СИНТЕТИЧНИ РЕГУЛАТОРИ НА РАСТЕЖА И ПРИЛОЖЕНИЕТО ИМ В ПРАКТИКАТА SYNTHETIC GROWTH REGULATORS AND THEIR PRACTICAL APPLICATION (MINI REVIEW)

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Abstract

There are many chemical compounds in the plant-growing practice, used for regulation of the growth, development, productivity and sustainability of plants. The efficiency of the exogenous application of the synthetic compounds depends on the type and physiological age of the plants, as well as on the concentration and time of application of the relevant regulator. The synthetic growth regulators are usually divided into two groups. The first group includes compounds with structure and function similar to those of the natural growth regulators. These are for example the synthetic auxins, gibberellins, cytokinins (synthetic stimulators) and the ethylene-releasing substances (synthetic inhibitors). The second group comprises compounds without close analogues in plants but cause effects similar to the natural regulators. Apart from growth regulators, there are several other compounds used in the agricultural practice – herbicides, fungicides, insecticides, defoliants, desiccants, etc. They are not growth regulators but in many cases the difference between them and the growth regulators is hardly perceptible. Depending on the dose, a compound may be a growth regulator or a herbicide, fungicide, defoliant, and so on.

Key words: auxins, gibberellins, cytokinins, brassinosteroids, ethylene, retardants.

INTRODUCTION

In the higher plants the coordination of the processes of growth and development is actively supported by a group of specific substances called phytohormones. They contribute to the interaction between the cell tissues and organs. Their presence in the cell initiates and maintains harmonious growth, division and differentiation, ensuring normal growth and development of the entire plant.

After establishment of the importance of the endogenous growth regulators, an increased synthesis of a number of their analogues begins, which have a high physiological activity and are exogenouslly applied for regulation of the growth, in compliance with the human needs. The synthetic growth regulator may imitate the activity of a natural hormone. Thus upon its introduction the activity of the phytohormone increases. The regulator may be chemically identical to the hormone or may have a similar activity. The synthetic growth regulator may interfere in the process of biosynthesis or in the hormone transportation. Apart from the compounds with structure and function similar to those of the natural growth regulators, there are others used in agricultural practice which do not have similar analogues in plants. They have an absolutely different chemical structure but their effects resemble the natural compounds. The efficiency of the exogenous application of synthetic compounds depends on the type and physiological age of the plants, as well as on the concentration and the application time of the relevant regulator.

Apart from growth regulators, there are other compounds used in agriculture – herbicides, fungicides, insecticides, defoliants, desiccants, etc. They are not growth regulators but in many cases there is not a clear distinction between them and the growth regulators. Depending on the dose, a compound may be used for growth regulator or herbicide, fungicide, defoliant, etc. A typical example of this is the 2,4-dichlorphenoxyacetic acid (auxin) which is phytotoxic in comparatively low concentrations and due to this reason is mostly used as herbicide against broad-leaved weeds.

In this review, there are examples of the use of synthetic growth regulators in order to improve the quality and quantity of agricultural production.

PRESENTATION

Synthetic stimulators

Synthetic regulators from the group of auxins

The synthesis of indoleacetic acid in 1934 marked the beginning of obtaining similar compounds of high biological activity (Thimann and Koepfli, 1935; under Basra, 2000). Usually the synthetic auxins show higher physiological activity than the natural ones because they are preserved unchanged in the plant tissues for a longer period of time. This is explained by the fact that after their adoption by the plants, the synthetic auxins are not decomposed by the enzyme IAA-oxydase. Practically the plants do not have enzymatic systems to destruct the exogenously supplied auxins very quickly. The endogenous auxins may form inactive conjugates (e.g. IAA-aspartate), while their synthetic analogues either do not connect into complex compounds or do it considerably seldom.

The synthetic auxins of practical importance are some derivates of carbonic acids – indoleacetic acid (IAA), 1-naphthylacetic acid (NAA), indolylbutyric acid (IBA), indole fatty acid (IFA), 2,4-dichlorophenoxyacetic acid (2,4-D). Indoleacetic acid is seldom applied in practice because it is easily decomposed. Due to its extremely high activity 2,4 dichlorphenoxiacetic acid is phytotoxic in comparatively low concentrations and because of this is mostly used as herbicide. Apart from higher physiological activity, the synthetic auxins show more diverse physiological activity when compared with the endogenous natural compounds from this group. This is a precondition for their use in different trends of plant-growing (Kozlowska et al., 2007).

