Original scientific paper
Оригиналан научни рад
UDC 633.492:631.524.84(497.4)
DOI 10.7251/AGREN2301013Z

University of Banjaluka, Faculty of Agriculture
Agro-knowledge Journal

Influence of plant covering with nonwoven agrotextile on the vegetative growth characteristics and yield of sweet potato (*Ipomoea batatas* L.): A Slovenian case study

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Abstract

The objective of this study was to evaluate the impact of cultivar and covering with nonwoven agrotextile on vegetative growth parameters and the productivity value of sweet potato (*Ipomoea batatas* L.). A field experiment was conducted during the 2018 growing season, at the experimental field of the Biotechnical Faculty in Ljubljana (46° 04′ N latitude; 14° 31′ E longitude, 305 m above sea level). The soil was gravel clay with a pH of 6.7, and a soil depth of 40–60 cm. The research involved the following Slovenian cultivars of sweet potatoes: Lučka, Janja, and Martina. Distance between rows was 1.2 m, while in-row distance was 1.4 m. The experiment was conducted in a randomized complete block design with plots arranged factorially and replicated four times. The seedlings were planted on 20 May. A half of the plots were covered with polypropylene nonwoven textile (17 g/m2). The uncovered half of the plots served as control plots. The recommended cultural practices were performed as needed during the experiment. The temperature under the covers was on average 5.5 °C higher than in the unprotected area. The crops were harvested 132 days after planting. Covering significantly and positively affected vegetative growth – that is the height of the vines, leaf number, leaf area index, and haulm dry weight. In contrast, the nonwoven polypropylene cover had no significant effect on the number of branches per crop. The use of agrotextile significantly increased tuber length and diameter, tuber number, tuber weight, and total yield in comparison with traditional cultivation with no plant cover. Statistical analysis showed that cv. Janja had the significantly higher yield (7.49 t/ha) compared to cv. Lučka (6.68 t/ha) and cv. Martina (6.16 t/ha).

Key words: sweet potato, *Ipomoea batatas L.*, cultivars, nonwoven agrotextile, yield components

Introduction

The sweet potato [Ipomoea batatas (L.) Lam] is a gamopetalous dicotyledon and belongs to the order Polemoniales and the Convolvulaceae family (morning glories), which includes about 45 genera with about 1,000 species. The sweet potato is a vine and technically a perennial, but it is treated as an annual vegetable when cultivated (Moulin et al., 2012).

Based on the number of related species and the analysis of their morphological variation, the geographical centre of origin of Ipomea batatas has been thought to be between the Yucatan Peninsula in Mexico and the Orinoco River in Venezuela. Ipomea batatas is a hexaploid ($2n = 6x = 90$) species; the basic number of chromosomes is $x = 15$ (Da Silva et al., 2012).

The genus Ipomoea is composed of about 600 to 700 species, mostly annual or perennial herbaceous vines with a few erect shrubs found in the tropics. The sweet potato and other relatives are grouped in the Batatas section, which includes 16 taxa (Cao et al., 2009). According to Kowyama et al. (2000), this section consists of three cytogenetic groups, namely, group A, B, and X; while A and X are self- and cross- compatible, group B that the sweet potato belongs to is self-incompatible but cross-compatible.

Depending upon the species, virtually all parts of the plant can be used for human consumption, including leaves, young shoots, seeds, and root tubers (Takahata et al., 2010). Dolinski and Olek (2013) estimated that sweet potato roots and leaves contain phytochemicals with significant medicinal value as antioxidant properties that might beneficiate human health. This crop is also used for animal feed and in the industries for starch extraction, production of industrial alcohol, acetic acid, and yeast. It is a rustic crop which produces well in poor nutrient soils conditions, and it is often related to low incidence of pests or diseases, high drought tolerance, and low production costs. Moreover, the sweet potato is widely adaptable to various climates and farming systems (Novak et al., 2007).

The sweet potato influences the food supply chain particularly in developing countries, where it is the fifth most important food crop in terms of production with 113 million tons of storage roots produced annually. It produces a large amount of energy per day, comparable to cereals (Karan and Şanli, 2021).

In the past years, the sweet potato has increasingly become popular in Slovenia also. The Slovenian germplasm collection of sweet potato comprises commercial varieties, breeding clones, and other materials brought in from other parts of the world (Africa, Asia and USA).

