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ORIGINAL ARTICLE

Features of morphogenesis, donor-acceptor system formation and efficiency of crop production under chlormequat chloride treatment on poppy oil

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The paper present the results of the study of chlormequat chloride treatment on poppy oil. The use of chlormequat chloride at the budding phase led to an increase in the poppy seed oil productivity (*Papaver somniferum* L.) and was not accompanied by the accumulation of residual amounts of the drug in the seeds above the permitted norms. Under the action of the drugs, there is a correction of donor-acceptor relations in the plant, which was realized through the redistribution of photoassimilates from vegetative growth for the needs of carpogenesis. Deceleration of linear growth at the beginning of vegetation due to the action of chlormequat chloride led to intensive formation of a large number of leaves, leaf surface, optimization of the mesostructure of leaves and increased deposites in vegetative reserves of nonstructural carbohydrates. The formation of a more powerful acceptor sphere is associated with an increase in stem branching and, accordingly, by the laying of a greater number of fruits, the main acceptors of assimilates in the second half of the vegetation. It has been found out that vegetative organs should be considered not only as an intermediate depot of assimilates of carbohydrate nature, but also as a temporary receptacle of nitrogen compounds and nutrients. The increase of the plant load on the plants in the experimental variant also determined a more intense flow of carbohydrates, nitrogen-containing compounds and nutrients, which eventually ensured the growth of the seed production. It has been established that the use of chlormequat chloride resulted in a significant increase in the content of nitrogen and phosphorus and the reduction of potassium content in poppy meal. The growth in the poppy seed oil content of alkaloids under the influence of chlormequat chloride should be considered as an important practical result of these studies, which may be of great interest to the pharmacological industry.
Keywords: Morphogenesis; donor-acceptor system; retardants; productivity; poppy oil (*Papaver somniferum* L.)

Introduction

The determination of mechanisms of donor-acceptor system functioning opens possibilities for assimilates of artificial translocation on carpogenesis needs (formation and growth of fruits) in order to optimize the crop production process. It is common knowledge that the functioning of donor (photosynthetic tissues and organs) and acceptor spheres (growth zone, deposition of assimilates in reserve and active metabolism zones) are interconnected by different regulation systems in such a way that the photosynthetic activity of donor sphere is determined by the growth rate of plant (Kiriziy et al., 2014; Yu et al., 2015; Bonelli et al., 2016). The application of plant growth regulators permit to artificially change the rate of growth processes. Thus, the artificial change in growth rate under the phytohormones and synthetic growth regulators treatment on the plant allows simulation of different degrees of tension between donor (source) and acceptor (sink) zones in order to determine the features of formation and donor-acceptor functioning at different periods of ontogenesis (Poprotska and Kuryata, 2017; Kuryata et al., 2017; Rogach et al., 2018). The plant growth regulators have a significant effect on morphogenesis that originate to analyse the depositing process of assimilates to different organs and tissues of the plant due the anatomical-morphological and physiological changes. This approach allows to establish the translocation of photosynthetic products between vegetative and generative organs in the plant, but also the mineral elements between them at different rates of growth.

The most widely used synthetic growth regulators are retardants. These synthetic compounds lead to inhibit growth processes (Kasem and Abd El-Baset, 2015; Carvalho et al., 2016; Kuryata and Kravets, 2018), accelerate the transition to resting state (Kuryata, 2009), increase plant resistance to unfavorable environmental factors (Barányiová and Klem, 2016; Fahad et al., 2016; Yang et al., 2016). These comounds are significantly different in their chemical structure, but cause the same effect-they lead to less cell elongation and cell division, thereby making plants more compact, without causing abnormal deviations. The artificial limitation of vegetative growth with sufficient activity of assimilation apparatus leads to the translocation of assimilates towards the fruit formation under retardants treatment, resulting in yield increase and crop quality improvement (Altintas, 2011; Pavlista, 2013; Helaly et al., 2016; Macedo et al., 2017; Kuryata and Polyvanyi, 2018). At the same time, the issue of physiological mechanisms coordination of growth retardation and crop production increase under retardants application is not sufficiently studied. It is grounded that the physiological effect of this compounds is realized due to the inhibion of gibberellin biosynthesis in plant or the blocking formation of hormone-receptor complex, consequently, the already synthesized gibberellin is not reacted (Sang-Kuk and Hak-Yoon, 2014; Rademacher, 2016). The retardant type of the first group is chlormequat chloride (CCC)-2-chloroethyltrimethylammonium chloride $[Cl\text{-}CH_2\text{-}CH_2N(CH_3)_3]^+Cl^-$, which is obtained by the interaction of dichlorethan with trimethylamine at one stage under pressure and temperature of 80-900 °C. This compound is low-toxic, it does not educe the carcinogenic and blastomogenic properties, accumulate, decompose in the body and after 48 hours is deduced from it, which is determined by the most extensive use in plant cultivation. The antigibberillin effect of this compound is related to the inhibition of α-kauren-synthase activity in the formation of copalylpyrophosphate from geranylgeranyldiphosphate during the gibberellin synthesis (Kuryata, 2009). In most cases, the features of chlormequat chloride treatment on morphological, mesostructural and physiological-biochemical components of donor-acceptor system of agricultural plants are insufficiently studied. The data about the influence of this and other retardants on morphogenesis and oilseed crop production are insignificant and contradictory (Sumit et al., 2012; Matysiak and Kaczmarek, 2013; Koutroubas and Damalas, 2015, 2016; Kuryata and Khodanitska, 2018). In this regard, the objective of this study was to investigate the morphogenesis and features of formation and functioning of donor-acceptor relation system under chlormequat chloride application on poppy oil in connection with crop production.