One of the first trends in which growth regulators from the group of auxins are introduced to practice, is the stimulation of rooting of cuttings from vegetatively reproducing plants (Davis et al., 1985; Blazich, 1989). This method has been practiced even by the ancient Romans for the creation of new vineyards. However, while the cuttings from some plants are easily rooted, in other plant species rooting of the cuttings is very difficult, in others – almost impossible. This is why synthetic auxins are used for stimulation of root formation of cuttings from more than 200 plant species (Zhang et al., 2003). The following ones are perspective in this trend: naphtylacetic acid (NAA), indole fatty acid (IFA), indoleacetic acid (IAA) and the potassium salts of those acids. The potassium salts of the indicated acids have the advantage of being easily soluble in water at ambient temperature. Stimulation of rooting of cuttings is widely applied in a number of countries for rooting of fruit species (especially those with difficult rooting abilities), vines and a number of flowers (Kerin et al., 2004).

Another aspect of the use of synthetic auxins as stimulators of root formation and root growing is the treatment of the root system of seedlings, saplings and old trees during their engrafting. In this aspect auxines find application in fruit-growing (Basak, 2009). Upon taking the fruit trees out of the nursery garden their root system is torn to a different degree. Prior to their planting in a permanent place in the garden growth regulators of auxin type may be used for faster restoration and growth of the root system. For this purpose water solutions of IFA or NAA are recommended in concentrations (5-10 mg l^{-1}). The plants' roots are submerged in such solutions for 18-20 hours prior to their planting in a permanent place (Kerin et al., 2004; Kesari et al., 2009).

Stimulation of the rooting system of tomato, pepper, etc.seedlings through soaking of the roots into NAA solutions prior to planting is very effective. Plants treated in this way are distinguished for fast and powerful development of the rooting system and the ground parts of the plants, ensuring higher yields

In fruit-growing pre-harvest drop of fruits consumed fresh is very important. This problem is very often observed at the time of harvest maturity of the fruits of apples and pears. In order to limit damages from pre-harvest drop in a number of countries (the USA, Germany, Poland) synthetic auxins are used. Apart from reduction of the quantity of fallen fruits, the treatments create conditions for extension of the harvest period (Basak, 2009).

Some fruits in certain years bloom excessively and produce large volumes of fruits. However they do not reach the necessary quality because the trees are not able to feed them. In apples and pears this leads to exhaustion of the fruits and provision of insufficient quantity of blossoms for the following year. With a view to overcoming this problem, a number of states use auxin and ethylene-releasing preparations for rarefaction of the seed buds.

Synthetic regulators from the group of gibberellins

Gibberellin preparations produced under industrial conditions, contain mainly GA_3 and to a lesser degree GA_{4+7}. The application of these synthetic compounds leads to a reaction of the plants identical to that of the endogenous gibberellins (Takahashi et al., 1991; King et al., 2000). Due to the complexity of the molecule of the gibberellins they are obtained not chemically but biologically, similar to the antibiotics (microbiological biotechnology), using selected high-yield strains *Gibberella fujikoroi.*

GA preparations can be successfully used in fruit-growing for fruit growth control. Synthetic GA increase the size of fruits, influence their colour and shape and thus increase their market value (Facteau, 1982; Harrell and Williams, 1987). Cherries are most often sprayed with gibberellin three to four weeks prior to harvest. The so treated fruit are larger and harder compared with the untreated ones (Facteau, 1982; Zhang and Whiting, 2011). Similar reactions are found in other stone fruits (apricots – Southwick and Yeager, 1995 and nectarines – Zilkah et al., 1997).

Synthetic gibberillins can also be used in vine-growing for the purpose of increasing the largeness of the grape clusters and yields (Weaver, 1972). Increase in the fruit growth, supported by gibberellins in the seed varieties of vines is generally minimum. The increased size of the seed grape varieties is usually related to the smaller number of seeds inside the fruit, which leads to the presumption that the endogenous levels of gibberellin influence the fruit size and when such levels are high enough, exogenous application does not produce any effect (Basra, 2000).

Growth regulators from the group of gibberellins successfully regulate the processes of plant repose. Gibberellin preparations terminate the state of repose in case of freshly dug potato tubers thus ensuring a second harvest of potatoes (planting of the tubers almost immediately after their digging out) with a view to obtaining healthy planting material for the following year and for supply of the population with fresh potatoes in the late autumn months (Kozlowska et al., 2007).

