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FEATURES OF MORPHOGENESIS AND FUNCTIONING OF DONOR-ACCEPTOR SYSTEM UNDER ACTIONS OF GIBBERELLIN AND RETARDANTS TREATMENTS ON TOMATO PLANTS

Abstract. It was studied the features of growth processes, morphogenesis and functioning of donor-acceptor system of tomatoes under the influence of gibberellin and its antagonists – triazole derivative tebuconazole and ethylene releasing compound esphon in connection with crop productivity.

It was found that gibberellic acid (GK_3) and retardants caused a clear growth-regulating effect on the growth rate of plants, accompanied by changes in the mass ratio of organs. The most powerful donor sphere was formed under tebuconazole treatment, where the relative proportion of leaves from the total mass of the plant was higher during the whole period of vegetation.

It was established that leaves of tebuconazole and gibberellin treated tomatoes were characterized by the highest measurement of leaf area density value, chlorophyll content and net photosynthetic productivity compared to control, which created the prerequisites to enhance gross photosynthetic crop production. Formation of a more powerful photosynthetic apparatus in these variants of experiment and an increase in the content of sugars and starch in the vegetative organs of plants with subsequent reutilization to carpogenesis led to enhance the crop production of tomatoes. The triazole derivative compound tebuconazole proved to be the most effective for enhancement of crop yields in the field-based conditions.

Keywords: donor-acceptor system, gibberellins, retardants, morphogenesis, productivity, tomatoes (*Solanum lycopersicum* L.)

Introduction. In modern plant physiology, the regulation of donor-acceptor relations («source-sink» system) is considered as the highest level in hierarchy of processes that ensure the functioning of a plant as an integral system [6, 12, 32]. The regulation of these relationships, as a system of assimilates redistribution between the organs and tissues of a plant during ontogenesis, can be carried out at different levels of plant organism organization with the participation of various regulatory mechanisms [49]. This concept is used as for analysis of heterotrophic growth phases (seed germination) under conditions of sckoto- and photomorphogenesis, as for the actions of various growth regulators groups and abiotic environmental factors [33], and for analyzing the ratio of photosynthetic intensity and growth processes, where the first act as the main donor, and the last as an acceptor of assimilates [12]. It is also known that various types of reserve substances play the role of a buffer between photosynthesis as a «source» of assimilates and growth of structural substance of vegetative, storage and reproductive organs as a «sink» of assimilates, which determines the independence of growth processes from photosynthesis [34]. At the same time, it have not been studied enough the features of intermediate deposit assimilates in vegetative organs of the plant as an additional reserve, that is used in common with the newly formed forms of nonstructural carbohydrates in fruit growth development.

Application of phytohormones and synthetic growth regulators can artificially change the morphogenesis, activity of growth and photosynthetic processes, regulate plant loading with fruits and seeds. In essence, the utilization of such drugs with the opposite mechanism of action makes it possible to artificially simulate a different degree of stress “source-sink” relation system in the plant and find out, through which morphological, anatomical and physiological changes occur assimilates redistribution between plant organs.

It is known that changes in growth intensity are realized under phytohormones actions, in particular gibberellins, that significantly enhance growth processes [24, 36]. Besides, in modern plant cultivation, it is widely used a group of synthetic growth inhibitors with antigibberellin mechanism of action (retardants), that either reduce the synthesis of this phytohormone or block the formation of hormone-receptor complex that maked impossible the effect of already synthesized gibberellin. The application of retardants leads to a significant increase in crop production [8, 16, 31, 36].

Tomatoes occupy one of the leading places among vegetable crops. In Ukraine, this crop is grown mainly in the southern areas of the steppe zone (65-70 % of the total area) and in the forest-steppe zone (about 20 %) [39]. This vegetables are widely used for food in fresh and processed form, canning industry, due to their ecological plasticity, high yield, versatility in the use of fruits, biological value and taste. Tomatoes contain pigment lycopene, which is a strong antioxidant [5]. The study of donor-acceptor relations on tomato crop is advisable, since their acceptor zone - fruits constitute a significant part of the whole plant weight, that makes it possible to effectively evaluate the redistribution of substance flows between donor and acceptor spheres under the various factors effects. However, the analysis of literature data presents only a few amount of gibberellins and various types of retardants actions on morphogenesis, features of formation and functioning of photosynthetic apparatus, assimilates redistribution and mineral nutrition elements between the organs of tomato plants in connection with crop production. In this case, the issue of this study was to establish the functioning of donor-acceptor system and morphogenesis of tomatoes plants (*Solanum lycopersicum* L.) under gibberellin (gibberellic acid, GA_3) and its antagonists – triazole derivative tebuconazol and ethylene releasing compound esphon treatmentment in the formation of crop productivity.

Research results. **Anatomical and morphological characteristics of growth formation under the gibberellin and various types of retardants application on tomatoes**. The possibility of gibberellin and retardants treatment for the directional regulation of growth, development and metabolism is shown in a number of crops [4, 7, 17, 18, 26], but it remains insufficiently studied the features of anatomical structure of organs, the ratio of stem growth and leaf surface area formation during artificial stimulation and growth inhibition, as one of the central components of donor-acceptor system. Retardants – representatives of quaternary ammonium compounds [14, 37, 41, 50] are widely used to regulate the growth and development of agricultural plants in crop production. At the same time, there are few literature data that present the effect of triazole derivative and ethylene releasing compounds on morphogenesis and physiological and biochemical processes of vegetable crops [3, 7, 9, 27].

The study of the tomatoes growth dynamics in the field condition indicates that gibberellins and retardants used in the work caused a clear growth-regulating effect on growth rate of plants. Height of research plants increased significantly under gibberellic acid (GA_3) treatment and decreased for the both retardants interaction compared to control. It has been established that changes in the intensity of growth processes due to growth regulators application are accompanied by the redistribution ratio of dry matter weight between plant organs. The analysis of the average data over the research years shows that application of tebuconazol resulted on the formation of a more powerful donor sphere, where relative proportion of leaf weight in the total weight of plant was higher during whole period of growing season (at the stage of brown ripeness, this indicator was 48 ± 1,3 %, compared to control – 40 ± 1,2 %). At the fruitification stage (brown ripeness) a decrease of plant weight under 0,05 % esphon treatment is partly due to phytotoxic effects: leaves were twisted, ovaries fell off, leaf edge turned yellow. Signs of a phytotoxic effect by drug application were manifested on growth processes and plant development in the following weeks after treatment.