The sweet potato has not yet adapted well to Slovenian climate conditions. Therefore, farmers could diminish some of the dangers associated with its cultivation by adapting management processes to address the situation, for example, the soil surface directly with by agrotextile. The covering not only ensures protection against cold temperatures but also protects plants from heavy rainfall and hail, and against insects while improving plant growth and development from seeds (Qureshi et al., 2007). In addition, polypropylene (PP) covers decrease solar irradiation, wind impact and rates of evaporation while increasing air and soil humidity (Mermier et al., 1995).

The most used crop cover is the non-woven spun-bonded polypropylene (PP). Spun bonded PP covers are composed of continuous laments and they are extremely lightweight (approximately 30 g/m2), UV stable, and have a light transmittance of 70% (Midha and Dakuri, 2017).

Therefore, the current study was conducted to analyze the impact of spun bonded PP cover on the vegetative growth characteristics and yield on three field-grown sweet potatoes cultivated in the Upper Carniola Statistical Region (Slovenia).

Material and Methods

This case study was conducted during the 2018 growing season on the certified organic plot area of the Biotechnical Faculty in Ljubljana (46° 04′ N latitude; 14° 31′ E longitude, 305 m above sea level), which has been an area recently designated for potato (Solanum tuberosum L.) cultivation in the central Slovenia Statistical Region. The climate of the experimental area was characterized by a typical temperate continental climate. The average growing period rainfall was 642.8 mm and cumulative temperature was 362.2 °C.

Soil samples from the upper horizon (0-25 cm depth) were collected prior the experiment. Elemental analysis indicated that this soil was gravel clay with a pH of 6.7, an organic matter content of 3.6%, and phosphorus and potassium contents (ammonium acetate extraction) of 25 mg and 31 mg per 100 g of dry soil, respectively. The preceding crop in the year before the sweet potatoes were grown was annual ryegrass. Cattle manure was incorporated into the soil 20 days prior to seedling transplantation. Before planting, 450 kg/ha of N-P-K fertilizer (15-15-15) was incorporated into the soil. The remaining fertilizer, other than N, was applied uniformly across the plot areas to correct for any deficiencies indicated by the soil test results.

The factorial experiment had randomized block design. The first factor (main plot) consisted of three Slovenian cultivars: Lučka with orange skin and flesh colour, Janja with white skin and flesh colour, and Martina with purple skin and white flesh colour. The second factor consisted of agrotextile covered (PP-polypropylene, 17 g/m2 mass per unit area) compared with the treatment with no cover. The PP cover treatment was applied after the initial irrigation. The cover edges and ends were immediately secured with soil after installation. The plots were covered until harvest. The seedlings were planted on 20 May. The untreated seedlings were planted in the field on ridges, and each ridge was 30 cm wide and 30 cm high. The distance between rows was 1.2 m, whereas the in-row distance was 1.4 m. The length and width of the experimental plots were 16 m and 8 m, respectively. Therefore, the area of the plot was 128 m2. All crops were drip-irrigated, with one dripper line per row in all experimental plots. The drippers within the line were placed 50 cm apart.

The basic characteristics of all cultivars, adopted from Pipan et al. (2017), are described in Table 1.

Tab. 1. Descriptions and some characteristics of the sweet potato cultivars included in the research (Pipan et al., 2017)

	Cultivar		
	Lučka	**Janja**	**Martina**
Characteristics	***State of expression***	***State of expression***	***State of expression***
Plant growth habit	spreading	spreading	spreading
Length of primary shoots	medium	short	short
Pubescence of tip	absent or sparse	absent or sparse	dense
Leaf blade lobes	absent	three lobes	absent
Leaf blade shape	triangular	triangular	triangular
Leaf blade colour	green	green	green
Petiole length	short	short	short
Storage root shape	ovate	ovate	ovate
Storage root: ratio length/width	medium	elongate	medium
Storage root: main colour of skin	orange	white	purple
Storage root: main colour of flesh	orange	white	white

All recommended crop treatments such as irrigation, weed eradication, and plant protection were performed uniformly according to conventional cultivation methods.

