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REGULAR ARTICLE

Impact of cultivations technology on the yield of sweet potato (*Ipomoea Batatas* L) tubers

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ABSTRACT

The experiment was carried out in years 2014-2016 in Żyznów in Poland (49.83°N, 21.85°E). It was realized on the basis of a randomized sub-blocks method in the dependent system (split-plot) in three repeats. Factor of the first type were cultivation technologies: a) traditional technology – as a control object, b) technology using PE- sheeting, c) PP-agrotextile, as a cover. Factor of the second type were three species of sweet potato. Growing sweet potato under cover contributed to the increase in the total yield and commercial tubers, compared with traditional technology; wherein a greater effect as the total yield increases observed in the case of polyethylene, and in the case of commercial crop in cultivation under PP-agrotextile. Field production of sweet potato in Poland's climate and soil conditions enables the introduction into our daily diet of a new alternative vegetable with high nutritional value and high total and marketable yield. The cultivation of this type of vegetable can potentially influence future horticultural production and provide resources for the processing and pharmaceutical industries.

Keywords: Crop; Cultivation under cover; Structure yield; Sweet potato

INTRODUCTION

The sweet potato (*Ipomea batatas* L.) belongs to the *Convolvulaceae* family and it is original from South America. Due to Christopher Columbus, it was imported to the Europe about century earlier than classical potatoes - *Solanum tuberosum* L. (Šlosár 2016). According to FAOSTAT (2016), total world production of sweet potato tubers was more than 100 millions tones in 2014. The main production area was Asia (75.3 %), followed by (20.2 %), American continents (3.7 %) and Oceania (0.8 %). Sweet production in Europe presented the least part of its total world value (0.1 %) and the European was only 56 113 tones in 2014. The main European producers of sweet potatoes was Spain and Italy. From world-wide aspect, China is the main producer of sweet potatoes within recent period. Sweet potato, also known as *Ipomoea batatas*, is a valuable vegetable with high production potential and various applications. The usable parts of the cultivar are leaves and underground tubers weighing up to 3 kilograms and growing out of lateral roots. They are round, oval or spindle-shaped, with white, cream, yellow, orange or purple skin. The flesh can be white, pink, orange or purple. Sweet potato leaves and tubers are characterized by a high nutritional value, in particular high content of antioxidants, vitamins and minerals (Zuraida, 2003; Adelia, 2007; Caliskan et al., 2007; Abubakar et al., 2010; Tokusoglu and Yildrim, 2011; Doliński and Olek, 2013; Krochmal-Marczak et al., 2014; Mohanraj and Sivasanka 2014; Grace et al., 2014; Tang et al., 2015; Šlosár et al., 2016; Suparno et al., 2016). In recent years, the interest of this species has increased in the world, die to the diverse use of tubers in the nutrition of humans and animals, as well as its use in food pharmaceutical processing (Krochmal-Marczak et al., 2014; Sawicka et al., 2018). The underground part of the vegetable is used in the production of sugar, alcohol beverages, meal, starch syrup, dehydrated products, fries, crisps, candied products and in deserts, soups and baby food (An, 2004; Odebode et al., 2008; Tan, 2015). According to An (2004), sweet potato is also used in probiotic food production. It can be consumed after cooking, frying or baking. According to the FAOSTAT

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(2016), the largest producer of sweet potato is Japan, followed by China and the United States. Sweet potato tubers are used as food for humans and animals in many countries of the world (Johnson et al., 2015). In recent times, also in Poland the interest in the cultivation of sweet potato as a species with very high nutritional values has increased. Therefore, there is an urgent need to disseminate knowledge about its cultivation. Professor Sawicka initiated its introduction in Polish conditions. Researches concerning its agronomical practices are continued Krochmal-Marczak (Krochmal-Marczak and Sawicka 2009; 2010; Krochmal-Marczak et al, 2014). The yield results in Polish climate and soil conditions encourage further research on the improvement of sweet potato production technology in Poland (Krochmal-Marczak and Sawicka 2009; 2010). Because of its origins from the warm subtropical climate, it requires appropriate thermal conditions and humidity, especially in May, when there is a high risk of spring frosts occurrence (Krochmal-Marczak and Sawicka 2009; Wees et al., 2016). Therefore, the aim of researches was to assess the impact of growing technology under covers on the total and marketable yield of tubers among several species of sweet potato.

