

## EFFECT OF SPRINKLER IRRIGATION ON GROWTH OF PAULOWNIA SHAN TONG TREES AT FIRST TWO YEARS OF CULTIVATION IN LIGHT SOIL

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**Abstract.** The effect of sprinkler irrigation on the growth of Paulownia Shan Tong trees was investigated. The field experiment was carried out during the years 2016-2017 on sandy soil in the forest nursery Białe-Błota (Bydgoszcz Forest Division, Poland). The experiment was established as one factorial. The variability factor was irrigation: S- sprinkler irrigation and C- without irrigation (control). The irrigation scheduling was done according to tensiometer indications. Irrigation was started, when the water potential in the soil was – 40 kPa. Sprinkler irrigation was done using the NAAN sector sprinklers. Water for irrigation was taken from a deep well. The process included the controls of growth parameters: tree height, trunk diameter, number of leaves. It was found that the sprinkled seedlings of Paulownia Shan Tong were significantly higher than those growing in the non-irrigated plots. The sprinkler irrigation applied in the experiment resulted in an increase in the number of leaves of Paulownia. By analysing the results of the study on the trunk diameter, leaf number, it may be stated that irrigation watering significantly influenced the tested parameters. Irrigation significantly increased the height of Paulownia trees. The positive effect of the usage of sprinkler irrigation may indicate the possibility of effective application of this method in field cultivation of Paulownia Shan Tong.

**Keywords:** Paulownia, Shan Tong, growth, forest nursery, sprinkler irrigation.

### Introduction

Paulownia species are indigenous to China and have been used as agroforestry trees for over 2600 years due to their many positive attributes and multifaceted uses. The genus was named in honour of Queen Anna Pavlovna from The Netherlands (1795-1865), the daughter of Tsar Paul I of Russia [1]. It is also called the Chinese Empress tree, the Princess tree or the Kiri tree. Zhao-Hua et al. [2] state that there are nine major species in the Paulownia genus, which are all native to East Asia. Paulownia, in particular *P. tomentosa*, has been planted as an ornamental tree in NW Europe since the early 1800's, but has not been considered as a possible commercial species in the region until the last few years. The results of the studies, based on the data gathered from the existing sites, presented by Jensen [3], indicate that Paulownia species and the hybrids could grow successfully as a commercial agroforestry crop in north-western Europe. Paulownia can be propagated by seeds, roots or stem cuttings. There are many commercial hybrids, available for sale from plant nurseries, depending on the climate and commonly available in Europe. Wenhua [4] noted that some excellent Paulownia hybrids have been bred in recent years, for example, Paulownia fortunei x, Paulownia tomentosa that provide up to 30 % higher timber volume than Paulownia elongate, while still being suitable for intercropping.

Paulownia trees are characterized by a wide range of uses. The goals of Paulownia planting are site reclamation, animal waste utilization, rapid biomass production, or pulpwood for paper production [5]. Paulownia is an appropriate tree for intensive management in hardwood plantations with short rotation because of its rapid growth, ability to stump sprout and the wide variety uses for its wood and fiber. Paulownia does not require replanting after harvest, because it regenerates from stump sprouts. Paulownia wood is used for a multitude of products, because it is attractive, strong, lightweight, quick-drying, versatile and has good resonance qualities. The wood is easily worked and will not split or crack when spikes are driven into it or with rapid drying [6]. Due to the high price of balsa, Paulownia wood is also used as an element of composite construction material, which can replace balsa wood in sandwich structures applied among ships, aircrafts, automobiles or wind energy systems [7]. It has been recorded that an 8-10 year old Paulownia tree can produce 100 kg of fresh leaves per year [8]. The leaves and flowers of Paulownia are rich in nitrogen and other nutrients, which could serve as good natural fertilisers [8]. Furthermore, the leaves of Paulownia have high nutritive content suitable for ruminants [9] and can be ensiled as a fodder crop. The leaves are also fed to pigs and rabbits [2;8].

