SMALL-PLOT EXPERIMENTS WITH GRADED CHINESE SILVER GRASS (*MISCANTHUS SINENSIS*) RHIZOMES

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Abstract. Different categories of rhizomes, graded by length and bud number, were studied in small-plot experiments with and without irrigation, and finally the percentage of emerged and growing Miscanthus plants was evaluated. Pre-emergence irrigation under the given weather conditions accelerated shoot emergence and improved the homogeneity and reliability of the process but by June the initially observed salient differences practically disappeared and no statistically significant difference could be identified between plots that had been and those that had not been irrigated. In the case of rhizomes 'A' and rhizomes 'B' an over 97% and an over 86% crop density was found, respectively. The number of shoots per plant was regularly counted and evaluated during the growing season. Our findings prove that the grading of the rhizomes after their mechanised cutting and lifting, which results in a significant increase in the costs of the production of the propagating material, does not entail a statistically significant advantage in terms of the density of the Miscanthus population, if there is sufficient rainfall during the growing season.
Keywords: *Chinese silver grass, rhizome, biomass, alternative energy*

Introduction

Findings of research projects and surveys conducted in recent years across the world show that the economies relying on fossil energy sources are not sustainable (Atkinson, 2009). The most crucial issues of the 21st century will therefore include those relating to the quality of soil, water and air, to energy as well as the availability and accessibility of these. Consequently, the fate of a country with geopolitical and natural conditions and resources similar to those available in Hungary depends heavily on how it manages to replace the economic model based on conventional energy sources with an alternative economic model. Energy saving and energy efficiency and the increased utilisation of renewable energy sources as well as increased reliance on the country's own resources are crucial elements of an economic model laying down the groundwork for a sustainable future. The key strategic objectives of the energy policies of Hungary and those of the EU include optimising the combined accomplishment of the safety of supplies, competitiveness and sustainability as primary goals with a view to long term considerations as well. The Renewable Energy Roadmap worked out on the basis of the EU's energy and climate package sets out a goal of a 20% share of renewable energy sources – including 10% utilised in the transport sector – along with a 20%

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improvement in energy efficiency and a reduction of the emission of greenhouse gases to 20% of the 1990 emission level, by 2020.

At present some 40% of Hungary's energy consumption is based on natural gas (Tóth, 2004). Some 37% of the power output is generated in the nuclear power plant of Paks (Bíró, 2010). A total of 80% of the natural gas consumed in Hungary is imported, the bulk of which comes from Russia. The amount of imported energy may be reduced by improving the efficiency of consumption and by replacing imports with alternative energy sources. The respective shares of a number of renewable energy sources can be increased in Hungary but the greatest potential lies in the use of biomass (Csoknyai, 2007; Percze et al., 2009). The advantages of using biomass as an energy source include not only the fact that it is produced locally and that the energy stored in it can be used at any time but also that it is 'carbon neutral' in that it does not increase – to any considerable degree, at any rate – the presence of greenhouse gases (Lukács, 2009).

Research and experiments on the possibilities of the utilisation of annual herbaceous grass species by the energy sector have been underway since the mid-eighties in Europe and in the USA. In the USA an indigenous plant the perennial switchgrass (Panicumvirgatum), while in Europe the various Chinese grasses (Miscanthus spp.) have been found to be suitable for this purpose (Behnke et al., 2012). The yields of Chinese grasses depend primarily on the amount of available water while those of switchgrass are affected primarily by the soil's nitrogen supply (Lewandowski et al., 2003; Wang et al., 2012). Comparisons of the two plant species have shown that Miscanthussinensis is primarily the species that can be most economically grown thus research in Europe has come to be focused on this single species, which is becoming an increasingly popular energy crop (Heaton et al., 2004).

Miscanthus sinensisis intended to be produced primarily for the purpose of generating energy in the future, therefore it will be utilised for the most part by the burning of the dry parts of the plant to produce domestic hot water, steam and electricity. The energy content of the dry matter of *Miscanthus sinensis*is 18 MJ/kg, accordingly, the calorific value of the biomass produced on one hectare of land (20 tonnes) equals that of 12 tonnes of black coal or 8,000 litres of oil (Fogarassy, 2001). The basis production of this grass in large volumes is the elaboration of a production technology that is successful in Hungary and that can be adapted to different sites (Pósa et al., 2009; Percze et al., 2009).

