SCIENTIFIC HORIZONS
Journal homepage: https://sciencehorizon.com.ua
Scientific Horizons, 26(2), 54-65

UDC 635.21:631.531.02:632.38:632.16
DOI: 10.48077/scihor.26(2).2023.54-65

Physiological and biochemical justification of second-crop potatoes (*Solanum tuberosum* L.)

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Article's History:
Received: 18.12.2022
Revised: 18.02.2023
Accepted: 8.03.2023

Suggested Citation:
Melnyk, O., Dukhina, N., Pastukhov, V., Semenchenko, O., & Ilinova, Ye. (2023). Physiological and biochemical justification of second-crop potatoes (*Solanum tuberosum* L.). *Scientific Horizons*, 26(2), 54-65.

Abstract. The relevance of the conducted studies lies in the need to improve the technology of growing potatoes from freshly picked tubers in the conditions of summer planting to improve the quality of seed material. The purpose of the study was to determine the influence of the physiological and biochemical state and varietal characteristics of potato plants on the ability of freshly harvested tubers to form high-quality seed material for second-crop potatoes in the Forest-Steppe of Ukraine. Field, statistical, computational, analytical, and laboratory methods were used to conduct the study. It is identified that harvesting the first crop for planting with freshly picked tubers during the flowering phase and within two weeks after its completion is ineffective for some varieties. Therewith, the first crop averages 18.5 t/ha, and the second – 5.1 t/ha. Some varieties have a low germination rate from freshly picked tubers

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(from 4 to 76%) or are not formed at all. This is due to the accumulation of germination inhibitors (abscisic acid etc.) in maturing tubers, which causes deep natural dormancy of tubers. It is proposed to consider the activity of germination inhibitors in freshly harvested tubers using allelopathic testing, which allows for determining the optimal time for their collection and planting. This ensures germination rate at the level of 80-87%. Therewith, the first crop of tubers is from 10.1 to 15.0 t/ha, and the second – from 26.2 to 9.3 t/ha. The dependence of the content of abscisic acid with the accumulation of starch in tubers allows visually determining their suitability for germination by the chemical reaction of vegetable juice with an iodine solution. The practical value of the study lies in the possibility of obtaining two crops of seed potatoes per year, while the first crop is formed in 60-70 days, and the second – 90-100 days from planting. Despite the relatively low yield, the resulting seed material is physiologically young, free from diseases and has a high productivity potential. This allows for shortening the seed production scheme, increasing the reproduction rate of potatoes, and saving resources

Keywords: potatoes; seed production; freshly picked tubers; two crops; reproduction rate; allelopathic testing

INTRODUCTION

The need to research the possibility of forming high-quality potato seed material in the Forest-Steppe of Ukraine is justified by negative climate changes and the complication of the humanitarian crisis in the country. An increase in average daily air temperatures and uneven soil moisture supply in the region led to a substantial decrease in the yield of agricultural crops, in particular, potatoes, using conventional cultivation technology. The formation of seed material under these conditions becomes ineffective due to the intensive degeneration of plants during sequential reproduction. Seed material improved by biotechnological methods needs variety renewal after 3-5 years of reproduction in this region. Providing farmers with high-quality seed material of promising potato varieties is possible if the seed production technology is adapted to modern growing conditions.

R. Vozhehova *et al.* (2021) note that optimal conditions for the growth and development of potato plants are formed when the average daily air temperature is not higher than 18-21°C. Therewith, the soil moisture content should be at least 65-70% of the lowest moisture capacity. According to V. Pastukhov (2021), over the past 25 years, there has been a substantial increase in average daily air temperatures in the eastern Forest-Steppe region of Ukraine. In critical phases of plant development, which are the budding and flowering phases, temperature values exceed perennial values by 1.1-2.4°C. Therewith, precipitation has a heavy rain character, which leads to compaction and overheating of the soil. Under these conditions, the formation of tubers is inhibited. Their development is accompanied by physiological disorders. In addition, in July-August, plants are intensively re-infected with insects that carry viruses (aphids, cicadas, etc.). This leads to an acceleration of the degeneration of potato plants.

Climate researchers predict that an increase in CO_2 concentration will lead to an increase in the efficiency of using solar radiation, which can contribute to the growth of potential yields in some regions (George *et al.*, 2017; Rana *et al.*, 2020). However, increased heat and drought, which will be observed in areas with insufficient hydrological supply, will cause increased stress in plants and reduce their productivity (Yagiz *et al.*, 2020; Muhie, 2022).

