THE EFFECT OF WATER AVAILABILITY ON SHOOT AND CULM PROPERTIES OF A DEVELOPING *PHYLLOSTACHYS IRIDESCENS* GROVE

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Abstract. A three year experiment was carried out on sandy soil with a vegetatively propagated single clone of *Phyllostachys iridescens* in Gödöllő, Hungary to investigate the effect of water availability on the number of developing and aborted shoots and the number, diameter and height of culms in a newly planted grove. Part of the experimental plot was provided with drip irrigation and irrigated 3 times a week during the vegetation period from April until the end of October in all years. The first experimental year (2010) was a moist year, while during the second (2011) and third year (2012) there was drought during spring and summer. The number of shoots that developed into culms did not significantly increase over the years in unirrigated control plants, while in irrigated plants there was a three to four fold increase in culm recruitment compared to initial values. There was no significant difference between treatments in culm diameter and culm height during the first two experimental years. However, there was a five fold significant difference in these parameters in the last year. We found a strong (R^2=0.90, P=0.001) correlation between culm diameter and culm height. Our results prove that water supply during the growing season is of vital importance to developing temperate bamboos.

Keywords: *bamboo, Bambusoideae, Shibataeinae, irrigation, drought*

Introduction

There is a rising global interest in the use of bamboos as they are regarded as renewable resources with strong regeneration potential (Potters et al., 2013). *Phyllostachys* species are important in the agriculture of East-*Asian* countries (Ma et al., 2014). In Europe they are important mainly in ornamental horticulture, but their agricultural potential other than as ornamentals has not been fully investigated and exploited in Europe (Gielis et al., 2012). *Phyllostachys* species are among the fastest growing plants (Ueda, 1960; Ueda et al., 2009) with high canopy transpiration (Komatsu et al., 2012) regardless of culm age (Tsuruta et al., 2016), which is comparable to coniferous forests (Komatsu et al., 2010; Ichihashi et al., 2015). Thus water status during the growing season is of vital importance to temperate bamboos (Kleinhenz and Midmore, 2001). Besides the works of Gratani et al. (2008) and Van Goethem et al. (2013a, 2013b, 2014) little work has been done on the ecophysiology

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of bamboos under the warm temperate climatic conditions of Europe. Also there are few research results related to the effect of water supply, specifically of drought on the physiology and performance of bamboos (Liu et al., 2014, 2015). Therefore the aim of the present study was to investigate the relationship between water supply and shoot and culm properties in the temperate bamboo *Phyllostachys iridescens*.

Review of literature

Phyllostachys is a temperate bamboo genus belonging to *Poaceae,* (subfamily *Bambusoideae,* tribe *Bambuseae,* subtribe *Shibataeinae*) and its species are mainly native in warm temperate regions of SE China (Yi et al., 2008; Ma et al., 2014) and since centuries they have additionally been grown in neighbouring countries including Korea and Japan (Zhengping and Stapleton, 2006), where they have become naturalised (Torii and Isagi, 1997; Kobayashi et al., 2015). Similarly to other monocarpic, monopodial genera of *Bambuseae* (Abe and Shibata, 2012, 2014; Matsuo et al., 2014) *Phyllostachys* are monocarpic, and reproduce mainly vegetatively (Isagi et al., 2016) from nodal shoots developing from the underground rhizome system (Ito et al., 2015) which comprises 39-57 % of the total biomass (Umemura and Takenaka, 2014). *Phyllostachys edulis (syn. P. pubescens)* is the most important species covering 30% of bamboo forests covering a total area of over 7,2 million hectares in China (Zhou et al., 2011; Kleinhenz and Midmore, 2001). *Phyllostachys* species are greatly versatile in their agricultural use, primarily used in forestry, the culms processed for wood industry purposes in Asia (Ma et al., 2014). The young developing culm shoots are harvested for both fresh market and for use as processed vegetables in food industry (Chongtham et al., 2011). Other bamboo applications include use in the form of bamboo charcoal as absorbent to treat drinking water (Mizuta et al., 2004), as a high yielding biofuel (Scurlock et al., 2000; Darabant et al., 2014), the leaves as forestry by-products used as food additives (Zhang et al., 2007) and traditionally prepared tea (Kim et al., 2012). In Asia some *Phyllostachys* taxa have long been used in phytotherapy (Chen and Chen, 2004) due to their phytochemical content (Hu et al., 2012; Tanaka et al., 2014) and antioxidant properties (Nagai et al., 2009; Neményi et al., 2014, 2015). *Phyllostachys* taxa are also important as ornamentals (Miwa and Hasegawa, 2007; Ma et al., 2014) including *P. iridescens* (Zhu et al., 1994). *P. iridescens* which is native in Zhejiang, Jiangsu, Anhui and widely introduced into many provinces is also used as vegetable and the culms for various farm implements and construction (Zhu et al., 1994). The natural distribution of bamboos is greatly affected by the amount and yearly distribution of precipitation (Biswas 1988; Qiu et al., 1992; Saha et al., 2009). Sufficient and evenly distributed precipitation during the spring-summer-autumn growing season is extremely important for bamboos (Kleinhenz and Midmore, 2001). Limited water availability leads to drought stress that greatly affects the growth and yield of crops in many places of the world (Lipiec et al., 2013; Bodner et al., 2015). The work of Kleinhenz et al. (2003) on the effects of irrigation and fertilization on *Phyllostachys edulis* growth and yield remains a standard reference. They reported that the growth and yield of shoots was substantially affected by soil water availability. They found that different irrigation rates exhibited tremendous differences in shoot yield, indicating that a steady water supply during the period of shoot development greatly benefits bamboo production. Their study revealed that investigating treatment effects on individual ramets is problematic, because the level of interconnectedness of the rhizome systems is unknown (Li et al., 2000), which makes the delineation of experimental plots problematic. Drought stress affected the photosynthetic carbon and nitrogen metabolism of dwarf bamboo *Fargesia rufa* which differently regulated its carbon and nitrogen metabolism to improve its capacity of osmotic adjustment and employed its metabolites to protect against membrane lipid peroxidation (Liu et al., 2015). Under the maritime warm temperate climatic conditions of Western Europe the work of Van Goethem et al. (2013a, 2013b, 2014) in Ireland and in South Europe that of Gratani et al. (2008) in Italy remains the basic bamboo physiology related research to date. To date there is no available research on the ecophysiology or performance of temperate bamboos under the continental warm temperate climate of Central Europe.