At the fruit formation and fruitification stage (green ripeness) the largest number of leaves was formed due to increase stem branching under esphon and tebuconazole application (Fig. 1). The number of leaves in the variant of gibberellin treated plants significantly increased from green to brown ripeness of fruitification stage that can be explained by the general positive effect of phytohormone on plant growth. An increase in the number of leaves is accompanied by a significant increase in the leaf area. Maximum leaf surface area was noted under tebuconazole and gibberellin aplications at the green ripeness fruitification stage. Leaf area of esphon treated plants was increased due to phytotoxicity symptoms removal at the fruitification stage (brown ripeness).

Thus, action of gibberellin and retardants on tomato plants is realized through the reconstruction of donor-acceptor relation due to the ratio in accumulation and redistribution of organs weight. The application of retardant tebuconazole led to forme a more powerful donor sphere of the plant where the relative proportion of leaves in the total weight of a plant was increased during whole period of carpogenesis (fruits growth and formation), which is an important prerequisite for improving the crop yield [23].

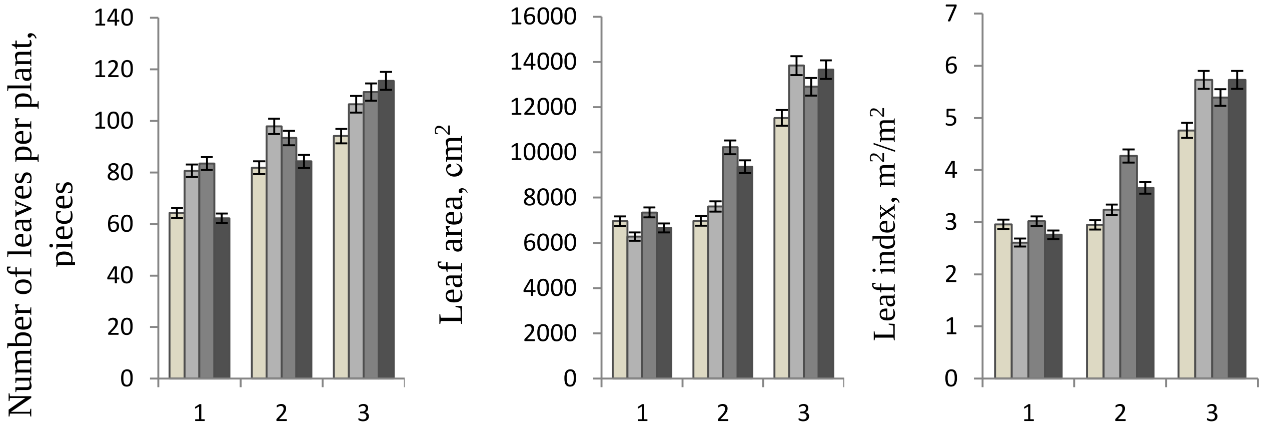

Fig. 1. Leaf apparatus formation of tomatoes hybrid Solerosso under retardants and gibberellin treatment (mean values for 2015-2017 years)

1 – fruit formation stage; 2 – fruitification stage (green ripeness); 3 – fruitification stage (brown ripeness)

– control; – 0,05 % esphon; – 0,025 % tebuconazole; – 0,005 % gibberellin

The comparative analysis of gibberellin, esphon and tebuconazole interaction on stem anatomical structure of tomatoes indicates that treatment with drugs led to changes in the histogenesis of this plant organ. In particular, the more intensive growth of gibberellin treated plant was accompanied by the formation of a thinner stem due to a decrease in the thickness of bark, wood, core and epidermis. The obtained results indicate that gibberellin application caused formation of more developed tissues of primary origin: hypodermis and collenchyma. In this variant it was noted the formation of a larger number of vessels (xylem) in a layer of wood – 14,61 ± 0,49 pcs. against to control– 13,21 ± 0,34 pcs., however, those elements were smaller (77,37 ± 2,56 µm) compared to control (81,47 ± 3,17 µm). Similar tendencies were noted for the shoot core: the linear dimensions of central parenchymal cells and the cells of perimedular zone were smaller compared to control. Conversely, the stem of tebuconazole treated plants was thickened mainly due to an increase in thickness of bark – 467,03 ± 5,67 µm and core – 7427,74 ± 179,44 µm compared to control – 448,79 ± 8,62 µm and 6932,68 ± 203,61 µm respectively.

Analysis of leaf mesostructure organization testified that changes in the thickness of leaf blade of drugs treated plants are due to the growth of photosynthetic tissue – chlorenchyma (Table 1). Thus, 0,025 % tebuconazole and 0,005 % gibberellin treatment leads to an increase in the linear dimensions of spongy and cell volume of the columnar parenchyma – the main assimilation tissue of the leaf. However, those indicators of 0,05 % esphon application were less control and can be concluded about changes in the nature of marginal meristem activity of the leaf under under antigibberellin compounds action. Significant changes have occurred in epidermal tissue of the leaf. The analysis of the research results suggest that tebuconazole application resulted in an increase in the thickness of leaf's upper and lower epidermis compared to control. The opposite effect was observed for esphon and gibberellin interaction – thickness of epidermis cells decreased. In all variants of research plants, the number of stomata per unit leaf area increased, while the area of a stomata decreased.

Table 1. Influence of retardants and gibberellin on the leaf mesostructural organization of tomatoes hybrid Solerosso

Measurements	control	0,05 % esphon	0,025 % tebuconazole	0,05 % gibberellin
Thickness of leave, µm	247,69±7,43	198,46±6,94*	272,35±7,28*	264,46±6,25*
Thickness of chlorenchyma, µm	211,27±6,74	168,06±5,21*	227,77±7,18*	228,92±6,35*

Volume of palisade parenchyma, μm^3	46299,25± 1435,28	42279,95± 1310,68*	58613,09± 1817,01*	55750,79± 1512,05*
Length of spongy cells, μm	20,77±0,44	22,31±0,69*	23,17±0,75*	22,07±0,46*
Width of spongy cells, μm	15,49±0,48	14,07±0,43	14,71±0,45	15,15±0,43
Thickness of upper epidermis, μm	20,39±0,59	16,49 ±0,47*	24,61±0,75*	18,33±0,56*
Thickness of lower epidermis, μm	16,02±0,46	13,92±0,45*	19,98±0,67*	17,22±0,45*
Number of stomatas on 1 mm^2 of abaxial leaf surface, pieces	27,23±0,68	30,88±0,98*	37,05±1,19*	41,11±1,21*
Area of a stomata, mcm^2	397,01±10,91	391,87±9,75	365,23±9,68*	307,33±1,25*

* - difference is significant at p<0,05.