MATERIALS AND METHODS

Plant material

The experiment was carried out in years 2014-2016 in Żyznów (49.83°N, 21.85°E, Poland). It was realized on the basis of a randomized sub-blocks method in the dependent system (split-plot) in 3 repeats. Factor of the first type were cultivation technologies: a) traditional technology – as a control object, b) technology using PE- sheeting, c) PP-agrotextile, as a cover. Factor of the second type were 3 species of sweet potato (Carmen Rubin, Beauregard and White Triumph). Sweet potato seedlings, created during the *in vitro* propagation, were planted at a spacing 40 x 75 cm in mid-May. Size of plots to harvest was 15 m^2. Organic fertilization was used in autumn, in the form of manure (amount: 25 tha^{-1}). In spring, the field was harrowing, and then before planting, mineral fertilizers, in quantities of: N - 80 $kgha^{-1}$,P - 34.9 $kgha^{-1}$ and K-99.6 $kgha^{-1}$, were sown. During the growing season, cultivation works were conducted in accordance with principles of Good Agricultural Practice. Sweet potato harvesting began in the end of September in 2014, while in 2015-2016 – in mid-October. Sweet potato harvest was made by a potato digger. After harvesting, the total and trade crop was estimated assuming as the marketable fraction – tubers with weight >0.40 kg. Moreover, the distribution of tuber fractions: >0.20, 0.21-0.40, 0.41-0.60, 0.61-0.80, 0.81-1.00, >1.00 kg, was conducted.

Soil agrochemical characteristics

The soil, which took part in the experience, characterized by a slightly acidic reaction (6.0–6.5 pH in KCl), humus content – 1.8%, from high to very high content of assimilable phosphorus (69–116 mg kg^{-1} P) and the average content of potassium and magnesium (90–123 mg kg^{-1} K and 33–51 mg kg^{-1} Mg soil dry matter).

Weather conditions

Distribution of temperatures and precipitations in analyzed years of researches was diverse, as it is illustrated in Fig. 1. In 2014, the first half of the growing season was

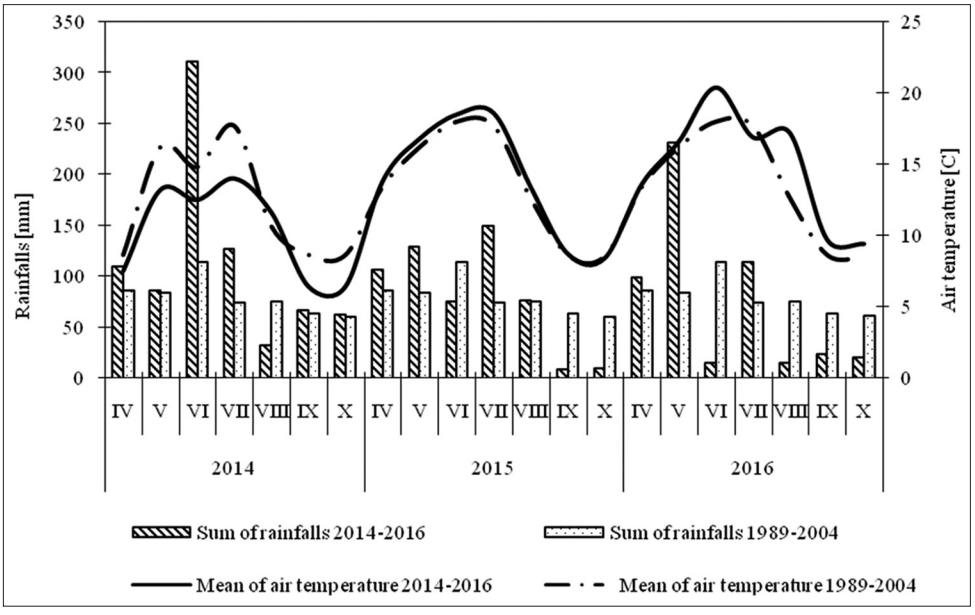

Fig 1. Rainfalls and air temperature during the vegetation period of sweet potato according to meteorological station of Research Centre for Cultivar Testing in Experimental Station for Cultivar Testing in Dukla.

very wet and warm, while the second half – wet and cold. In 2015, May and June were humid and warm, July was wet, and August and October were average in terms of precipitations and air temperature. In 2016, May and June were wet and very warm, and the remaining months were very dry with an air temperature lower than the long-term average (Fig. 1).