The conventional scheme of potato seed production is based on the use of the material improved by the method of culture of apical meristems. Elite potatoes (base material) are obtained from the source material improved in this way for four years (Bondarchuk, 2010). However, due to changes in weather conditions in the region recently, it has not been possible to form a full-fledged seed material with high productive potential.

Under these weather conditions, the formation of potato seed material is possible with a second-crop culture. Similar technology, as evidenced by L. Boiarkina *et al.* (2020), is used in the south of Ukraine and avoids the negative impact of adverse conditions on the formation of potato seed tubers. Therewith, the first crop is harvested before the period of maximum air temperatures, and the second crop is formed at favourable temperatures in September-October. This technology allows for avoiding the re-infection of plants with virus-carrying insects and forming a crop of physiologically young tubers with high productive potential. The second-crop technology of obtaining seed material allows potato seed production on a two-year cycle.

The effectiveness of a second-crop culture largely depends on the suitability of potato varieties for the intensive formation of the first crop of tubers. According to K. Mori (2015) and J.P. Hyun (2021), it is most appropriate to use varieties that quickly form a developed vegetative mass that prevents overheating of the soil. The value of soil cover for the formation of the second tuber crop is slightly lower. More substantial is the duration of the dormant period, which is a varietal property. It is most appropriate in the conditions of eastern Ukraine to use early and medium-early varieties to obtain two potato crops. Among the 194 potato varieties zoned in Ukraine, 40 early-maturing and 25 medium-early varieties are recommended for the conditions of the Forest-Steppe region (State register of plant varieties suitable for dissemination in Ukraine in 2022, 2022).

However, the presence of varietal features in relation to the physiological and biochemical mechanism of the deep natural dormant period requires further research.

The purpose of this study is to determine the influence of the physiological and biochemical state and varietal characteristics of potato plants on the ability of freshly harvested tubers to form high-quality seed material for a second-crop culture in the Forest-Steppe of Ukraine.

MATERIALS AND METHODS

Field research in 2012-2018 was conducted in the soil and climatic conditions of the eastern Forest-Steppe of Ukraine in accordance with the "Methodical recommendations for conducting research with potatoes" (Kutsenko *et al.*, 2002).

During 2012-2014, methods for removing freshly picked tubers from dormancy were examined on potato varieties Serpanok and Skarbnytsia, which provided for their pricking, germination, chemical treatment with stimulants, and a combination of these operations.

In 2014-2015, potato varieties of Ukrainian selection Tyras, Skarbnytsia, Serpanok, Ivankivs'ka rannia, Strumok, Shchedryk, Partner, Povin', Hlazurna, Kimmeriia were examined. Spring planting was conducted in the third decade of April, summer planting of freshly picked tubers of the varieties under study – in the flowering phase.

In 2016-2018, laboratory studies were conducted on the activity of germination inhibitors in freshly picked tubers of the Tyras variety using the method of allelopathic testing. Therewith, white mustard seeds were sprouted in an extract from the vegetable juice of freshly harvested tubers of different harvesting periods (control – distilled water). The biotesting was conducted by analogy with laboratory studies on the allelopathic interaction of other vegetable plants (Harbovska *et al.*, 2020; Semenchenko *et al.*, 2020). Determination of starch content in freshly picked tubers was conducted according to the relevant state standard (DSTU 4953:2008, 2009). The presence of colouration of vegetable juice of tubers was determined by adding an iodine solution to it at a concentration not exceeding 5%. In the field, the first crop of Tyras tubers was harvested 60, 63, 66, 69, and 72 days after planting. A four-component chemical solution (thiourea – 1%, potassium rhodanide – 1%, gibberellin – 0.0005%, succinic acid – 0.002%) was used to inactivate the action of inhibitors (Bondarchuk, 2019). After processing, freshly picked tubers were planted to produce a second crop, which was harvested after 98, 95, 92, 89, and 86 days, respectively.

The weather conditions of 2012-2018 were substantially different, which is typical for this geographical area. This allows for assessing the suitability of the examined varieties for second-crop cultivation technology and investigating the physiological and biochemical state of potato plants depending on the time of harvesting the first crop. Notably, the temperature conditions of the growing season of the eastern Forest-Steppe of Ukraine, according to perennial data, are characterised by long hot periods, which causes the riskiness of potato growing in this region. According to the conventional technology of growing seed potatoes, its critical phases of development fall on the maximum increase in average daily air and soil temperatures, which negatively affects the processes of stolon and tuber formation (Archive of meteorological data, n.d.).