Thus, the enhancement of leaf donor potential due to gibberellin and tebuconazole application occurred due to an increase in the leaf surface area and optimization of leaf mesostructural characteristics. Esphon treatment increased in the leaf surface area by a decrease in the volume and linear dimensions of leaf chlorenchyma cells [20, 21].

Structural and functional organization of photosynthetic apparatus and trophic support of morphogenesis for gibberellin and various types of retardants interaction on tomato plants. Formation of leaf surface is one of the central factors determining the productivity of plants. The results of the studies on morphogenesis of agricultural plants under application of growth regulators with different mechanism of action show that an increase in the number of leaves, their weight and leaf surface area is accompanied by a change in important indicators that characterizing the potential productivity of a unit of leaf surface: leaf area density value, chlorophyll content and net photosynthetic productivity [13, 19, 25].

The results of the study indicate that in all experimental variants during the period of fruit formation there is a gradual increase of important indicators – leaf area density value (LADV) that characterize the potential photosynthetic productivity of unit leaf surface (Table 2). Tebuconazole tomato leaves were characterized by the highest value of this indicator. This correlates well with the results of mesostructural characteristics of triazole derivative compounds treated plants, where at the end of growing season the leaf thickness was greatest. Maximum value of this factor was noted at the end of growing season at the brown ripeness fruitification stage under gibberellin application, while the leaf area density value of esphon treated plants was small during whole period of growing season that also correlated with the lamina thickness of ethylene releasing compound applicated plants (see Table 1). Plant growth regulators treatment does not lead to significant changes in the chlorophyll content, this indicator at the fruit formation stage was close to control in all experimental trials (Table 2). However, at the end of growing season, the chlorophyll content of both retardants and gibberellin treated plants remained higher compared to control. Changes in the accumulation of chlorophylls and significant morphological changes in the leaf apparatus due to the drugs interaction lead to significant differences in the chlorophyll index of plants according to the trials of experience. At the green ripeness fruitification stage, tebuconazole and gibberellin application increased in this indicator and esphon decreased it compared to control during the whole fruiting period. The obtained data indicated that tebuconazole and gibberellin increased in the net photosynthesis productivity and esphon decreased in this index compared to control at the green ripeness fruitification stage (Table 2). Net photosynthetic productivity (NPP) is characterized by photosynthetic productivity of unit leaf surface, which with the increase in area leaf surface under tebuconazol and gibberellin action created the prerequisites to enhance gross photosynthetic crop production and accumulation of a greater number of photoassimilates in the plant [22].

Table 2. Anatomo- and physiological parameters of leaf apparatus of gibberellin and retardants treated tomatoes hybrid Solerosso

Indicators	control	0,05 % esphon	0,025 % tebuconazole	0,05 % gibberellin
Fruit formation stage				
Leaf area density value, mg/cm^2	1,79±0,06	1,78±0,03	2,12±0,05*	1,71±0,03
Total chlorophyll content (*a*+*b*), % per leaf fresh matter weight	0,72±0,022	0,72±0,021	0,74±0,021	0,71±0,020

Chlorophyll index, g/m^2	1,92±0,05	1,79±0,05	2,79±0,09*	1,82±0,05
Net photosynthetic productivity, $g/(m^2 \cdot day)$	6,41±0,16	4,70±0,12*	10,83±0,43*	6,37±0,18
Fruitification stage (green ripeness)				
Leaf area density value, mg/cm2	2,88±0,09	2,22±0,07*	2,93±0,07*	2,74±0,08
Total chlorophyll content (a+b), % per leaf fresh matter weight	0,71±0,011	0,73±0,012	0,76±0,021*	0,77±0,021*
Chlorophyll index, g/m2	2,01±0,06	1,79±0,04*	2,23±0,07*	2,06±0,06
Net photosynthetic productivity, g/(m2 ·day)	7,32±0,17	7,23±0,19	8,29±0,31	9,52±0,27*
Fruitification stage (brown ripeness)				
Leaf area density value, mg/cm2	3,57±0,08	2,92±0,08*	4,54±0,13*	4,34±0,12*
Total chlorophyll content (a+b), % per leaf fresh matter weight	0,54±0,011	0,79±0,022*	0,71±0,021*	0,71±0,021*
Chlorophyll index, g/m2	1,54±0,04	1,49±0,04	2,13±0,06*	1,62±0,06
Net photosynthetic productivity, g/(m2 ·day)	6,54±0,19	4,41±0,11*	9,36±0,21*	6,44±0,11

* - difference is significant at $p<0,05$.

The obtained results indicate that in the vegetative organs of tomato plants – roots, stems and leaves at the fruit formation stage are accumulated more nonstructural carbohydrates (sugars + starch) than in the control due to formation of a more powerful donor sphere under plants grows regulators treatment (Fig. 2).

Obviously, this is a consequence of the enhanced photosynthetic work of leaf apparatus of treated plants. The highest content of carbohydrates in all stages of the fruitification phase was noted in stems of tomato plants, that indicates the powerful depositing capabilities of this vegetative organ. At the same time, tebuconazole and gibberellin application increased the amount of sugars and starch in the roots, stem and leaves of plants during the whole fruitification stage. It can be concluded that this indicates some of their redundancy, which is not fully spent on the fruits formation and growth, but is temporarily accumulated to reserve that is deposited in vegetative organs and then used at the stage of transition from green to brown ripeness.

