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The effect of plant density on the yield of sweet potato

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SUMMARY

A field study was conducted in South-East Hungary during the main cropping season of 2016, 2017 and 2018, with the objective of determining the effect of plant spacing on the productivity of sweet potato. Production technology experiments of four repetitions were set up in a randomized block design on sandy soil. The performed treatments consisted of four variations of plant spacing (row distance x plant-to-plant distance): 80 cm x 20 cm, 80 cm x 30 cm, 100 cm x 20 cm, 100 cm x 30 cm. The plant material was the Hungarian registered sweet potato variety 'Ásotthalmi-12'. Analysis of variance revealed that planting density significantly affected the average yield of storage roots. The highest yield per plant was achieved with the 100 cm x 30 cm (2016, 2017), as well as with the 80 cm x 30 cm (2018) setups. On hectare level, our results showed that the highest plant density of 62,500 plants ha^{-1} (80 cm x 20 cm setup) could give the highest yield. Comparing the highest tons ha^{-1} results to those achieved with the plant spacing setups resulting in the highest yield per plant, the differences can be even 13 or 14 tons at hectare level. This finding underlines the importance of choosing the proper planting density towards the higher end.

Keywords: *sweet potato, planting density, yield*

INTRODUCTION

Batata or sweet potato (*Ipomoea batatas* (L.) Lam.) is a root crop of tropical-subtropical origin which is cultivated in the temperate zone, too. Along with several European countries, it has also been also grown in Hungary for decades, but the increase of its growing area was stimulated by the consumers' demand in the last couple of years.

Sweet potato is an important crop in many parts of the world. It is used not only as a staple food, but it is also an important industrial raw material for animal feed and alcohol production in different countries. Sweet potato is rich in secondary metabolites, especially antioxidant compounds including anthocyanins, carotenoids and vitamin C (Teow et al., 2007; Yoshinaga et al., 1999).

In Hungary, sweet potato is cultivated for more than thirty years (Horváth, 1991b,c). From the results of the experiments of Horváth (1991a) it was concluded that sweet potato can be successfully grown in our region. In Hungary, consumers' demands for sweet potato cannot be fulfilled even though the producers' interest is also intensively increasing. In spite of the published cultivation technology sheets and experiences, yield stability is still not solved, growing site- and genotype-specific advices are still missing.

In Hungary, the storage root yields range between 18 and 25 ha^{-1}, depending on the production site and the technology applied (http1). Sweet potato grows best where average temperatures are 20 °C. The crop can be damaged by frost, and this fact restricts the cultivation of sweet potato in the temperate regions to areas with a minimum frost-free period of 4-6 months (Negeve et al., 1992; Berényi and Szabó, 2001). According to Kay (1973), it grows best where the average temperature is 24 °C. At temperatures below 10 °C its growth is severely retarded.

Singh and Singh (2002) explained that the establishment of an optimum population per unit area of the field is essential to get maximum yield. Therefore, the optimum plant population of individual crops should be worked out under suitable environmental conditions. Norman (1963) described that both too narrow and too wide spacing do affect yields through competition (for nutrients, moisture, air, radiation, etc) due to the inefficient utilization of the growth factors. A number of factors also influence spacing: fertility status of the soil, moisture availability, growth pattern of the crop and cultural practices.

The row distance generally applied in sweet potato production is between 70 and 107 cm, the most preferred being 100 cm. The usual plant-to-plant distance is 17 to 30 cm, with 30 cm being most widely used (Bavec and Bavec, 2006; Clark, 2013; http2).

Recommended plant spacing for sweet potato in different countries are: 30–40 cm within the row by 102–112 cm between the rows in Ontario (OMAFRA, 2010), 25–36 cm by 91–122 cm in Kentucky (Coolong et al., 2012) or 25–30 cm by 81–107 cm in North Carolina (NCSPC, 2015). These correspond to planting densities of about 22,000 to almost 50,000 plants per hectare.

The planting density in sweet potato is a major factor that influences growth and yield (Onunka and Nwokocha, 2003).

Hence, evaluation of different planting densities is pertinent to improve the production and productivity of the crop. Therefore, this research was conducted to determine the effect of planting density on the growth and yield of one sweet potato cultivar.