Gibberellins may be used in brewery for the purpose of obtaining malt. When growing barley at the appropriate temperatures, they accelerate the synthesis of hydrolytic enzymes in the aleurone layer.

Synthetic regulators from the group of cytokinins

Synthetic cytokinins (CT) may successfully be applied for improvement of the quality of perishable decorative plants. It has been proven (Tjosvold et al., 1994; Serek et al., 1996), that synthetic cytokinins inhibit the activity of ethylene, thus preventing the leaves from turning yellow and aging in a number of foliar decorative plants and such ones grown for blossom cut (roses, chrysantemums, etc.) Exogenous cytokinins can be applied with equal success through spraying and watering the plants.

Synthetic cytokinins, in combination with gibberellins (e.g. benzyladenin, gibberellins GA_4 and GA_7) are used for regulation of the shape, size and mass of the apple fruit (Unrath, 1974; Steiner et al., 2013).

Synthetic CT find wide application in plant technologies. Together with auxins, they are the most widely used growth regulators in food environments for plant tissue crops (Kozlowska et al., 2007). Selectivity has been established for the influence of cytokinins and auxins in *in vitro* cultivation in their physiological activity depending on the different *in vitro* systems, the plant type and in many cases even the cultivar (Ganeva et al., 2009).

Synthetic regulators from the group of brassinosteroids

Synthetic brassinosteroids (BRs) increase the yield of wheat, rice, maize, sugar beet, rapeseed, charlock and potato (Rao et al., 2002). After application of BRs the yield of wheat increases from 5.7 to 6.3 t per ha^{-1}, in rice – from 4.6 to 6.3 t ha^{-1} (Janeczko, 2005). Ramraj et al., (1997) - (under Matysiak and Adamczewski, 2009) report increased yield of potatoes by 4 t ha^{-1}. In soy synthetic BRs increase the content of chlorophyll *a*, chlorophyll *b* and total chlorophyll There is a stimulating effect on the intensity of the process of photosynthesis which subsequently has a positive effect on the yield (Cevahir et al., 2008). Synthetic brassinosteroids increase the nutrient value of the produce obtained. It has been proven for example that in peanuts BRs increase fat content from 40 to 60%, the sugar content in sugar beet and in some fruits (watermelon, grapes) they improve their gustatory qualities - (Khripach et al., 2000).

The preparations containing brassinosteroids, are registered in countries as China and Russia and are used in the cultivation of sugar cane, tobacco, tea, rapeseed, potatoes, tomatoes, cucumbers, pepper and cereals (Matysiak and Adamczewski, 2009).

Synthetic inhibitors

Ethylene-releasing preparations

Ethylene, which is a gas, is used in the form of ethylene-releasing preparations, for example Flordimex, etc. Ethylene-releasing preparations are applied for the overcoming of lodging and increase in the cereal yields. Lodging is one of the most serious problems in the production of cereals, especially in the application of high doses of nitrogen fertilizers under high levels of air humidity. As a means of decreasing the height of plants, increase in the stem thickness and the sustainability against lodging the use of ethylene-releasing preparations is expedient. Ethylene producers release ethylene in plants, which inhibits the movement of auxins in the stem tissues, thus reducing their ability to stimulate stem elongation (Jankiewicz, 1997; Kozlowska et al., 2007).

In fruit-growing practice ethylene-releasing preparations may be successfully used for regulation of fruit-bearing capacity. Some fruit types (apples, pears, peaches) in certain years have abundant blooms and produce large quantities of fruit but they do not reach the necessary commercial qualities due to the inability of the trees to feed them. This leads to exhaustion and provision of insufficient number of buds for the following year. For the purpose of overcoming the alternative fruit-bearing and regulation of the loading of the trees with fruit the use of Flordimex is recommended (Basak, 2009). Ethylene-releasing preparations are successfully used for fruit ripening. The ethylene contained therein has a stimulating effect on the formation of the colour specific for the ripe fruit (Abeles et al., 1992; Larrigaudiere et al., 1996).

Current knowledge of the interference of ethylene in the process of fruit ripening can be used in two ways. The first way is to help for the fast and simultaneous ripening of the fruit in response to the market requirements and for facilitation of mechanized harvesting. For this purpose ethylene-releasing preparations may be used for cherries, sour cherries, apples, pineapples, blueberries, coffee, cranberries and figs (Arteca, 1996).