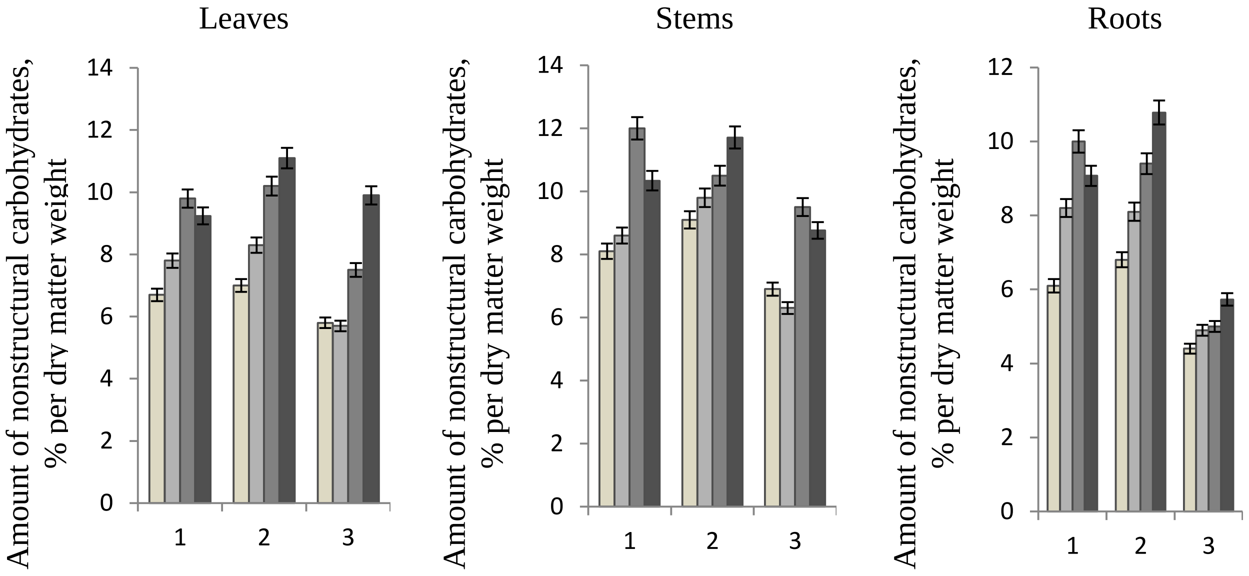

Fig. 2. Amount of nonstructural carbohydrates (sugar+starch) in vegetatives organs of tomatoes hybrid Solerosso under application of growth regulators

1 – fruit formation stage; 2 – fruitification stage (green ripeness); 3 – fruitification stage (brown ripeness)

– control; – 0,05 % esphon; – 0,025 % tebuconazole; – 0,005 % gibberellin

The analysis of various forms of carbohydrates content in tomato organs in terms of dry matter suggests that during the whole fruiting period (from the fruit formation stage to brown ripeness fruitification stage) the reducing sugars content in the roots and stalks of tomato research plants decreased. However, from the green ripeness fruitification stage, when the fruits was already fully formed and growth processes completed, to the brown ripeness fruitification stage for the leaf was observed not an decrease, but an increase in the reducing sugars content (esphon – from 1,37±0,04 % to 1,65 ± 0,02 %; tebuconazole – from 1,81 ± 0,05 % to 2,32 ± 0,05 %; gibberellin – from 1,74 ± 0,02 % to 2,36 ± 0,07 % compared to control – from 1,96 ± 0,04 % to 1,94 ± 0,06 %). It was also observed a strong decrease in the sucrose content in the leaves of experimental trials. Thus, this indicator under esphon treatment decreased from 1,02 ± 0,02 % at the green ripeness stage to 0,59 ± 0,01 % at the brown ripeness stage; under tebuconazole – from 0,82 ± 0,02 % to 0,39 ± 0,01 %; under gibberellin – from 1,15 ± 0,01 % to 0,51 ± 0,01 % compared to control – from 0,79 ± 0,02% to 0,47 ± 0,01 %. Since sucrose is the main transport form of carbohydrates in the plant, the transport of sugars from leaves to fruits stops earlier than from roots and stem, resulting in an increase in the reducing sugars content.

Thus, application of gibberellin and retardants leads to a more intensive accumulation of nonstructural carbohydrates (sugars and starch) in the vegetative organs of research tomato plants with subsequent active reutilization of these substances on the fruits formation and growth needs. The stem plays an important role of temporary assimilates depot, which is amplified under the influence of tebuconazole and gibberellin treatment. In the second half of fruiting period, the nonstructural carbohydrates content in the stem and roots decreased as a result of their utilization to carpogenesis.

The main regularities of photosynthetic processes and redistribution of assimilate flux throughout a plant with varying growth rates of individual organs have been studied sufficiently within the framework concept of donor-acceptor system functioning [6, 12, 15]. However, the specific features of mineral nutrients assimilation and their redistribution through the plant organs for the gibberellin and retardants application have not been systematically studied in connection with productivity of crop.

Analysis of total nitrogen content in the vegetative organs of tomato plants treated by growth regulators indicates significant differences in the accumulation and redistribution of this nutrient according to the trials of experience. Application of drugs had insignificant effect on the nitrogen content in the roots of plants, it was more clear the fluctuations of this indicator in the stems of tomatoes. It was noted a significant decrease in the nitrogenous compounds content of all treated trials from fruit formation stage to green ripeness fruitification stage (gibberellin treated trial – 1,81 ± 0,01 % to 1,65 ± 0,02 %; esphon treated trial – 1,86 ± 0,02 % to 1,52 ± 0,03 %; tebuconazole treated trial– 1,54 ± 0,02 % to 1,36 ± 0,01 % against the control – 1,54 ± 0,02 % to 1,53 ± 0,02 % by dry weight matter). In our opinion, such a decrease in the nitrogen content cannot be explained by biodilutions, since the vegetative growth of tomatoes slows down significantly during the period of growth and fruit formation. In this regard, we assume that changes in the element content of treated plants compared to control are determined by the outflow of nitrogen-containing compounds from stem to fruit formation. It was established that the main donor of nitrogen in tomato plants were leaves. The most significant changes in the content of this element were in the control – from 3,29 ± 0,02 % at the stage of fruit formation to 2,34 ± 0,01 % at the brown ripeness fruitification stage, as well as in esphon – from 3,51 ± 0,02 % to 2,68 ± 0,06 % and gibberellin – from 3,37 ± 0,07 % to 2,67 ± 0,04 % by dry weight matter, respectively, due to intensive nitrogen outflow during the whole vegetation period on the fruits formation. Less intense fluctuations in the content of this element under triazole derivative tebuconazol application, apparently, is connacted with the fact that plant developed the largest leaf surface and leaf weight that led to forme high gross accumulation of nitrogen in them, and therefore the carpogenesis needs are covered.