The plant analyzed in this paper is a hybrid of Paulownia called Shan Tong, characterized by very rapid growth (trunk diameter, after 8-10 years, reaches 50 cm), resistance to low temperatures (to -27 °C), strong root system and large leaves (up to 60 cm wide), light and easy to processing wood

(40 % lighter than pine) [10]. In Poland, Paulownia Shan Tong is a new species, introduced due to the potential benefits of growing for paper, furniture and biomass production. There is a very rare number of publications about Paulownia in Poland. The experiments on the influence of chosen saccharides on the growth and development of the in vitro shoot cultures of Paulownia tomentosa were made by Litwińczuk and Bochnia [11]. The researches to examine the usefulness of Paulownia tomentosa for cultivation for biomass in south-eastern Poland were made by Jacek and Litwińczuk [12]. The results of their researches show that Paulownia plantations can be recommended in sandy soils under the condition of provision of an irrigation system. Sprinkler irrigations systematically deliver optimal doses of water to plants and are characterized by a high water utilization rate [13]. The effect of using this type of irrigation is to provide conditions for production of valuable seedlings [14].

The main aim of the study was to determine the influence of sprinkler irrigation on the growth parameters of Paulownia Shang Tong in the first two years of growing on light soil in a low rainfall area.

### Materials and methods

The experiments were carried out during 2016 and 2017 vegetation seasons at the forest nursery "Białe Błota" (Bydgoszcz Forest Division, Poland). Experiments were run on a brown podzolic soil formed from a loose sandy soil. Two years old seedlings (from rootstock) were planted in two rows with spacing of 5 meters in a row and 3 meters between the rows. The experiment was designed as one-factorial trial. The main factor was: irrigation, used in two variants (sprinkler irrigation and control – without irrigation). During the experiment the following features were determined: height, diameter of the trunk and the number of leaves. The obtained data, according to the design of the experiment, were tested by one-factorial analysis of variance with the Tukey test (Statistica – ANOVA).

**Meteorological conditions.** The average air temperature during the 2016 vegetation season was 14.9 °C and for 2017 vegetation season 14.3 °C (Table 1). As compared to the multiyear average (1981-2010), 2016 was characterized by the highest average temperature (+0.4 °C). But the average temperature of 2017 was slightly lower. Temperatures higher than mean values for 1981-2010 were observed in April, May, June and September of 2016. 2017 was characterized in mostly months with the temperatures lower than multiyear average. Total rainfall measured during the vegetation season of 2016 was 358 mm and was higher than the average value from many years by 27.6 % (77.5 mm) (Table 2).

Table 1

#### Air temperature in the vegetation periods 2016 and 2017 in the vicinity of Bydgoszcz

| Years                               | Air temperature, °C |      |      |      |      |      |       |
|-------------------------------------|---------------------|------|------|------|------|------|-------|
|                                     | IV                  | V    | VI   | VII  | VIII | IX   | IV-IX |
| 2016                                | 8.3                 | 14.7 | 17.7 | 18.3 | 16.4 | 14.3 | 14.9  |
| 2017                                | 6.8                 | 13.4 | 16.8 | 17.7 | 17.7 | 13.1 | 14.3  |
| 1981-2010                           | 7.9                 | 13.3 | 16.1 | 18.6 | 17.9 | 13.1 | 14.5  |
| Average 2016-2017                   | 7.6                 | 14.0 | 17.2 | 18.0 | 17.0 | 13.7 | 14.6  |
| Deviation from long-term average, % | -3.8                | +5.3 | +6.8 | -3.2 | -5.0 | +4.6 | +0.8  |