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MATERIALS AND METHODS

The performed field experiments were carried out in 2016, 2017 in Domaszék and in 2018 in Ásotthalom in South-East Hungary, on moderately alkaline sandy soil. The change of site was necessary due to an intense infection by white grubs detected during the second crop year.

Soil samples were randomly taken from a depth of 0-30 cm from the experimental fields before planting. As a next step, the composite soil samples were analyzed at Hódmezővásárhely Soil Testing Laboratory for the determination of the selected physical-chemical properties of the soil (*Table 1*).

Table 1

Results of soil analysis in Domaszék and Ásotthalom

Site	pH-KCl	Total salt	Soil plasticity	$CaCO_3$	Humus	P_2O_5	K_2O	Na	Mg
		m per m %	K_A	m per m %	m per m %		mg kg^{-1}		
Domaszék	7.70	0.04	29	3.46	0.94	824	145	15.6	55
Ásotthalom	7.56	0.02	29	3.03	0.65	308	80	7.9	15

The experimental setup was Randomised Complete Block Design (RCBD) with four repetitions. The experiments consisted of four plant spacing setups (row distance x plant-to-plant distance): 80 cm x 20 cm, 80 cm x 30 cm, 100 cm x 20 cm, 100 cm x 30 cm. The four population densities in numbers of plants per hectare are shown in *Table 2*. The certified Hungarian variety 'Ásotthalmi-12' provided the plant material in all experiments. The sweet potato cuttings (slips) were derived from the Bivalyos Tanya Family Farm and the planting was performed on 29th May 2016, 4th June 2017 and 31th May 2018, with cca. 450 slips on the whole experimental area of 150 m^2. Spring tillage was followed by soil disinfection on one occasion before planting. The cuttings were planted manually with a dibble. In 2016 and 2017, for nutrient supply, the fertilizer Volldünger® Linz Classic (14-7-21) was applied. In 2018, the fertilizers were applied through an irrigation system with variable NPK rates in various development stages of the crop. The NPK fertilizers were used in the forms of calcium ammonium nitrate (27% N), superphosphate (20% P_2O_5) and potassium sulphate (51% K_2O), respectively. Weed control was done manually on the whole experimental area in all years. The storage roots of the experimental plots were harvested in bulk per plot and the mean yields per plant were calculated in each year. The sweet potato storage roots were harvested after five months each year using digging fork accordingly. The corresponding yields in tons ha^{-1} and yield per plant were determined and analyzed. The experimental plots were harvested on 9th and 15th October 2016, on 15th October 2017 and on 29th of September 2018. The harvesting was done when the vines of 90% of the plant population in each plot turned yellow or senesced and the tubers reached maturity as shown by cracking of the soil above the tuber.

Table 2

Plant population density

Spacing	Plants ha^{-1}
80 cm x 20 cm	62,500
80 cm x 30 cm	41,600
100 cm x 20 cm	50,000
100 cm x 30 cm	33,333

Statistical analysis

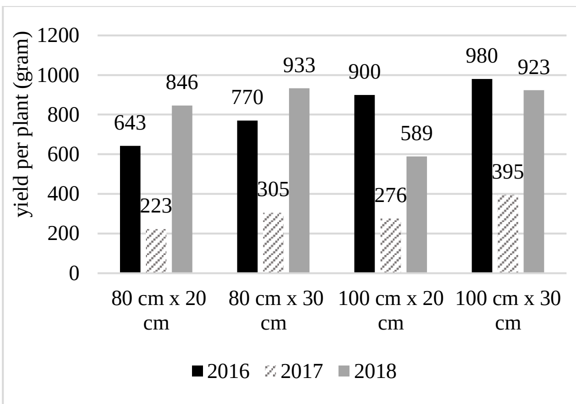
Data were subjected to analysis of variance (ANOVA). Significant differences between treatment means were separated using least significant difference ($LSD_{5\%}$) test at 5% level of significance (Harnos és Ladányi, 2005).

RESULTS AND DISCUSSION

Effect of plant density on the yield per plant (gram)

The analysis of variance revealed that planting density significantly ($P < 0.05$) affected the average yield of tuberous roots. In 2017, the yields achieved with 100 cm x 30 cm plant density compared to the other densities were significantly different *(Table. 3)*. *Figure 1* shows that the highest yield per plant was achieved with the 100 cm x 30 cm setup in 2016 (980 g) and in 2017 (390 g). In 2018, the 80 cm x 30 cm gave the best result per plant (930 g). Results showed that closer plant density decreased the yield per plant.

