes. It grows to a height of 2 to 3 m and is grown in Egypt from about eight to ten years (Ismail and Moustafa, 2012). The plant resembles sunflower, but it also produces a large number of edible underground tubers, which are knobble and resemble ginger in appearance. So it sows for its immature flowers. The tubers are smaller, crisper and sweeter than potato. Inulin accumulates in the stems and tubers of artichokes in large quantities.

Fructans and fructose resulting from hydrolysis of fructans can be used in human diet or in industrial and medical applications (Monti et al., 2005). Jerusalem artichoke is one of the main sources of inulin in plants (Saengthongpinit and Sajjaanantakul, 2005). Its protein has a high nutritional value because it has almost all the essential amino acids but also because of its good balance (Rakhimov *et al.*, 2003). It is considered a suitable animal feed so it uses as a forage crop (Seiler and Campbell, 2004). In recent decades, Jerusalem artichoke was considered as a biomass crop for ethanol because it usually produces high levels of carbohydrates (Denoroy, 1996). The production of biogas from biomass is economically viable under certain conditions, and the possibility of increasing the cultivation of Jerusalem artichoke has increased scientific interest in this crop (Gunnarson *et al.*, 1985). Jerusalem artichoke is grown primarily for tubers that can be eaten fresh or cooked. Leaves and stems are rich in protein, fat and pectin. Also, it is said that the alcohol of fermented tubers is of better quality than sugar beet.

It grows at a high density, which leads to the intensity of shading and reduces the competition of other plants so it is a good weed eradicator. It is also good in ridding fields from the quack grass. (Margaritis and Bajpai, 1982).

The experiment aimed to study the horticultural performance of the Egyptian Jerusalem artichoke plants i.e., growth, yield, and yield components along with the chemical compositions of different sugars content.

MATERIALS AND METHODS

Two Jerusalem artichoke (Egyptian clone) experiments were carried out in the Vegetables Scientific Experimental Farm, Horticulture Department, Faculty of Agriculture, Minia University, Minia, Egypt in two successive summer seasons of 2015 and 2016. The chemical analyses were conducted at the National Center for Radiation Research and Technology, Atomic Energy Authority, Nasr City, Cairo, Egypt.

Plant Material:

Jerusalem artichoke tubers were kindly obtained from the Vegetative Propagated Vegetables Department, Egyptian Agricultural Research Center, Giza, Egypt.

Experimental Design:

The soil (clay loamy soil) was well prepared before plantation and distributed into many plots (3x3.5 m) in a Complete Randomized Design (CRD). The plots consisted of rows 70 cm apart and the seed tubers were planted in the middle of each row (30 cm apart of each other) and were slightly covered with smooth soil. The recommended NPK doses according to the Egyptian Ministry of Agriculture Protocol was used for the treatments fertilized with the full doses of NPK were as follow; ammonium nitrate (33.5%N) at 200 kg dose per fed, calcium super phosphate (15.5%P_2O_5) at 300 kg dose per fed, and potassium sulphate (48%K_2O) at 50 kg dose per fed.

Recorded Data:

Horticultural Characteristics:

Data of the plant height (cm) and the number of branches/plant were recorded before blooming and when plants were fully vegetative grown. The average fresh weight of plants and tubers (kg); (ten plants and their tubers were randomly collected from each replicate) along with the number of tubers/plant were recorded after harvesting the plants in the beginning October of 2015 and 2016. The average dry weight of the collected plants (g) was recorded after complete drying of these plants in an open sunny place.

Chemical Analysis:

Mono and Di Sugars Extraction:

For mono and di sugars extraction, dried tubers (0.1 g) were dissolved in100 ml distilled water before the injection into HPLC.

Inulin Extraction:

The extraction procedures of inulin were as follow:

- About 0.1 g powdered samples or fructooligo saccharide standard were weighed in 250 ml conical flask followed by the addition of 100 ml 1% sulfuric acid solution.
- The hydrolysis of both samples and the standard were done by using the autoclave for 1h at 121ºC.
- After autoclaving, all samples and the standard were left for cooling at room temperature.
- The pH was adjusted to 5-6 by using calcium carbonate.

All samples and the standard solution were filtered by using syringe filter (0.45 mm) before the injection into HPLC. The detection was by the refractive index at 80 °C column temperature and solid $CaCO_3$ was added to raise the pH to between 6 and 7 (determined by a pH meter). Results were given by g/kg DW.