Statistical analysis

The results obtained were subjected to statistical analysis. The ANOVA test analysis was performer, while the significance of differences between mean values was determined using the Tukey's (LSDα=0,05) test. The statistical analysis of the study results were carried out using the Statistica 10.0 Software (StatSoft Inc., USA).

RESULTS

Total crop of sweet potato in the experiment averaged 31.2 tha^{-1} and it can be considered as a quite high (Table 1).

Cultivation technology significantly differentiated a total crop of tubers. The best yielding effect was obtained in the cultivation technology with the use of polyethylene (perforated) foil (17.7%), the lower, but also important, yielding effect was achieved in the cultivation under the polypropylene unwoven fabric (7.9%), in comparison with the traditional crop without covers (Table 1).

Genetic characteristics of studied species decided in the greatest degree about the crop mass. Cultivar with the best crop was an oval-shaped, red-skinned and white-fleshed cultivar originating from Israel – Carmen Rubin, and the cultivar with the lowest yield – a spindle-shaped, white-skinned and white-flashed Italian cultivar White Triumph. Beauregard cultivar yielded significantly higher than White Triumph, but almost two lower than Carmen Rubin (table 1).

Weather conditions in the years of researches significantly determined the size of tubers' crop. The highest value of this feature was obtained in 2013, which was characterized by high value of precipitations and high air temperature in the period of tubers' tuberization, and the lowest one - in humid and cool 2011 (Table 1).

Tubers with the weight of 0.41-0.60 kg constituted the largest part (39.5%), while the lowest part was presented by tubers with a weight of >1 kg (3.7%) (Table 2).

Among tested variations, the most favourable structure of tubers' mass participation in the crop was presented in Carmen Rubin, because of the highest participation in the yield of large tubers weighting from 0.41 to more than 1 kg, while the lowest structure was in the smallest tubers with the weight of <0.20kg and 0.21-0.40 kg. The least favorable yield structure was observed in the White Triumph variety, because of the highest participation of the smallest tubers, and the lowest structure in tubers with a weight of 0.61-0.80 kg; 0.81-1.00 kg and >1.0 kg. Beauregard variation was characterized by the highest participation of tubers with a mass of 0.21-0.40 kg, while it did not significantly differ in the amount of tubers weighting 0.61-0.80 kg from Carmen Rubin variety Rubin. White Triumph cultivar had the least tuber weighing 0.61-0.80 kg. (Table 2).

Application of perforated polyethylene foil contributed to the increase in the participation of the smallest tubers with a weight of <0.20 kg, and to reduce the participation of tubers with a weight of 0.21-0.40 and 0.41-0.60 kg in comparison with the traditional cultivation technology. Cultivation of sweet potato with the use of polypropylene unwoven fabric contributed on the one hand to increase the proportion of tubers with a weight of 0.61-0.80 kg, 0.81-1.00 kg and >1.0 kg, and on the other hand to reduce the proportion of tubers with a weight of 0.20 kg,

Table 1: The influence of the technology of tillage, cultivars and the conditions of tillage on part and the crop of tubers trade sweet potato

Experimental factors	Total crop of tubers (tha-1)	The share of commercial tubers (%)	The crop of commercial tubers (tha-1)
Technology of cultivation			
Traditional	28.7[a]	56.6[a]	16.3[a]
PE-sheeting	33.8[b]	57.4[a]	19.4[b]
PP-agrotextile	31.0[c]	65.2[b]	20.2[b]
Cultivars			
Beuregard	25.5[a]	58.5[a]	14.9[a]
Carmen Rubin	49.8[b]	67.3[b]	33.5[b]
White Triumph	18.3[c]	54.7[c]	10.0[c]
Years			
2014	23.5[a]	52.4[a]	12.3[a]
2015	32.8[b]	55.3[b]	18.1[b]
2016	37.3[b]	68.6[c]	25.6[c]
Mean	31.2	59.6	18.9