Our research has shown that the Chinese silver grass is not particularly exacting in terms of soil quality, i.e. it can be successfully grown in areas of less favourable conditions or in places that are subject to periodical water pressure (de Souza et al. 2013). Its water requirement is similar to that of maize: 500-600 mm/year. The plant's seeds are sterile, therefore it can only be propagated by vegetative means (using small plants or rhizomes). The development of an adequate crop stand is facilitated by good tillage, optimum timing of planting (end-March to mid-May) and the use of high quality propagating material. It is more difficult, however, to ascertain the quality of rhizomes as a propagating material than that of sowing seeds. According to literature the most important parameters of rhizome quality include length and bud number (Ubierna et al., 2013). Propagating material can be produced manually, which is a labour-intensive and time consuming process whereby the amount of propagation material that can be produced is strongly limited but the output is more standardised in terms of rhizome size. In the course of the mechanised lifting of the rhizomes some problem may arise from the heterogeneity of the sizes of the rhizomes, while the subsequent grading substantially increases the costs of production (Pósa et al., 2011).

According to international literature on the subject the rhizome size that is suitable for planting is between 10 and 15 cm, but, as has been explained, producing rhizomes of this size entails substantial additional costs.

In an experiment set up by the Crop Production Institute of the University of Gödöllő we compared two different lots of propagating materials – of different parameters but originating from the same site after identical treatments – with and without irrigation.

Materials and methods

The experiments were set up at Gödöllő in 2011 in a random block arrangement, in a sandy loam soil of favourable water transport characteristics, of PH_{KCl}:6,12, K_A: 29 and 1.28 % humus content. 6-10 cm long rhizomes with 5 buds each (A) were compared in a small plot experiment (3 m^2/plot) to rhizomes 3-5 cm in length with not more than 3 buds each (B), with irrigation (W) and without irrigation (NW), in three iterations. The rhizomes were planted on 13.05.2011 with 15 rhizomes per plot, with 50 cm distances both between the rows and between plants in the each row. Irrigation took place on 13.05.2011 and 26.05.2011, delivering 10 mm of water on both occasions. Soil moisture measurement was taken at 10 cm intervals on the day after irrigation, using a PT-1 type soil moisture meter based on conductivity of electricity. The changes in the number of plants and the number of sprouts per plant were monitored once a week during the growing season.

The data were evaluated with the method of variance analysis, using the Microsoft Excel 2010 program.

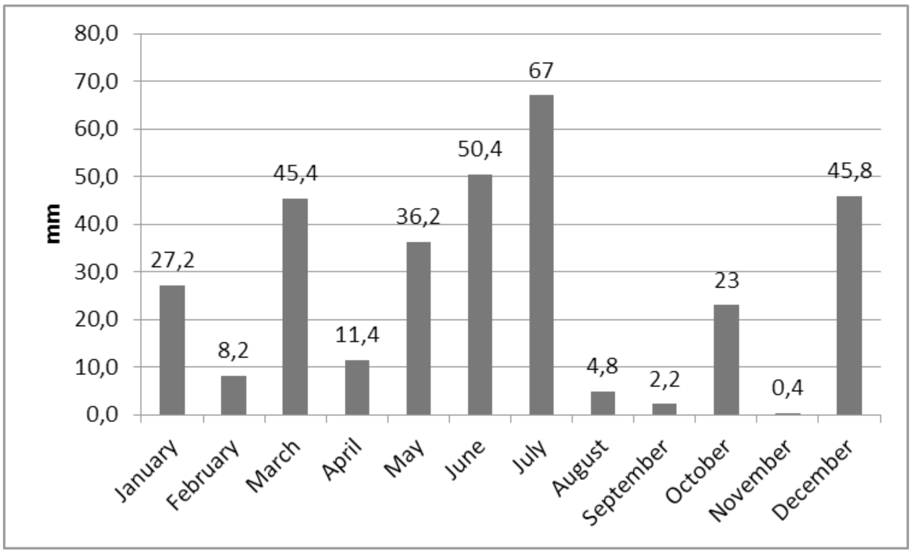

Figure 1. *Precipitation and mean temperature data 2011, Gödöllő*

The spring of 2011 saw average rainfall – *Fig. 1* – therefore we found no significant differences in terms of moisture content in the 10-20 cm soil layer. Pre-emergence irrigation probably makes more difference in a drier year (such as 2009 had been).