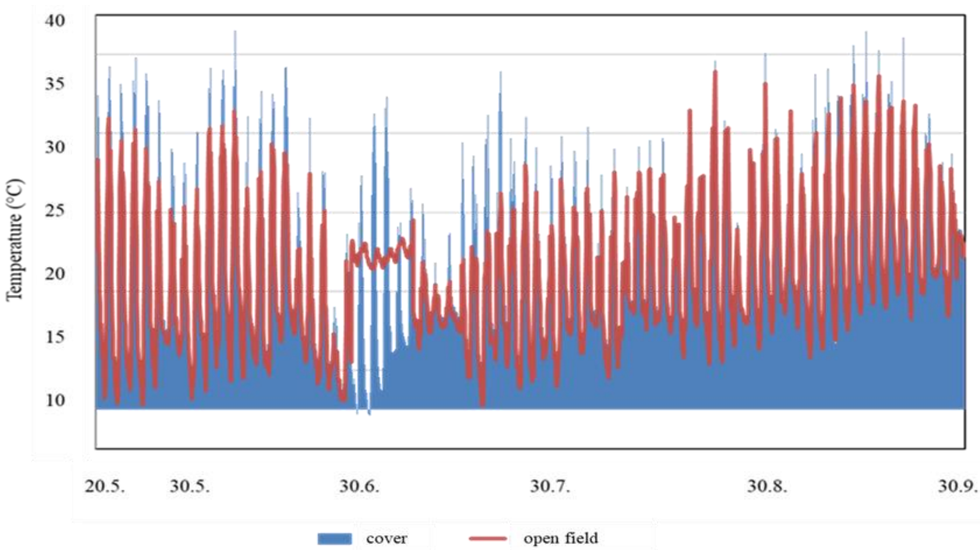
The tubers were harvested simultaneously for all cultivars at optimum maturity by hand from 5 m of the middle two rows from each main plot, 132 days after planting using a spading fork. The fork was inserted below the ridges of the plants and turned upright to expose storage roots. Vines with storage roots were uprooted and the tubers were handpicked and placed in net bags.

Analysis of variance was performed to assess the significance of the treatment effects. Differences between treatment means were compared using the Tukey's multiple range test at confidence level of 0.05.

Results and Discussion

Throughout the growing season, the air temperature matched the long-term data. The season's precipitation quantity was just beneath the average. The weather conditions were adequate for sweet potato crops growth. Temperatures were registered using the DL-121TH Voltcraft USB data loggers, which were installed 20 cm above the soil surface under the agrotextile and in open air. The thermal distinctions among the covered crops and open air were greater at the beginning of the growing period. With the growing season advancing, the values of daily average temperatures in open area and under cover were more-or-less increasing and, therefore, the distinction between non-cover and covered plots was investigated. Daily temperatures during the growing period are shown in Figure 1. The air temperature under the cover was 4.2-6.8°C higher than the open field temperature in the daytime, while little difference was observed at night. This was primarily due to the higher maxima under the cover.

Rattin et al. (2018) have reported covers increase air temperature around the crop and their use has been associated with increased plant growth. Some researches (Moreno et al., 2005) have demonstrated higher air temperature under covers and attributed it to cover permeability and the modified thermal regime inside.



Graph. 1. Meteorological conditions during growing period of the sweet potato

The results of the present study on the impact of plant cover and cultivars on selected variables are shown in Table 2. It can be seen that the characteristics of different cultivars and plant cover of sweet potato varied between cultivars. Significance differences among the crop characteristics were also reported by Gitore et al. (2021). Hossain et al. (2022) suggested that these differences may be due to the genetic and environmental distinctions.

Results indicated that main vine length at harvest depended both on the plant cover and on the cultivar itself. However, the vine length is a key factor in arrangement of plant populations in a certain land area. The most productive cultivar in terms of main vine length was cv. 'Lučka' (215 cm). The vine length obtained from cover treatment was significantly longer (236 cm) than that from no cover treatment (162 cm). According to Zhang et al. (2018), the vine length can be affected by various factors, such as effects of wind speed, soil fertility, light quality, and light quantity.

The branch number of cv. 'Lučka' (36.4/plant) was the highest amongst cultivars. On the other hand, the results showed that plant cover had no significant effect on the branch number. Somda and Kays (1990) mentioned that branching of sweet potato appeared to be dependent not only on production technology and environmental conditions but also on the genotype.

Genetic features of the cultivars had a significant influence on the number of leaves per plant. The greatest number of leaves were found in cv. 'Lučka' (540). A higher number of leaves/plant was formed by sweet potato plants under agrotextile (568 leaves/plant) compared to uncovered plants (446 leaves/plant). Struik (2007) stated that the number of leaves per plant is a significant morphological property, as it affects the development of the above-ground mass, that is, assimilation surface area. According to Xu and Huang (2000), plant leaves balance as the largest percentage of canopy and play an essential function in all physiological activities of crops, such as PAR absorption, transpiration and photosynthetic potential of the crop, being completely dependent on the leaf area index (LAI).

