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Potato plant growth acceleration and yield increase after treatment with an amino acid growth stimulant

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Abstract. An increase in the productivity of potato plants and natural resistance of tubers to external influences during growth, while preserving the qualitatively new properties of tubers in the process of low-temperature preservation, can be achieved through the effect of bioactive compounds on the metabolism of potato plants in our work, we used a regulator derived from the hydrolysis of natural collagen down to low molecular weight fractions and pure glycine. The evidence of its effectiveness is based on shortening the growing season and increasing plant productivity as well as the content of bioactive and nutrient compounds in their storage organs, reducing losses during low-temperature preservation caused by natural biological processes, physiological diseases and damage by microorganisms. The paper deals with issues related to the growth and development of potato plants and their storage organs until the growing season is over and a possible increase of potato productivity after the planting material was treated with an amino acid growth regulator.

Key words: glycine, potato, tubers, dormancy breaking, phenological phases, yeld.

INTRODUCTION

Different growth stimulants are widely used in agriculture to increase crop yields (Marenych et al., 2019, Mazur et al., 2019). There are many different studies indicating the effect on potato yield and quality of various methods of treating potato seed tubers by different stimulating factors before planting. Different methods are used for breaking potato tuber dormancy. Physical methods of impact (temperature, electric current), chemical treatment, and biochemical methods based on the use of phytohormones are being actively studied. So, in the studies of Kocacaliskan et al. (1989), Deligios et al. (2017), Haider et al. (2019) proved the effectiveness of applying electric current to disturb the dormancy of potato tubers. V. Eremeev et al. (2008 and 2012) successfully used thermal shock for tuber dormancy breaking. The use of GA_3 contributes to an increase in tuber yield (Bruinsma et al 1967; Salimi et al., 2010; Virtanen et al., 2013;

Gemeda et al., 2017). However, a negative effect of GA_3 on the development of sprouts and plants after such GA_3 artificial termination method has been proven by Bruinsma et al. (1967). Thiourea terminates the dormancy of tubers in potato cultivars with weak dormancy or in which the dormancy period ends (Struik & Wiersema 1999). Various sources of scientific literature have shown that thiourea acts as a catalase inhibitor and leads to an increase in the concentration of hydrogen peroxide, which plays an important role in the mechanism of interruption of tuber dormancy (Mani et al., 2013). Its application terminates the dormancy of tubers and enhances their germination on potato tubers. The most effective for disturbing the dormant period and increasing the number of sprouted micro-tubers is a method when they are treated with 250 mM of thiourea and 60 mM of hydrogen peroxide. Both of these substances affect the hormonal regulation and antioxidant effect of enzymes, which leads to dormancy in tubers (Virtanen et al., 2013; Gemeda et al., 2017). In addition, it was proved that the treatment with thiourea accelerates the emergence of seedlings, and has a positive effect on the number and height of stems, as well as on the yield of tubers (Suttle, 2008; Hosseini et al., 2011; Germchi et al., 2011; Mani et al., 2013). The feasibility of effective use of bromoethane for tuber dormancy breaking has been proved by W. Coleman (1982).

In order to increase the effectiveness of the effect of artificial dormancy of tubers on plant development and, accordingly, to increase the potato yield, many researchers have proved the advantage of combining several agents simultaneously. W. Coleman (1987), as well as R. Fazal et al. (2001) and L. Secretaria et al. (2018), used several chemicals and growth regulators in experiments to disturb dormancy of potato tubers, as well as to verify their subsequent exposure on the productivity in greenhouse conditions. Rindit-treated tubers showed the highest germination rate among all varieties. Thiourea-treated tubers caused the highest number of germinated sprouts compared to all other treatments. A comparison of two dormancy methods was carried out by Wróbel et al (2017), using aqueous solution of GA_3 and kinetin (standard 1) as well as aqueous solution of GA_3, thiourea and daminoside (standard 2) with the method based on ethanol. They also tested the effect of ethanol alone or in combination with GA_3 and / or kinetin on dormancy and the germination of potato tubers. They showed that the use of an aqueous solution of gibberellic acid (GA_3) and kinetin (standard 2) is the most effective method for to disturbance of dormancy and stimulation of growth of sprouts. Experiments have shown that the use of a standard 2 - aqueous solution of GA_3, thiourea and daminoside is the most effective approach to overcome dormancy, especially for varieties with a long dormant period. W. Coleman, (1998) reported the high efficiency of the use of carbon dioxide, oxygen and ethylene for breaking the dormancy of tubers and increasing the rate of germination.