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Results and discussion

Experiments with Miscanthus propagating materials have been conducted by a number of foreign and Hungarian scientists have been studying (Jones and Walsh, 2001; Jorgensen, 1995; Mikó, 2007; Percze et al., 2009; Pósa et al., 2011). Johnes and Walsh (2001) studied the wintering of 20 cm rhizomes with multiple buds. In planting shorter than 10 mm and longer than 10 mm rhizomes Jorgensen (1995) found that 34% of the shorter rhizomes and 82% of the longer than 10 cm rhizomes grew sprouts. The production of high quality propagating material is crucial for Miscanthus production therefore in our experiment we carried out a comparative study of Miscanthus rhizomes in local circumstances.

Table 1. *Soil moisture content measurements (m/m %) (Gödöllő, 2011)*

	14.05.2011		27.05.2011		04.06.2011		11.06.2011	
	W	NW	W	NW	W	NW	W	NW
Surface	22.2	20.2	13.3	7.7	6.8	5.6	4.2	4.4
10 cm	**25.9**	**25.7**	**25.6**	**24.2**	**22.8**	**21.6**	**24.1**	**24.6**
20 cm	**26.4**	**25.9**	**26.8**	**24.8**	**28.0**	**24.5**	**25.9**	**26.6**
30 cm	27.3	26.6	28.5	26.7	26.8	27.2	28.7	29.1
40 cm	28.7	28.3	31.3	29.6	29.4	29.0	31.5	31.6
50 cm	30.2	30.1	31.7	31.0	31.6	30.9	32.4	32.0

Table 1 presents soil moisture data for the 1st month following the date of planting, in a weekly breakdown. The moisture content of the 10-20 cm soil layer is of relevance for Miscanthus as the rhizomes were planted at this depth and later on the bulk of the rhizomes is also to be found in that layer. At the time of planting (13.05.2011) the soil moisture content was around 26 m/m % in the planting depth, thanks to the 45 mm rain in March – *Fig. 1* – so the first shoots appeared within a week of planting. The subsoil moisture content was satisfactory (26.6-30.1 m/m %). Though there were no significant differences between the irrigated plots and those without added water (approx. 1 m/m %) yet the average plant number was higher in the irrigated plots in the case of both rhizome types (A and B). (*Fig. 2*).

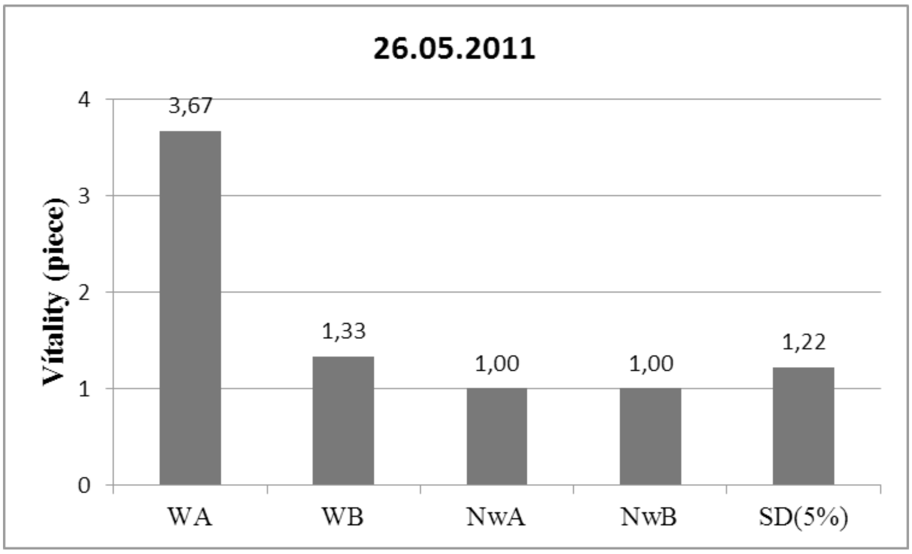

Figure 2. *Number of plants grown, per treatment, as an average of plots (Gödöllő)*

Fig. 2 shows the average plant number per plot on the 13th day following the day of planting – the average number of plants in the WA plots was 3.667. There was a significant difference between the WA plots and all of the other ones (WA, NwA, NwB). There was no statistically proven difference between the plots without irrigation (NwA, NwB). In the case of the 6-10 cm rhizomes (A) with irrigation we found significantly more plants than in the plots without irrigation. In the case of the 3-5 cm rhizomes (B) irrigation (WB) resulted in an increment of 33% over the plots without irrigation (NwB). The data show that irrigation may increase the success of emergence since the shoots of the irrigated rhizomes emerged faster and in larger numbers than those going without irrigation.