Methods

The experiment was conducted on poppy oil plants cv. Berkut recommended for the Forest-steppe, Steppe and Polissya regions of Ukraine in Vinnytsia region from 2012 to 2014. The experiment followed a randomized block design (10 m^2) with five replications. The treatment was applied via foliar spraying of OP-2 with aqueous solution of 0.5% chlormequat chloride (per active compound) once in the morning at the time of initiation of budding to complete wetting of leaves. The control plants were treated with water.

Morphometric measurements were determined every 10 days. For the biochemical analysis, the samples were determined by the liquid nitrogen fixation and dried in a drying-oven at 85 °C. Mesostructural organization of leaves during the field-based micro-trial setup was studied at the end of the vegetative season at a fixed material of the middle-layer leaves of the shoots, which completely stopped their growth. For preservation a mixture of equal parts of ethanol, glycerol and water (1:1:1) with addition of 1% formalin was used. Measurement of cell sizes was performed by using a microscope "Mikmed-1" and ocular micrometer MOB-1-15x. Determination of individual cell size of chlorenchyma was carried out after the maceration of leaf tissues with a 5% solution of acetic acid in 2 mol/l hydrochloric acid. The content of phosphorus by the formation of a phosphoric-molybdenum complex was determined, the total nitrogen content was determined by Kjeldahl, the content of sugars and starch was determined applying the iodometric method, chlorophylls were determined by spectrophotometric method on the spectrophotometer SF-16 (AOAC, 2010) with five analytical replications of the research. The leaf index (LI) is defined as the green leaf area per unit ground of surface area. The net photosynthetic productivity (NPP) is characterized as the growth of dry matter per day for unit leaf surface. The oil content in poppy seeds was determined by the extraction with petroleum ether using the Soxhlet apparatus. Determination of individual fatty acids quantitative content in poppy oil was carried out by gas chromatography. Chromatograph Crystal 2000 (Russia) (AOAC, 2010) was used. The glass columns of 1500 × 2 mm, filled with sorbitol intertop-super +5% neoploss 400, granularity of sorbent 0.16-0.20 mm were used. The rate of gas passing-carrier (nitrogen) was 70 ml/min. The temperature of column- 2000 °C, evaporator- 2300 °C, flame-ionize detector- 2400 °C. The analytical repetition of studies is fivefold.

Investigation of alkaloids content was carried out by gas chromatography with mass-selective detection of organic components to qualitatively and quantitatively determination (Davydyuk et al., 2009). The samples of plants were dried at a temperature of 110 °C to constant weight, crushed and sifted through a sieve (1 × 1 mm). The band-and-hook hinge was poured by 1 ml of 25% ammonia solution; left for swelling for 15 min then was extracted by 25 ml of chloroform with constant stirring on a magnetic stirrer for 30 min. The extract was filtered through a paper filter and resulting chloroform extract was evaporated in a stream of cold air and dry residue was dissolved in 1 ml of methanol. 1 ml of methanolic solutions obtained were analyzed on a chromato-mass spectrometer in the following conditions: instrument- GC/MS Agilent Technologies 6890/5975 B; capillary column- HP 19091S-433 (HP-5MS), length - 30 m, diameter- 0.32 mm, phase- 0.25 μm, constant flow- 1.5 ml/min, gas carrier- helium; injector- auto injector 7683, Split 20: 1, evaporator temperature 250 °C; stove-the initial temperature 75 °C, exposure 2 minutes, heating gradient- 15 °C/min, the final temperature-300 °C, exposure 8 minutes. The detector is mass-selective, the temperature of interface is 280 °C, ionization-electron impact, ionization energy- 70 eV, temperature of the ion source is 230 °C, the temperature of the quadrupole-150 °C. Sample for analysis- 1 μl. The analytical repetition of studies is fivefold. Mass-chromatogram analysis was performed using the MSD ChemStation D.03.00.611 software using the NIST mass spectrum database.

