

STUDY OF THE EFFICIENCY OF SWEET POTATO GROWING IN THE FOREST-STEPPE OF UKRAINE BY DIFFERENT METHODS OF SOIL MULCHING

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Abstract

Sweet potato (*Ipomoea batatas L.*) is a new crop for soil and climatic conditions of Ukraine, the active implementation of which is hindered by the lack of recommendations on technological aspects of cultivation. One of the important technological measures for growing sweet potatoes is the use of soil mulching, which improves the water regime and regulates the thermal regime of the soil; prevention of weed growth and growth of sweet potato shoots to the soil. Thus, the aim of the research is to determine the efficiency of growing sweet potatoes in the Forest-Steppe of Ukraine by different methods of soil mulching.

Field research was carried out on typical low-humus light loamy chernozem on loess loam.

It was noted, that when growing sweet potatoes on ridges, the introduction of mulching the soil with black polyethylene film provides more active growth of the vegetative mass throughout the growing season (5.33 shoots/plant with a total length of 252.1 cm), while growing without ridges has a positive effect on plants growth due to the general absence of mulch (2.53 shoots/plant with a total length of 107.8 cm).

The use of ridges and mulching the soil with black polyethylene film causes the yield of sweet potato tubers at 34.8 t/ha, while the mulching of the soil with straw, the yield was 18.3–21.9 t/ha, without mulching – 13.0–17, 1 t/ha. Mulching with black polyethylene film ensures the accumulation of vitamin C and starch in sweet potato tubers. When growing the culture on ridges by this method of mulching, the maximum level of vitamin C according to the experiment (4.78 mg/100 g) and starch (11.73 %) was noted.

The introduction of mulching and ridge formation involves additional material and labor costs, but helps to reduce weed control and tuber digging costs. When growing sweet potatoes on ridges with mulching with black polyethylene film, the minimum additional labor costs for the formation of a unit of yield (1.95 man-minutes/kg of tubers) were noted, while without mulching and without ridges this figure was 6.76 man-minute/kg.

Keywords: mulching of soil, yield of sweet potato tubers, biochemical composition of tubers, labor costs.

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1. Introduction

The main advantages of growing sweet potatoes (*Ipomoea batatas L.*) are high yields and nutritional value. The roots of the culture contain a large amount of potassium, antioxidants (especially

in varieties with orange and purple pulp), vitamins A and C, groups B (B₁, B₂, B₃, B₆, folic acid), iron, phosphorus, calcium, magnesium [1–3]. Sweet potatoes are rich in complex carbohydrates and fiber, so it is recommended for people with diabetes and athletes. The use of sweet potatoes helps to increase immunity, regulates blood pressure, relieves stress, is good for eyesight [4–6].

Despite the fact that in the world the culture of sweet potatoes is quite common (in terms of production ranks third after potatoes and yams), for the soil and climatic conditions of Ukraine there are no ready-made technological solutions for growing this crop. It should also be noted, that sweet potato is a tropical plant, air temperatures below 10 °C negatively affect its development, and at temperatures of 0 °C and below the plants die, the roots rot.

One of the important technological measures for growing sweet potatoes is the use of mulching materials, which is due to several reasons:

- reduction of water evaporation by the soil surface (improvement of the soil water regime);
- regulation of the thermal regime of the soil;
- prevention of weed growth;
- prevention of growth of sweet potato shoots to the soil [7–9].

The biological feature of sweet potato plants is the formation of additional roots in the internodes of shoots at their contact with the soil surface. At the same time, the formation of small tubers (1–3 cm in diameter) is possible, which significantly reduces the yield of the main tubers in the bush.

As mulching materials in the technological schemes of growing sweet potatoes, both materials of organic origin (straw, hay, fallen leaves, shredded wood, bark, etc.) and synthetic (polyethylene film of different colors, agrofiber, agrofabric, etc.) are used.

