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RESEARCH ARTICLE

Adaptability of *Solanum tuberosum* to changes of ecological growing condition

I.M. Kovalenko[1], V.M. Kovalenko[1], Ye.Yu. Butenko[1*], V.M. Sobran[2] , L.V. Kriuchko[1], V.I. Dubovyk[2]

[1]Sumy National Agrarian University, Gerasim Kondratyev Str. 160, 40021, Sumy, Ukraine; *andb201727@ukr.net
[2] Institute for Potato Research of National Academy of Agrarian Sciences of Ukraine, Chkalova Str. 22, Nemishaieve, Borodianka district, Kyiv region, 07853, Ukraine

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Abstract

Ecological effect from implementation of our research results was achieved by restoring and realizing genetic potential of *Solanum tuberosum* varieties. Increasing adaptive capacity of *Solanum tuberosum* provided the reduction of quality production losses, optimization of growing technology. It allows reducing the cost of resources and materials at different stages of the production process. Selection of perspective varieties with high adaptive potential allowed adjusting the variety policy of *Solanum tuberosum* in the region and having a positive impact on environmental situation.

Keywords: Adaptability, variety, *Solanum tuberosum*, productivity, starch, marketability

Introduction

Solanum tuberosum is one of the most valuable agricultural crops. It guarantees food security in many countries, including Ukraine, as well as a balanced diet. Among all crops, from 1 hectare of *Solanum tuberosum*, the largest amount of energy is obtained, the same as from Ipomoéa batátas-166*103 kJ. It produces 2.2 times more protein than Ipomoéa batátas, 1.8 times more than corn and rice. Tubers have all essential amino acids for humans, as in wheat grain and other crops which largely provide human nutrition. Potato starch is absorbed by humans in 10 minutes, while wheat starch and other cereal starch are absorbed up to 1.5 hours-2.0 hours.

Solanum tuberosum belongs to the crops of temperate climates. At the same time, its specificity is manifested in special requirements for external conditions. They are different even within the plant. With optimal moisture for the growth of aboveground part, the optimal air temperature is 17°-21°, and for tuber formation and growth is 15°-18° (Tesliuk et al. 1992). The problem of obtaining steady and high potato yields in recent years is very acute. It is connected with climate change, as it is indicated by both domestic (Kulbida and Barabash 2009) and foreign researchers (Cleland et al. 2007; Wang Chun-ling et al. 2014). Climate changes affect not only plant growth and development, yield capacity and product quality, but also running of phenological phases (Van Ort et al. 2012). And, since people cannot adjust meteorological conditions without very high cost, the main effort should be aimed at the creation and selection of adaptive varieties, especially the ones resistant to high temperatures and water shortages (Levy et al. 2007).

Regarding the cultivation of plants *in vitro*, the main attention of foreign researchers is focused on the study of the impact of physiologically active substances: auxins (Gudeva et al. 2012; Mhamdi et al. 2017), jasmonic acid (Kumlay 2016) on the growth and development of test-tube plants. The influence of sterilization conditions on the engraftment, growth and development of tube plants was also widely studied (Xhulaj 2018). In contrast to above-mentioned works, only a few publications (Singh et al. 2012) consider such an important issue as increasing adaptive potential of test-tube plants and micro-bulbs in the phase in *vitro-in vivo*. The share of micro-bulbs which formed plants according to the data of the authors was 85%, and test-tube plants in soil-50% and bio-compost-79%, which once again proves the importance of

the problem proposed for consideration.

Materials and Methods

The situation in potato growing is the following: most of the varieties included in the State Register of varieties suitable for distribution in Ukraine are not widespread in production because of a sharp decline in their productivity. It is happening due to the loss of their potential. Therefore, as a result of screening, those varieties should be selected which are characterized by high adaptability. It will positively affect the overall crop yield capacity.

Optimization of many factors which control the course of physiological and biochemical processes *in vitro* allows plants to restore their productive potential. However, the transfer of test-tube plants *in vivo* is stressful for them, and therefore negatively affects their successful further usage. Despite some progress in this regard, the problem of complete function restoration by plants under field conditions has not been worked out, and this reduces the effectiveness of the micro-clonal propagation method in the production.