The amounts of residual chlormequat chloride were determined by thin-layer chromatography on the plates "Silufol UV-254" of "Kavalier" company (the Czech Republic). Chromatography was carried out in a thin layer of cationite. As a mobile solvent 23% sulfuric acid was used. The plates were immersed in an 11% aqueous solution of phosphoric-molybdenum acid, followed by thirty-minute flushing with water. After this, the plate was immersed in a 1% solution of tin chloride in 10% hydrochloric acid. The amount of chlormequat chloride was calculated by determining the optical density magnitude of chromatogram sample that was analyzed, and the standard solutions were measured on a spectrophotometer SF-18 (Russia) at a wavelength of 730 nm. The tables and figures show mean values for the three years of research and their standard errors. The statistical processing of results was performed using the computer program "Statistica-6" StatSoft Inc. The reliability of obtained results between control and experiment varients was assessed with the use of a student's t-test.

Results

The analysis of results indicate that application of chlormequat chloride caused a typical effect on the linear growth of poppy oil plants (Espindula et al., 2010; Spitser et al. 2015; Wang et al., 2016). At the period of active growth, the treated plants were lagging behind compared with control plants from 5 to 14 % in different years of the study depending on the weather conditions of the growing season. In most cases, there was a significant thickening of the stem, which increased the resistance of the plants to reliance and created technological advantages in harvesting (Figure 1).

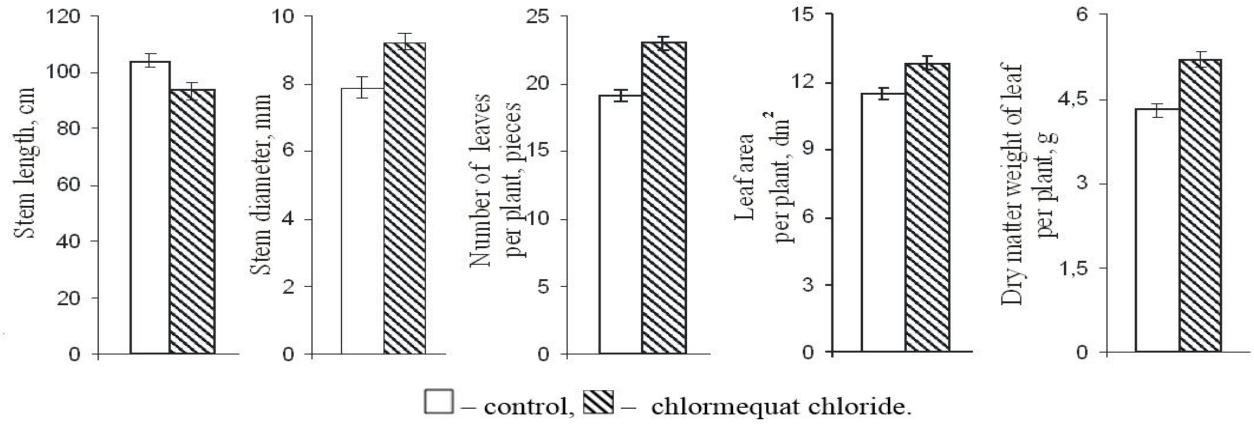

Figure 1. Morphometric measurements under chlormequat chloride treatment on poppy oil.

Photosynthetic activity has an important implication on the plant productivity, which is determined by the area of leaf surface, the leaves' number and functioning duration, the mesostructure of leaves as well. The analysis of recent studies has shown that artificial restraint of plant growth processes is accompanied by significant changes in morphogenesis that is related to the formation of donor sphere of plant under retardants of various classes' treatment (Matsoukis et al., 2015; Wang et al., 2016). Consequently, the evidence of this study suggests analyzing the features of growth and formation of leaf surface as factors that determine the power and term of photosynthetic apparatus functioning under chlormequat chloride treatment on plants.

The obtained results of the study indicate that there was a significant difference in the number of leaves, their area and weight between experimental plants and control variants (Figure 1).