Statistical Analysis:

The experiment was conducted in a complete block design (CBD) manner. Three replicates per treatment were evaluated. All data were statistically analyzed by the analysis of variance (ANOVA) technique and the means were separated by Duncan Multiple Range test (Duncan, 1955). All statistical tests were performed at a 5% significance level.

RESULTS AND DISCUSSION

Vegetative Growth Characteristics :

The Jerusalem artichoke (Egyptian clone) plants grow very well under the Middle Egypt conditions. There were differences in the shape and size of tubers (Fig. 1). Tuber size variations partially accounted for the difference in tuber yield. Chubey and Dorrel (1974) reported that tuber weight ranged from 12 g for a native clone to 438 g for a specific Russian clone.

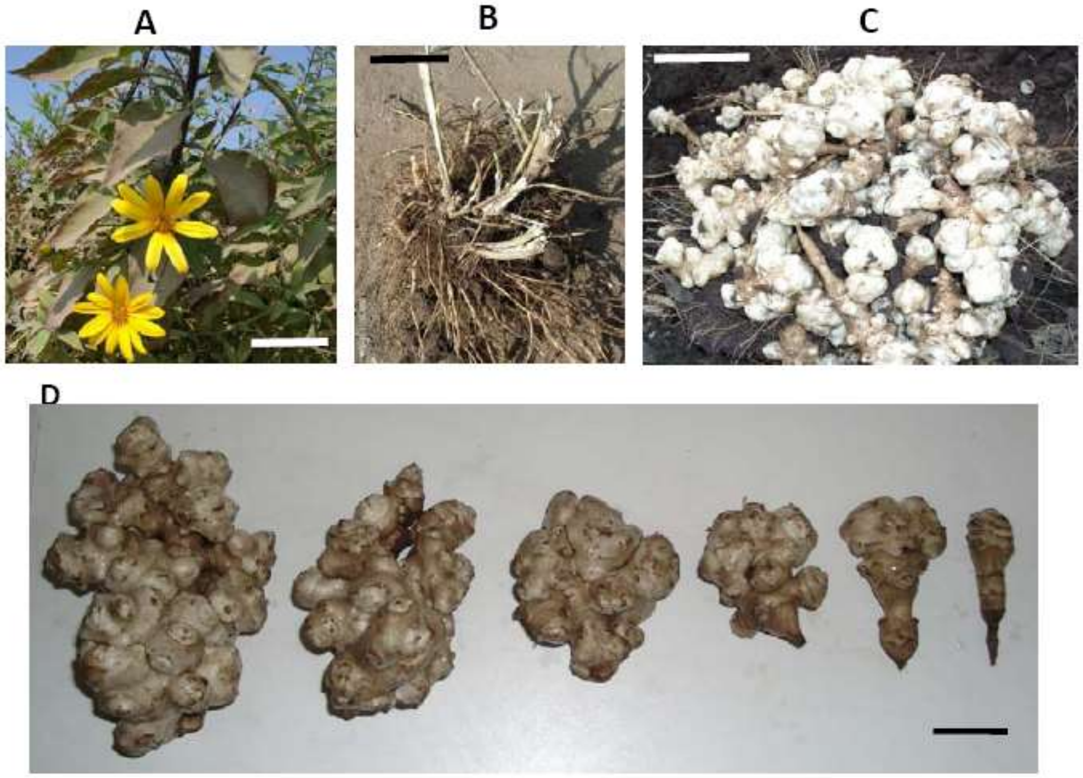

Fig. 1. Photos of Jerusalem artichoke plant's different organs, A) Whole plant shows leaves and flowers, B) Roots and crown, C) Tubers yield from one plant, D) Tubers' different sizes and shapes. All pars are 10 cm long.

Plant Height (cm):

The mean performances of plant height in two seasons are presented in Fig.(2). The highest value observed for the second season (204.33 cm) compared with the first season (201 cm). Similar results were reported by Kosanic *et al*. (1984).