An alternative to the treatment with ethylene-releasing preparations is the application of synthetic auxins, which enhance the production of endogenous ethylene. Acceleration of the fruit and reduction of the strength of their retention to the branches is of great interest with reference to the cherries and sour cherries, especially when the fruits are intended for industrial processing and mechanized harvesting with shaking machines. After the use of the Flordimex, the fruit ripen simultaneously and the strength necessary for their picking up is reduced by 50-60%, which relieves the mechanic harvesting. Similar results are reported in several cultivars of plums and apples intended for industrial processing (Basak, 2009). The second method is delay in ripening for the purpose of increasing the life of fruits in storehouses. Extended shelf life can be achieved through blocking of biosynthesis or the activity of ethylene or through the use of conditions removing ethylene from the fruit environment.

With the help of the ethylene-releasing preparations leaf falling can be regulated. It has been found out that these processes depend on the ratio between IAA and ethylene. In case of auxine priority, the process of falling is delayed and in case of increased content of ethylene, it is accelerated. This comes to show that with the help of synthetic auxins and preparations releasing ethylene in plants, leaf falling can be purposefully managed. In this aspect ethylene-releasing preparations can be applied as defoliants in young fruit trees in nursery gardens. Defoliants cause flow of nutrients from the leaves to the leading shoots thus ensuring their better ripening and increasing their sustainability to low winter temperatures (when they are planted in a permanent place in the autumn). Upon storage of young fruit trees in refrigerator boxes defoliation limits transpiration, which leads to drying of the plants (Basak, 2009).

In vegetable-growing ethylene-releasing preparations are applied in medium early and late field production of tomatoes and pepper (including red pepper for grinding), intended for mechanized gathering. When treated, the fruits ripen for 7-15 days, depending on the temperature. The yields rise considerably (by around 60%), as the preparations cause simultaneous ripening of the fruits, which is very important for the single-time mechanized harvesting. The calming effect of the ethylene-releasing preparations on fruit ripening is of considerable interest for the late growing of tomatoes and pepper, with a view to reduction of the losses from early autumn frosts.

Ethylene-releasing preparations are successfully used for regulation of sex differentiation in some plants. In pumpkin cultures (cucumbers, melons, water melons) in the production of seedling there is a positive effect of treatment with Flordimex, etc. Under its influence the number of female blooms increases and their blooming is stimulated. The growth of the central stem is suppressed and more side branches appear. This has a favourable influence on the larger number of female blooms (by around 40%), which is a precondition for formation of standard fruits, reaching harvest maturity simultaneously. The total yield increases by more than 25% (Kerin and Berova, 2001). Sex differentiation depends on the ratio between gibberellins and ethylene. If necessary (for example in seed production, in paternal cultivar of cucumbers) the increase in the number of male blooms may be achieved by treating the plants with gibberellic preparations (Kozlowska et al., 2007).

Ethylene-releasing preparations may be used in decorative gardening for delay in flowering (Stanley and Cockshull, 1989), for selective abortion of blossoms (Furutani et al., 1989), for leaf falling (Woolf et al., 1992), as well as for reduction of the stem height and increase in their strength. (Tayama and Carver, 1990).

Retardants and other synthetic growth regulators

Retardants are substances able to suppress growth processes in plants (Grossmann, 1992; Rademacher, 2000; Ryan et al., 2003). They retain cell elongation and cell division in the stem tissues and physiologically regulate the plants' height. Suppression of stem growth leads to acceleration of the formation of reproductive organs (Banovetz, 1993; Gent, 1995). Under their influence the functional activity of the roots related to increased active absorption of water from the soil increases (Moetska-Berova, 1995; McCann and Huang, 2007). Retardants contribute to the more intensive green colouring of the leaf blade, do not cause structural anomalies and often increase plant productivity (Moetska, 1987; Reddy et al., 1996; Berova and Zlatev, 2000; Matysiak and Adamczewski, 2009). By stimulating the growth of the root system, retardants contribute to the resistance to drought (Steinberg et al., 1991). They can improve the reaction of the plants to other types of stress, such as extreme temperatures, contaminants and pesticides (Fletcher and Hofsra, 1985, Saito et al., 2006).

In many cases the activity of the retardants is contrary to the activity of the gibberellins, by reason of which they are regarded as antagonists of gibberellin. Retardants have very good motility in plants' tissues. Upon treatment of the ground parts of the plants, they move from top to bottom and upon treatment of the roots through their application in soil – from bottom to top (Kerin and Mojecka, 1987; Latimer et al., 1995; Wichard, 1997). Spraying is attractive as it can be applied relatively fast. Treatment through watering is more labour-consuming but produces a more long-lasting and uniform reaction of the plants. When imported in soil, retardants keep unchanged for a different period of time, depending on the type of retardant, type of soil, the availability of microorganisms, destructing their molecules (Dicks, 1972; Li et al., 2011).