With the intensification of the technological process of growing sweet potatoes, the use of black polyethylene film as mulch has become widespread, the effectiveness of which has been proven in many studies by the effect on the yield of marketable tubers [10, 11]. The efficiency of using polyethylene film for mulching sweet potato plantations increases significantly when growing crops on ridges [12]. It is effective to combine mulching with black polyethylene film with mycorrhization of *Glomus mossaei* sweet potato plants [13] and application of mineral fertilizers N₈₀P₃₅K₁₀₀ [14]. In Poland, mulching the soil with polyethylene film provides an increase in the yield of sweet potato tubers by 17.7 %, the yield of marketable tubers – by 8.0 % [15, 16]. According to Chinese scientists, mulching the soil with black polyethylene film helps to increase the content of dry substance, starch, anthocyanin in the tubers, increasing the activity of a number of enzymes [17].

Black polyethylene mulch is the most available and often used among others. It effectively absorbs ultraviolet, visible and infrared solar radiation, increases the heat of the arable layer of the soil by absorbing large amounts of radiation. Color variation of polyethylene mulch is designed to change the microclimate at the level of plants and soil. Color change affects the spectral balance, quality and quantity of light, which affects the growth and development of many plants, including plant yields [18]. It is noted, that mulching the soil with silver and red polyethylene films provides maximum overall yield and one of marketable tubers. The use of red polyethylene film significantly increased the content of nutrients in the tubers compared to other uses of colored film and without mulching [19]. According to Chinese researchers [20], the use of black polyethylene film is more effective than white, which is explained by the optimization of the temperature under the film within the limits favorable for the growth of sweet potato plants. In Romania, the use of transparent film as mulch provides the formation of yields of different varieties of sweet potatoes in the range of 24.3–37.7 t/ha, dark-colored film – in the range of 22.3–38.6 t/ha [21]. The use of polyethylene film reduces the density of the soil, increases the porosity and nutrient content of the soil. This type of mulch causes an increase in the content of chlorophyll in the leaves of sweet potato plants, increases the rate of photosynthesis, increases the content of soluble sugar and the content of adenosine triphosphate [22].

Of the synthetic mulching materials in the technology of growing sweet potatoes, agrofabric, which increases the yield of sweet potatoes by 15.2 %, is also used [14]. The use of black

non-fabric textiles causes a significant increase in the average weight of tubers, yield and content of vitamin C in tubers [23].

The most effective and widespread method is mulching the soil surface with post-harvest crop residues. Straw of cereals at a significant reduction in livestock in Ukraine is a cheap material. Mulching the soil with straw increases the percentage of nutrients, used by plants from fertilizers and soil, ensuring an increase in the efficiency of mineral fertilizers (nitrogen – by 55–60 %, and phosphorus and potassium – by 15–20 %) [24]. According to North African scientists, mulching of the soil with newspapers provides reducing the level of weeds and increasing the yield of sweet potatoes, while the use of compost and grass mulch determines the maximum level of weeds [11].

Thus, in different soil and climatic conditions, the effectiveness of different methods of mulching the soil in the technological schemes of growing sweet potatoes differs quite significantly. Therefore, determining the efficiency of growing sweet potatoes in the Forest-Steppe of Ukraine by different methods of soil mulching is an urgent issue.

2. Materials and Methods

The study was conducted during 2019–2021 in the laboratory of agrochemical research and product quality of the Institute of Vegetable and Melon Growing of the National Academy of Agrarian Sciences of Ukraine (Selectsiyne village, Kharkiv region, Ukraine). The soil of the experimental plot is typical low-humus light loamy chernozem on loess loam. The arable layer (0–25 cm) contains:

- humus 4.3 %;
- hydrolyzable nitrogen – 139.0 mg/kg;
- mobile phosphorus – 106–119 mg/kg;
- exchangeable potassium – 93–125 mg/kg of soil;
- hydrolytic acidity – 2.8 mEq per 100 g of soil;
- pH of the salt extract – 5.7;
- the amount of absorbed bases – 26.0 mEq per 100 g of soil.