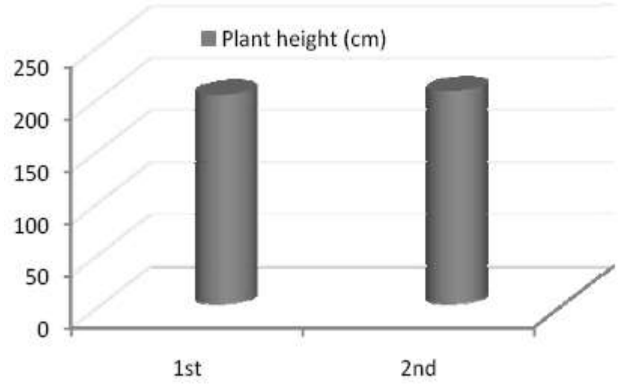

Fig. 2. Plant height (cm) of Jerusalem artichoke in the first (1st) and second (2nd) seasons

Shoot Fresh and Dry Weights:

The recorded results in Fig. (3) showed that the highest values of average shoot fresh weight are 2.33 kg in the first season but in the second season was 1.83 kg,while, the shoot dry weight was 1.180 and 1.20 gin the first and second seasons respectively (Fig 3).

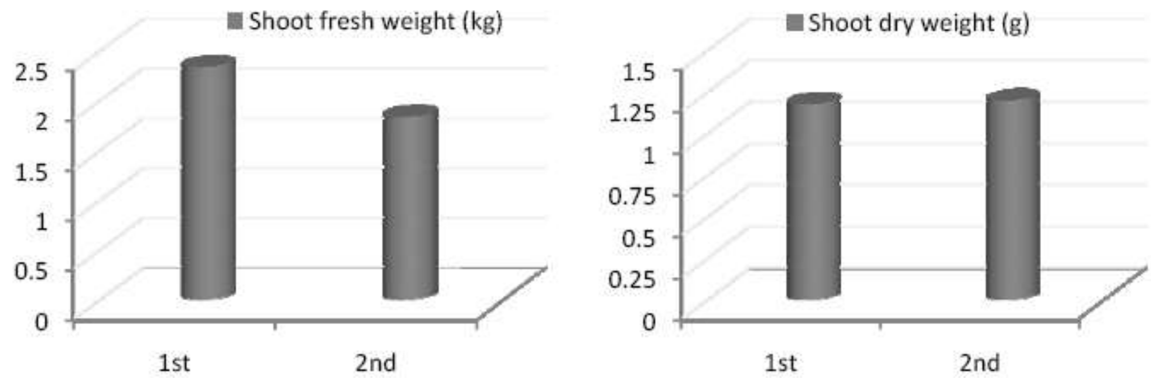

Fig. 3. Shoot fresh weight (kg) and shoot dry weight (g) of Jerusalem artichoke plants in the first (1st) and second(2nd) seasons.

Tubers Fresh and Dry Weights:

The tuber fresh and dry weight in the first season reached to 4.53 kg/plant and 27.4 g/100 g FW respectively, but in the second season, were 4 kg/plant and 26.87 g/100 g FW respectively, (Fig 4). Kloj Andersen (1992) reported that the characteristics of tubers are not affected by the tuber size.