The climate of the Forest-Steppe zone is moderately warm, but with an unstable supply of moisture. Weather conditions during the vegetation period of the study years 2017-2019 were different and had a significant impact on the formation of yield capacity and quality indices of *Solanum tuberosum*, which made it possible to research the reaction of varieties on agrotechnological techniques which were studied in experimental variants.

Weather conditions in 2017 were characterized by an increase of average daily temperatures in the spring-summer period and uneven distribution of precipitation over decades. During the spring period, the average daily air temperature was 10.2°, which is 2.1° higher than the long-term one 8.1°. Precipitation was 248.8 mm-188% while the long-term ones-132 mm. The sum of active air temperatures above +10° in the spring period was 795°, while the long-term one-620°.

During the summer, the average daily air temperature was 21.5°C, with a long-term index of 19.2°C. Precipitation was 87.6 mm, which is 104.8% with a long-term index of 83.5 mm. The sum of active air temperatures above + 10° during the summer period was 1982°, with the long-term index-1790°.

Under conditions of 2018, the planting-germinating period was provided with main meteorological factors for the formation of seedlings at the level of optimal, or close to their parameters. During the spring period, the average daily air temperature was 9.6°, which is 1.5° higher than for many years (8.1°). Precipitation was 54.4 mm-41% with a long-term index of 132 mm. The sum of active air temperatures above +10° for the spring period was 553°, with the long-term index of 620°. The average daily air temperature during the summer was 21.1°C, which is 1.7°C higher than the average long-term index. Precipitation was 126 mm, which was 63% at the norm of 200 mm. The sum of active air temperatures above +10° during the summer period was 1937°, with the long-term index-1790°.

During the planting-germinating period of 2019, frosts were observed on the soil surface from -1° to 0°. The last frost on the soil surface was registered on the 29th of May. For the period of "blossoming-fruiting", the optimal conditions are average daily air temperature 16-20°C, precipitation amount of 60 mm-70 mm, relative soil moisture 60%-70%. The average daily air temperature during the summer period was 22.4°, which is 3° higher the long-term one. Precipitation was 100.1 mm, which is 50% with a long-term index of 200 mm. The sum of active air temperatures above +10° during the summer period was 2683°, with the long-term index -2247°.

The soils of experimental plots are typical deep low-humus medium-loam black soils, the arable layer of which is characterized by main indices: humus content - 3.89%, salt pH-5.8, the sum of absorbed bases-30.2 mg-eq., the content of easily hydrolyzed nitrogen-8.7 mg/100 g.

The scheme of the experiment includes the study of the impact on *Solanum tuberosum* degeneration in the following variants: 1. Control (generally accepted technology of potato growing); 2. Straw (intercrop rows are covered with straw); 3. Black coating (intercrop rows are covered with black polyethylene); 4. Tying up the plants (reducing of bush habitus), three times repeating. The experimental area is 873 m^2, the number of plots is 108, the total area of one plot is 8.08 m^2, accounting area-2.7 m^2. Varieties of all ripeness groups from different selection institutions were involved in the study.

During the vegetation period, phenological observations and accounting of plant diseases were carried out. The starch content was determined by a specific mass. The harvest was gathered after completely dying off of the aboveground mass of plants separately in each repeating. The mass of tubers per plot was determined, the number and weight of marketable tubers were counted, fractionally according to the methods of research with Solanum tuberosum (Methodical recommendations for researching potatoes, 2002). Potato growing technology is typical for the zone. The experiments were conducted according to generally accepted and tested methods. Varieties, as components of the gene pool of Solanum

tuberosum, were planted in single-row plots of 11 bushes in a row. Observations of plant growth and development were carried out according to the methods elaborated by the Institute of Potato Growing (2002).