It testifies to the fact that these measerements of chlormequat chloride of treated plants were higher compared to the control plants and found a more powerful donor potential of the photosynthetic apparatus at the period of poppy pods formation and growth. Poppy oil plants are characterized by a short period of development and a rapid rate of leaf death, especially of the lower layers. The data suggests that the treated plants had a large number of leaves and a large leaf surface at the end of vegetation, which provides an additional assimilate source for the fruit growth.

It was found that the growth of the total area, number and weight of leaves of experimental plants are primarily ensured by the process of more intensive stem branching due to the formation of secondary shoots. Thus, under chlormequat chloride application, this measure was 3.0 ± 0.11** shoots compared to the control plants -2.5 ± 0.09 (the difference is significant at $P<0.001$). The strengthening of stem branching under retardant treatment is a general reaction of plants to the effect of antigibberellin compounds-retardants that it was noted earlier on another crops (Kuryata, 2009; Sousa et al., 2016).

The important coenotic indicator of plants is the leaf index. The latter was higher in plants, treated with chlormequat chloride, which is also an important prerequisite for increasing the crops production (Figure 2).

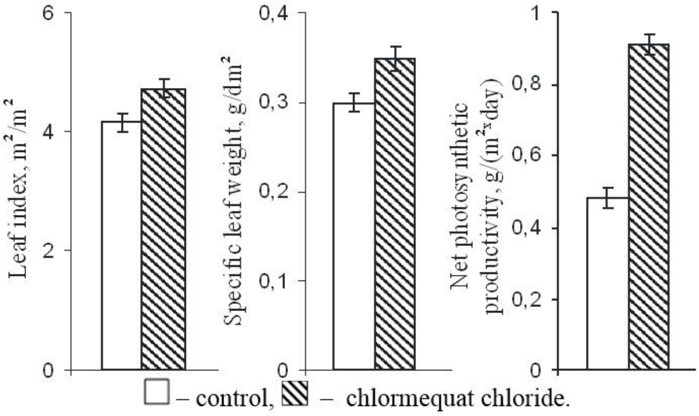

Figure 2. Formation and functioning of photosynthetic apparatus under chlormequat chloride application on poppy oil.

The data suggest that the leaves of treated plants are characterized by a higher specific leaf weight. It is known that this measure characterizes the power of photosynthetic apparatus: the positive correlation between the photosynthesis intensity and this measure is explained by an increase in the concentration of the main structural elements and photosynthetic pigments, with the direct participation of which is carried out the CO_2-assimilation. The specificity of action of the various retardants on this measure should be considered. In particular, the application of uniconazole on Polygonum cuspidatum decreased this measure (Sugiura et al., 2015).

It testified to the fact that an increase of specific leaf weight caused the structural changes in it under drug treatment, which determines the evidence from this study to suggest the causes of this phenomenon. Physiological condition of the leaf is in close cooperation with its structural features defined in the scientific literature as a "mesostructure". The application of mesostructure characteristics allows analyzing the photosynthetic function of the leaf in many cases, but it was hardly analyzed under retardant effects. The analysis of mesostructure characteristics has shown that the thickness of leaves, thickness of chlorenchyme, and the length and thickness of parenchyma cells significantly increased under chlormequat chloride application (Table 1). The analogous results are obtained on potato culture (Rogach et al., 2016).

Table 1. Mesostructure characteristics of leaves under chlormequat chloride treatment on poppy oil (milky maturity phase, M ± m, n=20).

Measurements	Control	CCC
Thickness of leaves, μm	233.3 ± 5.91	292.6 ± 5.99***
Thickness of chlorenchyma, μm	127.5 ± 2.93	169.7 ± 2.06***
Length of parenchyma cells, μm	43.7 ± 0.92	52.8 ± 1.07***
Width of parenchyma cells, μm	22.9 ± 0.84	33.9 ± 1.04***
Total chlorophyll content (a+b), % per fresh matter weight	0.22 ± 0.002	0.25 ± 0.003***

Note: * -difference is significant at P<0.05, **- P<0.01, ***- P<0.001

It should be noted that there is no clear differentiation of the assimilation of parenchyma (chlorenchyme) on the palisade and spongy cells of poppy oil plants. The increase of chlorenchyma partial fraction in the overall structure of the leaves due to the formation of larger assimilation of cells of treated plant is a positive factor affecting the pigment content and photosynthetic processes. The data suggest that chlormequat chloride significantly increases the chlorophyll content of a poppy oil leaf. The analogous effect of retardant paclobutrazol is found on *Camelina sativa* L. Crantz (Kumar et al., 2012).