Chlormequat chloride (CCC) has a wide sphere of activity, fast decomposition in plants and application in agriculture. The practical use of CCC raises the question of its persistence in soil and its destruction in plants. It has been found out that the retardant is destructed for 3-4 weeks after its incorporation in soil. Part of CCC is released in soil and in the guttation fluid. In soil it is subjected to microbiological processes without rendering considerable influence in their course (Tsirkov et al., 1981). Studying of residual quantities of the preparation in pepper plants shows that 80 days after treatment in the roots, stem and leaves there is no active substance of the retardant (Kerin and Mojecka, 1987). Similar results are reported in tomatoes (Kerin and Boshnakov, 1981; Ostrzycka and Borkowski, 1982), potatoes (Volkova et al., 1976), barley, maize and tobacco (Stephan and Schutte, 1970) and pear (Hau et al., 2000). The mechanism by which CCC carries out its regulatory activity is generally related to suppression of biosynthesis, transport and physiological reactions of gibberellins.

Initially CCC was applied in the growing of cereals, in the fight against lodging. With the discovery of CCC in 1960s as a retardant (Tolbert, 1960) and its spreading as a commercial preparation (Cycocel) after 1964, the problem with wheat lodging was partially resolved (Fletcher and Kirkwood, 1982; Espindula et al., 2009). Presently its application, in combination with high doses of nitrogen fertilizers, is a standard technology for wheat growing in many European countries. For example in Germany more than 60% of the areas are treated with this retardant (Basra, 2000). Practically CCC has influence on almost all cultivars of wheat although its effect is expressed to a different degree. Treatment of wheat with CCC causes reduction of the plant's height (by 10-30%) and at the same time the diameter and stem strength increase, thus stabilizing it against rain and strong winds (Kefeli and Prusakova, 1985; Prusakova, 1987). Similar results were reported for the triticale (Moetska-Berova 1995), barley (Herbert, 1982; Larsson, 1982; Emam and Moaied, 2000), rye (Münch, 1977; Hoffman, 1984), oats (Höfner, 1981; Gans et al., 2000), maize (Knittel and Lang, 1984; Terek, 1986) and sunflower (Golubov, 1986). Together with ethylene-releasing preparations, the use of retardant CCC is a considerable advantage, contributing to the increase in the productivity of the plants under conditions causing lodging (high fertilizer rates, dense sowing, excessive moisturizing).

The retardant CCC also reduces the stem growth rate in the vegetable crops. The inhibition effect has been reported for tomatoes (Dumitrescu and Stoicescu, 1972; Sady, 1972; Borkowski, 1992), potatoes (Radwan, et al., 1971; Rex, 1992), pepper (Moetska, 1988) etc. The biggest effect of the retardant was found to be in the period of pricking off. After that the difference between the treated plants and the control is reduced, which conforms to the established duration of activity of the preparation (Moetska, 1987). The delayed growth in height leads to more compact habitus of the plants and this increases the quality of the seedling (Moetska, 1988).

Controlling of plants' height with the retardant CCC is also successful in the decorative plants - *Pyracantha coccinea* (Henderson and Nichols, 1991), *Tibouchina urvilleana* DC. (Roberts et al., 1990), *Euphorbia pulcherrima* (Gianfagna, 1995), *Chrysanthemum cinerariaefolium* Viz. (Haque et al., 2007), *Hibiscus coccineus* (Medic.) Walt., *H. radiatus* Cav., *H. trionum* L., (Warner and Erwin, 2003), etc.

The retardant improves water exchange of the plants. A number of authors (Nazarenko and Grinchenko, 1982; Dea et al., 1982) report that cereals treated with CCC have properties typical for plants resistant to drought: powerful root system penetrating deep in soil, short stem, reduced transpiration, increased water content in the leaves and stem tissues, reduced penetration of protoplasm for electrolytes. Under the influence of the retardant the fraction content of water changes. The quantity of related water increases. The positive influence of the retardant on the water balance of the plants was reported in sunflower (Stoynova and Zafirova, 1986), tomatoes (Kefeli and Prusakova, 1985; Borkowski, 1992) etc. The reasons for the increased resistance of the plants under the influence of CCC are not perfectly clear. The reduced leaf area of the plants treated with the retardant means less transpiration surface, which in its part reduces loss of water (Davis and Curry, 1991). CCC may cause closing of the stomata, which also reduces transpiration (De et al., 1982). The retardant enhances accumulation of the reserve assimilates in the stems of the treated plants, thus enabling maintenance of the turgor at reduced leaf water potential (Bode and Wild, 1984; Knapp et al., 1987).