Results

Solanum tuberosum, as a crop with vegetative propagation, is characterized by the fact that with long-term permanent usage of seed material a progressive decline in yield is observed with every other year. Yield decrease is accompanied by morphological changes of the plant itself. It straggles in growth, and its leaves lose typical features of the variety of its strands, wrinkles, twists, changes color. The creation of optimal conditions for growing *Solanum tuberosum* is important for the provision of all necessary biological needs of plants. *Solanum tuberosum* belongs to the plants whose cells have low osmotic pressure, that is why it is unstable against changes in humidity.

According to the results of our research, it was found that deficiency of moisture, high air temperatures accelerate degeneration of *Solanum tuberosum* (Tab. 1). The selection of varieties resistant to degeneration is an important factor in determining the essence of this problem.

The average values of productivity for the years of research revealed a significant reaction of *Solanum tuberosum* varieties to the studied factors. The ripeness group also had an impact on productivity. Thus, the highest productivity (on average for 2017-2019) was provided by variety Slovianka (medium ripe) 778.1 g/plant in the straw variant and 691.5 g/plant in the polyethylene coating variant. A slightly lower reaction norm was in the varieties Nagoroda (early) 654.2 g/plant, Anatan (medium ripe) 642.1 g/plant in the variant of tying up and Shchedryk (medium early) 637.9 g/plant in the polyethylene coating variant. The lowest reaction norm was found in the middle-early variety Svitanok Kyivsky (ranged from 260.6

Table 1. The influence of meteorological conditions on productivity of *Solanum tuberosum* varieties depending on the studied factors, g/plant.

Variety (ripeness group)	Variant	Years			Average for 2017-2019
		2017	2018	2019	
Tyras (early)	control	328.3	394.1	300.0	340.8
	straw	461.9	381.0	333.3	392.1
	polyethylene coating	399.4	386.2	322.2	369.3
	tying up	610.0	348.7	425.0	461.2
Riviera (very early)	control	511.9	502.4	262.5	425.6
	straw	347.5	467.5	320.0	378.3
	polyethylene coating	659.5	524.4	450.0	544.6
	tying up	599.9	687.5	466.7	584.7
Shchedryk (middle-early)	control	576.7	615.3	420.0	537.3
	straw	457.8	565.7	614.3	545.9
	polyethylene coating	642.8	542.3	728.6	637.9
	tying up	580.4	636.7	612.5	609.8
Nagoroda (early)	control	668.3	514.9	700.0	627.7
	straw	772.0	455.1	380.0	535.7
	polyethylene coating	834.7	581.9	350.0	588.9
	tying up	758.3	587.5	616.7	654.2
Svitanok Kyivsky (middle-early)	control	388.1	186.9	300.0	291.7
	straw	392.5	314.3	250.0	318.9
	polyethylene coating	370.3	152.8	316.7	279.9
	tying up	384.7	130.6	266.7	260.6
Souvenir Chernihivsky (middle-early)	control	330.8	254.8	436.4	340.7
	straw	637.6	722.5	500.0	620.0
	polyethylene coating	520.8	264.3	437.5	407.5
	tying up	569.6	706.0	314.3	530.0
Slovianka (medium-ripe)	control	597.4	481.7	555.6	544.9
	straw	820.2	414.1	1100.0	778.1
	polyethylene coating	781.6	618.0	675.0	691.5
	tying up	785.7	554.0	610.0	649.9
Anatan (medium-ripe)	control	500.0	366.3	455.6	440.6
	straw	841.9	420.4	428.6	563.6
	polyethylene coating	956.4	356.7	400.0	571.0
	tying up	837.0	356.0	733.3	642.1
Javir (medium-ripe)	control	254.5	271.2	450.0	325.2
	straw	326.0	417.9	350.0	364.6
	polyethylene coating	386.6	357.1	433.3	392.4
	tying up	440.8	508.1	255.6	401.5

g/plant-318.9 g/plant) and the medium-ripe variety Yavir (325.2 g/plant-401.5 g/plant). The other varieties did not show a significant reaction to the studied factors and were characterized as stably average by productivity.