Materials and methods

Plant material and measurement of culm shoot longitudinal growth

The experiment was carried out in 2010, 2011 and 2012 on an experimental plot supervised by the Institute of Horticulture, Szent István University, Gödöllő (47°35′N, 19°21′E), Hungary, characterised by a continental temperate climate. The annual mean temperature is 9.4 C, the average annual precipitation is 590 mm. The experimental site is in a low hilly area, on a gentle south-western slope. Bamboo planting material (balled and burlapped), propagated by division (from 50 cm rhizome with 2 culms attached) from a single clone of *Phyllostachys iridescens*, were planted in September of 2009. Planting material was grouped in two sizes below 2 m height (1.5 m average) and above 2 m height (2.5 m average) the later marked as (XL). The two size plants were planted randomly in 3 rows at a spacing of 4 m between rows and plants, 20 and 10 plants per size (1.5 m and 2.5 m (XL) height respectively) treatment each. The experimental plot was on brown forest soil, composed of sand, sandy loam in texture consisted of 69% sand, 22% silt, and 9% clay, 1.57 g cm^{-3} bulk density, 19% field capacity, neutral in pH, free from salinity (0.16 dS m^{-1}) and low in organic carbon. Agroblen 2:1:1 N:P:K plus microelements inorganic 6 months slow release fertilizer was spread around the plants and worked in, during the end of March in each year. The plot was manually weeded and there was no need for plant protection. All plants were monitored for dates of shooting and culm shoot vertical growths were recorded every two-three days (Monday, Wednesday and Friday) during the shoot growing season in spring. Longitudinal growth measurements were carried out on individually tagged developing culm shoots using measuring rods in cm. The longitudinal growth measurements were carried out on individual culm shoots until their first true tip leaf developed. Also longitudinally non developing shoots were monitored until they were aborted and dried out. Culm diameter was measured in the middle of the first aboveground internode using a digital calliper.

Measurement of environmental parameters and irrigation

Air temperature (°C) and precipitation (mm) were recorded during the course of the experiment (*Fig. 1* and *Fig. 2*). Air temperature was measured every hour by

Campbell CR21X meteorological instrument with sensors (Campbell Scientific Inc. Loughborough, UK). From the randomly planted 20 and 10 plants per size (1.5 m and 2.5 m (XL) height respectively) treatment all XL plants were irrigated, while 10 plants of the smaller 1.5 m height planting material were irrigated, the remainder 10 were unirrigated control. Plants were irrigated between April 1 and November 1. Potential evapotranspiration (ET_0) was calculated from that used for other vegetable crops (Helyes and Varga, 1994; Helyes et al., 2015). Plants were irrigated to daily potential evapotranspiration. The amount of irrigation was estimated from expected daily average temperature divided by five expressed in millimetres (Eq.1). Calculation method of the amount of irrigation was based on weather forecasting data, corrected by the amount of precipitation. Temperature forecast of Hungarian Meteorological Service (http://www.met.hu/idojaras/elorejelzes) for every next two, two and three day intervals per week were used to calculate the daily potential evapotranspiration (ET_0).

$$I_d = \left(\frac{T_{\min} + T_{\max}}{2}\right) / 5 \qquad \text{(Eq.1)}$$

If precipitation covered the irrigation demand until the next irrigation date there was no irrigation, but if it was less than irrigation demand, the amount of ET_0 was supplied. Plants were irrigated by calculated amount of water on every Monday, Wednesday and Friday morning. Irrigation water was applied by drip irrigation. The spacing between the emitters was 0.3 m, with discharge rates of 4 Lh^{-1}.

Statistical analysis

Results were expressed as the average plus/minus standard deviations. The data were analysed by two-factor analysis of variance (ANOVA) with repetitions and the means separated using the LSD test at $p=0.05$ and for the regression analysis with Microsoft ® Excel 2007 Analysis Toolpack (Microsoft Corporation., Redmond, Washington).

Results

The change of minimum and maximum air temperature during the course of the vegetation period did not show much deviation between 2010-2012 and there were no air temperature extremes ($0>T^{o}C<40$) during above ground culm development (from end of April) during the three years *(Fig. 1)*.

The course of precipitation was different when comparing the three years, 2010 being one of the rainiest years in 70 years while both 2011 and 2012 produced well below the average rainfall which affected the unirrigated plants. Drought was most pronounced between the beginning of April and end of May, spring being the main culm shooting season in both years and again from the end of July until the end of October especially in 2011 (*Fig. 2*).

Regarding the annual change of developed culm shoot numbers, significant differences were observed between the unirrigated control and irrigated treatments in 2011 and 2012, while there was no significant difference in the extremely wet year of 2010 in the number of newly recruited shoots per year (*Fig. 3*).

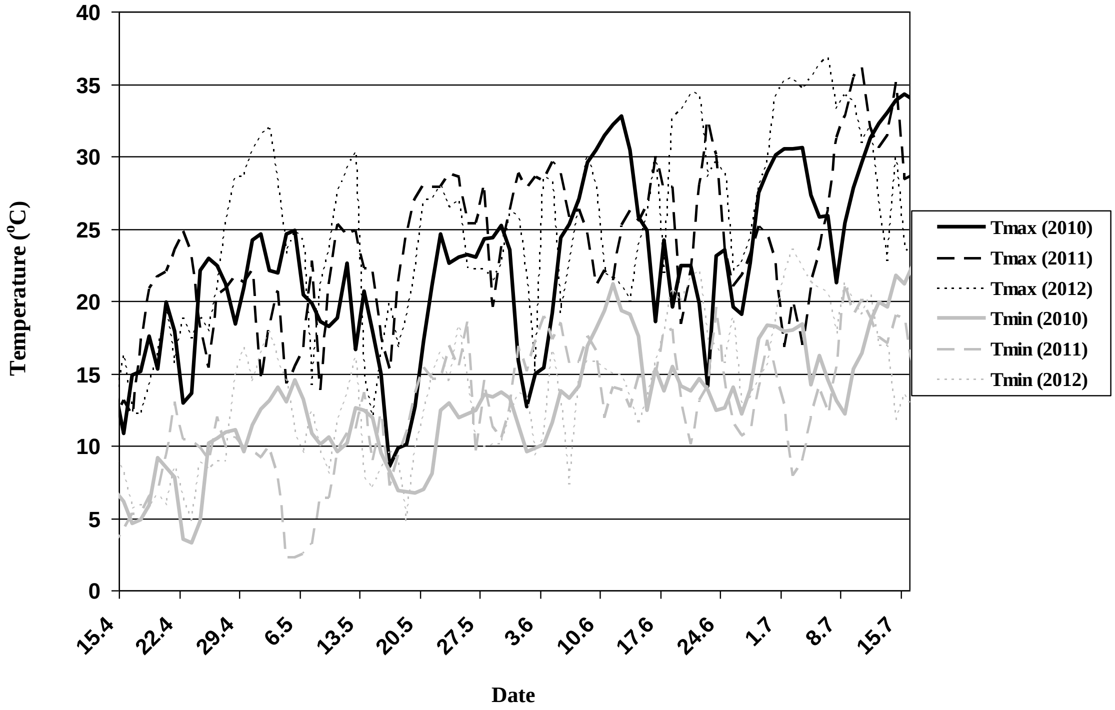

Figure 1. *Change in air temperature (daily minimum and daily maximum temperature) during the shoot growing period of the examined years of 2010-2012.*