The analysis clearly indicates that an improvement of phytometric and mesostructure measurements of leaves and chlorophyll content by chlormequat chloride contributed to the enhancement of photosynthetic activity of leaf apparatus, consequently net photosynthetic productivity significantly increased (Figure 2). An analogous effect of chlormequat chloride was observed on ginkgo plants (Zhang et al., 2013), and uniconazole-on soybean plants (Yan et al., 2015). This measure defined the photosynthetic productivity per unit leaf surface. It can be concluded that the increase of the total leaf area formed a more powerful donor sphere of poppy oil plants, treated with chlormequat chloride.

It has been found that drug application on the poppy plants caused changes in the accumulation and translocation of nonstructural carbohydrates between organs during the growing season. The total carbohydrate content (sugars and starch) during the whole vegetation was greater in leaves and roots of chlormequat chloride treated plants compared to the control plants (Figure 3). The strengthening of starch accumulation under paclobutrazol treatment on Landoltia punctata L. plants in another work was noticed (Liu et al., 2014). It testifies to the fact that this retardant blocks the attracting activity of the growth zones, decreases the outflow of assimilates to them and temporary deposits the carbohydrates in vegetative organs.

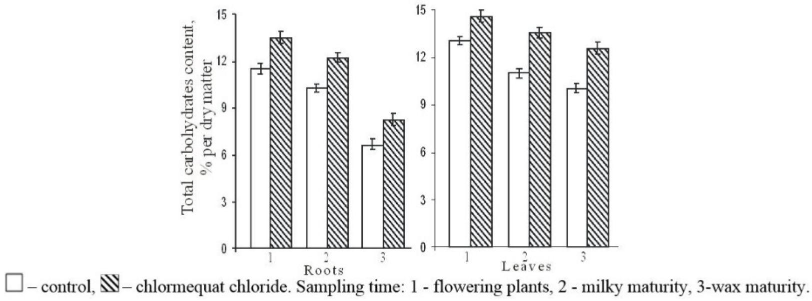

Figure 3. Total content of carbohydrates (sugars+starch) in vegetative organs of poppy oil under chlormequat chloride treatment.

The growth processes of vegetative organs significantly reduced after the budding phase that is determined by formation a powerful acceptor zones-poppy pods, the main sink of assimilates, which decreased the carbohydrates content in vegetative organs during ontogenesis.

The analysis of the donor-acceptor system of plants is established on the features of assimilates accumulation and translocation-photosynthetic products. In most cases, the features of nutrients translocation between plant organs in connection with the artificial changes in photosynthetic activity and growth are not adequetly explored. The obtained results indicate significant changes in the nitrogen, phosphorus and potassium dynamics under retardant interaction.

The retardants application on the accumulation and transport of nitrogen-containing compounds by plant roots are not adequetly explored. In particular, the application of uniconazol on soy increased the content of nitrate, ammonium nitrogen and amino acids in xylem sap (Yan et al., 2013). It has been found that the enhancement of carbohydrate content in vegetative plant organs of poppy oil under the chlormequat chloride treatment was accompanied by a decrease of the total nitrogen content in the roots and leaves of control and experimental variants (Figure 4).

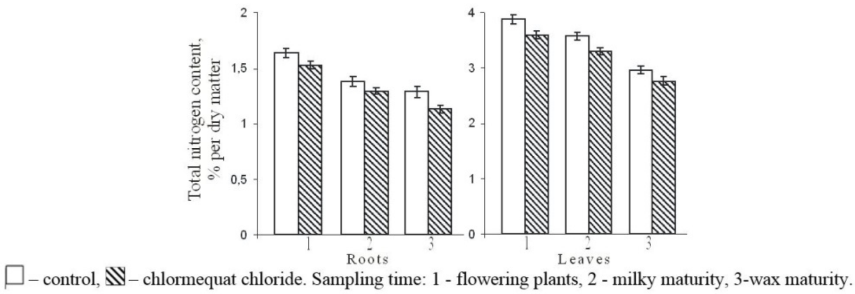

Figure 4. Effect of chlormequat chloride on total nitrogen content in roots and poppy oil leaves.

The maximum amount of nitrogen-containing compounds in the leaves and roots was noted at the initial stages of the study, while the total nitrogen content in the leaves was significantly higher than that of the roots. At the end of vegetation, the nitrogen content significantly decreased in the tissues of vegetative organs. At this period, the growth of vegetative organs actually stopped, the gradual decrease of the nitrogen content in the leaves and roots can not be explained by simple biodegradation. At this stage, new acceptor centers-poppy pods are actively formed and grow, and such dynamic of nitrogen content indicates its active reutilization for the carpogenesis needs.