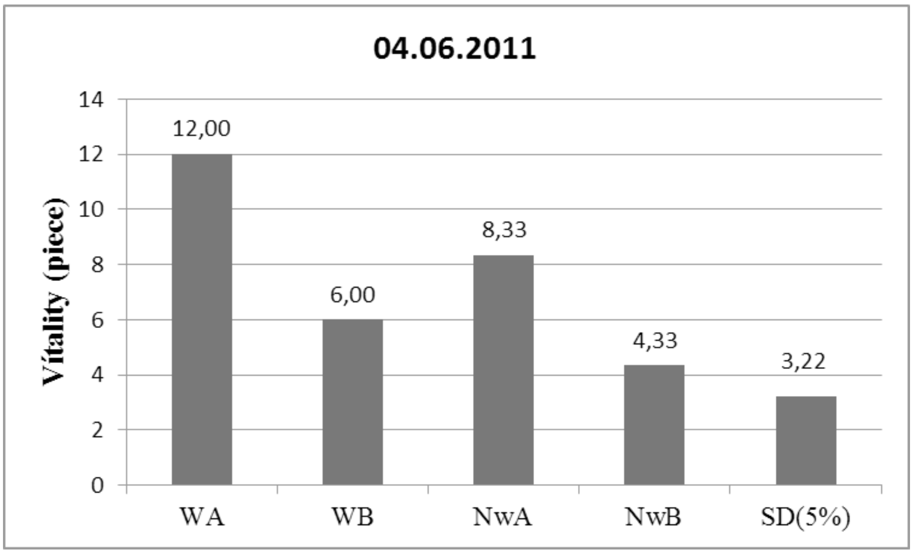

Figure 3. *The number of emerged shoots per treatment, as an average of the plots (Gödöllő)*

Fig. 3 shows the average plant numbers per plot on the 21st day after planting. The largest number of plants was counted in the WA plots (average: 12). The differences between the WA and the WB plots were found to be statistically significant. A comparison of the WA to the NwB plots showed that 30 % more shoots appeared in the irrigated area than in the area without irrigation and this is a statistically confirmed difference. No significant difference was found between WA and NwA plots but the growth in the irrigated plots was higher by an average of 38.46 %. In the plots without irrigation nearly twice as many rhizomes grew shoots in the NwA plots than in the NwB plot and this was a statistically confirmed difference. The soil's moisture content was between 21.6 and 28 m/m %.

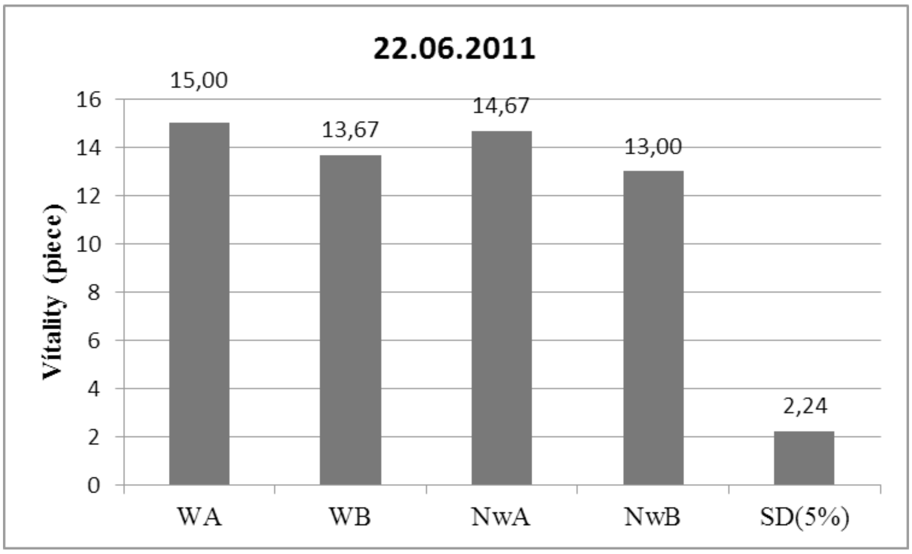

Figure 4. *The number of emerged plants, per treatment and in an average of plots (Gödöllő)*