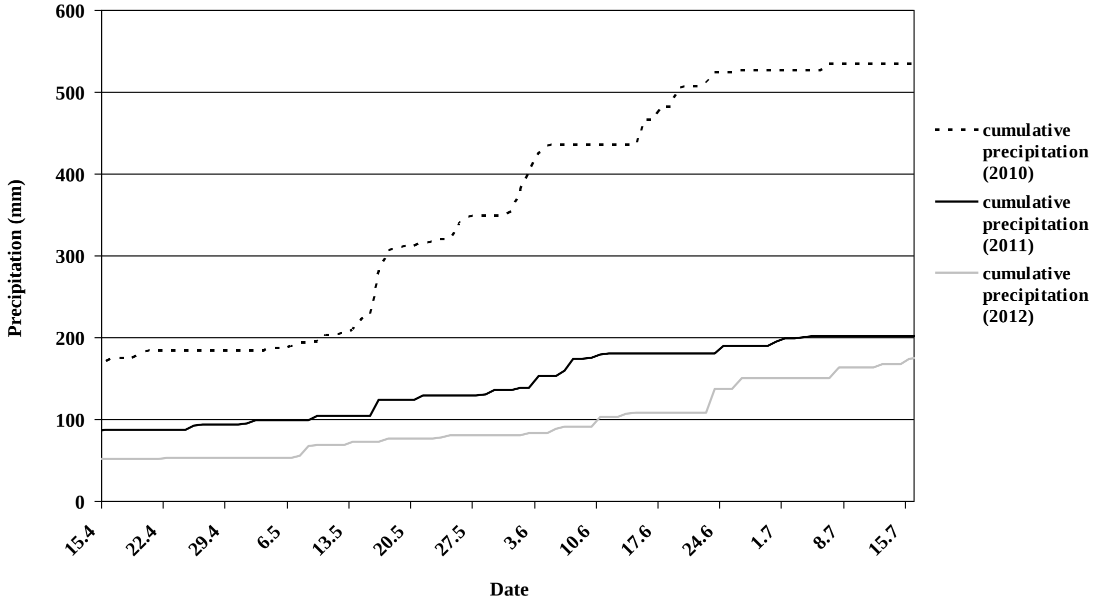

Figure 2. *Course of cumulative precipitation during the shoot growing period of the examined years of 2010-2012.*

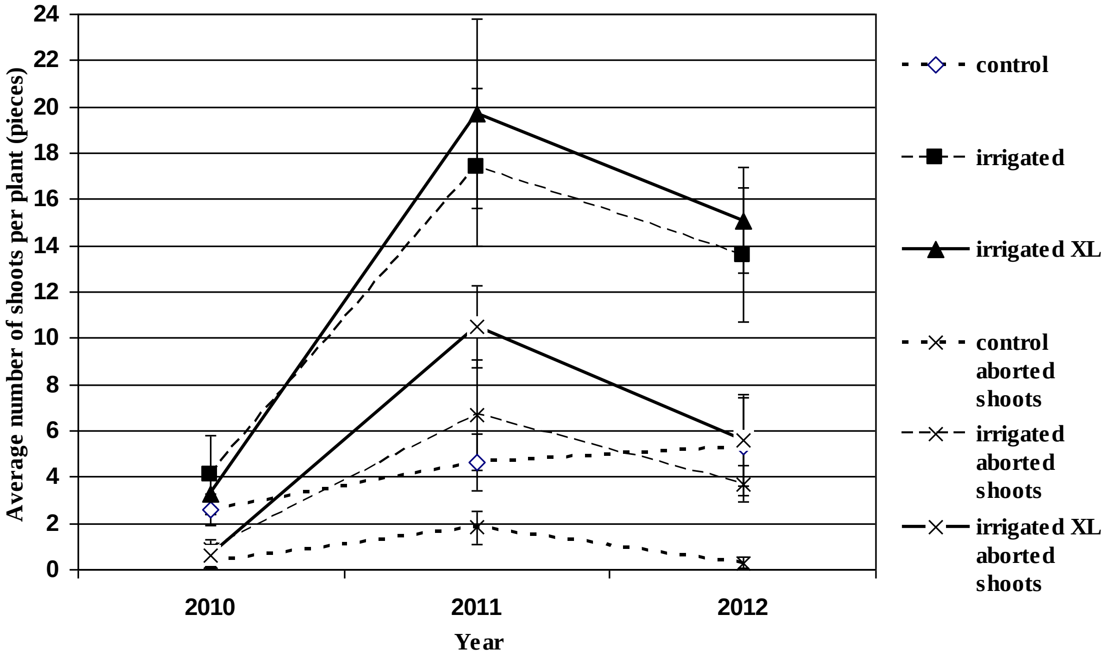

Figure 3. *Change of shoot number in irrigated and unirrigated (control) plants of normal and extra size (XL) during the examined years of 2010-2012.*

In the unirrigated control treatment there was no significant difference between years in the number of shoots that developed into culms. A four times higher shoot number (74% and 77% rise in irrigated and irrigated XL treatments respectively) was observed in 2011 compared to the unirrigated control. In 2012 the difference was almost three fold (62% and 65% rise in irrigated and irrigated XL treatments respectively) compared to the unirrigated control. The above tendency was true for the number of aborted shoots that did not develop into culms. The difference was three to five fold (74% and 83% rise in irrigated and irrigated XL treatments respectively) in 2011 while in 2012 a 94% and 96% rise was evident in irrigated and irrigated XL treatments respectively compared to the control. But there was no significant difference between the two irrigated size treatments (XL) in the number of aborted shoots in either of the examined years. We can summon from the above that around one quarter to one third of all the new shoots aborted regardless of water availability during all three years. Regarding the size at which shoots aborted in the irrigated treatments, it can be seen from *Fig. 4* that the average size of aborted shoots increased (by 34%) over the years, but this difference was not significant.