The increase of phosphorus content in the leaves during vegetation in control and treated plants was noted, which indicates the important role of that element in photosynthetic processes during the fruits formation and growth (Figure 5). The lower element content in the leaves under chlormequat chloride application is bound, apparently, with an increase in outflow to the poppy pod, the number of which increased under compound application. The phosphorus content in the roots of poppy oil decreases during the vegetation in the control and experiment variant and at the end of the vegetation, it was minimal in the version with chlormequat chloride. The results of the study suggest that the more intense element reutilization is realized for the fruits formation needs-the more the number of poppy pods under retardant treatment increases (Table 2).

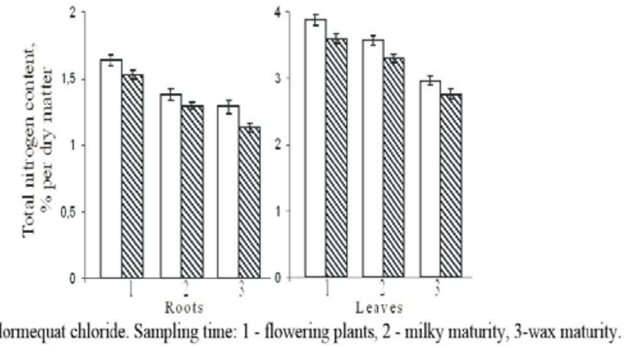

Figure 5. Phosphorus content in vegetative organs of poppy oil under chlormequat chloride application.

It was found that the application of antigibberellin compounds marked a decrease in potassium concentration in the leaves and roots relative to the control variant (Figure 6). At the end of vegetation, the element contents in the leaves and in the roots diminished. Obviously, this is also due to the increase in the outflow of element to the generative organs that are formed.

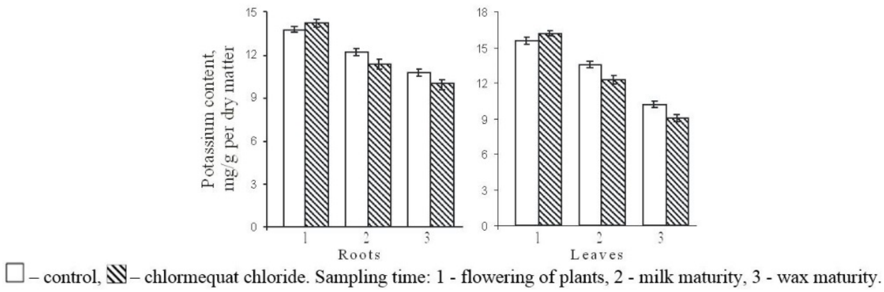

Figure 6. Potassium content in roots and leaves of poppy oil under chlormequat chloride treatment.

It common knowledge that in the ontogenesis, constant coordination of growth processes and photosynthesis is carried out by trophic regulation of donor-acceptor relations. The obtained data indicates that application of chlormequat chloride on the poppy oil plant formed a more powerful leaf apparatus, prolonged leaf life that forming an excess of assimilates to ensure the seed growth. the positive influence on the pods formation under drug treatment as a result of increased nutrients reutilization from vegetative organs was manifested. It was found that chlormequat chloride application resulted in a significant enhancement of the poppy pods number per plant that resulted on the stimulation of photosynthetic processes (Table 2). At the same time, the weight of thousands seeds and the total seed weight in a pod grew, which led to an increase of the crop production. The improvement of crop production was noticed by other researchers (Sawan, 2013; Pobudkiewicz, 2014; Panyapruek et al., 2016; Kuryata and Golunova, 2018).

Table 2. Effect of chlormequat chloride on crop production of poppy oil cv. Berkut (M ± m, n=25).

Measurements	Control	CCC
Number of pods per plant, pieces	2.5 ± 0.09	3.0 ± 0.11**
Seed weight in a pod, g	3.0 ± 0.10	3.5 ± 0.12**
Weight of 1000 seeds, g	0.5 ± 0.02	0.6 ± 0.01**
Yield, c/ha	8.4 ± 0.25	9.5 ± 0.26**

Note: * -difference is significant at P<0.05 **- P<0.01, ***- P<0.001.