In the present study, the same trend of variation was determined for the LAI. It varies considerably depending on the cultivar and production conditions. The LAI is defined as the ratio of total projected leaf area per unit of ground surface area and is commonly used to assess the photosynthetic potential of crop growth (Zhang et al., 2018).

In the case of the LAI, the cv. 'Lučka' is significantly superior to all others. The LAI for covered plants was significantly higher on average by 6.2 m2/m2 compared to the plants cultivated without covers. According to Liu et al. (2012), a higher LAI value could cause an increase in yield and improve its quality. On the other hand, Dukuh (2011) claimed that a higher LAI in sweet potatoes did not have a positive influence on tuber yield as the continuous growth of leaves limited tuber development. The obtained results are in harmony with the results obtained by Fang et al. (2019), which showed that a higher LAI in sweet potatoes did not confer any advantage in the final tuber yield.

Together with the LAI, the plants differed in the amount of the haulm dry weight/plant. To obtain the dry weight (DW), fresh haulms were dried at 60oC for 48 h in a forced air oven. When comparing the cultivars, cv. 'Lučka' obtained the highest value (415 DW/plant) than cv. 'Janja' (350 DW/plant) and cv. 'Martina' (294 DW/plant). Additionally, it has been shown that the cover treatment was the most suitable for the haulm dry weight/plant. The plants under agrotextile elicited significantly higher haulm dry weight/plants (432 DW/plant) compared to the uncovered treatment (356 DW/plant).

Tab. 2. The vegetative features of the sweet potato cultivars measured in the field trial run in 2018

Treatment	Vine length (cm)	Branches (no/plant)	Leaves (no/plant)	Leaf area index (m^2/m^2)	Haulm dry weight (g/plant)
Cultivar					
Lučka	215 a	36.4 a	540 a	20.6 a	415 a
Janja	134 b	25.3 b	432 b	15.6 b	350 b
Martina	156 b	27.8 b	412 b	14.8 b	294 c
Crop cover					
Cover	236 a	28.6	568 a	21.4 a	432 a
No cover	162 b	26.4	446 b	15.2 b	356 b
Significance					
Cultivar (C)	*	*	*	*	*
Plant cover (P)	*	NS	*	*	*
C x P	NS	NS	NS	NS	NS

The tuber characteristics and yield of sweet potato cultivars is presented in Table 3. No effect of cover application was observed on the length and diameter of tubers. On the other hand, the cultivar significantly affected these parameters. At final harvest cv. 'Martina' had the longest tubers (29.8 cm) and cv. 'Janja' had the largest diameter (8.2 cm). Similar to our findings, Reddy et al. (2018) also reported oscillation in the tuber size of sweet potato. Hossain et al. (2022) noticed that such variation may reflect soil types, production practice, growing season, as well as genetic factors.

The number of tubers per plant with adequate proportion is one of the most relevant yield parameters. In our study, the number of tubers produced by each plant was affected by the cultivar potential and agricultural practices. The highest value was found in cv. 'Lučka' with 5.2 tubers/plant. Other cultivars gave almost similar values between 3.2 and 3.6 tubers/plant. The use of the agrotextile significantly increased the tuber number (5.3 tubers/plant), in comparison with the cultivation without plant covering (3.9 tuber/plant). These results agree with the findings of Hayati et al. (2020).

The fresh tuber weight was also found to vary among the cultivars as well as covered and uncovered treatments. Cv. 'Martina' (324 g) showed a significant difference in comparison with cv. 'Lučka' (216 g), but not with cv. 'Janja' (258 g). According to Widaryanto and Saitama (2017), the deviation in yield among cultivars is influenced by meteorological conditions, diseases caused by viruses, and the genetic makeup of the crop. It was further noted that cultivation technologies had a significant effect on the weight of tubers. The weight of tubers grown under agrotextile was significantly higher (278 g) than in the sweet potatoes cultivated without covering (194 g).