It is clear from the three years data that aborted shoots that do not develop into culms are of 14-21 cm average size.

There was no significant difference in height of new culms produced in 2010 regardless of planting size (XL) or irrigation treatment as can be seen on *Fig. 5*. Compared to culm height values of 2010 culm height started to rise in 2011 regardless of water availability or plant size (XL).

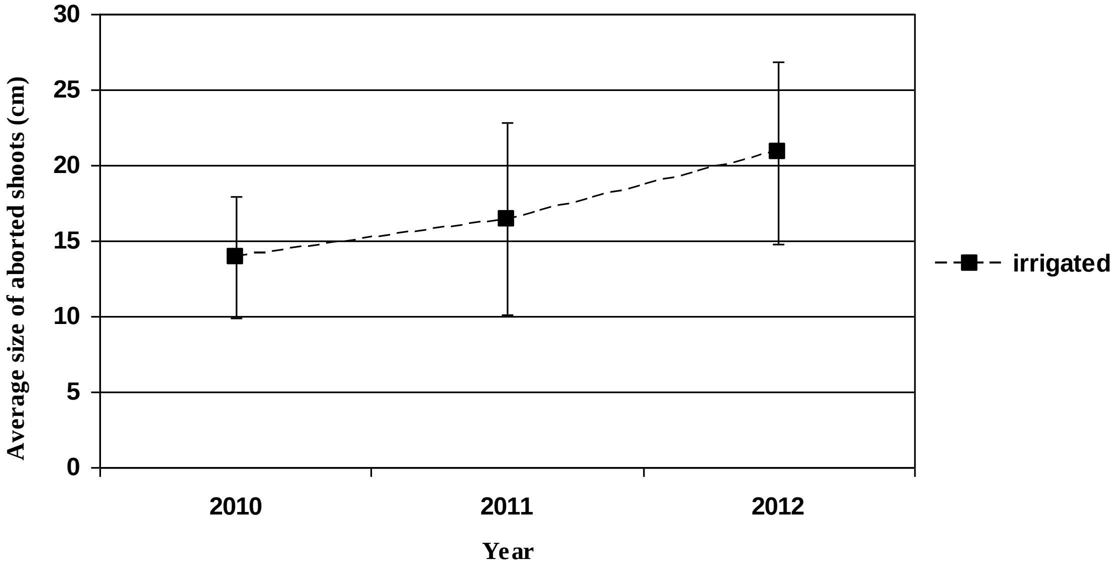

Figure 4. *Annual change in the average size of aborted shoots.*

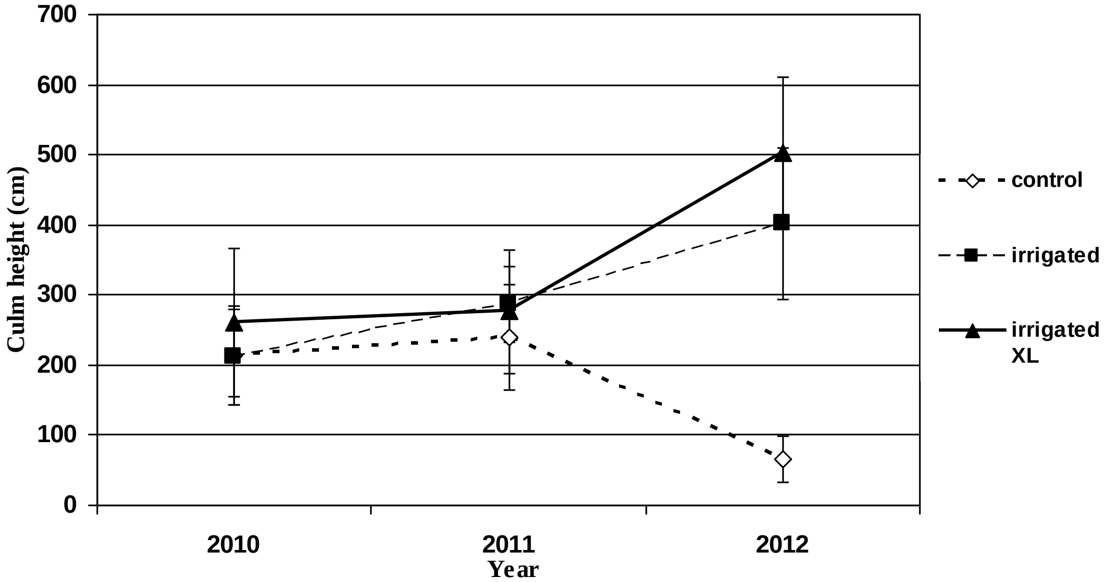

Figure 5. *Annual change in average culm height in unirrigated and irrigated plants.*

The 12 to 24% rise in culm height in 2011 compared to 2010 was not significant. In 2012 the irrigated treatments gave significantly different results compared to the unirrigated control. Compared to 2011 there was a 29 % to 43% rise in culm height in 2012 in both irrigated size treatments (XL) respectively. The difference between the two irrigation size treatments (XL) was not significant. While in the unirrigated control a 71% decrease was observed, which difference was also significant compared to the 2011 value. Culm diameter changed similarly to culm height over the examined years (*Fig. 6*).