Table 2

#### Rainfall in the vegetation periods 2016 and 2017 in the vicinity of Bydgoszcz

| Years                               | Rainfall, mm |      |       |       |       |      |       |
|-------------------------------------|--------------|------|-------|-------|-------|------|-------|
|                                     | IV           | V    | VI    | VII   | VIII  | IX   | IV-IX |
| 2016                                | 28.7         | 51.4 | 98.1  | 133.8 | 55.3  | 19.4 | 386.7 |
| 2017                                | 40.8         | 56.3 | 54.3  | 118.9 | 126.1 | 78.4 | 474.8 |
| 1981-2010                           | 27.0         | 49.3 | 52.8  | 69.8  | 62.6  | 46.0 | 307.5 |
| Average 2016-2017                   | 34.7         | 53.8 | 76.2  | 126.3 | 90.7  | 48.9 | 71.8  |
| Deviation from long-term average, % | +28.5        | +9.1 | +44.3 | +80.9 | +44.9 | +6.3 | +35.7 |

In the case of 2017, the rainfall was very high and was equal nearly 475 mm (167 mm more than the multiyear sum). In the months from May to July, there was higher rainfall than the average for many years (1981-2010) during the season in 2016. Particularly high rainfall was recorded in July, in which the precipitation amounted to 133.8 mm (91.7 % more than in many years). In August and September there was a decrease in precipitation. Particularly precipitation in September was 57.8 % lower than the long-term average. In 2017 the amount rainfall of each month was higher than the multiyear average. The highest amount was measured in July, August and September.

**Irrigation.** Irrigation was done using a solid-set hand-line irrigation system with overhead impact sprinklers mounted on risers. The irrigation radius of the sprinklers was  $R = 10$  m. The water output was  $2.5 \text{ m}^3 \cdot \text{h}^{-1}$ . Water for irrigation was taken from the retention reservoir located in the forest nursery. Natural precipitation was measured using a Hellmann rain gauge and was 358 mm in this period. Sprinkling irrigation was started 14 days after tree seedlings planting (1 May) and ended on 30 September at the 2016 vegetation season. In 2017 the irrigation was started in May. During the first 14 days after planting, the seedlings did not form leaves. Irrigation was used to supplement natural rainfall. Sprinkler irrigation was realized in accordance with the recommendations for forest nurseries on open areas. Terms of irrigation and irrigation doses were established according to tensiometer indications. Irrigation was started, when the water potential in the soil was  $-40$  kPa. The first irrigation was performed 14 days after seedlings planting in 2016. The total irrigation doses applied from 1 May to 30 September were 170 and 120 mm for 2016 and 2017, respectively (Fig. 1).

The height of Paulownia trees, trunk diameter (measured at the height of 5cm) and the number of leaves for two variants of the experiment were determined.