Analysis of meteorological data (according to the Merefa weather post) covering the growing season of potatoes with the first and second tuber crops indicates a tendency of daily increase in air temperatures during 2012-2018. Their increase compared to the perennial average values ranged from 0.1 to 2.9°C. Special attention is paid to the period from mid-June to the third decade of September when the hottest weather is observed. Freshly picked tubers during this period are just beginning active vegetation and the transition to autotrophic nutrition. The formation of tubers of the second crop occurs in relatively moderate conditions, starting from the third decade of September to the end of October (Fig. 1).

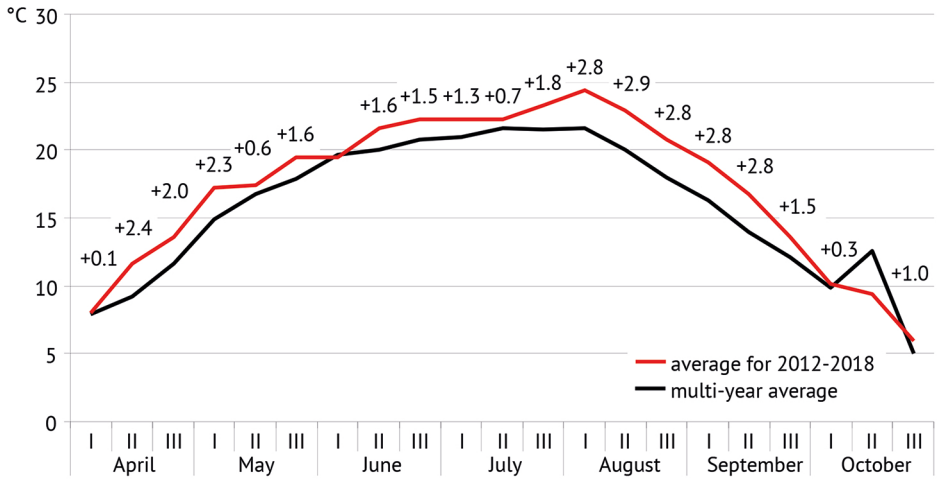

***Figure 1**. Average daily air temperature during the potato growing season, 2012-2018*
***Source:** compiled by the authors*

The increase in maximum and average daily air temperatures was mostly due to a reduction and uneven precipitation over time. This led to dry periods during the potato growing season (Fig. 2).

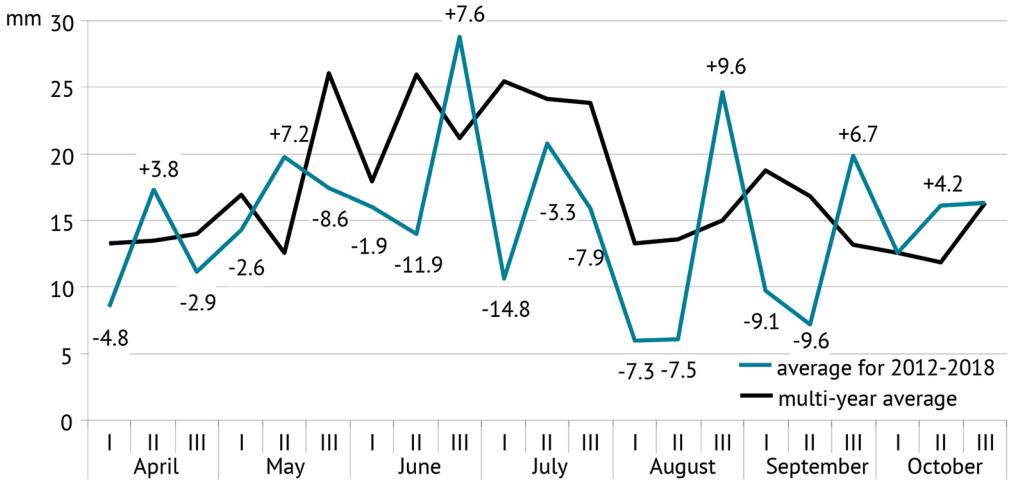

***Figure 2**. Precipitation dynamics during the potato growing season, 2012-2018*
***Source:** compiled by the authors*

For the period from 2012 to 2018, the amount of precipitation during the growing season averaged 313.0 mm, which is 53.1 mm less than the perennial value. Special attention should be paid to the progressive decrease in precipitation in the period from the beginning of July to mid-August, when there was a decrease in the amount of precipitation by 40.8 mm. The small amount of precipitation that was observed during the growing season was mainly heavy rain and was not productively absorbed by plants. The general deterioration of the hydrothermal regime in relation to the biological requirements of potatoes confirmed global trends in climate change and expected forecasts for Ukraine.

