The effect of different planting methods on the yield and spad readings of sweet potato (*Ipomoea batatas* L.)

Péter PEPÓ

University of Debrecen, Agronomy Faculty, Institute of Crop Sciences, Debrecen, Hungary
E-mail: pepopeter@agr.unideb.hu

Abstract: A small-plot field experiment was established to examine the sweet potato variety Ásotthalmi 12 in the case of various planting methods on chernozem soil in 2017. The obtained experimental results showed that, by using appropriate agrotechnical solutions, sweet potato can be successfully grown with favourable yields also in Hungary (the marketable tuber yield was between 23.2-50.7 t ha-1). As opposed to bibliographical references, higher yields were obtained in flat planting than in ridge planting at both row spacing values - 1.0 m (32.2 t ha-1 and 23.2 t ha-1, respectively) and 0.75 m (50.7 t ha-1 and 39.4 t ha-1). The 0.75 m row spacing was more favourable than 1.0 m. The proportion of non-marketable tubers was also more favourable (lower) in flat planting (9.97-10.9%) than in ridge planting (13.03-15.57%). During the growing season, the SPAD readings of the sweet potato leaves increased between July and August, reaching their peak in mid-August (39.61-50.31). SPAD readings decreased until harvesting (38.89-43.31 on 7th October). Positive correlation was observed between the marketable tuber yield and SPAD readings on 10th July (0.632xx) and 21st July (0,664xx).

Keywords: sweet potato, planting technology, yield, SPAD

Introduction

The structure of field crop production in Hungary greatly simplified during the past decades (*Pepó* 2011), resulting in the fact nearly 85% of cropland is occupied by the five main crops which are grown on the largest area (wheat, maize, sunflower, barley, rape). This simplified sowing structure significantly increased the ecological, agronomic and economic vulnerability of crop production. On the one hand, it would be necessary to increase the sown area of traditional crops (legumes, root and tuber crops, fodder crops) and to introduce new crops on the other. In the recent years, sweet potato (*Ipomoea batatas* L.) appeared as a new crop and its sown area has been (moderately) increasing (about 500 ha in 2017) as farmers from various regions started to grow it. Sweet potato is originally a perennial crop from South and Central America, produced as an annual crop in Hungary. Currently, sweet potato is the seventh most significant food crop in the world, while it is ranked the 4th in tropical countries (*Julianti* et al. 2017). Sweet potato is an essential food source in many countries of Africa and Asia (*Bowell-Benjamin*, 2007; *Low*, 2011). The tuberous root of sweet potato contains valuable nutrients and carbohydrates and is rich in vitamins (C, B_1, B_2, B_6, E, *Woolfe* 1992). For this reason, sweet potato production is constantly becoming more widespread in developing countries (*Hartemink* 2003). Sweet potato is grown on very different (fertile and nutrient-deficient) soils around the world due to its favourable adaptation abilities (*White and Zasoski*, 1999; *Yan* et al., 2006; *Zuo and Zong*, 2011).

Due to the topical origin of sweet potato (a short-day plant in need of warm temperature and water), only early ripening varieties can be grown in a way that the vegetation period is lengthened with planting. Sweet potato prefers neutral – slightly acidic (pH: 6-7) soils with loose structure (*Lebot* 2009). It is mainly cultivated using the ridge planting method, but flat planting can also be carried out (*Clark* 2013). However, research focusing on the production technology of sweet potato is still relatively limited. *Szarvas* et al. (2017) concluded that the yield of sweet potato did not increase as a result of fertilisation on alluvial soil properly supplied with nutrients. The examinations of *Kuepper* (2014) showed the significance of the applied planting method.

According to the examinations performed by *Szarvas* et al. (2017), the yield of sweet potato was higher in flat planting than in ridge planting. The row spacing, plant density could effect the yield of batata because of different water utilization, canopy shading, radiant energy utilization (*Funnah and Matsebullar*, 1984; *Ojikpong* et al., 2007) and they could modify the photosynthesis, leaf production (*Onunka* et al. 2011). *Nwokocha* et al. (2000) and *Ikerogu* (2003) stated that neither row spacing nor density affected the batata yields.

The agronomical, morphologic and physicochemical attributes of sweet potato varieties were examined in detail mainly by researchers in subtropical and tropical countries (*Solomon* et al., 2015; *Picha*, 1985; *Tairo* et al, 2008; *Loretan* et al., 1989; *Chen* et al., 2006; *Surayia* et al., 2006). Sweet potato tuberous root is a commercially valuable organ that provides a high level of biomass and nutrients per hectare. Grafting experiments have suggested that the productivity of sweet potato is due to the sink strength of tuberous root i.e. its capacity to deposit and store the products of photosynthesis (*Hozyo* et al., 1971; *Harn*, 1977). Unfortunately there is little experimental data available in relation to how photosynthetic capacity (SPAD and LAI) affects the yield of sweet potato. Based on the analyses performed by *Su* et al. (2009), a strong positive correlation was observed between SPAD readings and the chlorophyll content of sweet potato leaves.