The experiment of two factors:

- 1) factor A – growing on ridges and without them (ridges 20 cm high and 60 cm wide at the top);
- 2) factor B – the use of different types of mulching materials (without mulch, covering with a layer of straw 5–6 cm, covering with black polyethylene film with a thickness of 120 microns).

The studies were conducted in accordance with generally accepted methods [25, 26]. The total area of the plot was 33.6 m², the accounting area was 21 m², and the iteration was four times. In the study, sweet potatoes of the Slobozhansky Ruby variety were grown under drip irrigation, planting schemes (100+40)×25 cm and application of N₃₇₀P₃₇₀K₄₅₀ under main tillage with foliar fertilization with a complex fertilizer “Nutrivant plus universal” (Israel) 2 kg/ha in 3 terms.

3. Results

The growth processes of sweet potato plants significantly depended on the method of cultivation and the type of material for mulching the soil (**Table 1**). If you grow sweet potatoes on ridges, the active growth of the vegetative mass of plants provides the use of black polyethylene film as mulch. Thus, with the active growth of the vegetative mass, 5.33 shoots are formed on a plant with a total length of 252.1 cm (without mulch 3.67 units/plant and 158.7 cm, respectively). The use of straw as mulch causes a certain lag in the growth of the vegetative mass of sweet potato plants relative to control, which indicates the formation of less susceptible conditions for the development of plants under a layer of straw. We explain this negative effect by allelopathic secretions of straw, which inhibit the growth of young plants of the culture.

At the end of the growing season at growing sweet potatoes on ridges, the use of black polyethylene film as mulch causes the formation of more developed plants (with 10.44 shoots on a plant

with a total length of 987.8 cm). With the use of straw and without mulch, the biometric parameters of plants at the end of the growing season are much lower.

When growing sweet potatoes without the formation of ridges (on a flat soil surface), in the phase of active growth of the vegetative mass, the best biometric parameters of plants are formed without the use of mulch (2.53 shoots per plant with a total length of 107.8 cm). When mulching the soil with straw or polyethylene film, these parameters were significantly lower (1.80–1.93 units/plant and 65.3–68.0 cm, respectively).

Table 1

The biometric indicators of sweet potatoes for different methods of growing and mulching the soil (average for 2019–2021)

Mulching type	Growing method			
	On ridges		Without ridges	
	Shoots number, un/plant	Shoots summary length on a plant, cm	Shoots number, un/plant	Shoots summary length on a plant, cm
Phase of active growth of the vegetation mass (I decade of July)				
Without mulching	3.67	158.7	2.53	107.8
Straw	3.13	111.1	1.80	65.3
Polyethylene film	5.33	252.1	1.93	68.0
MED _{0.95} by years	0.32; 0.36; 0.51	12.4; 26.2; 34.1	0.12; 0.16; 0.22	4.22; 6.17; 7.5
End of vegetation (I decade of September)				
Without mulching	8.52	743.6	6.23	487.4
Straw	8.15	763.4	3.73	393.4
Polyethylene film	10.44	987.8	5.92	470.0
MED _{0.95} by years	0.56; 0.51; 0.78	23.4; 36.7; 41.0	0.24; 0.26; 0.51	12.6; 34.1; 24.8

In the future, at the end of the growing season, according to the biometric parameters, there is no significant difference between mulching the soil with polyethylene film and without the use of mulch, while the use of straw forms less developed sweet potato plants.

The maximum level of sweet potato yield is ensured by the use of black polyethylene film as a mulching material (**Fig. 1**). With this method of mulching for growing plants without ridges, the yield was 21.8 t/ha, for growing on ridges – 34.8 t/ha.

Growing sweet potatoes on ridges provides a significantly higher level of yield, regardless of the method of mulching the soil.

