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RESEARCH ARTICLE

The influence of synthetic growth promoters on morphophysiological characteristics and biological productivity of potato culture

V.V. Rohach*, T.I. Rohach, A.M. Kylivnyk, S.V. Polyvanyi, N.V. Bayurko, L.O. Nikitchenko, O.O. Tkachuk, O.A. Shevchuk, L.S. Hudzevych, N.V. Levchuk

Vinnytsia Mykhailo Kotsiubynskyi, State Pedagogical University Ostrozhskogo St. 32, Vinnytsia, 21000, Ukraine;
*rogachv@ukr.net

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Abstract

The influence of synthetic plant growth promoters of 1-NAA, GA_3, and 6-BAP on growth, leaf apparatus and productivity of the Santé potato culture is investigated. It is found that GA_3 increased plant height, number of leaf blades, and weight of their dry matter. All preparations increased leaf area and thickened leaf chlorenchyma. The volume of columnar parenchyma cells increased under the action of GA_3 and 6-BAP, and the cell size of the spongy parenchyma only after the use of GA_3. The stem chlorophyll-bearing parenchyma thickened under the action of 6-BAP. In the plants, treated with 6-BAP, the content of chlorophyll in leaves and chlorophyll index of plants increased. The leaf index increased after the use of GA_3 and 6-BAP. Under the action of GA_3, the net productivity of photosynthesis increased. All growth promoters increased the dry weight of the whole plant and the yield of potato tubers.

Keywords: *Solanum tuberosum* L., morphogenesis, growth promoters, leaf apparatus, mesostructure, chlorophyll, yield

Introduction

The growing needs of modern agricultural production require finding new means and ways to improve crop productivity and the quality of their products. Growth regulators-stimulants (Rohach 2017) and inhibitors (Kuryata et al. 2016) are an important component of current crop technology. The interest in this group of compounds is due to a wide range of their effects on plants. Growth regulators can direct individual stages of ontogeny to mobilize the potential of the plant organism (Koteswara Rao et al. 2017) and to more effectively implement their genetic program (Mao et al. 2018), as well as to increase plant resistance to abiotic (Muhammad and Muhammad 2013) and biotic (Zhao et al. 2017) environmental factors. Such stimulants as native phytohormones (Muhammad and Muhammad 2013) and their synthetic analogues (Mao et al. 2018) are the most used group of growth regulators. With the help of these compounds, the intensity and orientation of physiological processes in a plant organism can be influenced (Poprotska et al. 2019).

Plant productivity is largely determined by the strategy of redistribution of assimilates, the ratio of growth processes and photosynthesis, between which a dynamic state is established with constant adjustment of the magnitude of donor-acceptor relationships depending on various external influences (Yu et al. 2017). It is the native hormones and their synthetic analogs that can regulate physiologically-biochemical processes in the plant and direct the flow of assimilate to economic tissues and organs (Alexopoulos et al. 2017).

In this regard, the purpose of our study was to study the effect of synthetic analogues of the major stimulatory hormones-auxins, cytokines and gibberellins-on potato growth, development and productivity.

Materials and Methods

Small-scale field experiments were laid on the lands of "Berzhan P.H." farm in Horbanivka village, Vinnytsia region during the growing periods of 2013-2015. Planting of potatoes of middle-early cv. Santa was carried out on 18.04.2013, 03.05.2014 and 12.05.2015 according to the scheme 70 cm × 30 cm. The plot area is 33 m^2, the experiment replication is fivefold.

The plants were treated in the morning with a backpack sprayer OP-2 until complete wetting of leaves with 0.005% solutions of gibberellic acid (GA_3), 1-Naphthylacetic acid (1-NAA) and 6-Benzylaminopurine (6-BAP) in the budding phase 14/06/2013, 06/17/2014 and 06/19/2015. The control plants were sprayed with tap water. Phytometric indicators (plant height, mass of dry and wet matter of plant organs, leaf area) were determined on 20 plants (AOAC 2010).

The selection of materials for the study of leaf mesostructure was carried out at the beginning of the budding phase, followed by their fixation. To preserve it, a mixture of equal parts of ethyl alcohol, glycerol and water was added with the addition of 1% formalin. Determination of cell size and thickness of chlorenchyma was performed using a microscope "Mykmed-1" and an eyepiece micrometer MOV-1-15x. For mesostructural analysis, the leaves of the middle-tier were selected. The size of individual cells of the chlorenchyma was determined on preparations obtained by the method of partial maceration of the leaf tissues. Maceration agent is a 5% solution of acetic acid in hydrochloric acid (2 mol/l). The stem anatomy was determined in its middle part (AOAC 2010).