The effect of amino acid treatment with collagen hydrolysate on the biochemical processes occurring in potato plants is expressed in the accumulation of bioactive and nutrient compounds in the storing organs of plants and in the acquisition of increased natural resistance to stresses required for longer low-temperature preservation in the process of growth and development. Such influence can be achieved only through the impact on intracellular metabolism. The mechanism of glycine's effect on plant development is described in detail in a number of publications (Murashev et al., 2009; Kolomicheva & Murashev, 2011; Murashev et al., 2011). They discuss the development of plants, the characteristics of plant products that are developed under the effect of glycine, and the protective mechanisms acquired by a plant's storage organs.

The biochemical features of storage organs in plants and their permanently functioning protective mechanisms, enabling longer low-temperature preservation with retained consumer qualities, nutritional and biological value, are formed under the effect of the treatment with a plant growth regulator. In view of this, it is necessary to consider the processes developing in the planting material immediately after processing in collagen hydrolysate water solution as well as during the formation of tubers, while simultaneously observing the development of the above-ground parts of potato plants and their development phases. So, the purpose of this work is to consider issues related to the changes occurring in potato seed material when it is treated with a growth regulator and during the formation of storage organs in potato plants, including the problem of yield, as well as the formation of potato plants themselves in the context of improving quality indicators of raw plant produce.

MATERIALS AND METHODS

The influence of the growth regulator obtained by collagen hydrolysis on plant development and the formation of productive parts of plants was studied on the Nevsky and Izora potato varieties for five years (2014–2019). The studies were carried out in triplicate, with the calculation of the standard deviation during mathematical processing of the reliability of the data (Dospekhov, B.A., 2012). Potato tubers were treated in an aqueous solution of collagen hydrolyzate for 10 min by completely immersing them in solution. The control was tubers of the same grade and quantity treated with water containing no drug. After processing, the tubers immediately planted the earth. The work presents the results of experiments obtained when processing potatoes with an effective concentration at which the results of the action on plant development and tuber formation achieve the maximum effect (Bolshakov, 1999).

To study the effect of the growth regulator on the growth processes of tubers, the seed tubers of cv. Nevsky was soaked in aqueous solutions of collagen hydrolyzate with various concentrations, then dried and stored for 10 days at a temperature of 12 ... 14 °C. The control was tubers of the same variety, treated only with water that did not contain the drug, and stored similarly as experimental ones. After 10 days, the change in the chemical composition (on the content of solids, monosaccharides, sucrose, starch, ascorbic acid), the enzymatic activity (on the activity of catalase) and the darkening (enzymatic and chemical) in the experiment and control were evaluated.

During the growing season of potato plants and after harvesting, the chemical composition, enzymatic activity and darkening were determined in the experimental and control versions of tubers. By visual observation, the effect of collagen hydrolyzate on the rate of passage of the growth phases of the experimental and control plants of the Nevsky and Izora varieties was determined. When assessing the effect of collagen hydrolyzate on the yield of Nevsky and Izora varieties, the average weight of tubers from one bush for each of the varieties was determined, depending on the treatment.

The biochemical and physico-chemical studies of potato tubers were carried out according to the following methods given by A. Ermakov (Ermakov, 1988): the starch content in potatoes was determined by the polarimetric method; the content of mono- and disaccharides was determined by the cyanide method ; the level of enzymatic and chemical darkening was determined by the photocolorimetric method; catalase activity was determined by permanganometric method; ascorbic acid was determined by titration with Tilmans paint; determination of the activity of hydrolytic enzymes (α and β-amylases) was carried out by the colorimetric method; the content of water and solids was determined by drying the sample to constant weight.

RESULTS AND DISCUSSION

It is known that the nutrients of potato tubers are a source of plastic material and energy during plant germination. Potato tubers grown from seed material that has undergone pre-treatment with an amino acid growth regulator acquire a higher nutritional and biological value, as well as the ability to be stored for a longer time. Results of a study of the effect of treatment with an amino acid growth regulator on maternal potato tubers Nevsky are presented in Tables 1 and 2.