RESULTS AND DISCUSSION

The main problems of second-crop technology are the intensity of tuber crop formation and the ability of freshly harvested tubers to come out of dormancy. Harvesting of the first crop of tubers is recommended to be conducted during mass -flowering and within two weeks after its completion (Osypchuk *et al.*, 2012). Only certain varieties, mainly early-maturing and medium-early, can form a full-fledged crop of seed tubers in such a short period of time in the conditions of the eastern Forest-Steppe of Ukraine. According to the results obtained, the yield above average (18.5 t/ha) at the time of flowering is formed by the varieties Tyras (19.4 t/ha), Skarbnitsa (22.5 t/ha), Shchedryk (19.4 t/ha), and Ivankivs'ka rannia (27.0 t/ha). The harvest from summer planting with freshly picked tubers was formed only by the varieties Tyras, Skarbnitsa, Serpanok, Ivankivs'ka rannia, and Strumok. Their average yield was 10.2 t/ha. The highest yield (14.5 t/ha) was provided by the Tyras, Skarbnitsa (11.0 t/ha), and Serpanok (10.8 t/ha) varieties. Other varieties, due to uneven germination, had a decrease in the second crop of seed potatoes. For the Ivankivs'ka rannia variety, it was 7.9 t/ha, and for the Strumok variety – 6.7 t/ha. Such varieties as Shchedryk, Partner, Povin', Hlazurna, and Kimmeriia did not form shoots for harvesting tubers during the mass flowering of plants and for two weeks after its completion (Fig. 3).

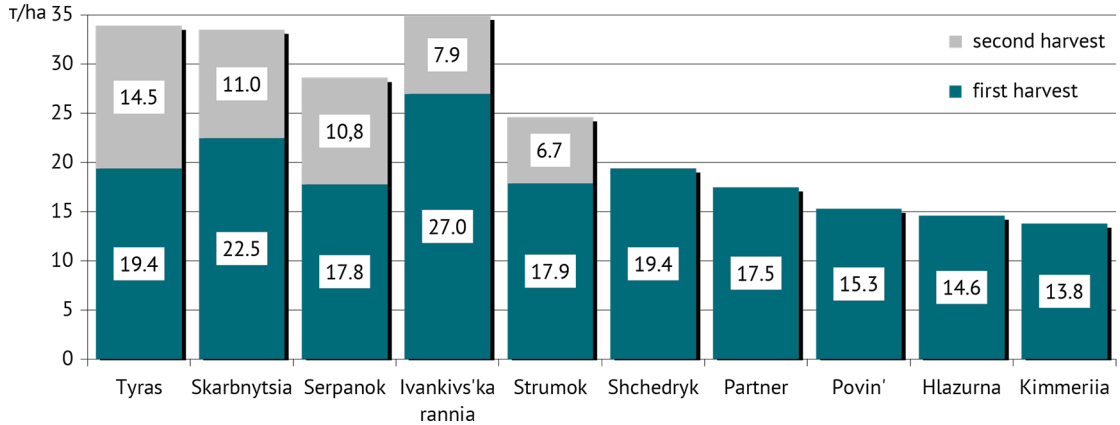

***Figure 3**. Potato yield for a second-crop culture, depending on the variety, average for 2014-2015, t/ha*
***Source:** compiled by the authors*

The reaction of the potato varieties under study to growing in a second-crop culture allows them to be divided into three groups: varieties that react well; varieties that react poorly; varieties that almost do not react. It is worth paying attention to the fact that such a division is conditional and applies only to cultivation according to the method that involves harvesting the first crop of tubers at the onset of the flowering phase.

Tubers of the first crop gradually accumulate inhibitors (abscisic acid, caffeic acid, cinnamon, scopoletin, coumarins) during growth and development, which cause tubers to enter a state of deep natural dormancy (Gemeda, 2017). Therewith, the shoots of freshly picked tubers are delayed or not formed. Thus, the germination rate of the examined varieties ranged from 4 to 76%, depending on the variety (Table 1).