Thus, during the years of research, high-adaptability to growing conditions in terms of productivity was shown by medium-ripe *Solanum tuberosum* varieties Slovianka and Anatan, medium-early variety Shchedryk and early Nagoroda. In this case, each of them demonstrated individual norms of reaction to meteorological conditions and experimental variants.

Significant volumes of potato production in Ukraine (in terms of growing volume the country is in the top ten of world potato producers) form the potential for its supply to the world market, at the same time, there is a barrier on this way- unsatisfactory quality and high cost of production (Grechkosiy 2019). Increasing adaptability of *Solanum tuberosum* will increase yields and improve quality characteristics of the final product, and therefore the practical application of scientific developments is a contribution to the strengthening of the country export potential. It should be emphasized that the export of high-quality seeds is today a significant opportunity for the country in the world market of resources for potato growing.

Processing plants require not just tubers, it is a question of increased demand for quality raw materials *Solanum tuberosum* with appropriate content of dry matter, starch, reducing sugars, certain shape and size. That is why processing plants are willingly looking for producers of raw materials in Ukraine. But here becomes decisive *Solanum tuberosum* quality which directly depends on the variety and maintenance of growing technologies (Makulsky 2020).

Thus, the starch content in *Solanum tuberosum* becomes one of the most important quality indices and evaluation

Table 2. The starch content in *Solanum tuberosum* varieties of different ripeness groups depending on the studied factors,%.

Variety (ripeness group)	Variant	Years			Average for 2017-2019
		2017	2018	2019	
Tyras (early)	control	14.0	17.0	15.6	15.5
	straw	15.4	16.0	17.4	16.3
	polyethylene coating	12.3	16.5	15.4	14.7
	tying up	15.1	12.0	16.3	14.5
Riviera (very early)	control	10.9	14.4	12.1	12.4
	straw	11.6	11.5	9.9	11.0
	polyethylene coating	12.1	14.8	10.0	12.3
	tying up	13.7	13.4	9.8	12.3
Shchedryk (middle-early)	control	15.4	9.8	14.9	13.4
	straw	16.6	11.8	18.6	15.7
	polyethylene coating	16.0	10.0	13.7	13.2
	tying up	14.4	10.0	16.2	13.5
Nagoroda (early)	control	16.2	16.8	12.9	15.3
	straw	17.6	13.0	16.9	15.8
	polyethylene coating	13.1	17.9	15.3	15.4
	tying up	14.9	15.4	14.8	15.0
Svitanok Kyivsky (middle-early)	control	23.1	23.1	23.9	23.4
	straw	25.7	15.8	20.6	20.7
	polyethylene coating	19.9	20.4	21.1	20.5
	tying up	18.9	16.3	20.6	18.6
Souvenir Chernihivsky (middle-early)	control	13.0	11.2	11.5	11.9
	straw	15.6	13.6	13.3	14.2
	polyethylene coating	14.3	11.8	11.0	12.4
	tying up	15.6	10.3	9.9	11.9
Slovianka (medium-ripe)	control	10.0	12.5	10.1	10.9
	straw	12.3	10.0	13.9	12.1
	polyethylene coating	11.6	11.3	14.7	12.5
	tying up	10.0	13.5	14.7	12.7
Anatan (medium-ripe)	control	11.9	10.0	13.3	11.7
	straw	15.8	12.5	16.6	15.0
	polyethylene coating	15.1	13.7	15.7	14.8
	tying up	11.3	11.2	12.7	11.7
Javir (medium-ripe)	control	13.2	13.6	16.0	14.3
	straw	15.3	12.7	13.3	13.8
	polyethylene coating	13.5	15.4	15.2	14.7
	tying up	11.8	12.9	13.8	12.8

criteria for commodity production and culinary properties of this crop. In our studies, we analyzed the starch content in *Solanum tuberosum* on the background of the adaptive productivity potential of different by ripeness groups varieties and realization of genetic potential (Tab. 2).