Table 1. The effect of collagen hydrolysate on the changes in the chemical composition of seed potato tubers of cv. 'Nevsky'

Components of chemical composition, g per (100 g, wet weight)	Control	Experiment
Dry matter, %	20.0 ± 0.01	19.8 ± 0.01
Total sugar (monosaccharides + sucrose)	1.14 ± 0.05	1.26 ± 0.05
Monosaccharides	1.00 ± 0.05	1.04 ± 0.05
Sucrose	0.140 ± 0.01	0.220 ± 0.02
Starch	9.02 ± 0.4	8.82 ± 0.4
Browining, absorbance units		
total	0.056 ± 0.005	0.068 ± 0.005
enzymatic	0.025 ± 0.003	0.031 ± 0.003
chemical	0.031 ± 0.003	0.037 ± 0.003
Catalaze (CA) activity, mg H_2O_2 g^{-1}	0.030 ± 0.005	0.038 ± 0.005
Vitamin C, mg per (100g, wet weight)	15.4 ± 1	14.0 ± 1

Table 2. The effect of collagen hydrolysate on the changed in the chemical composition of seed potato tubers, cv. 'Nevsky' calculated on a dry weight basis

Components of chemical composition, g per (100 g, dry weight)	Control	Experiment
Dry matter, %	20.0 ± 0.01	19.8 ± 0.01
Total sugar (monosaccharides + sucrose)	5.69 ± 0.3	6.38 ± 0.3
Monosaccharides	4.99 ± 0.3	5.26 ± 0.3
Sucrose	0.699 ± 0.05	1.11 ± 0.1
Starch	45.0 ± 1	44.6 ± 1
Vitamin C, mg per (100 g, dry weight)	61.5 ± 4	56.9 ± 4

From an analysis of the results, presented in Tables 1 and 2, it follows that the treatment of seed with a collagen hydrolyzate activates hydrolytic processes in tubers. This is indicated by a decrease in starch content and an intensive accumulation of mono- and disaccharides in seed tubers. The total content of low molecular weight carbohydrates, represented by the sum of monosaccharides and sucrose, in comparison with the control increases by 10.5%, mainly as a result of an increase in the sucrose content in the tubers processed.

The reason for these changes is the action of endogenous auxin, the synthesis of which in tubers is enhanced as a result of treatment with a growth stimulator. It is known that under the action of auxin, hydrolytic enzymes are activated (Kuznetsov &

Dmitrieva, 2005), which leads to a more intensive conversion of starch and other spare substances in germinating potato tubers into well-soluble and easily transported substances that quickly reach the growth points.

In addition, another direction of action of auxin is to increase the intensity of respiration (Medvedev, 2004). Therefore, the increase in glucose in stimulated tubers is not as significant as sucrose due to its immediate use as a substrate for respiration. This is also indicated by a decrease in the solids content in stimulated tubers. Therefore, glucose in experimental tubers is more involved in the respiration process during which ATP synthesis occurs, without which the implementation of energy-dependent processes of germination of potato tubers is impossible.

Thus, endogenous auxin accelerates the germination of potato seed tubers due to activation of hydrolytic enzymes and respiratory enhancement (Medvedev & Sharova, 2014). During which glucose is consumed and ATP (adenosine triphosphoric acid) is synthesized to realize energy-dependent growth processes. The accelerated decomposition of reserve nutrients, which occurs under the influence of amino acid treatment, creates the necessary conditions for their rapid involvement in plant growth processes and the beginning of the formation of healthy plant materials capable of long-term refrigerated storage.

There are two types of darkening - enzymatic and non-enzymatic (chemical) (Burton, 1985; Flaumenbaum et al., 1986). Processing potato seed tubers with a growth regulator increases both enzymatic and chemical browning in tubers. The reason for the increase in non-enzymatic browning of tubers is the activation of starch hydrolysis and the accumulation of glucose, which is capable of non-enzymatic glycosylation.

The treatment of tubers reduced the vitamin C content of tubers by 9.4% compared with the control. This is due to the activation of metabolic and redox processes in the seed material. This is also indicated by the activation of catalase, the induction of which occurs with an increase in the content of reactive oxygen species (ROS - reactive oxygen species). This fully applies to the increase in the content of hydrogen peroxide during oxidation-reduction processes occurring in potato tubers under the influence of the growth regulator, which catalase breaks down (Sharova, 2016).