Suppression of the vegetative growth under the influence of CCC in many plant species leads to acceleration of the formation of the reproductive organs. Chlormequat accelerates blooming of tomatoes, increases the number of blossom buttons and buds of the plants (Borkowski et al., 1989; Borkowski, 1992). Similar results have been reported for cucumbers (Marlow, 1980; Zhukova, 1983). The effect of the application of the retardant is expressed in significant shortage of the main stem, development of many short branches and increase in the number of female blooms. This leads to increase in the number of fruits and the yield respectively. The increased number of blooms under the influence of CCC has also been reported in pepper (Moetska and Kerin, 1987). The research show that in this crop CCC increases the vitality of the pollen and reduces the degree of bunch stem necrosis (by 12% on average). This in its part leads to increase in the number of fruits and has a positive effect on the yield.

Recently some compounds from the group of triazoles and imidazoles are of considerable interest because together with the fungicidal effect, they also show retardant properties (Fletcher et al., 1986; Jacobs and Berg, 2000). Triazoles inhibit turning of lanosterol into ergosterol in the fungi and block the synthesis of some predecessors of gibberellins in plants (Grossman, 1992; Rademacher, 1997). This explains their fungotoxic and growth regulatory properties (Fletcher and Hofstra, 1988; Sponsel, 1995). Imidazoles show a similar effect – they impede the formation of ergosterin in the fungi and block the synthesis of gibberellin (Davis and Curry, 1991; Rademacher, 1997).

The specific effects of triazoles and imidazoles on plants include reduced height as a result of the inhibition of the gibberellin synthesis in the growing parts of the plants, induced by them. This effect is observed in all types of plants: annual and perennial, cultivated plants and wild species (Davis and Curry, 1991; Grossman, 1992; Whipker et al., 1994; Moetska-Berova, 1995; Moetska-Berova et al., 1995; Mojecka-Berova and Kerin, 1995; Berova and Zlatev, 2000). Until present the only known exception is *Hedera helix* L. (Horrell et al., 1990). According to Fletcher et al. (2000) the shorter stems (with shortened internods) correlate to a reduced number of cells, short cortical cells and reduced xylem length. Such preparations have a similar efficiency for the reduction of the stem length of the plants treated with them. For the purpose of achieving the same effect, the concentrations of chlormequat chloride should be considerably higher (Basra, 2000).

The plants treated with triazoles and imidazoles are characterized by smaller but broader and thicker leaves and more cuticular wax compared with the controls (Wood, 1984; Gao et al., 1988; Benton and Cobb, 1995; Fletcher et al., 2000). Therefore the leaves have a higher dry weight per unit area (Davis et al., 1988). According to some authors (Tezuka et al., 1989; Benton and Cobb, 1995) increase in the leaf thickness can be explained with the development of an additional layer of cells in the fungal parenchym of the mesophyll.

In case of limited vegetative growth, triazoles and imidazoles lead to redistribution of the photo assimilates in favour of the reproductive manifestations of the plants (Richardson et al., 1986; Dheim and Browning, 1988; Borkowski, 1992; Benton and Cobb, 1995; Moetska-Berova, 1995; Mojecka-Berova and Kerin, 1995; Berova and Zlatev, 2000). A similar effect has been observed in apples (Elfving et al., 1990), peaches and nectarines (Martin et al., 1987).

Apart from its activity as fungicides and growth regulators, triazoles and imidazoles increase tolerance of different types of plants to abiotic stress – drought (Asare-Boamah et al., 1986), atmospheric contaminants (Upadhyaya et al., 1991), etc. This is why they are called „plant multiprotectants“ (Fletcher and Hofstra, 1985).

CONCLUSIONS

1. Growth and development regulation of plants is an important problem for the agricultural science and practice.

2. The indicated examples of use of synthetic growth regulators do not exhaust all possibilities for solution of this problem.

3. There are other synthetic substances applied in the agricultural practice, such as fungicides, herbicides, leaf fertilizers, etc.

4. As new methods of plant protection combined preparations are used more and more often, also including substances with growth regulation properties.

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