The use of straw has a somewhat negative effect on the formation of biometric parameters of sweet potato plants. But mulching the soil with straw helped to improve the yield of sweet potato tubers compared to the control without mulch, both for growing plants on ridges (4.8 t/ha) and without them (3.3 t/ha).

The use of black polyethylene film for mulching plantations causes an increase in the content of starch (11.73–12.12 %) and vitamin C (4.20–4.78 mg/100 g) in the fruits, regardless of the method of cultivation (**Table 2**). However, this method of mulching shows a tendency to reduce the content of total sugar in the tubers (2.85–2.92 %) and a significant decrease in the dry substance content when growing sweet potatoes on ridges (12.6 %).

Sweet potato tubers with a high content of biochemical components are formed by growing on ridges with straw mulching. The dry substance content is 16.1 %, total sugar – 3.07 %, starch – 11.4 %, vitamin C – 4.05 %.

It is clear, that the introduction of mulching the soil with film and straw, as well as the formation of ridges, causes additional costs of materials and labor. At the same time, mulching reduces the cost of weed control, and ridge cultivation technology improves the digging of tubers.

The use of black polyethylene film as a mulching material reduces the cost of labor for the care of sweet potato plants (planting, manual weeding, digging) to the level of 6.67–6.79 man-minutes/m. In the control without mulching, these indicators were 8.79–8.91 man-minutes/m² (Table 3).

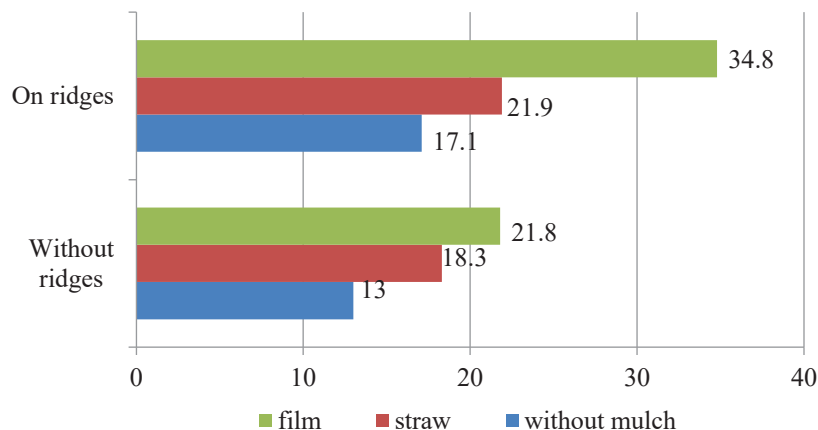


Fig. 1. Yield of sweet potato tubers depending on the type of mulching material and method of cultivation, t/ha: MED_{0.95} for factor *A* for 2019 – 1.87, for 2020 – 1.73, for 2021 – 1.30; MED_{0.95} for factor *B* for 2019 – 1.98, for 2020 – 1.86, for 2021 – 1.34; MED_{0.95} for factor *A*×*B* for 2019 – 2.02, for 2020 – 1.88, for 2021 – 1.45

Given the level of yield of sweet potatoes in different methods of cultivation and mulching, the minimum labor costs for the formation of crop yields are provided by growing sweet potatoes on ridges with mulching film (1.95 man-minutes/kg), maximum – without ridges and without mulching (6.76 man-minutes/kg).

Table 2

The biochemical composition of sweet potato tubers depending on the type of mulching material and method of cultivation (average for 2019–2021)

Soil mulching	Content in tubers, %			
	Dry substance	Total sugar	starch	Vitamin C, mg/100 g
Without mulching	13.4	3.02	9.94	3.90
Straw	16.9	2.93	11.43	3.91
Polyethylene film	14.5	2.85	12.12	4.20
Without mulching	15.6	3.20	11.50	3.77
Straw	16.1	3.07	11.40	4.05
Polyethylene film	12.6	2.92	11.73	4.78
HIP _{0.95} by years	1.11; 1.29; 1.32	0.36; 0.36; 0.27	1.05; 1.13; 1.4	0.24; 0.42; 0.49