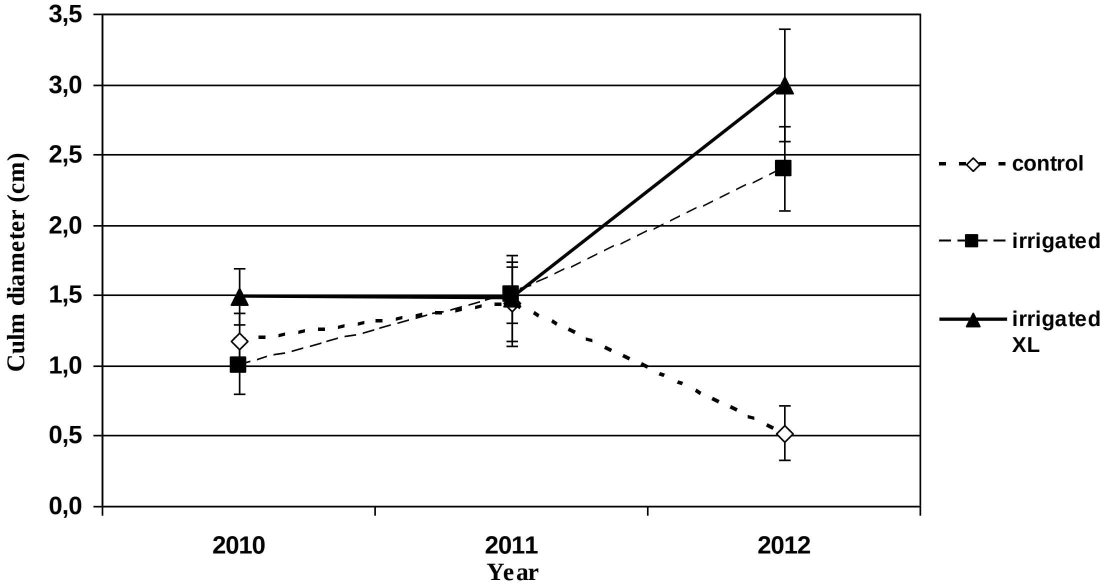

Figure 6. *Annual change of average culm diameter in unirrigated and irrigated plants.*

When comparing culm diameter values of 2010, there is no significant difference between irrigated and unirrigated plants or initial planting size treatment (XL). Culm diameter started to rise in new culms produced in 2011 except in the larger planting stock (XL) plants and this rise was regardless of water availability. In 2011 up to 32% rise in culm diameter was observed compared in to 2010 but none of the differences were significant. Compared to the unirrigated control and the values of 2011, irrigated treatments gave significantly different results in 2012. There was a 36 to 49% rise in culm diameter in 2012 in both irrigated size treatment (XL) respectively. The difference between the two irrigation size treatments (XL) was not significant just like in the case of culm height. Theunirrigated control produced declining values and a 67% decrease was observed, which difference was also significant compared to the 2011 value. Again there was no significant difference between the two irrigated size treatments (XL).

Since there was such a similarity in tendency of change between the parameters of culm height and culm diameter (*Fig. 5* and *Fig. 6*), we investigated the relationship between the two factors (*Fig. 7*).

To investigate the relationship between culm diameter and culm height a regression analysis was carried out (*Fig. 7*). The equation describing the relation is $y= -11.606x^2+199.15x+11.642$ ($r^2=0.909$). From this we can conclude that there is a strong positive relation between culm diamater and culm height in *P. iridescens*.

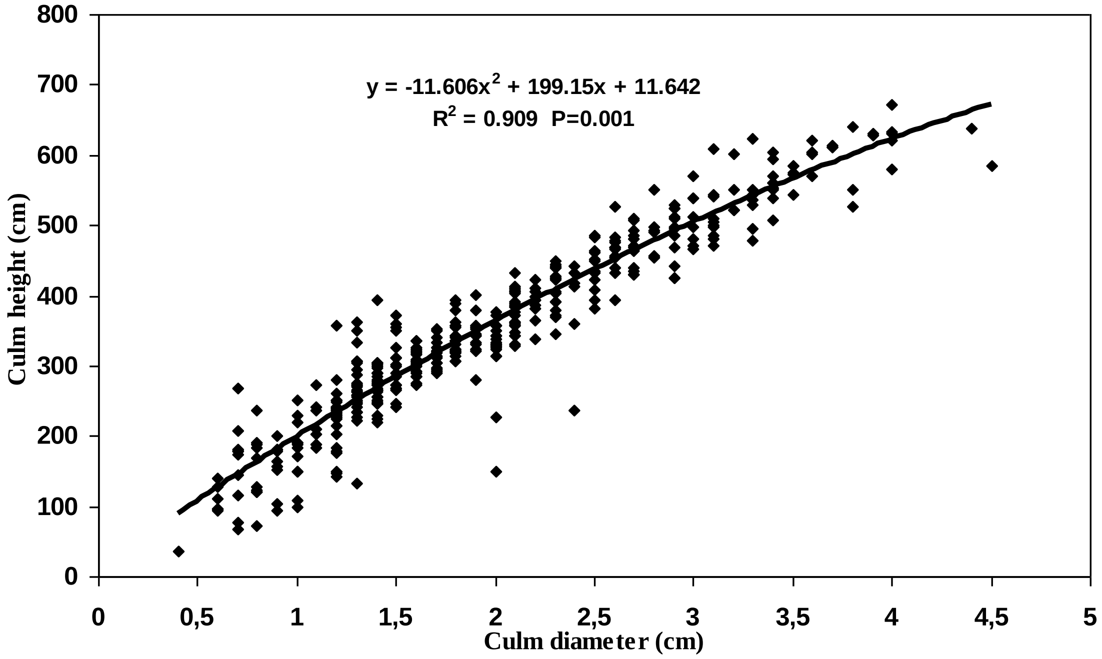

Figure 7. *Relationship between culm height and culm diameter (2010-2012)*

Discussion

As stated by Liu et al. (2014 and 2015) there is little research related to water supply, and effect of drought in bamboos. In a three year experiment with other monocotyledonous plants (*Miscanthus giganteus*, F1 hybrid of *Saccharum hybrid x Miscanthus spp.* and *Arundo donax*) Burner et al. (2015) report a significant increase in dry matter yield in irrigated plants compared to rainfed plants.

Our findings regarding decreasing shoot numbers in controlunirrigated plants are underlined by Kleinhenz et al. (2003) who have reported that without irrigation during the shooting period (76-237 mm precipitation/year/two months) of *P. edulis*, growth was only better in an area where underground water from an adjacent pond was available. The considerably lower (77 and 82 % respectively) number of shoots in 2010 compared to 2011 and 2012 is a result of plant establishment, since the bamboos were planted out in 2009 and the smaller unextended and underdeveloped rhizome and the remaining culm and canopy system was not able to support a larger number of shoots as reported in the trials by Gielis (2012) with other bamboo species. Our results from 2010 which show that there was no significant difference between irrigated andunirrigated plants is due to the fact that 2010 was the rainiest year in the past 70 years, thus providing sufficient precipitation for the controlunirrigated plants. Both 2011 and 2012 were years characterised by low precipitation and longer periods with no or little rain which is clearly reflected in the significant differences in new shoot numbers between irrigated andunirrigated plants.