The application of chlormequat chloride resulted in a slight decrease of the oil content in the seeds. In particular, the oil content was 45.6 ± 0.03 ***% under retardant treatment compared to the control variant-46.3 ± 0.03% (the difference is significant at P<0.001). The existence of palmitic (C16), palmitoleic (C16: 1), stearic (C18), oleic (C18:1), linoleic (C18:2), arachic (C20), α-linolenoic (C18:3), gondoic (C20:1) acids was determined by chromatographic analysis of the oil content in control and treated variants. The data indicates that there were no significant changes of the total saturated and unsaturated higher fatty acids content and their correlation in the control and chlormequat chloride treated variants (Table 3).

Table 3. The effect of chlormequat chloride on the content of higher fatty acid in poppyseed oil (%, M ± m, n=5).

Measurements	Control	CCC
C16 palmitic acid	7.90 ± 0.037	7.76 ± 0.025*
C16:1 palmitoleic acid	0.09 ± 0.003	0.11 ± 0.003 **
C18 stearic acid	1.77 ± 0.011	1.91 ± 0.018**

C18:1 oleic acid	18.14 ± 0.027	18.33 ± 0.031**
C18:2 linoleic acid	71.27 ± 0.242	70.83 ± 0.231
C18:3 α- linolenoic acid	0.62 ± 0.012	0.75 ± 0.013**
C20 arachic acid	0.16 ± 0.003	0.22 ± 0.005***
C20:1 gondoic acid	0.05 ± 0.001	0.09 ± 0.005**
Content of unsaturated higher fatty acids	90.17 ± 0.285	90.11 ± 0.283
Content of saturated higher fatty acids	9.83 ± 0.051	9.89 ± 0.048
Unsaturated/saturated fatty acids	9.17 ± 0.23	9.11 ± 0.24

Note: * -difference is significant at P<0.05 **-P<0.01, ***-P<0.001.

Poppy oil-cake is used for feeding animals, therefore its chemical composition is important. It is common knowledge that the oil and nitrogen content in seed of oil crops is correlated: a decrease in the oil content is accompanied by an increase in the protein content. The analysis of the data suggests this regularity-the application of chlormequat chloride led to a significant increase in nitrogen content of poppy oil-cake. Chlormequat chloride treatment decreased the potassium content and increased the phosphorus content in the oil-cake (Figure 7).

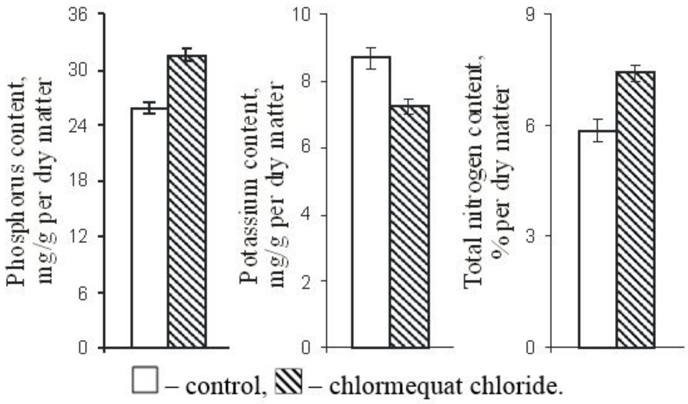

Figure 7. Mineral nutrients content in poppy oil-cake under application of chlormequat chloride.

It has been established that retardant application on poppy oil plant had a significant effect on the alkaloid content in poppy pods. At the end of vegetation, the content of alkaloids in the treated poppy pods was higher than in the control variant (Table 4).

The results of the study has shown that chlormequat chloride treatment increased the content of narcotic alkaloids-morphine, codeine and tebaine. It was found an insignificant amount of the non-narcotic alkaloids: neopine, papaverine, narcotine, oripavine in the poppy pods at waxy maturity phase.

Table 4. The effect of chlormequat chloride on alkaloid content in poppyseed oil at waxy maturity phase (%, per dry matter, M ± m, n=5).

Measurements	**Control**	**CCC**
Morphine	0.11 ± 0.011	0.26 ± 0.011***
Codeine	0.02 ± 0.001	0.03 ± 0.002**
Tebaine	0.01 ± 0.001	0.02 ± 0.001**
Neopine	0.01 ± 0.001	0.02 ± 0.001**
Papaverine	0.07 ± 0.002	0.11 ± 0.003***
Narcotine	0.08 ± 0.003	0.10 ± 0.002*
Oripavine	0.01 ± 0.001	0.03 ± 0.002**

Note: *-difference is significant at P<0,05 **- P<0.01, ***-P<0.001.