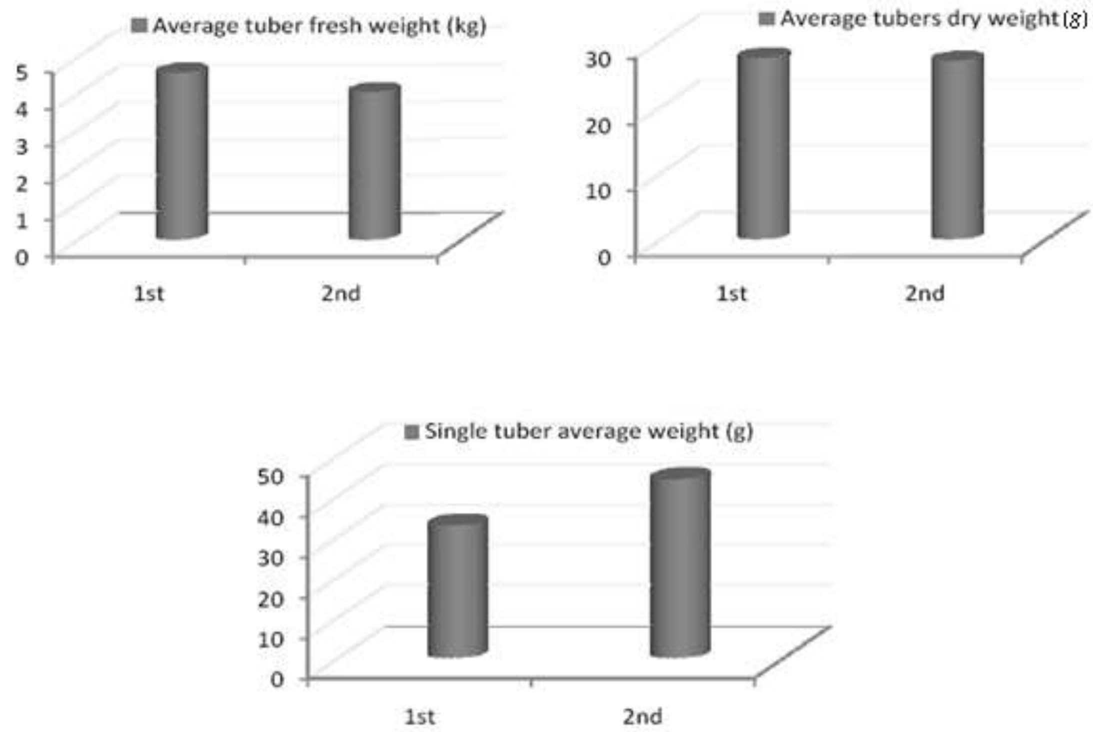

Fig. 4. Average tubers fresh weight (kg), average tubers dry weight (g) and single tuber average weight (g) of Jerusalem artichoke in the first (1^{st}) and second (2^{nd}) seasons.

Concerning to the number of branches/plant and the average number of tubers/plant, the results presented in Fig (5) showed that in the first season were 42.67 branches/plant and 126 tubers/plant respectively, but in the second season were 41.67 branches/plant and 91.33 tubers/plant, respectively. The color of tubers are different, may be purple, yellow or white and these variations depend on a number of parameters such as plant variety, soil texture and available moisture. Shape and size of tubers also differ from a variety to another. The best varieties contain large tubers clustered near the main root as compared to other forms that give small tubers on long stems (Kosaric *et al*., 1984).

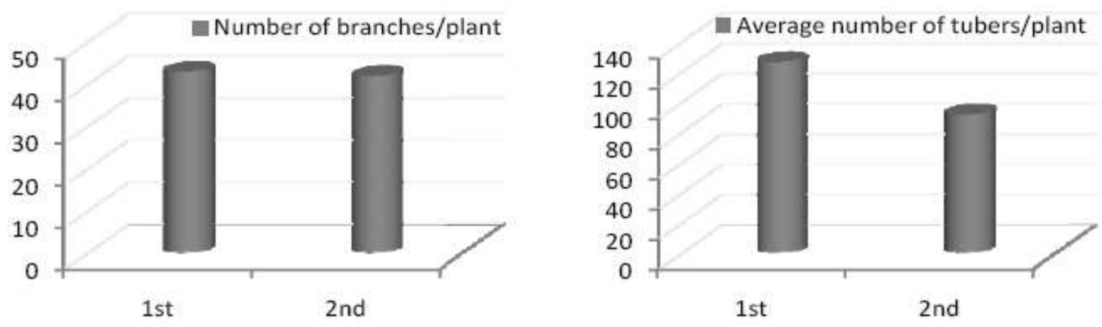

Fig. 5. Number of branches/plant and average number of tubers/plant of Jerusalem artichoke in the first (1^{st}) and second (2^{nd}) seasons.

Chemical Analysis:

Sugars Content:

Fig (6) shows the content of inulin, sucrose, glucose and fructose in Jerusalem artichoke where the content of inulin is about 462.67 and 460.10 g/kg DW in the first and second seasons, respectively, while the sucrose contents were 160.01 and 162.10 g/kg DW in the first and second seasons, respectively but the contents of fructose were 29.80 and 27.71 g/kg DW in the first and second seasons, respectively followed by glucose 19.46 and 17.61 g/kg DW in the first and second seasons, respectively. Similar results were found by Brkljača *et al.* (2014).

The tubers of Jerusalem artichoke primarily contain two types of carbohydrates, inulin and sugars (fructose and glucose) as reported by Gunnarsson *et al.* (2014). Inulin is an interesting compound, being a functional food ingredient (Kaur and Gupta, 2002). It contributes to the organoleptic properties of food, improves the stability of foams and emulsions, and when used as a gel in water it has fat-like properties (Franck, 2002). It has been shown that Inulin and oligofructose to stimulate the body's immune systems, increase calcium absorption and lower triglycerides content and fatty acids in the blood serum. They modulate hormonal levels of insulin and glucagon and reduce the incidence of colon cancer (Kaur and Gupta, 2002). Oligofructose has technological properties that are closely related to sugar and glucose syrup (Franck, 2002). Inulin and oligofructose are commonly found in nature and are found in about 15% of all flowering plants (Franck, 2002). However, at present, there are mainly two species, Jerusalem artichoke and chicory, which are used by industry for the production of inulin (Kaur and Gupta, 2002). The inulin yield per hectare is often higher in Jerusalem artichoke than in chicory.