***Table 1**. The germination rate of freshly picked tubers during summer potato planting, depending on the variety, average for 2014-2015*

No.	Variety	Similarity, %
1	Tyras	76
2	Skarbnytsia	67
3	Serpanok	48
4	Ivankivs'ka rannia	69
5	Strumok	66
6	Shchedryk	5
7	Partner	14
8	Povin'	18
9	Hlazurna	23
10	Kimmeriia	4

***Source:** compiled by the authors*

Low germination caused the thinning out of most of the varieties under study. As a result, this did not allow getting a second harvest of seed material of the Povin', Partner, Hlazurna, Kimmeriia, and Shchedryk varieties. This study suggests that when determining the timing of harvesting the first crop of tubers, it is necessary to consider the physiological and biochemical state of each variety. This is due to the fact that a certain part of the varieties in the flowering phase already forms tubers, which begin to enter a dormant state and almost do not form shoots. Therewith, a certain part of the varieties still continues to form stolons, from which tubers have not yet formed. It is advisable to determine the timing of harvesting freshly harvested tubers not by the onset of the phenological phase of flowering, but by the accumulation of germination inhibitors in maturing tubers. Therewith, harvesting of the first crop is proposed to be conducted when a sufficient number of tubers of the seed fraction have formed. This allows economically justifying the first terms of harvesting and determining in a timely manner the last terms at which seedlings can still be obtained.

Regardless of the growing region, the accumulation of germination inhibitors in maturing tubers largely depends on varietal characteristics. In accordance with the duration of the tuber formation period of each individual variety, the optimal time for harvesting and planting freshly picked tubers is individual (Haider, 2021). Weather conditions have a substantial impact on the physiological and biochemical state of potato plants. All factors that accelerate the maturation of tubers contribute to the accumulation of germination inhibitors (abscisic acid, cinnamon, scopoletin, caffeic acid, coumarins, etc.).

The suitability of freshly picked tubers for planting can be visually determined based on the condition of the peel. In physiologically young tubers that are still able to form shoots, the periderm layer is very thin and easily torn off. Therefore, these tubers should be planted immediately after harvesting, before they lose their turgor or rot. Therewith, before treatment with a solution of stimulants, it is advisable to make 10-20 pricks over the entire surface of tubers to the depth of the vascular ring. This technique also increases the germination rate of tubers by 6-13% (Table 2). Short-term germination of these tubers is ineffective, even when combined with chemical treatment with stimulants and pricking.

Field studies were conducted on the Tyras variety, which responds best to second-crop cultivation technology to determine the effect of the physiological and biochemical state of plants on the ability of freshly harvested tubers to form seedlings. The condition of freshly harvested tubers, depending on the time of harvesting, is shown in the figure (Fig. 4).

***Table 2**. Germination rate of freshly picked tubers depending on the method of pre-planting preparation and varietal characteristics, %, average for 2012-2014*

No.	Pre-planting treatment options	Variety	
		Serpanok	Skarbnytsia
1	Chemical treatment (control)	55	68
2	Chemical treatment + germination	27	30
3	Chemical treatment + pricking	68	74
4	Chemical treatment + germination + pricking	21	36

***Source:** compiled by the authors*

***Figure 4**. Freshly picked potato tubers of the Tyras variety after 60, 63, 66, 69, and 72 days of vegetation*
***Source:** compiled by the authors*

When harvesting the first crop 60 days after planting, the Tyras variety forms 25% of the tubers of the seed fraction suitable for planting. In the future, their share gradually continues to grow to 62%. In this case, the yield was determined by both the number and average weight of tubers. Its growth over 12 days was 4.9 t/ha (from 10.1 to 15.0 t/ha) (Table 3).

***Table 3**. Productivity of the first potato crop of the Tyras variety, depending on the time of harvesting, is average for 2016-2018*

No.	Duration of vegetation, days	Number of tubers, pcs./bush	Average weight of tubers, g	Seed fraction, %	Yield, t/ha
1	60	4.2	43	25	10.1
2	63	4.5	42	29	10.7
3	66	4.7	47	35	12.1
4	69	5.1	49	46	13.6
5	72	5.4	50	62	15.0

***Source:** compiled by the authors*

After pricking and short-term immersion in a four-component solution of stimulants, the tubers were immediately planted in the ground on the day of harvesting. Therewith, the activity of germination inhibitors in freshly picked tubers, namely in the eyes, was determined using biotesting. It is at the growth points that the main physiological and biochemical activity of maturing tubers is observed. Using other parts of the plant (tuber pulp or stem) to produce water extraction is less effective, presumably due to the low concentration of inhibitors in them and the presence of other chemicals. The difference in the amount of white mustard seeds sprouted on the extract in relation to those sprouted on distilled water indicates an increase in the content of inhibitors and their effect on growth processes (Fig. 5).

Figure 5. *Germination of white mustard seeds on extract from the juice of freshly picked tubers*
Source: *compiled by the authors*

Starting from the 60th day of vegetation, the number of germination inhibitors gradually increases in maturing tubers. According to the results of allelopathic testing, the activity of these inhibitors increases from 36 to 66% within 12 days. In turn, this leads to a decrease in the germination rate of freshly picked tubers of the examined variety from 87 to 38% (Table 4).