The results of the study indicate that the phosphorus content in the roots of esphon and gibberellin treated plants was higher compared to control during fruitification stage, while under tebuconazole application, the phosphorus content decreases significantly from fruit formation to brown ripeness fruitification stage, which indicates an increased outflow of this element to the fruits. The content of phosphorus compounds of tebuconazole treated trials in terms of the dry weight matter in stem also decreases significantly during the whole fruitification stage from 3,49 ± 0,05 g/kg to 2,64 ± 0,05 g/kg, in leaves – from 3,55 ± 0,07 g/kg to 3,16 ± 0,07 g/kg, as well as for gibberellin treatment – in stems from 3,79 ± 0,05 g/kg to 3,37 ± 0,05 g/kg, in leaves – from 3,91 ± 0,06 g/kg to 3,39 ± 0,09 g/kg, that indicates an intensive reutilization of this element on the formation, growth and ripening of fruits.

The potassium content in roots of gibberellin, tebuconazole and esphon treated plants at the stage of green and brown ripeness was higher compared to control. In the stem, it was noted a gradual decrease of potassium content for all experimental trials, and at the end of fruitification stage, the content of this element in organs was minimal. The lowest value of this indicator was noted in stems of research plants under application of gibberellin – 14,21 ± 0,11 g/kg and tebuconazole – 12,52 ± 0,16 g/kg against the control – 14,72 ± 0,16 g/kg per dry weight matter. It was observed a similar decrease in the potassium content in the leaves from growth and fruit formation stage to green ripeness fruitification stage. If there was a decrease in the element content in the leaves of gibberellin treated plants during the whole fruitification stage, then esphone and tebuconazole application increased in the potassium content from the green ripeness to brown ripeness fruitification stage, especially in tebuconazole treated trials, this the indicator grew from 9,82 ± 0,19 g/kg to 17,29 ± 0,24 g/kg against the control – from 11,67 ± 0,08 g/kg to 12,52 ± 0,13 g/kg per dry weight matter. An enhancement of the potassium content in leaves in tebuconazol variant is explained, obviously, by an increase in the relative proportion of element on the background of reducing sugars content, nitrogen-containing compounds due to their outflow to the growing fruit.

Thus, the vegetative organs of plant – root, stem and leaves are an important source of nitrogen, phosphorus and potassium supply to the fruits that form during fruitification stage. The reutilization of main nutrients from stem and leaves was more intense in gibberellin and triazole derivative compound tebuconazole treated plants [21, 38].

Features of production process under growth regulators influence on tomatoes. Processes of growth, photosynthesis and deposition of substances in the stock are played a main role in the formation of plant productivity, therefore the features of donor-acceptor system formation and functioning of agricultural plants with exogenous regulation of growth processes are very important. The analysis of literature data contains information about application of gibberellin and antigibberellin compounds in order to increase crop yields by anatomical, morphological, and physiological and biochemical changes in leguminous [10, 11, 44, 46], oilseeds [26, 31, 35], vegetables [2, 26 , 30], technical [42, 45, 47], ornamental [48] and other agricultural plants [1, 29, 42, 43].

Analysis of various types of growth regulators interaction on the tomatoes plants in the field condition indicate that the triazole derivative telaconazole treatment enhanced the crop yield by 28 % due to an increase in the average weight of one fruit (Table 3), the yield of growth stimulator gibberellin treated plants was close to control – the average weight of one fruit decreased with simultaneous increase in the number of fruits per bush.

It can be noted that under drugs treatment, the total acidity in all experimental trias was significantly increased, the sugar content increased and the ascorbic acid content decreased under the tebuconazole and gibberellin interaction, and the sugar content decreased due to esphon application compared to control. Fluctuations in product quality of treated tomatoes plants are without significant changes compared to typical product quality values for this crop.

Table 3. Product quality and productivity of tomatoes hybrid Solerosso plants under gibberellin and retardants treatment

Indicators	Control	0,05 % esphon	0,025 % tebuconazole	0,05 % gibberellin
Yield, t/ha	68,16±1,71	67,01±1,51	87,78±1,69*	69,03±1,07
Weight of fruits from one bush, kg	1,61±0,03	1,57±0,03	2,08±0,04*	1,62±0,04
Number of fruits on a bush, pieces	35,41±1,07	33,48±1,24	36,41±1,29	40,79±1,09*
Weight of one fruit, g	41,54±1,05	43,33±1,18	51,15±1,21*	37,16±1,93
Content of ascorbic acid, mg/100 g	26,38±0,82	26,59±0,73	22,95±0,58*	21,32±0,63*
Titrated acidity, g /100 g	0,58±0,02	0,69±0,02*	0,81±0,02*	0,77±0,02*
Reducing sugar, % per fresh matter	0,95±0,02	1,13±0,03*	1,27±0,03*	1,02±0,02*
Sucrose, % per fresh matter	0,68±0,01	0,35±0,01*	0,69±0,02	0,75±0,01*
Total sugars, % per fresh matter	1,65±0,03	1,49±0,04*	1,94±0,05*	1,79±0,03*

* - difference is significant at $p<0,05$.

Thus, application of gibberellin and retardants leads to the reconstruction of donor-acceptor relation system of the plant, formation of a more powerful photosynthetic apparatus, redistribution of assimilate flows to the fruit growth processes, more intensive use of reserved compounds from vegetative organs to carpogenesis needs, that lead to improve crop productivity.