The aim of our experiments was to examine the effect of different planting methods on the yield of sweet potato and the proportion of marketable yield, as well as to seek correlation between SPAD readings obtained in the growing season and the tuber yield of sweet potato.

Material and methods

The small-plot field experiment was established in the Demonstration Garden for students of the Institute of Crop Sciences of the University of Debrecen with three replications in 2017. Size of plots was 4 m^2.The previous crop of the experiment was winter wheat. Following the harvesting of the previous crop, the usual operations were performed on the soil (stubble cleaning and rolling, stubble maintenance, 30 cm deep autumn ploughing) and the properly loose structure and weed-free conditions of the soil were maintained with a cultivator in the spring. No nutrient replenishment was performed in the autumn. In the spring (22nd May 2017), complex artificial fertiliser (N:P_2O_5:K_2O = 13:19:19) and CAN (N = 27%) was applied on the plot. All fertilizers were applied in spring because of rainy weather in autumn. The following amounts of active ingredient were applied: N = 52+54 = 106 kg ha^{-1}, P_2O_5 = 76 kg ha^{-1}, K_2O = 76 kg ha^{-1}. No chemical weed control was applied on the experiment site. Sweet potato variety "Ásotthalmi 12" which adapted to Hungarian weather conditions was used in the experiment. The skin of its tuber is red and its pulp is orange, tasty and sweet. This variety grows long tendrils and provides good soil coverage. The cuttings were obtained from Bivalyos Tanya Kft. Planting was performed on 31st May 2017.

In the experiment, flat planting and ridge planting were performed in the case of both varieties. Row spacing values of 1.0 m and 0.75 m were examined in both production methods. The planting distance of plantlets was 0.3 m in the case of the different row spacing values.

4 mm irrigation water was applied (by sprinkling method) on the crop stand of the plots each day between 31st May-10th July 2017. Weather was very favourable from mid July up to the end of September so we did not used irrigation in this period of vegetation season.

Manual weed control was performed on four occasions in June 2017.

The experiment was harvested on 10th October 2017. During manual harvesting, the total tuber yield of the plots and the marketable and non-marketable tuber yield (tubers below 200g, damaged by insects and diseased tubers) were measured.

The main meteorological data before and during the growing season are shown in *Table 1*.

Table 1. The most important meteorological data of experimental site (Debrecen)

	Rainfall autumn and winter (mm) (09/2016-02/2017)	Rainfall in spring (mm) (03-05/2017)	June	July	August	September	Sum (mm) Mean (°C) in vegetation period
Rainfall							
2017 year	210.2	86.3	61.0	66.5	55.1	74.0	256.6
30 years mean	186.7	134.7	79.5	65.7	60.7	38.0	242.9
Temperature							
2017 year	-	-	20.9	21.0	22.1	15.5	19.9
30 years mean	-	-	18.7	20.3	19.6	15.8	18.6

Table 2. The most important traits of experimental soil (Debrecen)

Humus (%)	Soil plasticity K_A	pH H_2O	pH KCl	$CaCO_3$ (%)	AL-soluble P_2O_5 (mg kg^{-1})	AL-soluble K_2O (mg kg^{-1})
2.57	42.0	7.0	6.5	-	100.0	165.0

The analytical results of the experiment soil (*Table 2*) showed that the calcareous chernozem soil is mid-heavy and belongs to the loam soil physical group. The humus content (2.57%), AL-soluble P_2O_5 content (100.0 mg kg^{-1}) and K_2O content (165 mg kg^{-1}) of the soil are average.

The relative chlorophyll content (SPAD readings) of sweet potato leaves was measured on four occasions (10th July, 21st July, 17th August and 7th October 2017) during the experiment. Konica Minolta 502 meter was used to obtain SPAD readings. During each measurement session, 30 readings were obtained per plot in all three replications.

Results and discussion

The moderate, continental climate of Hungary is only partially suitable for the ecological needs of sweet potato. Accordingly, the great heat demand of the plant needs to be satisfied with a special treatment for producing the cuttings and irrigation is necessary due to its great water need. Regarding the growing season of 2017,

precipitation of the previous periods also need to be considered (*Table 1*) due to the chernozem soil of the experiment site which has favourable water management. The amount of precipitation in the autumn-winter period (210.2 mm) was higher than the multiple-year-average (186.7 mm). In the spring months, the amount of rainfall was lower than the 30-year-average (86.3 mm and 134.7 mm, respectively). Both the amount and distribution of rainfall in the growing season (between June and September) were favourable in 2017. In addition to the proper amount of precipitation and irrigation, the development of sweet potato was also helped by the fact that the mean temperature in each month of the vegetation period was 1.3-2.5 °C higher than the multiple-year-average (*Table 1*), except in September. There was a significant amount of rainfall and average temperature in September, which had a favourable effect on tuber growth.