Table 4. *Physiological and biochemical state of freshly picked potato tubers depending on the harvesting period, %*

No.	Activity of germination inhibitors, %	Germination of freshly picked tubers, %	Starch content in tubers, %	Presence of cell juice staining in reaction with iodine solution
1	36	87	6.2	No
2	42	80	6.3	No
3	52	59	6.4	No
4	57	50	6.8	No
5	66	38	6.9	Yes

Source: *compiled by the authors*

In maturing tubers, the peel parenchyma gradually accumulates storage substances, in particular, starch. There is evidence of a relationship between its content and the concentration of abscisic acid, which is an auxin antagonist and accelerates the maturation and entry of tubers into a natural state of deep dormancy (Tkashuk & Shevchuk, 2018). When harvesting, every three days there is a tendency to increase the starch content in freshly picked tubers from 6.2 to 6.9%. Therewith, the reaction of vegetable juice with an iodine solution can be observed by its intense colour in black and purple (Fig. 6). This allows determining the starch concentration in freshly picked tubers, at which abscisic acid and other inhibitors accumulate in an amount at which they begin to enter a state of deep natural dormancy and field germination sharply decreases.

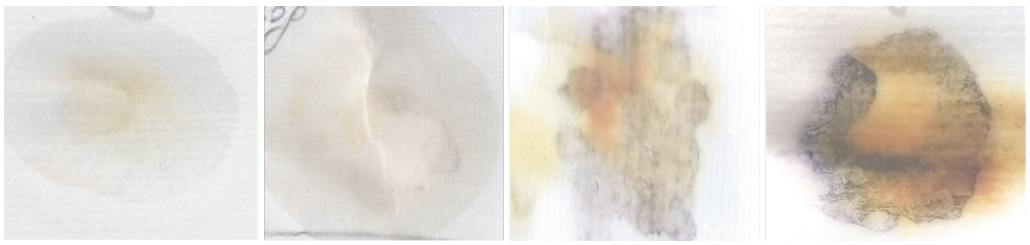

Figure 6. *Discolouration of vegetable juice from freshly picked tubers by chemical reaction with iodine solution depending on the starch content and harvesting time*
Source: *compiled by the authors*

Therewith, the yield from summer planting with freshly picked tubers is maximum during the first planting period (26.2 t/ha), and then decreases to 9.3 t/ha (Table 5). This is mostly due to a decrease in plant density due to a deterioration in germination, and a reduction in the growing season, which is limited by the onset of autumn frosts.

***Table 5**. Productivity of the second potato crop of the Tyras variety, depending on the time of harvesting, average for 2016-2018*

No.	Duration of vegetation, days	Number of tubers, pcs./bush	Average weight of tubers, g	Seed fraction, %	Yield, t/ha
1	98	7.0	77	54	26.2
2	95	7.0	80	49	25.2
3	92	7.0	67	41	15.0
4	89	6.3	74	50	14.1
5	86	5.0	67	38	9.3

***Source:** compiled by the authors*

Damage to the vegetative mass of plants by minor frosts on the soil surface occurs mainly in early October. In the future, a drop in air temperature at night to -3°C leads to substantial damage to the vegetative mass and causes a stop in the vegetation of plants (Fig. 7).

***Figure 7**. Condition of potato plants and their frost damage in October*
***Source:** compiled by the authors*

The second potato crop consists of physiologically young tubers, the vast majority of which are seed fraction. However, this material has a formed periderm and is suitable for perennial storage (Fig. 8).

***Figure 7**. Condition of potato plants and their frost damage in October*
***Source:** compiled by the authors*

Depending on the duration of the growing season, when the first and second crops of seed potatoes are formed, substantial changes are observed in the number of tubers formed. The largest number of tubers in the first crop was formed by plants after 72 days of vegetation (5.4 pcs./bush). However, in the second crop, the maximum number of tubers (7.0 pcs./bush) is formed during the first term of planting freshly picked tubers. This affects the value of the reproduction coefficient, which is the main indicator of the effectiveness of second-crop technology for growing seed potatoes. Depending on the experiment variant, it ranges from 1:26 to 1:10 (Table 6).