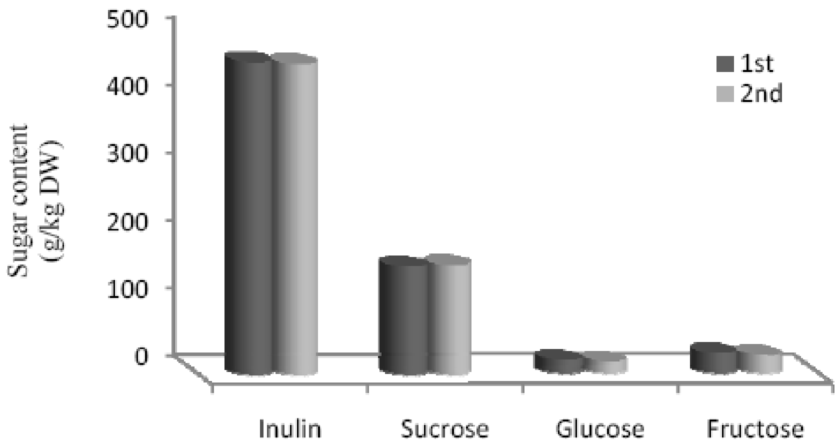

Fig. 6. The content of inulin, sucrose, glucose and fructose (g/kg DW) of Jerusalem artichoke tubers in the first (1^{st}) and second (2^{nd})seasons.

Inulin is broadly found in nature as a storage carbohydrate, mainly in plants of the Asteraceae family. It is a polysaccharide, similar to starch, and exists as a white powder with the neutral taste. Chemically, it is a linear biopolymer of D-fructose units connected by β (2,1) glycosidic linkages, and terminated with one D-glucose molecule linked to the fructose chain by an α (2,1) bond (Li *et al.,* 2015). Among its diverse pharmaceutical and food applications are: besides being a suitable stabilizer of vaccines, it is used as a diagnostic tool to assess renal function (Mensink *et al.*, 2015) and management of Type 2 diabetes, obesity and other blood sugar related health conditions (Kelly, 2008).

Conclusion:

It is clear that Jerusalem artichoke has been successfully planted in Middle Egypt and therefore can be grown widely in the new lands in Egypt for its high production of tubers, which contain a high percentage of sugars, especially inulin, which is used to feed diabetics. Also, the plant is used as animal feedstock.

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ARABIC SUMMERY

السلوك البستانى ومكونات المحصول ومحتوي السكر فى الطرطوفة
المنزرعة تحت ظروف مصر الوسطى

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الطرطوفة هى نبات قوى ذو كفاءة عالية فى التمثيل الضوئي. وهي تستخدم فى أغراض كثيرة مثل تغذية الانسان، والمواد الخام الحيوانية. كما انها مصدر هام للإينولين، والذي يعتبر مكون غذائى هام.

يعتمد تكوين الإينولين أو الفركتان على العديد من العوامل مثل التمثيل الضوئي ودرجة الحرارة. وقد اجريت هذه الدراسه لدراسة الخصائص البستانية و محصول الدرنات و تركيب السكر في سلالة الطرطوفه المصرية المزروعه تحت ظروف مصر الوسطى.

وقد أظهرت النتائج وجود فرق في شكل وحجم الدرنات. بالنسبة للقياسات المورفولوجية فقد بلغ ارتفاع النبات (٢٠١ و ٢٠٤,٣٣ سم) في الموسمين الأول والثاني على التوالي، وكان عدد الفروع/النبات ٤٢,٦٧ و ٤١,٦٧ في الموسم الأول والثاني، على التوالي.

وقد اثبتت هذه الدراسة انه من المهم زراعة نبات الطرطوفة فى مصر لإنتاجه العالى من الدرنات التى تحتوى على نسب عالية من السكريات المختلفة خاصة الإينولين كما ان النبات يستخدم كسماد للحيوانات. وتنمو النباتات تحت ظروف الجفاف وبالتالى فهى مناسبه للزراعة فى الاراضى الجديدة فى مصر للتسويق المحلى أو للتصدير لزيادة الدخل القومى لمصر من العمله الصعبة وكذلك سد الفجوة من سكر الإينولين اللازم لتغذية مرضى السكر.