Figure 1: **Effect of plant density on yield per plant (gram)**



Notes: unit of measure is gram per plant, LSD (0.05) = Least Significant Difference at 5% level *2017= $LSD_{5\%}$=0,07*

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Table 3

Analysis of variance table in 2017

Total						
Groups	Pieces	Data	Average	Variance	Standard deviation	
80 cm x 20 cm	4	892	223	1258	35.46	
80 cm x 30 cm	4	1218	304.5	3644.33	60.36	
100 cm x 20 cm	4	1103	275.75	2674.25	51.71	
100 cm x 30 cm	4	1580	395	2300	47.95	
Analysis of variance						
Factors:	SS	df	MS	F	p	F critic
Between the group	62246.18	3	20748.72	8.40	0.002	3.49
Inside the group	29629.75	12	2469.14			
Total:	91875.93	15				

Note: data marked with the same letter in the same column are not significantly different at the significance level of 0.05

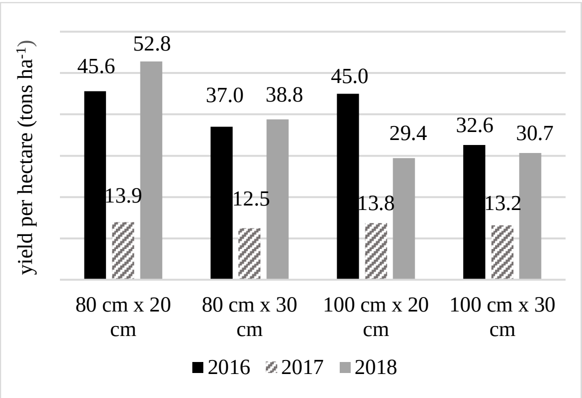
Effect of plant density on storage root yield (t ha^{-1})

Figure 2 shows that the best results at hectare level were obtained with planting at 80 cm x 20 cm in each year. Increasing plant density from 3.33 plants m^{-2} (100 cm x 30 cm) to higher levels of 6.25 plants m^{-2} (80 cm x 20 cm) increased the production of total storage root yields.

The population density of 62,500 plants ha^{-1} with planting at 80 cm x 20 cm produced the highest yield of 52.8 t ha^{-1} in 2018, followed by 45.6 t ha^{-1} in 2016, and 13.93 t ha^{-1} in 2017. The differences between the average yields in 2016 and 2017 were significant ($p<0.001$).

Comparing the highest tons ha^{-1} results to those achieved with the plant spacing setups resulting in the highest yield per plant, the differences can be even 13 or 14 tons at hectare level like in 2016 and 2018, respectively. At a generally low yield level as achieved in 2017, the difference is well below 1 ton (0.77 t ha^{-1}).

Figure 2: **Effect of plant density on storage root yield (t ha^{-1})**



Note: unit of measure is tons per hectare, $P\leq 0.05$.

CONCLUSIONS

This work reveals that higher plant density increases the total yield per hectare but decreases the yield per plant in sweet potato. Alvin et al. (2007) also reported that with increasing plant density, the yield of sweet potato increased. Ojikpong et al. (2007) described that maximum yields are obtained at a closer spacing. Krochmal-Marczak and Sawicka (2010) detected high genotype-dependency regarding the optimal in-row distance. The genotype-independent evaluation of their experiments, however, showed a medium size of in-row distance (40 cm) resulting in higher yields compared to both the lower (30 cm) and the higher (50 cm) ones.

The results of the experiments described here also indicate significant differences in storage root yields per hectare, the highest value being recorded at 80 cm x 20 cm plant density in each year. Comparisons with the yields of the setups resulting the highest yield per plant showed differences of 13–14 tons at a high general yield level, while the difference was negligible (0.77 tons) if the general yield level was low. Simple economic evaluations considering costs and incomes (data not shown) also confirm the beneficial effects of increased plant density. Further experiments are needed to evaluate the influence of plant density on the size and uniformity of tubers thus determining marketability.

It appears also that different yield parameters favour different population densities. It is therefore important to increase production and productivity of the crop by adopting different agronomic practices that include determination of optimum plant density.

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