CONCLUSION

Growth regulators with different mechanisms of action – gibberellic acid and retardants affected on the donor-acceptor systems formation and functioning of tomato plants, its anatomical, morphological and mesostructural characteristics, assimilating activity, deposition and redistribution of carbohydrates, nitrogen-containing compounds and mineral nutrients between vegetative organs and fruits, that significantly affects on the crop production. Growth regulators increased the assimilating surface area of plants compared to control, but this happened in various ways. Retardants increased the number of leaves and their area as a result of increased stem branching, whereas gibberellin increased it due to the intensification of linear growth. Gibberellin and tebuconazole treatment increased in the volume of assimilating parenchyma cells, leaf thickness, its specific weight, and the total content of chlorophylls that with an increse in the number of leaves enhanced chlorophyll index and net photosynthetic productivity. Application of esphon negatively affected on those indicators. The increase in photosynthetic productivity of tomato plants contributed to enhancement of assimilation to the plant organism under gibberellin and tebuconazole treatment, that was manifested in an increase in the content of nonstructural carbohydrates in vegetative organs compared to untreated plants. The stem plays an important role of temporary reserve of assimilates, which is amplified under tebuconazole and gibberellin interaction. In the second half of fruitification stage, the content of nonstructural carbohydrates in stem and roots decreased as a result of their utilization to carpogenesis. Gibberellin and tebuconazole treatment intensified the reutilization of nitrogen, phosphorus and potassium from vegetative organs to fruits of tomato plants. Esphon also influenced on the accumulation and redistribution of assimilates and nutrients in tomato plants, but to a lesser extent. As a result of tebuconazole and gibberellin treatment increased productivity of tomato plants without significant changes in product quality. In the first case, this was due to an increase in a weight of one fruit, in the second, due to an increase in the weight and number of fruits on the plant. Application of ethylene releasing compound esphon as retardant in order to increase the crop yield at the phase of budding was ineffective.

BIBLIOGRAPHICAL REFERENCES

1. Ali, M. T., Iqbal, V., Mushtaq, R., Parray, A., Ibrahim, A. (2017). Effect of plant growth regulators on rooting of kiwifruit (*Actinidia deliciosa*) cuttings. *Journal of pharmacognosy and phytochemistry*, 6(6), 514-516.

2. Altintas, S. (2011). Effects of chlormequat chloride and different rates of prohexadione-calcium on seedling growth, flowering, fruit development and yield of tomato. *African Journal of Biotechnology*, 10(75), 17160-17169. doi: 10.5897/AJB11.2706

3. Balakshyna, V. Y., Dykanev, H. P., Ustymenko, N. Y., Sheviakhova, E. A. (2008). Yspolzovanye rehuliatorov rosta pry vyrashchyvanyy selskokhoziaistvennykh kultur [Growth regulators application in growing crops]. *Sovremennye yssledovanyia*, 14-18. (in Russian)

4. Baranyiova, I., & Klem, K. (2016). Effect of application of growth regulators on the physiological and yield parameters of winter wheat under water deficit. *Plant Soil Environ*, 62(3), 114-120.

5. Benderska, O. V., Bessarab, O. S., Shutiuk, V. V. (2017). Analiz nakopychennia kontaminantiv plodamy tomativ ta zasoby yikh znyzhennia v ovochakh [Analysis of contaminants accumulation by the fruits of tomatoes and means of their reduction in vegetables]. *Electronic national university of food technologies*. (in Ukrainian)

6. Bonelli, L. E., Monzon, J. P., Cerrudo, A., Rizzalli, R. H., & Andrade, F. H. (2016). Maize grain yield components and source-sink relationship as affected by the delay in sowing date. *Field Crops Research*, 198, 215-225. doi:10.1016/j.fcr.2016.09.003

7. Brovko, O. V., Kuriata, V. H., Rohach, V. V. (2016).Vplyv hiberelinu na formuvannia fotosyntetychnoho aparatu ta produktyvnist pertsiu solodkoho

[Influence of gibberellin on the formation of photosynthetic apparatus and productivity of sweet pepper]. *Agrobiolohiia*, 1, 86-92. (in Ukrainian)

8. Carvalho, M. E. A., Castro, C. P. R., Castro, F. M. V., & Mendes, A. C. C. (2016). Are plant growth retardants a strategy to decrease lodging and increase yield of sunflowerю. *Comunicata Scientiae*, 7(1), 154-164. doi: 10.14295/CS.v7i1.1286

9. Hagye, S., Farooqi, A. H. A., & Gupta, M. M. (2007). Effect of ethrel, chlormequat chloride and paclobutrazol on growth and pyrethrins accumulation in *Chrysanthemum cinerariaefolium* Vis.. *Plant Growth Regul*., 51(3), 263-269.

10. Holunova, L. A. (2015). Diia khlormekvatkhlorydu na produktyvnist ta yakist nasinnia *Glycine max* L. [Influence of chlormequat chloride on productivity and seeds quality of *Glycine max* L.]. *Naukovi zapysky Ternopilskoho natsionalnoho pedahohichnoho universytetu imeni V. Hnatiuka. Seriia: Biolohiia*, 1(62), 66-71. (in Ukrainian)

11. Holunova, L. A., & Kuriata, V. H. (2012). Anatomo-morfolohichni osoblyvosti roslyn soi za kompleksnoi dii *Bradyrhizobium japonicum* i retardantiv [Anatomo-morphological features of soybean plants under complex action of *Bradyrhizobium japonicum* and retardants]. *Naukovi zapysky Ternopilskoho derzhavnoho pedahohichnoho universytetu. Seriia: Biolohiia*, 3(52), 79-83. (in Ukrainian)

12. Kiriziy, D. A., Stasyk, O. O., Pryadkina,G. A., & Shadchyna, T. M. (2014). Fotosintez. T.2. Assimilyatsiya CO_2 i mehanizmy jejyo regulyatsii [Photosynthesis. T. 2. Assimilation of CO_2 and mechanisms of its regulation]. Logos, Kiev. (in Russian)

13. Khodanitska, O. O., & Kuriata, V. H. (2017). Diia khlormekvatkhlorydu i treptolemu na morfohenez, produktyvnist ta zhyrnokyslotnyi sklad nasinnia lonu oliinoho [Effect of chlormequat chloride and treptolem on morphogenesis, productivity and fatty acid composition of oilseed flax]. *Vinnytsia : TOV «Nilan-LTD»*, 148. (in Ukrainian)

14. Koutroubas, S. D., & Damalas, C. A. (2016). Morpho-physiological responses of sunflower to foliar applications of chlormequat chloride (CCC). *Bioscience Journal*, 32(6), 1493-1501. doi:10.14393/BJ-v32n6a2016-33007

15. Kravets, O. O., & Kuryata, V. H. (2018). Osoblyvosti pererozpodilu elementiv mineralnoho zhyvlennia ta produktyvnist tomativ za dii folikuru ta esfonu. *Naukovi zapysky Ternopilskoho natsionalnoho pedahohichnoho universytetu imeni Volodymyra Hnatiuka. Seriia Biolohiia. Ternopil : TNPU im. V. Hnatiuka,* 2(73), 140-146. (in Ukrainian)

16. Kumar, A., & Sharma, N. (2016). Effect of growth retardants on growth, flowering and physiological characteristics of olive cultivar Leccino under reined condition of Himachal Pradesh, India. *Indian journal of agricultural research*, 50, 487-490.