Mean values followed by the same letters in columns do not differ significantly at = 0.05

Table 2: Influence of cultivation, varieties and growing conditions on the participation each tuber weight fraction in the total yield (average 2014-2016) (%)

Experimental factors	Fractions of tubers (kg)					
	<0.20	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.00	>1.00
Technology of cultivation						
Traditional	21.6[a]	21.7[a]	41.2[a]	9.11[a]	2.56[a]	3.76[a]
PE-sheeting	24.2[b]	18.4[b]	37.5[b]	13.3[b]	4.13[b]	2.56[b]
PP-agrotextile	20.9[a]	13.8[c]	37.2[b]	15.4[c]	7.98c	4.66[c]
Cultivars						
Beuregard	23.1[a]	18.4[a]	37.4[a]	12.7[a]	4.55[a]	3.75[a]
Carmen Rubin	18.5[b]	14.2[b]	42.1[b]	13.1[a]	6.35[b]	5.75[b]
White Triumph	27.6[a]	17.6[a]	41.2[b]	8.21[b]	3.24[a]	2.04[a]
Years						
2014	24.2[a]	23.4[a]	29.1[a]	15.1[a]	5.10[a]	3.10[a]
2015	22.3[b]	22.4[b]	27.6[a]	13.9[b]	7.65[b]	6.14[b]
2016	23.1[b]	8.25[c]	62.4[b]	3.03[c]	1.65[c]	1.50[a]
Mean	22.84	17.60	39.52	11.52	4.80	3.70

Mean values followed by the same letters in columns do not differ significantly at = 0.05

0.21-0.40, 0.41-0.60 kg in comparison with the traditional technology and perforated polyethylene foil (Table 2).

Meteorological condition in the years of researches significantly shaped the structure of tuber crop. The most favourable structure of the mass of tubers in the total yield was obtained in year 2012, in which the highest participation of the biggest tubers was observed, i.e. tubers with a weight from 0.61 kg do more than 1.0 kg, and the lower share of the smallest tubers with a weight of <0.20 kg. The highest participation of tubers with a weight of 0.41-0.60 kg was observed in 2016, which characterized by drought in the last three months of sweet potato growing. This value was even 2-times greater than in the other years of tests. On the other hand, mentioned year also brought the lowest participation of large tubers with a weight from 0.61 kg to over 1.0 kg. in very humid and cool 2014, the highest participation in the crop of tubers with a weight of <0.20 kg and 0.21-040 kg was recorded.

The participation of marketable tubers in general crop of sweet potato averaged 59.56%, and the average yield of this fraction for tubers >0.40 kg-18.93 t ha^{-1} (table 1). The greatest participation of tubers with this calibration, as well as the marketable yield, was obtained in cultivation with the use of polypropylene unwoven fabric, while the lowest one with the use of traditional technology without covers. Cultivation under the polypropylene unwoven fabric did not different significantly, both in terms of participation and marketable yield of tubers, from the variant with a polyethylene sheeting as a cover.

Genetic characteristics of examined cultivars decided in the largest extent about the participation and marketable yield of tubers. Carmen Rubin was characterized by the highest participation and crop of marketable tubers, and the lowest results – White Triumph. Beauregard cultivar had significantly higher participation and crop of tubers in this calibre than White Triumph cultivar, but it had twice smaller marketable yield that Carmen Rubin cultivar (Table 1).

Weather conditions in the years of researches had an essential effect on the amount of marketable yield of tubers. The highest value of this feature was obtained in 2016. That year was favourable for the cultivation of sweet potato. The lowest value was observed in humid and cool year 2014 (Table 1).

DISCUSSION

Total yield of sweet potato in conducted experiment averaged 31.18 t ha^{-1} and was high. Average, global yield of sweet potato is estimated at 15 t ha^{-1} (FAOSTAT, 2016). The best cultivars and families of sweet potato produce yield in China up to 32.3 t/ha (Yang et al., 1999). The value of this feature obtained on good soils with the use of irrigation and high nitrogen fertilization is estimated on the level of 30-73 t ha^{-1} by Njoku et al., (2001). According to Oliveira et al., (2010) and Agbede and Adekiya (2011) yield of sweet potato tubers cultivated on poor soils may be at the level from 13.1 to 15.4 t ha^{-1}. In central-eastern Poland, on brown soil, Krochmal-Marczak and Sawicka (2009) received 28.3 t ha^{-1}.