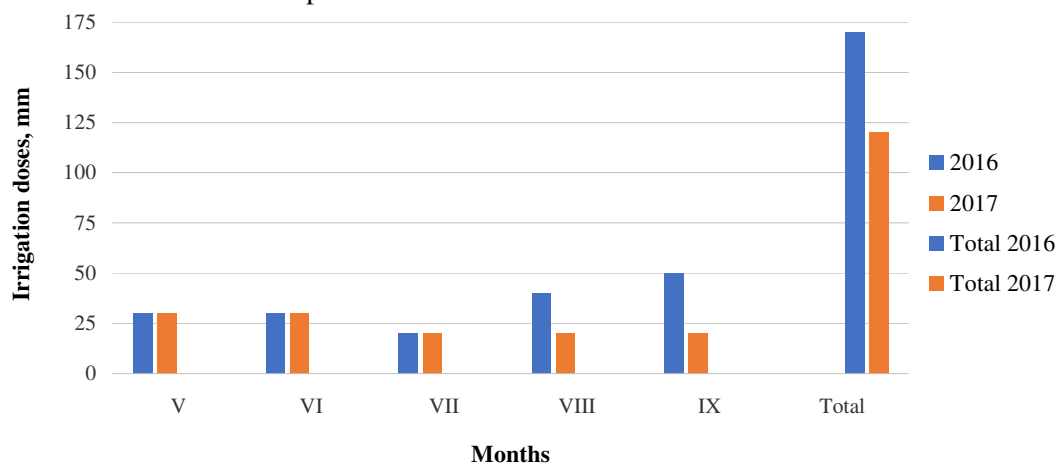


Fig. 1. Irrigation doses during in vegetation period 2016 and 2017

## Results and discussion

Sprinkler irrigation significantly affected the height of Shan Tong Paulownia (Fig. 2). The difference in plant height was observed throughout all months of the vegetation season. The biggest difference between the plant height in the variants of the experiment was observed in the second year of the study (2017). It was equal to nearly 100 cm. In the first year of cultivation the difference between the control and irrigated plants was lower and equal to 53 cm. During the two vegetation seasons (2016 and 2017), the irrigated Paulownia gave an average of 72 % more growth than the non-irrigated trees. The positive similar tendencies and effects of irrigation on the development of different trees in the region of Bydgoszcz were already observed in the case of species, such as Scots pine [15], white birch [16], European larch [17] and little leaf linden [18].

Analyzing the results of the study of the trunk diameter, leaf number and surface during the first two vegetation seasons (2016 and 2017), it can be stated that sprinkler irrigation had a significant influence on the tested parameters. The average increase of the trunk diameter for the control variant was equal to 26 mm, while for the irrigated Paulownia 40 mm at the first year of cultivation. But significantly higher increases were noted in the second year of the study 2017, 30 mm and 52 mm at the control and irrigated variants, respectively (Fig. 3). Analyzing the influence of sprinkling irrigation on the increase of the leaf numbers, two stages of growth can be observed (Fig. 4). During the first

year (2016), the numbers of leaves in both analyzed variants were higher in both variants than in the second year of the experiment (2017).

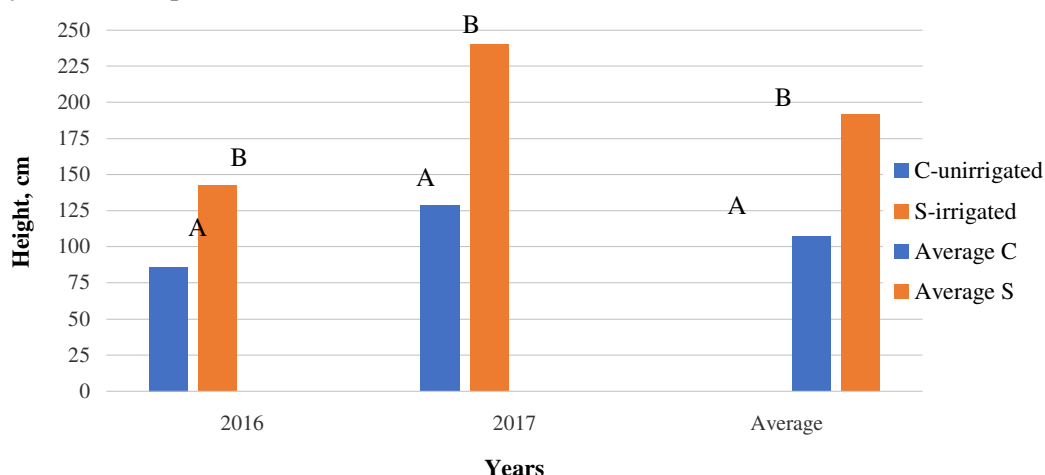


Fig. 2. Height of seedlings for irrigated and unirrigated Paulownia trees observed during 2016 and 2017 vegetation seasons: A, B – different letters mean significant differences at  $p < 0.05$

The results of the experiment are similar to the results presented by Mirkala J.E. and Rad S.R. [19], who have studied the influence of irrigation on Paulownia growth. They noted that more than 80 % of growth took place in the first 3 months of growing.