In our experiment we also observed that only around one quarter to one third of new shoots aborted while Li et al. (2000) have reported that 75-80% of shoots in *P. edulis* have aborted every year, without much yearly variation. While Ura et al. (2011) have shown that there is yearly variation in the percentage of aborted shoots depending on bumper (higher) or poor culm yield (lower) year. The difference in results compared to

Li et al. (2000) is in part probably due to inter-specific differences in vegetative characteristics of the observed two species, since *P. iridescens* is of medium culm diameter (4-7cm) and culm height (6-12m), while *P. edulis* is a large culm diameter (up to 20 cm) and culm height (up to 20m and more) species (Zhengping and Stapleton, 2006; Yi et al., 2008; Ma et al., 2014). The difference might also be attributed to different methodology since in the reports of Li et al. (1998) the non-developing shoots, stagnating in height were harvested as vegetables, while in our experiment new shoots were classified as aborted only after they have completely withered and dried out.

A ten fold increase in the number of culms 54 ± 8 (fully developing shoots in our case) has been reported by Piouceau et al. (2014) in a one year experiment in optimal irrigated plants of *P. aurea* grown under tropical climatic conditions, which is partly comparable to our findings with *P. iridescens* if we add up the total number of new shoots developing into culms (*Figure 3.*) for the three experimental years being 36-38 ± 4,4. The differences compared to our results are possibly due to inter-specific morphological differences (Zhengping and Stapleton, 2006; Yi et al., 2008; Ma et al., 2014) and the fact that our experiment was conducted under temperate climatic conditions. Also our initial planting material consisted of less developed propagating material with 2 culms each, while the planting material of *P. aurea* used by Piouceau et al. (2014) was more developed with 5,7 ± 2,3 culms per plant. Also results comparable to our findings were reported by Liu et al. (2014) where plants of dwarf bamboo *Fargesia denudata* subjected to moderate or severe drought stress exhibited a 42-51 % decrease in number of new shoots compared to irrigated treatment.

Our results which indicate that some of the culm shoots abort at an early stage in their development with a relatively small size (14-21cm +/- 6,4 cm) during all three years is in agreement with the results of Li et al. (1998) in *Phyllostachys edulis,* who have stated that in some shoots growth stagnates at an early stage, when the shoots are up to a few cm or dm tall and show symptoms of dying.

The lack of significant differences in culm heights and diameters irrespective of water supply in the first two experimental years (2010-2011) can be explained by the fact that internode number (thus culm height) is determined at a very early stage of shoot bud development (Ueda, 1960). So culm height was thus predetermined for new culms of 2010 in the fall of 2009 when all plants were irrigated to enhance rooting and establishment and during fall of 2010 characterised by record high precipitation for new culms of 2011. But because the vegetation period including fall of 2011 was characterised by drought, this had a drastic effect on culm height of new shoots of 2012.

The lower height of new culms of irrigated plants in 2010 and 2011 (41 to 67% and 29 to 43% respectively) compared to 2012 is again just as regards to shoot number possibly a result of plant development from a smaller rhizome system, culms and canopy which were not able to support the development of higher culms in the first two years as reported by Gielis (2012) with other bamboo species. In an experiment Piouceau et al. (2014) report only a 15% increase in culm height in irrigated plants of *P. aurea* grown under tropical climatic conditions. The differences compared to our results are possibly due to the fact that *P. aurea* is only a smaller (5-12 m) culm height species (Zhengping and Stapleton, 2006; Yi et al., 2008; Ma et al., 2014) and to the fact that the experiment of Piouceau et al. (2014) was only a one year trial. Also comparable results are presented by Liu et al. (2014) where a 26-36 % decrease in plant height compared to irrigated plants of dwarf bamboo *Fargesia denudata* subjected to moderate or severe drought stress was observed.

The smaller culm diameter in irrigated plants of 2010 and 2011 (66 % and 36 to 49 % respectively) compared to 2012 is also a sign of plant establishment as reported for other bamboo species by Gielis (2012). As in the case of culm height the report of Piouceau et al. (2014) give only a 26% increase in culm diameter after one year in optimal irrigated plants of *P. aurea* grown under the tropical climate of Reunion Island. The difference compared to our results again as in the case of culm height could possibly arise due to climatic and inter-specific morphological differences, since *P. aurea* is only characterised by a smaller (2-5 cm) culm diameter (Zhengping and Stapleton 2006; Yi et al., 2008; Ma et al., 2014) and also the difference in the time duration of the experiments.

The strong correlation that we found between culm diameter and culm height in *P. iridescens*, has also been reported in other *Phyllostachys* species, in the case of *P. bambusoides* (Ueda, 1960; Inoue et al., 2013), *P. nigra var. henonis* (Inoue et al., 2013) and for *P. edulis* (Ueda, 1960; Suga et al., 2011; Inoue et al., 2013; Gao et al., 2016).

Our results clearly show that there was no significant difference between the two size planting material, during the three years, therefore the use of larger planting material was not justifiable, since it did not produce significantly more or higher and larger diameter culms under irrigated conditions. Our findings also show that *Phyllostachys iridescens* is sensitive to drought stress during the growing season and should not be planted in plots with soils of low water holding capacity or where the subsoil watertable is too deep to influence plant water uptake, under temperate climatic conditions subjected to drought during the vegetation season.

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REFERENCES

[1] Abe, Y., Shibata, S. (2012): Spatial and temporal flowering patterns of the monocarpic dwarf bamboo *Sasa veitchii var. hirsuta*. - Ecological Research 27: 625-632.

[2] Abe, Y., Shibata, S. (2014): Flower and seed production in a series of flowerings from sporadic events before to after mass flowering of the dwarf bamboo *Sasa veitchii var hirsuta*. - Journal of Forest Research 19: 268-275.

[3] Abe, Y., Shibata, S. (2014): Seed germination and seedling establishment of the monocarpic dwarf bamboo *Sasa veitchii var hirsuta*. - Journal of Forest Research 19: 166-173.

[4] Biswas, S. (1988): Studies on bamboo distribution in north-eastern region of India. - Indian Forester 114: 514-531.

[5] Bodner, G., Nakhforoosh, A., Kaul, H.-P. (2015): Management of crop water under drought: a review. - Agronomy for Sustainable Development 35: 401-442.

[6] Burner, D.M., Hale, A.L., Carver P., Pote, D.H., Fritschi, F.B. (2015): Biomass yield comparisons of giant miscanthus, giant reed, and miscane grown under irrigated and rainfed conditions. - Industrial Crops and Products 76: 1025-1032.

[7] Chen, J.K., Chen, T.T. (2004): Chinese Medical Herbology and Pharmacology. - Art of Medicine Press, City of Industry.

[8] Chongtham N., Bisht, M.S., Haorongbam, S. (2011): Nutritional properties of bamboo shoots: Potential and prospects for utilization as a health food. - Comprehensive Reviews in Food Science and Food Safety 10(3): 153-169.