For implementation in the Forest-Steppe of Ukraine, it is recommended to grow sweet potatoes on ridges with mulching of the soil with black polyethylene film. To deepen the knowledge on the formation of optimal conditions for growing sweet potato plants, you can further investigate the effectiveness of the use of different thickness and color of the polyethylene film. It is also promising to study the effectiveness of different types of mulching materials for organic technologies for growing sweet potatoes. In such technologies, the main factor, influencing the nutrient regime of the soil and phytosanitary condition of crops, is the use of drugs with different microorganisms. Mulching with polyethylene film has had a positive effect on the quality of the tubers due to the lack of clogging and better absorption of

nutrients by plants. Growing on ridges gave good yields for all methods of mulching compared to growing without the use of ridges.

Because sweet potato is a tropical vine and at the end of the growing season generates a large green mass. And with the sharp onset of cold, which is inherent in these climatic conditions, all the leaf mass darkens, the process of dying begins, and pathogens reach the tubers through the creeping stems. Therefore, you need to immediately get rid of all the aboveground mass, which in production requires additional labor costs for cutting and harvesting cut stems and immediate digging of tubers. In general, the limiting factor is the temperature regime, which affects the overall length of the growing season, as a result deteriorating yield parameters.

Table 3

Calculation of additional labor costs for different methods of mulching sweet potatoes (average for 2019–2021)

Growing and mulching method	Time costs, man-minutes/m ²			Summary costs of man-minutes/m ²	Additional labor costs, man-minutes/kg of yield
	Planting of slips	Manual weeding	Harvesting		
Without ridges					
Without mulching	0.91	3.64	4.24	8.79	6.76
Straw	0.91	1.82	4.95	7.68	4.20
Polyethylene film	1.52	0	5.15	6.67	3.06
On ridges					
Without mulching	0.91	3.64	4.36	8.91	5.21
Straw	0.91	1.82	5.03	7.76	3.54
Polyethylene film	1.52	0	5.27	6.79	1.95

In temperate latitudes sweet potatoes are propagated vegetatively and planting material is selected from dug tubers. With the onset of cold weather, the development of plants stops, which does not allow the generative organs of sweet potato plants to develop, and in some varieties they are not formed at all. This circumstance makes it impossible to obtain sweet potato seeds under normal growing conditions, which is a significant obstacle to the selection and zoning of varieties.

Storage of tubers is problematic for large-scale production. Arranged storages for root and tuber crops in our area are designed for storage of cold-resistant plants with a temperature of 0–10 °C and humidity of 80–90 %. Sweet potato tubers should be warmed immediately after digging (treatment period) for 5 days at a temperature of 30–30 °C and humidity of 90–95 %. After the treatment period, the tubers should be placed in a ventilated container and stored in a room with humidity above 80 % and an average temperature of 15 °C, because at temperatures below 10°C tubers rot, and at temperatures above 18 °C begin to germinate, increasing humidity prevents their drying.

4. Conclusions

In the course of the research the efficiency of using ridges and mulching the soil with black polyethylene film for growing sweet potatoes in the Forest-Steppe of Ukraine has been determined. Under this technological approach, the yield of sweet potato tubers was 34.8 t/ha. An increase in the content of vitamin C (4.78 mg/100 g) and starch (11.73 %) in the tubers, a decrease in labor costs for the formation of a unit of yield (additional labor costs are 1.95 man-minutes/kg of tubers).

It is noted, that due to the influence on the biometric parameters of plants, mulching the soil with black polyethylene film is effective only for growing sweet potatoes on ridges. When growing crops without ridges, the positive effect on plant growth is due to the general absence of mulch.

The results of the study will be further used to develop other elements of sweet potato growing technology in soil and climatic conditions of Ukraine (fertilization system, irrigation, weed control) and to establish effective mulching parameters (selection of optimal film thickness and color, ridge height).

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