As follows from the data in Tables 1 and 2, in the mother tubers, catalase is activated under the influence of treatment with the growth regulator. The active state of catalase prevents the formation and accumulation of ROS in cells, which slows down the development of free radical oxidative processes in plant tissues (Sharova, 2016). Thus, DNA molecules are protected from damage, which ensures the normal development of plants. Violations of DNA molecules resulting from oxidation are considered as the main cause of developmental abnormalities and accelerated aging of living organisms. The active state of catalase is a characteristic feature that the modified plant material acquires under the influence of collagen hydrolyzate treatment. Catalase activation is consistent with the theoretical model of the action of an amino acid preparation on developing plants and continues to persist during the cold storage of plant generative organs (Murashev et al., 2014; Murashev, 2015 and 2016)

The effect of processing potato seed material with collagen hydrolyzate on the quality of potato storage organs has been investigated during plant vegetation. For this purpose, the composition of the experimental and control tubers of the Nevsky variety was analyzed in the middle of the growing season (the second half of July is 55 days after planting). The research results are presented in Table 3. From the presented data it follows that in the emerging tubers of experimental potatoes, the solids content increased by about 20%; the content of starch, sucrose and monosaccharides became significantly higher - by 50.1%, 93.8% and 164%, respectively; the vitamin C content in the experimental tubers is also 5.70% higher. Consequently, the action of the growth stimulator positively affects the vegetation of plants and the accumulation of bioactive and nutrients in storage parts. This is possible due to a fuller use of solar energy during photosynthesis of experimental plants under the influence of auxin (Kuznetsov & Dmitrieva, 2005).

In addition, studies were carried out on the chemical composition of tubers of experimental and control Nevsky potatoes after harvesting at the end of August (90 days after planting), which are shown in Table 3. It is interesting to compare the analysis results not only between the control and experimental potato varieties obtained in the end of the potato growing season, but also obtained in the middle of the growing season. By the time of harvesting in the tubers of the control and experimental potatoes, there was a significant increase in the dry matter content in the control, compared with the middle of the growing season. Therefore, the control potato is much closer to the experimental option for the solids content; and the excess solids content in the experimental tubers compared with the control potato tubers is only 1.20%.

Table 3. The effect of collagen hydrolysate treatment on the chemical composition of the emerging potato tubers of cv. 'Nevsky' in the process of growth and after harvesting, calculated on a wet weight basis

Components of chemical composition,	In the process of tuber growth		In freshly harvested tubers	
G per (100 g, wet weight)	Reference	Experiment	Reference	Experiment
Dry matter, %	14.8 ± 0.01	17.8 ± 0.01	21.5 ± 0.01	22.7 ± 0.01
Total sugar (monosaccharides + sucrose)	0.820 ± 0.05	1.26 ± 0.08	0.730 ± 0.05	0.70 ± 0.05
Monosaccharides	0.560 ± 0.03	0.950 ± 0.06	0.310 ± 0.05	0.320 ± 0.05
Sucrose	0.260 ± 0.02	0.310 ± 0.02	0.420 ± 0.03	0.400 ± 0.03
Starch	5.21 ± 0.3	7.82 ± 0.5	13.0 ± 0.7	15.2 ± 0.8
Vitamin C, mg per (100 g, wet weight)	13.3 ± 1	14.1 ± 1	27.2 ± 2	35.0 ± 3
Browning, absorbance units				
total	0.022 ± 0.002	0.030 ± 0.002	0.021 ± 0.002	0.04 ± 0.003
enzymatic	0.017 ± 0.001	0.021 ± 0.001	0.018 ± 0.001	0.00 ± 0.00
chemical	0.005 ± 0.001	0.009 ± 0.001	0.003 ± 0.001	0.04 ± 0.003

On total sugar content (monosaccharides + sucrose), the control and experimental potato varieties also almost leveled at the time of harvesting, but only in this case there was a significant decrease in the total sugar content in both potato varieties compared to the middle of the growing season. Moreover, in the experimental samples of potatoes, this decrease was more significant. Therefore, in experimental potato tubers, the total sugar content was slightly lower than in control potatoes - by 0.2%. At the same time, the dynamics of changes in the content of individual monosaccharides and sucrose in the tubers of both potato varieties is very interesting as they approach the end of the growing season.