17. Kuryata, I. V. (2012). Funktsionuvannia donorno-aktseptornoi systemy roslyn u protsesi prorostannia za dii hiberelinu i retardantiv [Donor-acceptor system functioning of plants in process of germination under gibberellin and retardants application]. *Fyzyolohyia y byokhymyia kulturnykh rastenyi*. 44 (6), 484-494. (in Ukrainian)

18. Kuryata, V. G., Golunova L. A., (2018). Peculiarities of the formation and functioning of soybean-rhizobial complexes and the productivity of soybean culture under the influence of retardant of paclobutrazol. *Ukrainian Journal of Ecology*, 8(3), 98-105.

19. Kuryata, V. G., Khodanitska, O. O. (2018). Features of anatomical structure, formation and functioning of leaf apparatus and productivity of linseed under chlormequatchloride treatment. *Ukrainian Journal of Ecology*, 8(1), 918-926. doi: 10.15421/2018_294

20. Kuryata, V. G., Kravets, O. O. (2016). Diia esfonu na rostovi protsesy i morfohenez tomativ [Effect of esfon on growth processes and morphogenesis of tomatoes]. *Naukovi zapysky Ternopilskoho natsionalnoho pedahohichnoho universytetu. Seriia Biolohiia*, 1(65), 80-85. (in Ukrainian)

21. Kuryata, V. G., Kravets, O. O. (2018). Features of morphogenesis, accumulation and redistribution of assimilate and nitrogen containing compounds in tomatoes under retardants treatment. *Ukrainian Journal of Ecology*, 8(1), 356-362. doi: 10.15421/2018_222

22. Kuryata, V. G., Kravets, O. O. (2017). Osoblyvosti nadkhodzhennia i pererozpodilu nestrukturnykh vuhlevodiv ta elementiv mineralnoho zhyvlennia mizh orhanamy tomativ za dii folikuru [Features of accumulation and redistribution of nonstructural carbohydrates and nutrition elements between organs of tomato plants under folicur treatment]. *Naukovyi visnyk Uzhhorodskoho universytetu. Seriia Biolohiia*, 42, 71-76. (in Ukrainian)

23. Kuryata, V. G., Kravets, O. O. (2017). Peculiarities of the growth, formation of leaf apparatus and productivity of tomatoes under action of retardants folicur and ethephon. *The Bulletin of Kharkiv national agrarian university. Series Biology*, 1(40), 127-132.

24. Kuryata, V. G., Kravets, O. O. (2018). Rehuliatsiia morfohenezu, pererozpodilu asymiliativ, azotovmisnykh spoluk ta produktyvnosti tomativ za dii hiberelinu y retardantu folikuru [Regulation of morphogenesis, assimilates partitioning, nitrogen-containing compounds and productivity of tomatoes under gibberellin and retardant folicur treatment]. *Fyzyolohyia rastenyi y henetyka*, 50(2), 95-104. (in Ukrainian)

25. Kuryata, V. G., Polyvanyi, S. V. (2015). Potuzhnist fotosyntetychnoho aparatu ta nasinnieva produktyvnist maku oliinoho za dii retardantu folikuru [Effect of retardant folicur on photosynthetic apparatus and seed productivity of oil poppy]. *Fyzyolohyia rastenyi y henetyka*, 47(4), 313-320. (in Ukrainian)

26. Kuryata,V. G., Poprotska, I. V., Rogach, T. I. (2017). The impact of growth stimulators and retardants on the utilization of reserve lipids by sunflower seedlings. *Regulatory mechanisms in Biosystems*,8(3), 317-322. doi: 10.15421/021750

27. Kuryata, V. G., Rohach, V. V., Buina, O. I., Kushnir, O. V., Buinyi, O. V. (2017). Vplyv hiberelovoi kysloty ta tebukonazolu na formuvannia lystkovoho aparatu ta funktsionuvannia donorno-aktseptornoi systemy roslyn ovochevykh paslonovykh kultur [Dynamics of accumulation and redistribution of different forms of carbohydrates in tomato plants under the action of regulators]. *Regulatory mechanisms in biosystems*, 8(2), 162-168. (in Ukrainian)

28. Matsoukis, A., Gasparatos, D., & Chronopoulou-Sereli A. (2015). Mepiquat chloride and shading effects on specific leaf area and K, P, Ca, Fe and Mn content of *Lantana camara* L. *Emirates Journal of Food and Agriculture*, 27(1), 121-125. doi:10.9755/ejfa.v27i1.17450

29. Panyapruek, S., Sinsiri, W., Sinsiri, N., Arimatsu, P., & Polthanee, A. (2016) Effect of paclobutrazol growth regulator on tuber production and starch quality of cassava (*Manihot esculenta* Crantz). *Asian Journal of Plant Sciences*, 15(1-2), 1-7. doi:10.3923/ajps.2016.1.7

30. Pateliya, C. K., Parmar, B. R., Kacha, H. L., Patel., S. K. (2014). Effectiveness of various growth retardants on growth and yield of Okra. *Journal of agriculture and crop science,* 1, 32-35.