Analyzing indices of starch content in potato tubers, it should be noted that the middle-early variety Svitanok Kyivsky significantly differed from other genotypes and provided maximum values of this index (18.6%-23.4%). The best variants were control (23.4%) and straw (20.7%). Several varieties showed similar varietal reaction: early by ripeness group Tiras (16.3%), Nagoroda (15.8%), middle-early Shchedryk (15.7%) and medium-ripe Anatan (15.0%). The straw variant was the most optimal for these varieties. The worst variant of the experiment in terms of starch content for all varieties was tying up (11.7%-18.6%). The only exception was medium-ripe variety Slovianka (12.7%) this variant turned to be the best for it.

Thus, *Solanum tuberosum* varieties of different ripeness groups in terms of starch content reacted almost equally positively and stably on the straw variant. Adaptive indices of genotypes were especially manifested in maximum and minimum values.

One of the characteristic features of plasticity and ecological adaptability of *Solanum tuberosum* varieties is the high yield of quality tubers, that is marketability. Based on data analysis of our research results concerning the marketability of *Solanum tuberosum*, the reaction norm of the varieties on main studied factors was established (Tab. 3).

Analyzing *Solanum tuberosum* marketability, we found the dependence of different origin varieties on

Table 3. Marketability of *Solanum tuberosum* varieties depending on meteorological and technological factors, %.

Variety (ripeness group)	Variant	Years			Average for 2017-2019
		2017	2018	2019	
Tyras (early)	control	96.3	61.8	89.4	82.5
	straw	96.1	75.5	93.9	88.5
	polyethylene coating	96.3	65.7	93.9	85.3
	tying up	94.4	71.7	90.7	85.6
Riviera (very early)	control	97.7	68.7	87.6	84.7
	straw	93.2	78.9	87.3	86.5
	polyethylene coating	99.1	68.2	92.2	86.5
	tying up	98.1	73.1	89.2	86.8
Shchedryk (middle-early)	control	94.4	74.7	90.6	86.6
	straw	96.8	88.1	94.1	93.0
	polyethylene coating	96.5	72.4	93.5	87.4
	tying up	99.4	79.6	90.3	89.8
Nagoroda (early)	control	94.7	62.4	91.3	82.8
	straw	94.5	72.4	95.6	87.5
	polyethylene coating	98.6	65.1	92.6	85.4
	tying up	96.5	56.7	93.7	82.3
Svitanok Kyivsky (middle-early)	control	90.3	55.9	75.9	74.0
	straw	90.9	63.0	83.1	79.0
	polyethylene coating	87.8	44.1	85.9	72.6
	tying up	94.3	51.9	85.2	77.1
Souvenir Chernihivsky (middle-early)	control	93.1	52.4	89.8	78.4
	straw	97.3	58.2	94.1	83.2
	polyethylene coating	98.5	60.2	88.3	82.3
	tying up	98.5	84.4	85.0	89.3
Slovianka (medium-ripe)	control	94.9	70.0	94.1	86.3
	straw	92.4	79.6	93.6	88.5
	polyethylene coating	93.9	75.1	95.4	88.1
	tying up	94.7	77.9	93.6	88.7
Anatan (medium-ripe)	control	92.7	67.5	95.6	85.3
	straw	97.8	71.3	92.0	87.0
	polyethylene coating	95.1	73.5	93.4	87.3
	tying up	93.9	79.0	93.4	88.8
Javir (medium- ripe)	control	94.3	70.5	94.7	86.5
	straw	96.9	80.4	88.4	88.6
	polyethylene coating	88.6	78.3	92.9	86.6
	tying up	96.8	79.1	91.1	89.0

technological factors. The highest indices of marketability were manifested in the middle-early variety Shchedryk (93.0%) in the straw variant. This variant was the best for early varieties Tiras (88.5%) and Nagoroda (87.5%). High results of marketability were achieved in medium-ripe varieties Yavir (89.0%), Anatan (88.8%), Slovianka (88.7%), middle-early Souvenir chernigivsky (89.3%), early Riviera (86.8%) in the tying up variant. Our research has shown that the marketability of Solanum tuberosum is an indicator that significantly depends on the manifestation of the genetic potential of varieties, environmental adaptability and meteorological factors.