The sucrose content in both potato varieties after harvesting increased, comparing with middle of the growing season, and the monosaccharide content decreased. Moreover, the decrease in the content of monosaccharides in both potato varieties occurred by a more significant value than the increase in sucrose content. If we consider the results of the control and experimental variants separately, then in the experimental potato the monosaccharide content decreased by a more significant amount than the sucrose content compared with changes in the tubers of the control potato. During the harvesting period, the monosaccharide content in the tubers of the potato treated with collagen hydrolyzate was only slightly (by 0.010%) higher than their content in the control potato tubers. The sucrose content in the tubers of the processed potato after harvesting turned out to be less than in the tubers of the control potato by 0.020%. A change in the content of monosaccharides in potato tubers is associated with a change in the dynamics of non-enzymatic browning of potato.

On starch content, the control variant approached the experimental one by the end of the growing season, nevertheless, this difference continued to remain significant and amounted to 2.20% compared with 2.61% in the middle of the growing season. Thus, the carbohydrate system, due to the processing of collagen hydrolyzate in experimental potatoes, prevailed over the control in terms of the most important indicator - starch content.

Along with the starch content, there is one more indicator according to which the experimental version of potato significantly exceeded the control one - this is the content of vitamin C. The tubers of the experimental potato at the end of the growing season contained 17.3% more starch, and in terms of vitamin C content they exceeded the control version by 28, 9 %. The increased content of vitamin C in the experimental plant products is a common pattern that arises under the influence of the processing of seed material with an amino acid solution (Kuznetsov & Dmitrieva, 2005). It indicates a large recovery potential that appears as a result of optimization of metabolic processes in cells.

During the growing season, significant changes occur in the values of the levels of darkening, both general and enzymatic and chemical. As follows from the data of Table 3 in the middle of the growing season, the experimental potato tubers significantly exceeded the control in all indicators of browning. At the end of the growing season, the situation changed to the opposite. The total and enzymatic browning in the potato treated with the growth regulator became much less than in the control.

Only by chemical darkening, the processed potatoes at the time of harvesting slightly continued to exceed the control variant. This is probably due, although with an insignificant, but higher content of monosaccharides in the experimental version compared to control tubers. The decrease in the level of chemical darkening of the experimental potato occurred during the growing season more significantly, in comparison with the control. If at the end of the growing season both varieties of potatoes did not differ much in chemical darkening, then during the growing season the experimental variant exceeded the control one in this indicator. The reason for this may be the equalization of the content of low molecular weight forms of carbohydrates in both variants as the potatoes ripen. In the experimental version, as the ripening, both the content of monosaccharides and the level of chemical darkening decreased. The chemical darkening accounts for an average of only 15% of the total level of darkening. According to Table 3, this ratio between chemical and enzymatic darkening is satisfied.

Since the bulk of the darkening is due to enzymatic darkening, it needs to be considered in more detail.

As mentioned earlier, both potato varieties, control and experimental, during the growing season, but even more at the time of harvesting, differ in the level of enzymatic darkening of tubers. The enzymatic component of the browning process directly depends on the activity of the polyphenol oxidase enzyme (Medvedev, 2004). This enzyme is activated by damage to plant organisms. Therefore, it is especially active in freshly harvested potatoes due to its participation in the healing of injuries received by tubers during harvesting (Polevoy, 1989). At the time of ripening of tubers in the control potato, the level of enzymatic browning is increasing, while in the potato treated with the growth regulator, enzymatic browning exceeds this the indicator of control potatoes during the growing season and then sharply decreases by the time of harvesting.

The low activity of polyphenol oxidase is a characteristic feature of plant products grown using the amino acid growth regulator (Murashev et al., 2013, 2014; Murashev, 2016). The low activity of polyphenol oxidase promotes the accumulation of phenolic compounds that perform various protective functions in plant tissues. They take part in the formation of lignin, and many phenols are inhibitors of IAA oxidase (Kuznetsov & Dmitrieva, 2005), which contributes to the accumulation of indolylacetic acid. Changes in the hormonal status of plants affect the characteristics of the relationship between the host and the parasite. Given that experimental potatoes are more resistant to phytopathagens, a change in hormonal status has a significant effect.