Cultivation technologies, used in the experiment, had a significant impact on the total and marketable yield of tubers among tested cultivars of sweet potato. The greatest yielding effect was obtained in the cultivation under the polyethylene sheeting, in the form of total yield's increase of 17.6% in comparison with the traditional technology, while the yield of commercial tubers significantly improved nonwoven polypropylene (15.2%). Krochmal-Marczak and Sawicka (2009) and Dvořák et al., (2012), under the impact of cultivation technology under covers from polyethylene

sheeting, obtained the overall sweet potato growth in the amount about 17.7%, while the marketable yield – 8.0%. According to Pszczółkowski and Sawicka (2010), cultivation under the polyethylene sheeting, brings many advantages, among others: accelerates the planting date of 2-3 weeks in comparison with an optimal period in a given region, allows for earlier obtaining marketable yield of tubers, contributes to the growth of total and marketable yield of tubers and protects plants from frosts. In the case of sweet potato, it is very important to protect young seedlings from spring frosts, because this species does not tolerate negative temperatures (An et al., 2003). Young plants *Ipomoea batatas* find under this cover much more favourable conditions for further growth. In the opinion of Pszczółkowski and Sawicka (2003), polyethylene sheeting does not limit the permeability of sunlight, is impermeable to water vapour, windproof and therefore, air closed between the soil and such a cover becomes very hot and saturates water vapour. Wadas (2010) claims, that the use of shields in the cultivation of early cultivars of sweet potato contributes to the productivity growth of tubers' marketable yield by improving the yield structure in favour of large tubers.

Genetic characteristics of examined cultivars in the largest extent decided about the mass of yield. According to Krochmal-Marczak and Sawicka (2009), differences in the size of tubers yield between cultivars of sweet potato and individual plants of the same variety depends on many factor, such as: colour of leaves, which is dominated by the genotype; development of root system responsible for the symptoms of drought; resistance to spring and autumn frosts and spring development. In practice genotypic and seasonal variability in seasons of year and years of use are important. It is extremely important, because of its impact on the field's architecture, especially during the summer, when it worsens as a result of deepening drought (Srisuwan et al., 2006).

The structure of yield's mass was dominated by tubers with a weight of 0.41-0.60 kg. The lowest part was presented by tubers weighting more than 1.0 kg. Similar results were also obtained by Krochmal-Marczak and Sawicka (2009). These authors claim that the diversity of tubers' yield and its structure is caused by the course of weather conditions that modify values of these features.

The participation of tubers of individual fractions in the yield was also modified by cultivation technologies, and especially by the use of unwoven fabric. In the opinion Pszczółkowski and Sawicka (2003); Hamoutz et al., (2004); Wadas, (2010), this technology influenced on the improvement of yield's structure in favour of large tubers. Own studies confirm this view Krzysztofik (2013) showed that the yield's structure is significantly positively associated with the length of plant shoots, number of tubers from plants, number of leaf floors and mass of tubers from one plant.

Genetic properties of cultivars have proven to be significantly differentiating feature of the tubers' yield. Researches of many authors (Srisuwan et al., 2006; Krochmal-Marczak and Sawicka 2009; 2010) present that these differences may results from characteristics of the genotype.

CONCLUSIONS

Cultvation of sweet potato under a cover contributed to the total and marketable yield, of tubers in comparison with the traditional technology; but a greater effect, in the form of the total yield increase, was observed when using the polyethylene foil, and in the case of marketable yield – during the cultivation under an unwoven fabric.

Due to the total and marketable yield of tubers, as well as a high participation of large tubers in the yield's structure, the most effective yielding variety is Carmen Rubin.

Field production of sweet potato in Poland's climate and soil conditions enables the introduction into our daily diet of a new alternative vegetable with high nutritional value and high total and marketable yield. It can also influence future horticultural production and provide resources for the processing and pharmaceutical industries.

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