Conclusion

The selection of perspective varieties with highly adaptive potential allowed us to adjust the variety policy of *Solanum tuberosum* in the region and have a positive impact on the environmental situation. As a result of potato quality assessment by complex indices the most positive adaptive potential and plasticity were showed by middle-early variety Shchedryk, early-ripening Tiras and Nagoroda, medium-ripening Anatan and Slovianka. The highest productivity of *Solanum tuberosum* varieties was formed in the variants with a polyethylene coating and straw, the starch content in the variant with straw, and the marketability of tubers in the variants with straw and tying up.

References

Tesliuk P.S., Kukh I.O., Nazar V.M., Pylypets I.M. (1992). Agrometeorological resources of potatoes. *Kyiv: Urozhay* **205**.

Kulbida M.I., Barabash M.B. (2009). Climate of Ukraine: past and future. *Kyiv* 342 ISBN 978-966-1555-30-2.

Wang C.L., Shen S.H., Zhang S.Y., Li Q.Z., Yao Y.B. (2015). Adaptation of potato production to climate change by optimizing sowing date in the Loess Plateau of central Gansu, China. *J Integr Agri* **14:** 398-409. https://doi.org/10.1016/S2095-3119(14)60783-8

Cleland E.E., Chuine I., Menzel A., Mooney H. A., Schwartz M.D. (2007). Shifting plant phenology in response to global change. *Trends Ecol Evol* **22:** 357-365. https://doi.org/10.1016/j.tree.2007.04.003

Van Oort P.A.J., Timmermans B.G.H., Meink, H., Van Ittersum M.K. (2012). Key weather extremes affecting potato production in The Netherlands. *Eur J Agron* **37:** 11-22. https://doi.org/10.1016/j.eja.2011.09.002

David L., Richard E. (2007). Adaptation of potato to high temperatures and salinity. Am J Potato Res **84:** 487-506. https://doi.org/10.1007/BF02987885

Mani F., Mhamdi M., Bettaieb T., Hannachi C. (2014). Shoot regeneration, micropropagation and microtuberization of potato (*Solanum tuberosum* L.) cultivars. J New Sci **7:** 215-226.

Gudeva L.K., Mitrev S., Nrajkova F. (2012). Micropropagation of Potato *Solanum tuberosum* L. Electr J Biol **8:** 45-49. https://ejbio.imedpub.com/micropropagation-of-potato-solanum-tuberosum-l.pdf

Kumlay A. (2016). The effect of jasmonic acid on the micropropagation of potato (*Solanum tuberosum* L.) under long days conditions. Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi **26:** 79-88. https://dergipark.org.tr/tr/download/article-file/205142

Xhulaj B., Gixhari B. (2018). In vitro micropropagation of potato (*Solanum tuberosum* L.) cultivars. Agri Forestry **64:** 105-112. http://www.agricultforest.ac.me/paper.php?journal_id=209&id=2822

Singh P., Agnihotri R.K., Bhadauria S., Rashmi Vamil, Sharma R. (2012). Comparative stady of potato cultivation through micropropagation and conventional farmsng methods. *Afr J Biotech* **119480:** 10882-10887. https://bioinfopublication.org/pages/article.php?id=BIA0002610

Methodical recommendations for conducting research on potatoes (2002). Ukrainian Academy of Agrarian Sciences, Institute of Potato. Nemishaevo: Intas 182.

Makulsky K., Zhytkov A. (2020). Potato 2020: Problems and prospects of industrial production. *Agroprofi*. http://www.agroprofi.com.ua/statti/1825-2020-3

Grechkosiy V., Achkevich O., Achkevich V. (2019). Potato growing: features of equipment and technology. *Agribusiness Today*. http://agro-business.com.ua/agro/mekhanizatsiia-apk/item/12646-kartopliarstvo-osoblyvosti-tekhniky-i-tekhnolohii.html