As a result of the properly performed agrotechnical operations and the relatively good weather, favourable yield was obtained in the

Table 3. Effects of planting method and row spacing on the yields of sweet potato (Debrecen, 2017)

Planting method Row distance	Total (gross) yield (kg ha^{-1})	Marketable (net) yield (kg ha^{-1})	Ratio of non-marketable yield (%)
Flat			
1.0 m between rows	35 497	32 200	9.97
0.75 m between rows	56 816	50 689	10.90
Ridge			
1.0 m between rows	27 467	23 233	15.57
0.75 m between rows	45 352	39 356	13.03
LSD$_{5\%}$	10 986	9 950	2.07

Table 4. Effects of planting method and row space on the SPAD readings of sweet potato (Debrecen, 2017)

Planting method Row distance	SPAD readings			
	10 July	21 July	17 August	07 October
<u>Flat</u>				
1.0 m between rows	44.05	50.31	49.72	38.89
0.75 m between rows	48.07	49.30	49.08	39.44
<u>Ridge</u>				
1.0 m between rows	40.14	39.61	48.93	42.47
0.75 m between rows	39.10	45.19	49.49	43.31
$LSD_{5\%}$	2.16	3.07	1.07	1.15

small plot experiment established on chernozem soil in 2017 (*Table 3*). The marketable yield of Ásotthalmi 12 was between 23.2-50.7 t ha^{-1}, depending on the applied production method (flat planting or ridge planting) and row spacing (1.0 m and 0.75 m). As opposed to experimental and general practice, flat planting provided higher yield than ridge planting under the given ecological and agrotechnical circumstances. The reason should be a better start situation for cuttings in the flat plots comparing with the ridge plots. The marketable yield was 32.2 t ha^{-1} in the case of flat planting and 1.0 m row spacing and 50.7 t ha^{-1} in the case of 0.75 m row spacing. The respective yields obtained in ridge planting were 23.2 t ha^{-1} and 39.4 t ha^{-1}. The obtained research results showed that the highest yields were produced at 0.75 m row spacing in the case of both production methods. The marketable yield in flat planting was 32.2 t ha^{-1} and 50.7 t ha^{-1} in the case of 1.0 m and 0.75 m row spacing, respectively (the difference in yield was 18.5

t ha^{-1}), while the respective values of ridge planting were 23.2 t ha^{-1} and 39.4 t ha^{-1} (i.e., the difference in yields was 16.2 t ha^{-1}). During harvesting, the weight of non-marketable tubers (tubers lighter than 200g, as well as damaged and diseased tubers) was also measured and the weight percentage of non-marketable tubers were calculated (*Table 3*). The obtained results showed that not only the amount of yield was higher in the case of flat planting, but the proportion of non-marketable tubers was also more favourable (lower) in the case of both row spacing values. In the case of flat planting, the proportion of non-marketable tubers was between 9.7-10.9%, while the respective range was 13.03-15.57% in ridge planting.

Within the same production method, row spacing did not have any significant effect on the proportion of non-marketable tubers.The obtained experimental results in relation to the different planting methods are in contrast

Table 5. Pearson correlation analysis among the planting method, row spacing, yield and SPAD of sweet potato (Debrecen, 2017)

	Marketable yield (kg ha^{-1})	SPAD readings			
		10 July	21 July	17 August	07 October
Planting method (ridge / flat)	-0.460[x]	-0.789[xx]	-0.847[xx]	-0.062[ns]	0.682[x]
Row spacing (1,0 / 0,75)	0.784[xx]	0.183[ns]	0.261[ns]	-0.015[ns]	0.130[ns]
Total yield (kg ha^{-1})	0.991[xx]	0.609[x]	0.613[x]	-0.078[ns]	-0.135[ns]
Marketable yield (kg ha^{-1})		0.632[x]	0.664[x]	-0.089[ns]	-0.131[ns]
Proportion of non marketable yield (%)		-0.343[ns]	-0.688[x]	0.169[ns]	0.061[ns]

[x] Correlation on $LSD_{0.05}$ level
[xx] Correlation on $LSD_{0.01}$ level
[ns] Non-significant

with most experimental results (*Clark*, 2013; *Kuepper*, 2014), i.e., higher yields were realised in flat planting, similarly to the findings of *Szarvas* et al. (2017). Relative chlorophyll content (SPAD readings) was measured on four occasions during the growing season (*Table 4*). The obtained measurement results showed that SPAD readings gradually increased during the growing season from early July to mid-August, followed by a reduction in October at the end of the vegetation period. SPAD readings were between 39.10-48.07 on 10th July, between 39.61-50.31 on 17th August and between 38.89-43.31 on 10th October.

According to the obtained results, SPAD readings in flat planting were higher than those in ridge planting in the case of both row spacing values. The canopy of plants in flat planting was better comparing with ridge planting.

Based on the results of Pearson's correlation analysis (*Table 5*), row spacing had a strong effect (0.784[xx]) on sweet potato yield/ha, while there was only a moderate correlation (-0.460[x]) in the case of the applied production method. Positive correlations were observed between tuber yield and SPAD readings on 10th July and 21st July (0.632[xx] and 0.664[xx], respectively), while there was no correlation on 17th August and 7th October (-0.089 and -0.131, respectively).

The research findings of 2017 gave some new results in comparison with previous occasions; but we intend to continue these experiments in the following year.

Acknowledgements

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