Cv. 'Janja' produced the highest yield per hectare (7.49 t/ha) compared to other cultivars. Additionally, it has been shown that cover utilization had an important influence on the total yield of tubers harvested at full maturity of sweet potato plants. The yield of the control – without the cover – was 4.51 t/ha on average, while under cover it was 8.76 t/ha. The results obtained are accordance with previous studies, showing that covering has a positive effect on productivity and yield of lettuce (Lactuca sativa L.) (Kopitar et al., 2022), cabbage (Brassica oleracea L.) (Khramov et al., 2019), potato (Solanum tuberosum L.) (Hamouz et al., 2005), kohlrabi (Brassica oleracea var. gongylodes L.) (Biesiada, 2008), cucumbers (Cucumis sativus L.) (Ibarra-Jimenez et al., 2004), Chinese cabbage (Brassica rapa L. supsp. pekinensis) (Hernandez et al., 2004), bell pepper (Capsicum annuum L.) (Sinkovič et al., 2017), and spinach (Spinacia oleracea L.) (Murakami et al., 2001).

Tab. 3. The tuber characteristics and yield of the sweet potato cultivars measured in the field trial run in 2018

Treatment	Tuber length (cm)	Tuber diameter (cm)	Tubers (no/plant)	Tuber weight (g)	Yield (t/ha)
Cultivar					
Lučka	23.5 b	5.4 a	5.2 a	216 b	6.68 b
Janja	20.5 b	8.2 b	3.6 b	258 ab	7.49 a
Martina	29.8 a	5.1 a	3.2 b	324 a	6.16 b
Crop cover					
Cover	26.4	7.4	5.3 a	278 a	8.76 a
No cover	24.8	5.2	3.9 b	194 b	4.51 b
Significance					
Cultivar (C)	*	*	*	*	*
Plant cover (P)	NS	NS	*	*	*
C x P	NS	NS	NS	NS	NS

Conclusion

Because sweet potatoes are of tropical origin, their cultivation in Slovenian climate conditions is associated with noticeable dangers, due to the frost possibility in the initial growth stage, which may cause serious damage to entire plantations.

Our experiment indicated that the agrotextile cover plays an essential role in the successful production of sweet potato. The use of polypropylene covers resulted in an increase of the vegetative growth and tuber yield, when compared with the traditional cultivation. Our findings may also simplify the choice of suitable cultivars for production in Slovenia.

Acknowledgement

This study was a part of the Bilateral project (Vegeteble production in Slovenia and Bosnia and Herzegovina from the point view of pressures on the environment) between the Republic of Slovenia and the Bosnia and Herzegovina (BI-BA/21-23-12, Slovenian Research Agency).

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Утицај биљног покривача нетканим агротекстилом на вегетативне карактеристике раста и принос слатког кромпира (*Ipomoea batatas* L.): Словеначка студија случаја

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Сажетак

Циљ овог истраживања био је процијенити утицај сорте и покривања нетканим агротекстилом на вегетативне параметре раста и вриједност продуктивности слатког кромпира (*Ipomoea batatas* L.). Теренски оглед је изведен током вегетације 2018. године, на огледном пољу Биотехничког факултета у Љубљани (надморска висина: 305 m; φ = 46° 04′; λ = 14° 31′). Земљиште је шљунковито глиновито, дубине 40-60 cm и реакцијом pH 6,7. Истраживањем су обухваћене сљедеће словеначке сорте слатког кромпира: Лучка, Јања и Мартина. Размак између редова износио је 1,2 m, док је међуредни размак био 1,4 m. Експеримент је постављен као факторијални оглед са четири понављања у блок систему. Садња биљака је обављена 20. маја. Биљке на половини парцела су покривене агротекстилом (17 g/m2), док су непокривене биљке служиле као контрола. Препоручене мјере његе су спроведене по потреби током експеримената. Температура испод агротекстила била је у просјеку за 5,5 °C виша. Вађење кртола је обављено 132 дана након садње. Покривање је значајно позитивно утицало на вегетативни раст - висина стабла, број листова, индекс лисне површине и суве маса биљке. С друге стране, покривање није показало значајан утицај на број грана по биљци. Употреба агротекстила значајно је повећала дужину и пречник кртоле, број кртола, масу кртола и укупан принос, у поређењу са традиционалним узгојем без агротекстила. Статистичка анализа је показала да сорта Јања има значајно већи принос (7,49 t/ha) у односу на сорте Лучка (6,68 t/ha) и Мартина (6,16 t/ha).

Кључне ријечи: слатки кромпир, *Ipomoea batatas L.*, сорте, агротекстил, компоненте приноса

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Received: October 21, 2022
Accepted: February 10, 2023