The application of synthetic growth inhibitors on the crops must be determined by the reliable control of the amount of residual drug substance in products. It was found that the amount of residual chlormequat chloride was 0.0013 mg/kg in the experimental sample. In accordance with the State Sanitary Rules and Regulations (8.8.1.2.3.4.-000-2001) in Ukraine, the amount of residual chlormequat chloride should not exceed 0.1 mg/kg for peas, buckwheat, grain and seed of flax, sunflower, poppy oil. Thus, the proposed regulation of chlormequat chloride application will not lead to the accumulation of excessive amount of drug substance in the seed.

Discussion

Exogenous application of phytohormones and synthetic growth regulators leads to the changes of the growth intensity of individual organs of the plant and the assimilate translocation from the donor zone of the plant (leaves, photosynthetic processes) to acceptor zones and processes, in particular, the carpogenesis-growth and fruit formation. The obtained results testify to the essential role of the morphological and mesostructural components on the donor-acceptor system of poppy oil plants. The application of chlormequat chloride inhibitor contributed to the formation of a more powerful donor sphere of the plant-the number and weight of leaves, the area of leaf surface per plant and the important coenotic indicator-leaf index were increased. It has been established that the stem branching was significantly increased under drugs treatment which caused such morphological changes. The interaction of drugs enhanced the donor function of poppy plants due to mesostructural changes in the leaves. The chlormequat chloride application formed a more powerful layer of chlorenchyma-the main photosynthetic tissue of the plant and incresed the linear sizes of chlorenchyma cells and the chlorophyll content in them. Thus, the intensification of growth processes under drug treatment contributed to the formation of a more powerful donor sphere of the plant and the unit of cenosis area, which created the prerequisites for enhacement of crop production. In particular, it was noticed that the content of non-structural carbohydrates (sugar+starch) was higher in the vegetative organs of treated poppy oil at the period of intensive growth.

It is common knowledge that one of the most powerful acceptors of assimilates is the carpogenesis processes-the growth and formation of fruits. The improvement of stem branching under drugs interaction resulted in the formation of a large number of flowers and fruits-poppy pods-that increased the acceptor capacity of the plant. The consequence of these changes was more intensive translocation of nonstructural carbohydrates on the formation and growth of fruits under chlormequat chloride. At the period of vegetative growth, the assimilate competition between fruits and vegetative growth zones is absent, the translocation of assimilates is aimed at the fruit formation, which led to a diminuation of the nonstructural carbohydrates content in vegetative organs.

It was noted that the largest nitrogen content was in the roots and leaves at the flowering phase, which was translocated to the carpogenesis during the growth and formation of fruit. The lower phosphorus content in the leaves and potassium content in vegetative organs of poppy oil was noted under chlormequat chloride. Consequently, vegetative organs may be considered not only as an intermediate source of carbohydrates assimilates but also as a temporary source of nitrogen-containing compounds and other elements of mineral nutrition. The enhancement of assimilates flow, nitrogen-containing compounds and nutrients led to an increase in the crop production that increased the number of poppy pods, the seed weight in a pod and the weight of a seed.

The obtained results of the study indicate that drugs application created some changes in the qualitative composition of poppy seeds. It has been confirmed that there is a correlation between the accumulation of oil and the nitrogen content-a slight decrease in the oil content was accompanied by an increase in the nitrogen content in the seeds under drug treatment. The practical significance of the studies has shown that application of chlormequat chloride increase the alkaloids content in poppy oil seed and has important implication for pharmacological industry.

Thus, the application of chlormequat chloride on poppy oil plants at the budding period leads to enhancement of the crop production due to the optimization of morphological structure of the plant, the mesostructural organisation of the leave and increase the attractive potential for fruits laying and formation.

Conclusion

It was studied that the application of chlormequat chloride at the budding phase led to an increase in the crop production of poppy oil and was not accompanied by the accumulation of residual drug substance in the seeds above the permitted norms. There is a correction of donor-acceptor relations in the plant, which is realized through the translocation of photoassimilates from vegetative growth for carpogenesis needs under drugs treatment. The deceleration of linear growth at the beginning of vegetation under chlormequat chloride application led to intensive stem branching, formation of a large number of leaves, leaf surface, optimization of leaf mesostructure and an increase of the reserves of nonstructural carbohydrates deposited in vegetative organs. The formation of a more powerful acceptor sphere is associated with an increase in the stem branching and, accordingly, by the laying of a greater number of fruits-main acceptors of assimilates in the second part of vegetation. The increase of plant loading is also determined by a more intense flow of carbohydrates, nitrogen-containing compounds and nutrients, which eventually improved the seed yield of the treated plant.

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