Fig. 4 shows the average number of plants that grew in the plots on the 39th day after planting. It is clear from the figure that no significant differences could be found between the plots. In the case of the longer rhizomes (WA and NwA plots) the rates of sprouting were 97.77-100 %. In the plots with the shorter rhizomes (WB NwB) 86.66 – 91.11 % of the rhizomes grew shoots.

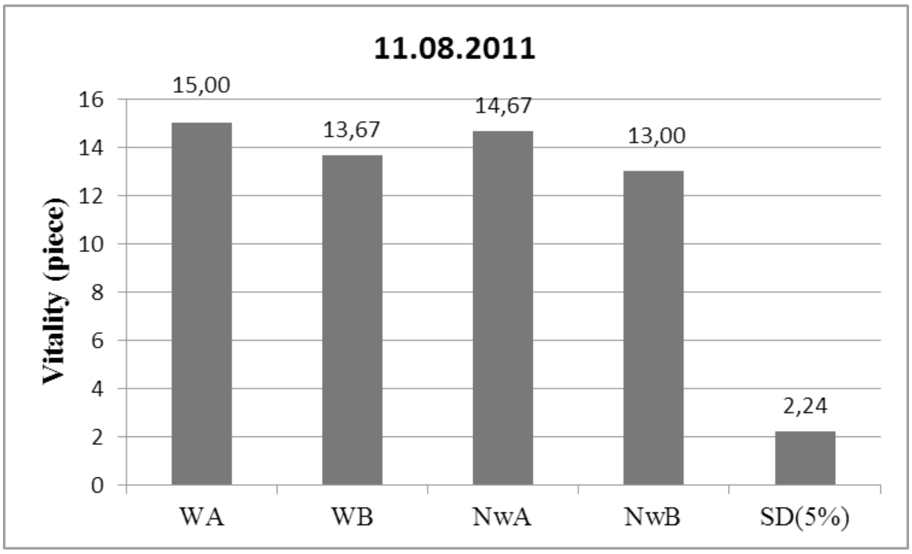

Figure 5. *The number of emerged plants, per treatment and in an average of plots (Gödöllő)*

No change in the results was found after the measurements taken in June, i.e. no significant differences were found between the treatments any more, thus *Fig. 5* shows results similar to those of *Fig. 4.*