On the other side, with high activity of polyphenol oxidases, quinones formed from phenols, which are active and nonspecific oxidizing agents, can disrupt the normal functioning of cells (Polevoy, 1989). The phenolic metabolism activated in this case requires significant energy expenditures and the consumption of nutrients for respiration. This situation occurs in the control, not processed potatoes. Processed potatoes have the ability to intensively form the wound periderm (Murashev, 2015). This ability probably compensates for the absence of the need to activate the protective system (polyphenol oxidase + phenols), which actively functions in the control potato in order to prevent infection through epidermal ruptures during the injury of tubers.

The effect of treatment with an amino acid growth stimulator was also reflected in the tuber ripening. This parameter is determined by the ratio of starch / sugar and sucrose / monosaccharides, the higher these ratios, the higher the degree of maturity and the better the ability to store potatoes. According to the results in Table 3, it follows that the ratio of sucrose / monosaccharides for both potato varieties during harvesting was equal to 1.30, and the ratio of starch / sugar was more favorable for experimental potatoes, for which it was 20.5. For control, this ratio turned out to be less - 17.7.

In cultivated potato the tuberization occurs at any length of daylight hours, however, a reduction in the duration of daylight hours, as well as lower temperatures at night, inhibiting vegetation, stimulate tuberization. In addition, the ability to form tubers depends on the stage of development of potato plants; it appears only when the plants come into maturity and this is due to a change in the hormonal background of plants (Medvedev 2004; Medvedev & Sharova, 2014). The ability to tuberization, as already mentioned, depends on the hormonal background, namely: on the ratio of auxins and cytokinins. Their ratio is affected by the length of the day, the reduction in daylight changes the ratio between auxins and cytokinins in favor of the latter. As aging in plant organisms increases the activity of IAA oxidase, as well as other oxidative enzymes.

IAA oxidase oxidizes auxin; as a result, the auxin content in plant tissues decreases with aging (Kuznetsov & Dmitrieva, 2005).

Tuberization is promoted by the reduced activity of oxidative enzymes such as polyphenol oxidase and peroxidase (Medvedev & Sharova, 2014). This may be due to several reasons. First of all, one should pay attention to the fact that the oxidation pathways catalyzed by non-mitochondrial oxidases (polyphenol oxidase, ascorbate oxidase) are not associated with the synthesis of ATP (Medvedev, 2004), which ensures the occurrence of all energy-dependent processes, including the need for accelerated plant development and intense tuber formation.

The formation of tubers requires a high content of low molecular weight carbohydrates. While in the ripened tubers the amount of low molecular weight carbohydrates (glucose + sucrose) decreases and the starch content increases (Kuznetsov & Dmitrieva, 2005). This is what is observed in practice mainly for experimental variant.

Thus, a whiter, higher degree of maturation is established for experimental potatoes. A high degree of maturity of storage organs of plants suggests a higher rate of their development during the growing season. The rate of passage of growth phases by potato plants is characterized by the duration of the interphase 'sprouting period – budding', presented in Table 4.

Table 4. The effect of collagen hydrolysate on the passage speed of growth phases in potato plants of cvs. 'Nevsky' and 'Izora' for two years of observations

Potato cultivar	Treatment version	Mean duration of the sprouting-budding interphase period, days	
		1st year	2nd year
Izora	Reference	20	17
Izora	Experiment	16	14
Nevsky	Reference	26	19
Nevsky	Experiment	22	16

According to the data given in Table 4, the experimental plants passed the growth and development phases at an accelerated pace, as a result of which the ripening time of the crop is reduced by an average of 5–10 days. Such a reduction is very significant for the northern regions with a short and unstable warm summer period suitable for crop production in open ground. The reduction in ripening time is the result of achieving the optimal ratio between the metabolic pathways of the conversion of substances in plant tissues, as a result of which the plastic material and plant hormones that control plant growth are synthesized in quantities necessary for accelerated growth and biomass accumulation.