Chlorophyll content was determined in fresh material on a SF-18 spectrophotometer (AOAC 2010). Net vegetation productivity, leaf synthesis and chlorophyll index (AOAC 2010) were established during vegetation. The yield was determined by the method of counting and weighing each section separately.

The results were statistically processed using the Statistical 6.0 computer program. One-factor ANOVA was applied (differences between the mean values were calculated using the Bunferoni-corrected ANOVA, considered to be significant at $P < 0.05$) (Van Emden 2008).

Results

It is established that synthetic plant growth and development stimulants 1-NAA, GA_3 and 6-BAP caused changes in the morphogenesis and productivity of *cv.* Sante potato plants.

In particular, it is found that the use of GA_3 led to an increase in the linear size of plants at this stage of vegetation by 17%. 1-NAA practically did not change this indicator, and under the action of 6-BAP plant height tended to decrease compared to the control sample (Tab. 1.).

Growth stimulants affected the leaf apparatus of potato plants. GA_3 increased the number of leaves and number of leaf plates per plant by 10 and 12%, respectively. The mass of the leaf dry matter increased by 13% and the area of the leaf surface by 34%. Under the action of 6-BAP, the number of leaves and leaf blade tended to increase, and the weight of leaf dry matter (20%) and leaf area increased significantly (13%). 1-NAA slightly reduced the number of leaves on the plant and practically did not change the number of leaf blossoms and the weight of

Table 1. Morphometry of *cv.* Sante potato plants under the action of growth promoters (tuber formation phase, mean data for 2013-2015, n = 20, x ± SE).

Experiment variant	Control	1-NAA	GA_3	6-BAP
Plant height, cm	50,18 ± 2,21	50,41 ± 2,27	*58,71 ± 2,36	46,03 ± 2,11
Number of leaves, pcs.	47,71 ± 2,32	45,53 ± 2,12	52,22 ± 2,46	49,82 ± 2,28
Number of leaf blades, pcs.	359,33 ± 11,61	351,78 ± 10,58	*401,17 ± 15,89	382,08 ± 14,09
Weight of dry leaf matter, g	103,93 ± 4,01	108,11 ± 5,29	*117,40 ± 5,05	*124,64 ± 5,41
Leaf area, cm^2	5200,31 ± 233,37	*5921,61 ± 248,74	*6969,26 ± 344,87	*5882,21 ± 222,06
The thickness of the chlorenchyma, μm	165,03 ± 4,68	*207,83 ± 5,70	*189,12 ± 5,01	*177,62 ± 4,01
The volume of cells of the columnar parenchyma, $μm^3$	10097,04 ± 337,62	11077,03 ± 393,29	*12347,11 ± 397,49	*11715,68 ± 370,76
The length of the cells of the spongy parenchyma, μm	20,17 ± 0,50	20,17 ± 0,51	*38,45 ± 0,86	*24,00 ± 0,62
The width of the cells of the spongy parenchyma, μm	20,52 ± 0,42	*22,13 ± 0,58	*31,55 ± 0,79	20,32 ± 0,41
The thickness of the chlorophyll-bearing tissue of the stem, μm	41,11 ± 1,13	*35,55 ± 0,79	*36,12 ± 0,76	*46,12 ± 1,07
Leaf index, m^2/m^2	3,03 ± 0,07	2,96 ± 0,06	*3,57 ± 0,08	*3,38 ± 0,09
The content of the amount of chlorophylls (a + b),% / weight of dry matter	0,53 ± 0,02	0,56 ± 0,02	*0,42 ± 0,02	*0,61 ± 0,03
Chlorophyll index, g/m^2	0,88 ± 0,04	0,99 ± 0,04	*0,74 ± 0,03	*1,22 ± 0,05
Weight of plant dry matter, g	69,58 ± 3,32	*80,81 ± 3,89	*98,81 ± 4,48	*87,83 ± 4,08
Net photosynthetic productivity, g/m^2 per day	5,12 ± 0,21	5,15 ± 0,23	*7,39 ± 0,32	5,78 ± 0,28
Average crop of tubers, c/ha	173,18 ± 8,44	207,27 ± 8,91	*233,76 ± 11,03	*220,85 ± 9,96

Note: $p<0.05$, one-row comparison by the difference between the mean values was calculated using the Bunferoni-corrected ANOVA leaf dry matter, but the area of leaves thus increased by 14%.