31. Polyvanyi, S. V., Kuryata, V. G. (2016). Fiziolohichni osnovy zastosuvannia modyfikatoriv hormonalnoho kompleksu dlia rehuliatsii produktsiinoho protsesu maku oliinoho [Physiological bases under modifiers of hormonal complex application for production process regulation of poppy oil].*Vinnytsia : TOV «Nilan-LTD»*, 140. (in Ukrainian)

32. Poprotska, I. V. (2017). Rehuliatsiia donorno-aktseptornykh vidnosyn u roslyn v systemi «depo asymiliativ – rist» u protsesi prorostannia [Regulation of donor-acceptor relations in the system of depot assimilates - growth in process of plants germination]. *Vinnytsia : TOV «Nilan-LTD»*, 122. (in Ukrainian)

33. Poprotska, I. V., Kuryata, V. G. (2017). Features of gas exchange and use of reserve substances in pumpkin seedlings in conditions of skoto- and photomorphogenesis under the influence of gibberellin and chlormequat-chloride. *Regulatory Mechanisms in Biosystems*, 8(1), 71-76. doi:10.15421/021713

34. Priadkina, H. O., Zborivska, V. P., Ryzhykova, P. L. (2016). Deponuvalna zdatnist stebla suchasnykh sortiv ozymoi pshenytsi za zminnykh umov dovkillia yak fiziolohichnyi marker yikh produktyvnosti [Stem deposition ability in modern winter wheat varieties under different environmental conditions as a physiological marker of their productivity]. *Visnyk ukrainskoho tovarystva henetykiv i selektsioneriv*, 14(2), 44-50. (in Ukrainian)

35. Rabert, G., Manivannan, P., Somasundaram, R., Panneerselvam, R. (2013). Triazole compounds alters the antioxidant and osmoprotectant status in drought stressed *Helianthus annuus* L. Plants. *Emirates Journal of Food and Agriculture*, 26 (3), 265-76.

36. Rademacher, W. (2016). Chemical regulators of gibberellin status and their application in plant production. *Annual Plant Reviews*, 49, 359-403.

37. Rohach, T. I. (2012). Vplyv sumishi khlormekvatkhlorydu i treptolemu na morfohenez ta produktyvnist soniashnyku [Effect of mixture of chlormequat-chloride and treptolem on morphogenesis and productivity of sunflower]. *Zbirnyk naukovykh prats VNAU. Seriia : Silskohospodarski nauky. Vinnytsia*, 1 (57), 121-127. (in Ukrainian)

38. Rogach, V. V., Kravets, O. O., Buina, O. I., & Kuryata, V. G. (2018). Dynamic of accumulation and redistribution of various carbohydrate forms and nitrogen in organs of tomatoes under treatment with retardants. R*egulatory Mechanisms in Biosystems*, 9(2), 293-299. doi:10.15421/021843

39. Sabluka, P. T., Mazorenko, D. I., & Maznieva, H. Ye. (2009). Tekhnolohii ta normatyvy vytrat na vyroshchuvannia ovochevykh kultur [Technologies and costs norms of growing vegetables]. *Kyiv: NNTs IAE*, 340. (in Ukrainian)

40. Sardoei, A. S., Yazdi, M. R., & Shshdadneghad, M. (2014). Effect of cycocel on growth retardant cycocel on reducing sugar, malondialdehyde and other aldehydes of *Cannabis sativa* L.. *International Journal of Biosciences*, 4(6), 127-133. doi:10.12692/ijb/4.6.127-133

41. Shahbaz, A. T., Ying, H., Hafeez, A., Ali, S., Khan, A., Souliyanonh, B., Song, X., Liu, A., Yang, G. (2018). Mepiquat chloride effects on cotton yield and biomass accumulation under late sowing and high density. *Field Crops Research*, 59-65. doi:10.1016/j.fcr.2017.09.032

42. Shevchuk, O. A., & Kuryata,V. H. (2015). Diia retardantiv na morfohenez, hazoobmin i produktyvnist tsukrovykh buriakiv [Effect of retardants on morphogenesis, gas exchange and sugar beet productivity]. *Vinnytsia: TOV «Nilan-LTD»*, 140. (in Ukrainian)

43. Tkachuk, O. A., & Kuryata,V. H. (2016). Diia retardantiv na morfohenez, period spokoiu i produktyvnist kartopli [Application of retardants on morphogenesis, period of rest and productivity of potatoes]. *Vinnytsia: TOV «Nilan-LTD»*, 152. (in Ukrainian)

44. Vashchenko, V. F., & Nam, V. V. (2010). Vliyanye etylenprodutsenta na ustoichyvost poseva yachmenia k polehanyiu [Influence of ethylene producers on the resistance of barley sowing to lodging]. *Ahrarna nauka*, 2, 15-17. (in Russian)

45. Wang, Y., Gu, W., Xie, T., Li, L., Sun, Y., Zhang, H., Li, J., & Wei, S. (2016). Mixed compound of DCPTA and CCC increases maize yield by improving plant morphology and upregulating photosynthetic capacity and antioxidants. *PLOS ONE*, 11(2):e0149404. doi:10.1371/journal.pone.0149404

46. Yan, Y., Wan, Y., Liu, W., Wang, X., Yong, T., & Yang, W. (2015). Influence of seed treatment with uniconazole powder on soybean growth, photosynthesis, dry matter accumulation after flowering and yield in relay strip intercropping system. *Plant Production Science*, 18,(3), 295-301. doi:10.1626/pps.18.295

47. Yang, L., Yang, D., Yan, X., Cui, L., Wang, Z., Yuan, H. (2016). The role of gibberellins in improving the resistance of tebuconazole-coated maize seeds to chilling stress by microencapsulation. *Scientific Reports*, 60, 1-12.

48. Yoon, H. K., Khan, A. L., Hamayun, M., Kim, J. T., Lee, J. H., Hwang, I. C., Yoon, C. S., Lee, I.-J. (2010). Effects of prohexadione calcium on growth and gibberellins contents of *Chrysanthemum morifolium* R. cv Monalisa White. *Scientia Horticulturae*, 123 (3), 423-427.

49. Yu, S. M., Lo, S. F., & Ho, T. D. (2015). Source-sink communication: regulated by hormone, nutrient and stress cross-signaling. *Trends in plant science*, 20(12), 844-857.

50. Zhang, W., Xu, F., Hua, C., & Cheng, S. (2013). Effect of chlorocholine chloride on chlorophyll, photosynthesis, soluble sugar and flavonoids of *Ginkgo biloba*. *Not Bot Horti Agrobo*, 41(1), 97-103. doi:10.15835/nbha4118294