***Table 6**. Seed productivity of Tyras potatoes with a second-crop culture depending on the time of harvesting, t/ha, 2016–2018*

No.	Number of tubers in the crop, pcs./bush		Reproduction rate
	first crop	second crop	
1	4.2	7.0	1:26
2	4.5	7.0	1:25
3	4.7	7.0	1:19
4	5.1	6.3	1:16
5	5.4	5.0	1:10

***Source:** compiled by the authors*

Therewith, it is determined not only by the number of tubers that the plant formed by a certain harvesting period but also by the number of plants that formed shoots during summer planting with freshly picked tubers of the first crop. That is why there is a high reproduction rate for the sequential propagation of seed potatoes in variants with the highest germination of freshly picked tubers.

Similar studies were conducted by Balashova *et al*. (2020) in the southern part of Ukraine. According to their results, the growing conditions of the region do not correspond to the biological requirements of the crop. According to this data, a substantial negative impact of climatic factors on the formation of potato seed material is a violation of the development of tubers and intensive degeneration of seed material. A corresponding scheme of potato seed production has been developed, which provides for a second-crop cycle of its cultivation. Therewith, harvesting of the first crop is proposed to be conducted during the flowering phase and within two weeks after it, and freshly picked tubers after appropriate preparation should be planted to obtain a second crop in autumn. The trend towards meteorological changes observed over the past 20-25 years in the Forest-Steppe of Ukraine creates conditions for the emergence of similar problems with the cultivation of seed potatoes in this region. The presented results confirmed the possibility of obtaining seed potatoes in a second-crop culture with a certain improvement in this technology.

Chernychenko (2012), Boyarkina (2019), and Vozhehova (2021) also note the need to adapt the technology of growing seed potatoes to climate change. They analysed the influence of meteorological conditions on the formation of the first and second potato crops and investigated the effectiveness of technological methods for planting dates, the fractional composition of tubers, irrigation, fertilisation, and the use of biologically active substances. The data obtained by researchers confirm the need to stimulate planting material to accelerate the emergence of seedlings, intensify the development of vegetative mass, and activate stolon and tuberous formation. They pay special attention to the varietal reaction of potatoes to second-crop cultivation technology. The potato varieties of Ukrainian selection proposed by Osypchuk (2012) allow forming stable yields of seed material in the soil and climatic conditions of southern Ukraine. However, according to the data of this study, these recommendations on the suitability of varieties require certain changes for use in the conditions of the Forest-Steppe of Ukraine, in particular, in its eastern part.

The influence of varietal characteristics on the ability of freshly picked tubers to come out of dormancy is noted by Balashova (2021). The results of this study confirm the data obtained by the researcher on the accumulation of germination inhibitors in tubers of the first crop and the need for the use of growth stimulants. The high efficiency of a four-component solution for interrupting the dormancy period has been proven: 10 g/l of thiourea +10 g/l of potassium rhodanide +20 mg/l of succinic acid +5 mg/l of gibberellin.

According to Semenchenko (2020), treatment of freshly picked tubers with a solution of fumar with gibberellin leads to an increase in the yield of the Dutch Impala variety by 1.8-1.9 t/ha, and solutions of bioglobin and reastim with gibberellin – the Ukrainian Zahadka variety. However, in this study, there is no high effect on the germination of freshly picked tubers, which can be explained by the physiological and biochemical features of the examined varieties.

Deligios (2020) notes a substantial effect of gibberellic acid on the release of tubers from dormancy.

Therewith, there is an increase in the effect of cutting tubers in half, which is confirmed by the results of this study on mechanical pricking them to the depth of the vascular ring. According to Gemeda (2017), the use of gibberellic acid to disrupt the dormancy of tubers also contributes to an increase in yield by 23-92% and an improvement in potato quality.

Haider (2021) draws attention to the physiological changes in tubers that accompany their dormant state. Of particular importance is the ratio between abscisic acid and cytokinin and between abscisic acid and gibberellic acid. The author also notes the inhibition of catalase and the accumulation of soluble carbohydrates. Therewith, Bajji *et al*. (2007) state about rapid and synchronous germination of tubers treated with thiourea (catalase inhibitor) or exogenous hydrogen peroxide. This confirms the data of this study on the accumulation of germination inhibitors in tubers (in particular, abscisic acid), the possibility of exposure to them by chemical methods, and information on the relationship with changes in carbohydrates (starch, etc.).

Thus, the results of the conducted studies largely confirm the previously obtained data on the substantial influence of the physiological and biochemical state and the varietal reaction of plants on the effectiveness of potato seed formation in the conditions of the Forest-Steppe of Ukraine using second-crop cultivation technology. Therewith, it is proposed to determine the activity of germination inhibitors of freshly harvested tubers based on the results of allelopathic testing and plan the number and timing of harvesting the first crop based on the iodine reaction with the cell juice of these tubers. In the future, this allows for getting full shoots and forming a second crop of high-quality seed potatoes.