[9] Darabant, A., Haruthaithanasan, M., Atkla, W., Phudphong, T., Thanavat, E., Haruthaithanasan, K. (2014): Bamboo biomass yield and feedstock characteristics of energy plantations in Thailand. - Energy Procedia 59: 134-141.

[10] Gao, X., Li, Z., Yu., H., Jiang, Z., Wang, C., Zhang, Y., Qi., L., Shi, L. (2016): Modeling of the height-diameter relationship using an allometric equation model: a case study of stands of *Phyllostachys edulis*. – Journal of Forest Research 27(2): 339-347.

[11] Gielis, J. (2012): Future possibilities for bamboo in European agriculture. Bamboo Thematic Network, http://www.bamboonetwork.org/downloads/gielis01.pdf

[12] Gratani, L., Crescente, M.F., Varone, L., Fabrini, G., Digiulio, E. (2008): Growth pattern and photosynthetic activity of different bamboo species growing in the Botanical Garden of Rome. - Flora 203: 77-84.

[13] Helyes, L., Nagy, Zs., Daood, H., Pék, Z., Lugasi, A. (2015): The simultaneous effect of heat stress and water supply on total polyphenol content of eggplant. - Applied Ecology and Environmental Research 13(2): 583-595.

[14] Helyes, L., Varga, Gy. (1994): Irrigation demand of tomato according to the results of three decades. - Acta Horticulturae 376: 323-328.

[15] Hu, C., Xu, D., Chen, H., Yuan, K. (2012): Contents of the total flavonoids and the total phenols and antioxidant activities in the leaf from different species of *Phyllostachys*. - Advanced Materials Research 343-344: 1103-1108.

[16] Hungarian Meteorological Service. 2010-2012. Temperature forecast of Gödöllő. http://www.met.hu/idojaras/elorejelzes

[17] Ichihashi, R., Komatsu, H., Kume, T., Onozawa, Y., Shinohara, Y., Tsuruta, K., Otsuki, K. (2015): Stand-scale transpiration of two Moso bamboo stands with different culm densities. – Ecohydrology 8: 450-459.

[18] Inoue, A., Sakamoto, S., Suga, H., Kitazato, H., Sakuta, K. (2013): Construction of one-way volume table for the three major useful bamboos in Japan. – Journal of Forest Research 18(4): 323-334.

[19] Isagi, Y., Oda, T., Fukushima, K., Lian, C., Yokogawa, M., Kaneko, S. (2016): Predominance of a single clone of the most widely distributed bamboo species *Phyllostachys edulis* in Asia. - Journal of Plant Research 129: 21-27.

[20] Ito, R., Miyafuji, H., Kasuya, N. (2015): Rhizome and root anatomy of moso (*Phyllostachys pubescens*) observed with scanning electron microscopy. - Journal of Wood Science 61:431-437.

[21] Kim, S. M., Jeon, J.-S., Kang, S.-W., Kim, W.-R., Lee, K.-D., Um, B.-H. (2012): Composition analysis and antioxidant activity of ojuk (*Phyllostachys nigra* Munro) leaf tea and shoot tea. - Journal of Applied Biological Chemistry 55: 95-101.

[22] Kleinhenz, V., Midmore, D.J. (2001): Aspects of bamboo agronomy. - Advances in Agronomy 74: 99-145.

[23] Kleinhenz, V., Milne, J., Walsh, K.B., Midmore, D.J. (2003): A case study on the effects of irrigation and fertilization on soil water and soil nutrient status, and on growth and yield of bamboo (*Phyllostachys pubescens*) shoots. - Journal of Bamboo and Rattan, 2(3): 281-293.

[24] Kobayashi, T., Fukushima, K., Hisamoto, Y., Inoue, A. (2015): The species biology of bamboos in Japan: from gene to landscape. – Plant Species Biology 30: 42-44.

[25] Komatsu, H., Onozawa, Y., Kume, T., Tsuruta, K., Kumagai, T., Shinohara, Y., Otsuki, K. (2010): Stand-scale transpiration estimates in a Moso bamboo forest: II. Comparison with coniferous forests. – Forest Ecology and Management 260: 1295-1302.

[26] Komatsu, H., Onozawa, Y., Kume, T., Tsuruta, K., Shinohara, Y., Otsuki, K. (2012): Canopy conductance, for a Moso bamboo (*Phyllostachys pubescens*) forest in Western Japan. – Agricultural and Forest Meteorology 156: 111-120.

[27] Li, R., Werger, M.J.A., De Kroon, H., During, H.J., Zhong, Z.C. 2000. Interaction between shoot age structure, nutrient availability and physiological integration in the giant bamboo *Phyllostachys pubescens*. - Plant Biology 2(4): 437-446.

[28] Li, R., Werger, M.J.A., During, H.J., Zhong, Z.C. (1998): Biennial variation in production of new shoots in groves of the giant bamboo *Phyllostachys pubescens* in Sichuan, China. -- Plant Ecology, 135: 103-112.

[29] Lipiec, J., Doussan, C., Nosalewicz, A., Kondracka, K. (2013): Effect of drought and heat stresses on plant growth and yield: a review. - International Agrophysics 27: 463-477.

[30] Liu, C., Wang, Y., Pan, K. (2014): Carbon and nitrogen metabolism in leaves and roots of dwarf bamboo (*Fargesia denudata* Yi) subjected to drought for two consecutive years during sprouting period. - Journal of Plant Growth Regulation 33: 243-255.

[31] Liu, C., Wang, Y., Pan, K., Jin, Y., Liang, J., Li, W., Zhang, L. (2015): Photosynthetic carbon and nitrogen metabolism and the relationship between their metabolites and lipid peroxidation in dwarf bamboo (*Fargesia rufa* Yi) during drought and subsequent recovery. - Trees 29: 1633-1647.

[32] Ma, N., La, G., Yang, L. (2014): The genus *Phyllostachys* in China. - Zhejiang Science and Technology Publishing House, Hangcsou.

[33] Matsuo, A., Tomimatsu, H., Suzuki, J.-I., Saitoh, T., Shibata, S., Makita, A., Suyama, Y. (2014): Female and male fitness consequences of clonal growth in a dwarf bamboo population with a high degree of clonal intermingling. - Annals of Botany 114: 1035-1041.

[34] Miwa, T., Hasegawa, J. (2007): Establishment of roofgarden with *Phyllostachys pubescens* at Kyoto Station Building. - Journal of the Japanese Society of Revegetation Technology 33(1): 300-302.