Indicators of mesostructural organization of leaf blade have a significant influence on photosynthesis. The results of our study of the mesostructure elements testify that all growth promoters significantly thickened leaf chlorenchyma. At the same time, the volume of cells of the most active part of the mesophyll, the columnar assimilation parenchyma, increased under the action of GA_3 and 6-BAP. The cell size of the spongy parenchyma significantly increased only after the use of GA_3 (Tab. 1.).

The leaf index is an important cenotic indicator of the power of the photosynthetic apparatus. GA_3 and 6-BAP were found to increase it by 18% and 12%, respectively.

Photosynthesis in potato plants is known to occur not only in the leaves but also in stems due to the development in the primary bark of the chlorophyll-bearing tissue. We found that GA_3 and 1-NAA significantly reduced, 6-BAP increased its thickness.

The morphophysiological activity of the leaf apparatus also significantly depends on the content of chlorophylls. Synthetic analogues of native hormone-stimulants are found to have different effects on the content of basic photosynthetic plant pigment in leaf tissues. In particular, under the action of 6-BAP the content of the amount of chlorophylls in the potato leaves increased by 15%. Under the use of GA_3 the content of chlorophylls decreased by 21%, and 1-NAA practically did not change its concentration.

Such an important cenotic index as the chlorophyll index can be determined if we have data on the content of chlorophyll in the leaves, the weight of their dry matter and the leaf area. It is found that under the action of 6-BAP, it increased significantly (39%), after treatment with GA_3 it significantly decreased (16%), and after the use of 1-NAA it practically did not change compared with the control variant.

Changes in the phytometric and mesostructural indices of the leaves and the increase in the content of chlorophylls under the influence of growth promoters contributed to the increase of photosynthetic activity of the leaf apparatus, which is evidenced by the increase of the dry matter mass of the whole plant by 16%-42% and higher values of the pure productivity of photosynthesis. Significantly, the latter increased after the treatment with GA_3. Morphophysiological changes under the influence of 1-NAA, GA_3, and 6-BAP resulted in tuber yield growth of 20%, 35%, and 28%, respectively.

Discussion

It is common knowledge that the key role in the production process of plants belongs to the photosynthetic apparatus, which is largely determined by the area of the leaf surface, the number and life expectancy of leaves, their mesostructural organization. Recent research has demonstrated that the artificial regulation of plant growth processes by phytohormones and their synthetic analogues is accompanied by significant changes in morphogenesis, which are connected to the formation of different levels of organization of the plant photosynthetic apparatus (Khodanitska et al. 2019). Given the essential morphophysiological aspects of the growth stimulants action, their application allows us to find out the importance of anatomic-morphological and mesostructural components in the implementation of the plant donor-acceptor relations and optimization of the production process.

The increase in photosynthetic activity of plants under the influence of GA_3 was determined primarily by the formation of a more powerful plant, an increase in the number of leaf plates and the total area of the leaf surface, as well as the thickening of chlorenchyma due to the growth of cells of both columnar and spongy parenchyma. This led to an increase in the net productivity of photosynthesis, the mass of plant dry matter and the yield of tubers.

Some different changes were made under the action of 6-BAP. The preparation, in addition to the growth of the area and mass of the leaves and the thickening of the chlorenchyma due to the cells of the columnar parenchyma, caused an increase in the content of chlorophyll in the leaves and an increase in the thickness of the chlorophyllous parenchyma of the stem.

Different approaches to optimizing the structure of the photosynthetic apparatus under the action of GA_3 and 6-BAP were manifested in increasing the leaf index in the first variant and the chlorophyll and leaf indices in the second one. Considering the higher values of productivity of economically valuable organs-tubers in the version with GA_3, it can be assumed that the growth of leaf index is a factor which is more important than the growth of the chlorophyll index.

Conclusion

Increase in the speed of growth processes under the influence of growth promoters' 1-NAA, GA_3 and 6-BAP on *cv.* Sante potato plantations thickened the leaves, increased the area of leaf surface and the mass of dry matter of the whole plant. The linear size of the potato plants increased under the action of GA_3, the number of leaf blades on the plant, the size of the cells of spongy parenchyma and increased the net productivity of photosynthesis. 6-BAP increased the concentration of chlorophyll in leaves, chlorophyll index of plantings and thickened the chlorophyll-bearing parenchyma of the stem. Gibberellin and cytokinin growth promoters increased dry leaf mass, columnar parenchyma cell volume, and leaf planting index. Such changes in the morphometric indices of plants under the influence of growth promoters of 1-NAA, GA_3 and 6-BAP caused a yield increase of 20%, 35% and 28% respectively.

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