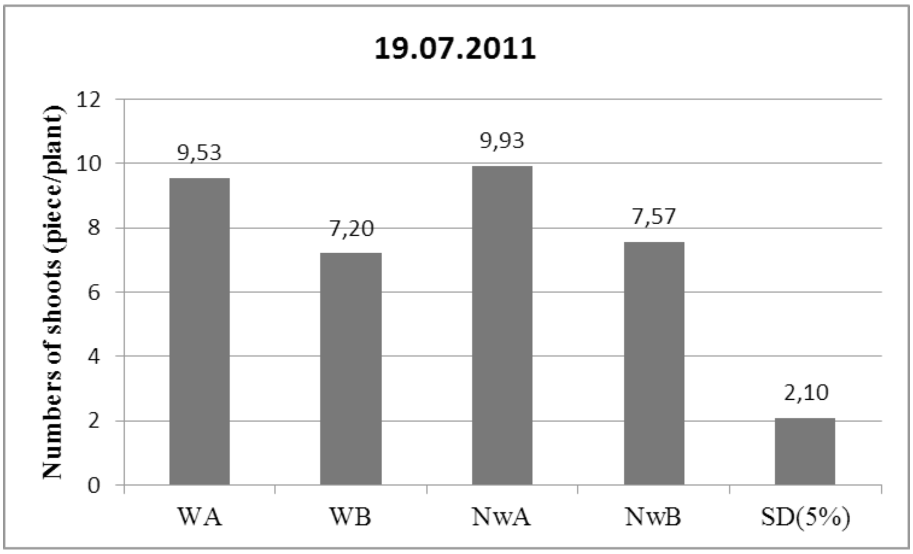

Figure 6. *Numbers of shoots per plant 1. (Gödöllő)*

The numbers of shoots per plant were established twice during the growing season. The results of the shoot counts on 19.07.2011 are presented in *Fig. 6*, showing significant differences between the WA and WB and the NwA and NwB plots. The average number of shoots in the WA plots was 9.53, that is 32.36 % more than in the WB plots. In the WA plots there were 25.89 % more shoots on an average than in the NwB plots but this cannot be confirmed statistically. The results of the NwA and NwB plots also differed significantly, an average of 31.17 % more shoots were counted in the NwA plots than in the NwB plots and 37.91 % more than in the WB plots. No significant differences were found between the WA and NwA and the WB and NwB plots, i.e. the impacts of the pre-emergence irrigation in the spring were no longer reflected by the number of shoots in July.

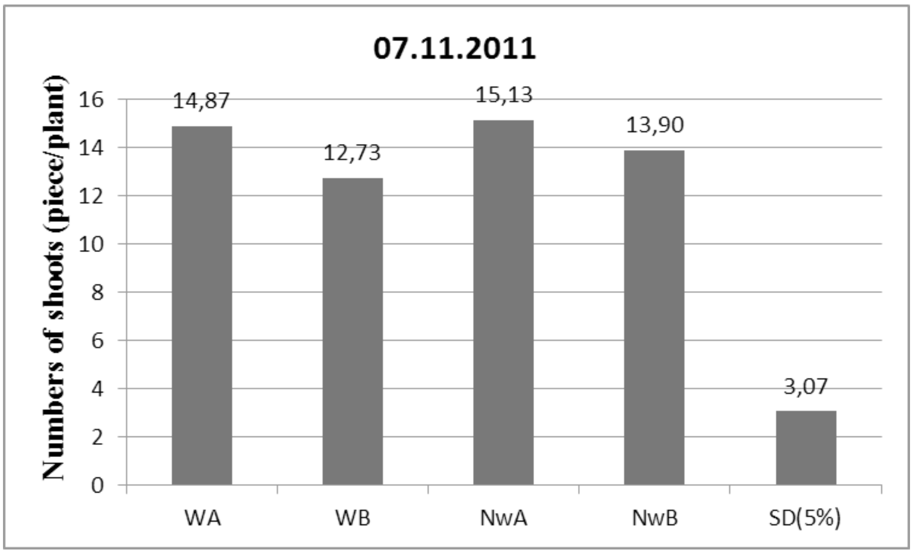

Figure 7. *Numbers of shoots per plant 2. (Gödöllő)*

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Fig. 7 shows the shoot counts of November. Though differences were found between the rhizomes of different lengths and bud numbers in the W and NW plots (with and without pre-emergence irrigation), these differences are not statistically significant. Accordingly, the average rainfall in that year in the spring and in the early summer – which is crucial for emergence and the growth of the new shoots – evened out the sprouting rates of the rhizomes and the numbers of shoots per plant.

Conclusions

It is concluded from the results of the experiment that the average rainfall in the spring and early summer evens out the sprouting rates of the propagating materials of different parameters (rhizomes A and B), in other words, the population density of Miscanthus. Although the longer rhizomes with more buds (A) emerges more quickly and more dynamically after planting, therefore during the first month after planting it shows a statistically higher number of emerged plants, yet by the time of the plant counts on 22.06.2011 this advantage had disappeared and no significant differences were found between the rates of emergence between the two different grades of rhizomes (over 97 and over 86 % in the case of grade ‘A’ and grade ‘B’ rhizomes, respectively). Thereby it was proved that grading after mechanised cutting and lifting of the rhizomes – entailing a significant increase in the costs of propagation material production – does not lead to a statistically confirmed advantage in the population density of Miscanthus, provided there is adequate rainfall in the growing season. Pre-emergence irrigation (2 × 10 mm) boosts the sprouting phase and makes it more reliable but in the case of a 25 m/m % moisture content – as was measured in our experiment in the 10-20 cm soil layer – this advantage diminishes and it remains below the significance level. The advantages of irrigation must be more prominent in a dry season.

Although the number of shoots per plant is significantly higher after planting in the case of the longer propagation materials bearing more buds (A), yet as the rhizomes grew the shorter (B) rhizomes also produced an increasing number of shoots and by the end of the growing season there was no significant difference between the numbers of shoots stemming from the different grades of rhizomes.

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