[35] Mizuta, K., Matsumoto, T., Hatate, Y., Nishihara, K., Nakanishi, T. (2004): Removal of nitrate-nitrogen from drinking water using bamboo powder charcoal. - Bioresource Technology 95: 255-257.

[36] Nagai, T., Suzuki, N., Tanoue, Y., Kai, N., Nagashima, T. (2009): Antioxidant activities of the extracts from bamboo powder as underutilized resource. - Journal of Food, Agriculture and Environment 7: 228-232.

[37] Neményi, A., Stefanovitsné-Bányai, É., Burján, Sz. Sz., Pék, Z., Hegedűs, A., Gyuricza,, Cs., Helyes, L. (2014): Seasonal variations in total antioxidant capacity and total phenolics content of leaves of *Phyllostachys* taxa using different extraction methods. - Notulae Botanicae Horti Agrobotanici Cluj-Napoca 42(1): 43-50.

[38] Neményi, A., Stefanovitsné-Bányai, É., Hegedűs, A., Gyuricza,, Cs., Barócsi, Z., Helyes, L. (2015): Total antioxidant capacity and total phenolics content of shoots of *Phyllostachys* taxa. - Notulae Botanicae Horti Agrobotanici Cluj-Napoca 43(1): 64-69.

[39] Piouceau, J., Panfili, F., Bois, G., Anastase, M., Dufossé, L., Arfi, V. (2014): Actual evapotranspiration and crop coefficients for five species of three-year-old bamboo plants under a tropical climate. - Agricultural Water Management 137: 15-22.

[40] Potters, G., Schutte, F., Van Goethem, D., De Nollin, S., Samson, R., Gielis, J. (2013): Bamboo as a crop in western europe - A swot analysis. - Acta Horticulturae 1003: 89-96.

[41] Qui, G.-X., Shen, Y.-K., Li, D.-W., Wang, Z.-W., Huang, Q.-M., Yang, D.-D., Gao, A.-X. (1992): Bamboo in sub-tropical Eastern China, in: Primary Productivity of Grass Ecosystems of the Tropics and Sub-tropics. Long, S.P., Jones, M.B., Roberts, M.J. (Eds), - Chapman and Hall, London.

[42] Saha, S., Holbrook, N.M., Montti, L., Goldstein, G., Cardinot, G.K. (2009): Water relations of *Chusquea ramosissima* and *Merostachys claussenii* in Iguazu National Park, Argentina. - Plant Physiology 149: 1992-1999.

[43] Scurlock, J.M.O., Dayton, D.C., Hames, B. (2000): Bamboo: an overlooked biomass resource? - Biomass and Bioenergy 19: 229-244.

[44] Suga, H., Inoue, A., Kitahara, F. (2011): Derivation of two way volume equation for bamboo, *Phyllostachys pubescens*. - Journal of Forest Research 16: 261-267.

[45] Tanaka, A., Zhu, Q., Tan, H., Horiba, H., Ohnuki, K., Mori, Y., Yamauchi, R., Ishikawa, H., Iwamoto, A., Kawahara, H., Shimizu, K. (2014): Biological activities and phytochemical profiles of extracts from different parts of bamboo (*Phyllostachys pubescens*). - Molecules 19: 8238-8260.

[46] Torii, A., Isagi, Y. (1997): Range expansion of bamboo species in southern areas of Kyoto Prefecture, Japan. – Japanese Journal of Ecology 47(1): 31-41.

[47] Tsuruta, K., Okumura, M., Kume, T., Ichihashi, R., Shinohara, Y., Kosugi, Y. (2016): Insignificant effects of culm age on transpiration in a managed Moso bamboo forest, Kyoto, Japan. - Hydrological Research Letters 10(1): 1-7.

[48] Ueda, K. (1960): Studies on the physiology of bamboo, with reference to practical application. - Bulletin of the Kyoto University Forests. 30: 1-169.

[49] Ueda, M.U., Tokuchi, N., Ogawa, R. (2009): High nitrate reductase activity in sprouts of *Phyllostachys pubescens*. - Journal of Forest Research 14: 55-57.

[50] Umemura, M., Takenaka, C. (2014): Biological cycle of silicon in moso bamboo (*Phyllostachys pubescens*) forests in central Japan. – Ecological Research 29: 501-510.

[51] Ura, M., Teraoka, Y., Takeuchi, I. (2011): The generation of undeveloped bamboo sprouts after strip cutting in an unmanaged Moso bamboo (*Phyllostachys pubescens*) stand. – Research Bulletin of the Kagoshima University Forests 38: 13-17.

[52] Van Goethem, D., De Smedt, S., Valcke, R., Potters, G., Samson, R. (2013): Seasonal, diurnal and vertical variation of chlorophyll fluorescence on *Phyllostachys humilis* in Ireland. - PLoS ONE 8(8): E72145.

[53] Van Goethem, D., Ooms, A., Bogaerts, L., Jespers, E., Klimina, I., Samson, R., O'Connor, D., O'Connell, P., De Nollin, S., Potters, G. (2013): Bamboo growth under Irish skies: Pushing the limits of a sturdy plant. - Acta Horticulturae 1003: 83-88.

[54] Van Goethem, D., Potters, G., De Smedt, S., Gu,, L., Samson, R. (2014): Seasonal, diurnal and vertical variation in photosynthetic parameters in *Phyllostachys humilis* bamboo plants. - Photosynthetic Research 120: 331–346.

[55] Yi, T., Shi, J., Ma, L., Wang, H., Yang, L. (2008): Iconographia Babusoidearum Sinicarum. - Science Press, Beijing.

[56] Zhang, Y., Xu, W., Wu, X., Zhang, X., Zhang, Y. (2007): Addition of antioxidant from bamboo leaves as an effective way to reduce the formation of acrylamide in fried chicken wings. - Food Additives and Contaminants 24: 242-251.

[57] Zhengping, W. and Stapleton, C. (2006): 34. *Phyllostachys*. In: Flora of China Editorial Commitee, Zhengi, W. and Raven, P. (eds): Flora of China. *Poaceae*. Vol. 22. - Missouri Botanical Garden Press and Science Press, Beijing.

[58] Zhou, G., Meng, C., Jiang, P., Xu, Q. (2011): Review of carbon fixation in bamboo forests in China. - Botanical Review 77: 262-270.

[59] Zhu, S., Ma, N., Fu, M. (1994): A compendium of Chinese bamboo. - China Forestry Publishing House, Beijing.