The attractive effect of phytohormones, which affect the flow of nutrients to the storage organs of plants, accelerates their formation and is reflected in an increase in potato productivity. The effect of collagen hydrolyzate on the productivity of potato plants is shown in Table 5.

Table 5. The effect of collagen hydrolysate on potato yield of cvs. 'Nevsky' and 'Izora' for two years of observations

Potato cultivar	Treatment version	Mean weight of potato tubers per plant, g,	
		1st year	2nd year
Izora	Control	260.6	417.4
Izora	Experiment	287.8	769.0
Nevsky	Control	357.7	1,078.0
Nevsky	Experiment	385.1	1479.0

In terms of yield of potato plants, the experimental potatoes of the Nevsky and Izora varieties in the first year of testing did not significantly exceed the control. However, during the second year of testing, the average tuber yield as a result of processing increased by almost 1.5 times. Statistical processing of the values of the mass of tubers from one bush of a 2-year crop showed the reliability of such a significant increase. In the following years of testing, the experimental version also exceeded the yield control, which is a manifestation of the general trend. It is possible that weather and climatic conditions for growing potatoes are superimposed on the preparation. Nevertheless, despite the fluctuations in weather conditions, treatment with an amino acid stimulator demonstrates a steady increase in plant productivity.

The accelerated development of plants is due to the fact that IAA actively affects the phases of cell growth. This hormone stimulates cell stretching and provides accelerated formation of the stem of development. This is due to the fact that IAA causes an influx of water into the cells. The flow of water into the cells lowers the viscosity of the cytoplasm, which causes an increase in the rate of chemical reactions that occur in them. In addition, auxin significantly changes the intensity of energy processes in plants. Under its influence, the intensity of photosynthesis increases and respiration increases. The conjugation of oxidation and phosphorylation increases (Medvedev & Sharova, 2014), which leads to a more efficient use of the respiratory substrate for ATP synthesis. An increase in the conjugation of oxidation and phosphorylation also reduces the release of physiological heat in plants without performing useful work on the implementation of energy-dependent processes.

It should be noted that the plant material obtained using the growth regulator is not only larger, but also more attractive in appearance, since it is less susceptible to phytopathological influences. So. for example, sugar beet root crops grown using collagen hydrolyzate were less affected by scab and necrosis (Sapronov et al., 2002; Sapronov et al., 2005). In addition, plant products obtained using collagen hydrolyzate are characterized by a more perfect form, characteristic for this type of plant products. The protective properties of root crops are enhanced even more when pure glycine is used as a growth regulator.

Thus, the experimental data confirm the provisions presented earlier about the mechanism of the effect provided by a glycine-containing amino acid preparation on the changes in maternal potato tubers, during the growth of potato plants and formation of their storage organs. This effect supposes changes in metabolic and energy flows within cells for acceleration of synthetic processes in plant organisms.

CONCLUSIONS

A treatment of potato seed tubers with a water solution of the amino acid preparation made from hydrolyzed collagen and having an increased content of glycine accelerates disintegration of starch in maternal tubers with mono- and disaccharides being formed. The content of low molecular weight carbohydrates increases by 10.5%, and they are rapidly involved in the growth processes so than the shoots receive more abundant nutrition.

The measured sucrose/monosaccharides ratio for the potato treated with an amino acid growth stimulant was equal to 20.5. It is the evidence of a higher maturation rate within the same period of time as in the reference version. Potato tubers treated with the growth stimulant also had a higher content of bioactive compounds, which grows on average by 15 to 50%. The increase of ascorbic acid content is approximately 8 mg per 100 g, fresh weight. The increase of starch content in potato averages 15 to 17% and reaches 15 to 16% of the tubers' wet weight.

A high degree of maturity in plant storage organs suggests an increased rate of their development during the growing season. Measuring the speed at which the potato plants had passed their growth phases showed that the length of the sprouting-budding interphase period reduced on average by 20%. The growing season of potato plants was 5 to 10 days shorter.

The treatment with an amino acid growth stimulant accelerates potato plant development, accompanied by a concurrent increase in productivity by 20 to 30%. Potato tubers grown with the use of collagen hydrolysate were prone to phytopathological changes to a considerably less extent.

The effective influence of the growth regulator produced from collagen on the development of potato plants and formation of their tubers is an evidence of fuller utilization of the potential reserved in plants.

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