CONCLUSIONS

During the study, it was identified that the second-crop technology of growing seed potatoes in the conditions of climate changes observed in the eastern Forest-Steppe of Ukraine allows obtaining seed material twice during one season. This allows for maintaining high seed quality and shortening the seed production scheme. In addition to the use of chemicals, to stimulate freshly harvested tubers of the first crop, it is advisable to prick their surface to the depth of the vascular ring. This improves germination by 8-13%, depending on the variety.

However, as the study showed, not all potato varieties are able to form the first crop of tubers before the flowering phase, which form shoots during summer planting. The germination rate of freshly picked tubers at the level of 48-76% was identified in the varieties Serpanok, Tyras, Skarbnitsa, Strumok, and Ivankivs'ka rannia. Therewith, the first crop is 17.8-27.0 t/ha, the second – 6.7-14.5 t/ha. According to the reaction to the second-crop cultivation technology, the examined varieties can be divided into three groups: varieties that react well; varieties that react poorly; varieties that almost do not react.

Harvesting of the first potato crop of the Tyras variety, depending on the physiological and biochemical state of the plants, allowed obtaining the germination rate of freshly harvested tubers at the level of 87 to 38%. This is largely determined by the activity of germination inhibitors, which gradually accumulate in the tubers of the first crop. The dependence of the content of abscisic acid, which is the main inhibitor of germination, with the concentration of starch in tubers allows using a chemical reaction with an iodine solution to visually determine the suitability of freshly picked tubers for summer planting. When harvesting the first crop of tubers of the Tyras variety, 60 and 63 days after planting, the maximum germination rate of freshly harvested tubers is observed, and the highest density of crops is formed. The reproduction rate is 1:26 and 1:25, respectively.

Further research on the mechanism of accumulation of germination inhibitors in the process of maturation of tubers will attract promising potato varieties to the process of seed production using second-crop technology in the soil and climatic conditions of the Forest-Steppe of Ukraine, which will halve the four-year seed production scheme and increase the reproduction rate.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

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Фізіолого-біохімічне обґрунтування двоврожайної культури картоплі (*Solanum tuberosum* L.)

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Анотація. Актуальність проведених досліджень полягає у необхідності вдосконаленні технології вирощування картоплі зі свіжозібраних бульб за умов літнього садіння для покращання якості насіннєвого матеріалу. Метою досліджень було визначення впливу фізіолого-біохімічного стану та сортових особливостей рослин картоплі на здатність свіжозібраних бульб формувати якісний насіннєвий матеріал за двоурожайної культури в умовах Лісостепу України. Для проведення досліджень використовувалися польові, статистичні, розрахунково-аналітичні та лабораторні методи. Встановлено, що збирання першого врожаю для садіння свіжозібраними бульбами у фазу цвітіння та впродовж двох тижнів після його завершення для деяких сортів є неефективними. При цьому, перший урожай складає в середньому 18,5 т/га, а другий – 5,1 т/га. Деякі сорти мають низьку схожість зі свіжозібраних бульб (від 4 до 76 %) або взагалі їх не утворюють. Це пояснюється накопиченням у дозріваючих бульбах інгібіторів проростання (абсцизової кислоти та інших), що спричиняє глибокий природний спокій бульб. Пропонуємо враховувати активність інгібіторів проростання у свіжозібраних бульбах за допомогою алелопатичного тестування, що дозволяє встановити оптимальні строки їх збирання та садіння. Це забезпечує схожість на рівні 80-87%. При цьому перший урожай бульб складає від 10,1 до 15,0 т/га, а другий – від 26,2 до 9,3 т/га. Залежність вмісту абсцизової кислоти з накопиченням у бульбах крохмалю дозволяє візуально визначити придатність їх до проростання за хімічною реакцією рослинного соку з розчином йоду. Практична цінність роботи полягає у можливості отримання двох врожаїв насіннєвої картоплі на рік, при цьому перший врожай формується за 60-70 діб, а другий – 90-100 діб від садіння. Не зважаючи на порівняно невисоку врожайність, отриманий насіннєвий матеріал є фізіологічно молодим, вільним від хвороб і має високий потенціал продуктивності. Це дозволяє скоротити схему насінництва, підвищити коефіцієнт розмноження картоплі та заощадити ресурси

Ключові слова: картопля; насінництво; свіжозібрані бульби; два врожаї; коефіцієнт розмноження; алелопатичне тестування