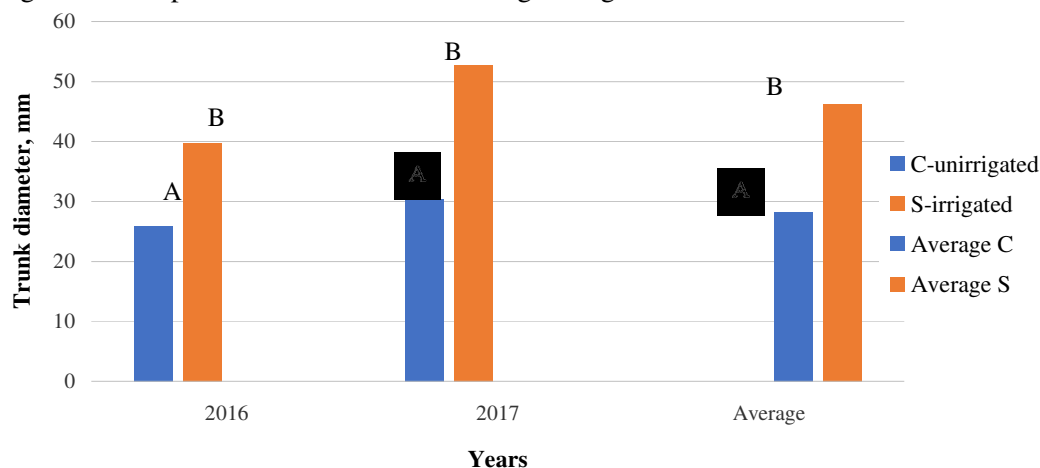


Fig. 3. Trunk diameter for irrigated and unirrigated Paulownia trees observed during 2016 and 2017 vegetation seasons. A, B – different letters mean significant differences at  $p < 0.05$

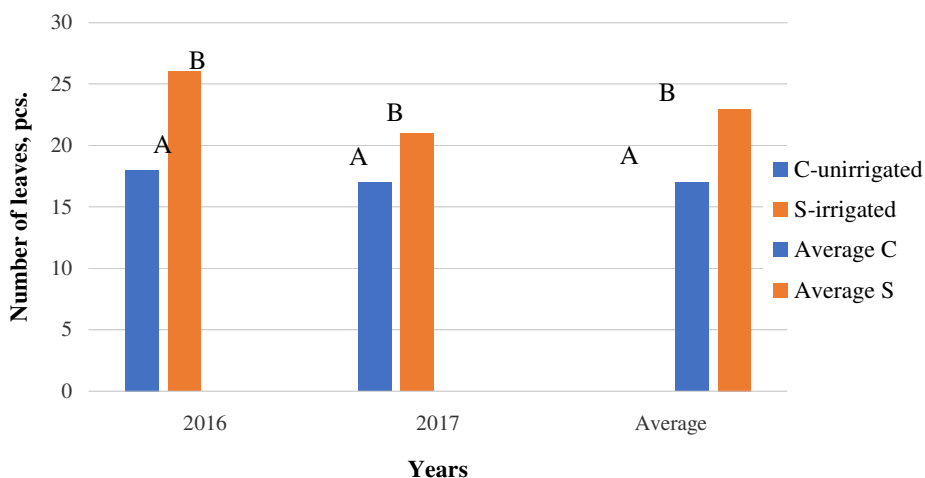


Fig. 4. Number of leaves for unirrigated and irrigated Paulownia trees observed during 2016 and 2017 vegetation seasons: A, B – different letters mean significant differences at  $p < 0.05$

## Conclusions

1. The highest significant increases thanks to irrigation of the height and trunk diameter were determined in the second year of the study (2017) and equal to nearly 100 cm and 22 mm for the height and trunk diameter, respectively.
2. Sprinkling irrigation significantly increases the leaf numbers in both years of the study, but the highest leaf numbers were obtained during the first vegetation season (2016).
3. The experiment has shown the usefulness of the irrigation technology in Paulownia trees cultivation in the Polish climatic conditions in very light soil.

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