PLANT GROWTH REGULATORS – THEORY AND PRAXIS

Růstové regulátory

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Souhrn, klíčová slova

Růstové regulátory jsou přirozené či syntetické látky se schopností regulovat některé z růstových a vývojových procesů u rostlin. Jsou schopny ovlivnit např. habitus a výnos nebo synchronizovat stárnutí a opad. Většina těchto látek byla odvozena od rostlinných hormonů nebo interferuje s jejich metabolismem či působením. Nejužívanější jsou retardanty.

Klíčová slova: auxiny, cytokininy, etylén, gibereliny, retardanty, růstové regulátory

Summary, keywords

Plant growth regulators are natural or synthetic compounds with the ability to regulate some growth and developmental processes. They influence e.g. habitus and yield or synchronize senescence and abscission. Most of these substances were derived from phytohormones or interferes with their metabolism or action. Retardants are the most common group.

Key words: auxins, cytokinins, ethylene, gibberellins, growth regulators, retardants

Plant growth and development is highly variable and dependent on environmental conditions and thus, in combination with ensuring good nutrition by fertilizers and protection by herbicides and pesticides, it is important that compounds regulating growth and developmental processes are used in agriculture and horticulture to reach the desired habitus or yield and to synchronize processes like senescence, and abscission etc. It is quite obvious that design of such regulatory compounds has been based mainly on our knowledge of the function of endogenous plant growth regulators – phytohormones. Compounds used today to regulate plant growth and development in agriculture and horticulture may be divided into three categories: 1. plant hormones and their synthetic analogues, 2. substances interfering with hormone metabolism and/or action and 3. miscellaneous synthetic compounds.

1. Plant hormones and their analogues

We have good evidence that phytohormones affect many developmental processes. Thus, hormones can be used to manipulate plant growth and development, both *in vivo* and *in vitro*. If we use natural substances, we usually face difficulties because of their rapid metabolism, which results in low effectiveness. That is the reason why synthetic analogues are often used.

Auxins: the predominant natural auxin, indole-3-acetic acid (IAA) is seldom used because of its instability. Its analogue, indole-3.-butyric acid (IBA), occurs in plant tissues and is much more stable and is often used for root initiation in cuttings. The synthetic auxins α-naphthylacetic acid (NAA) and 2,4-dichlorophenoxyacetic acid (2,4-D) are often used for rooting induction in cuttings or for promotion of callus growth, embryogenesis or root initiation in tissue cultures. Auxins may also be used to delay abscission and to regulate sex expression (Arteca 1996, Leyser 1997, Macháčková 1997). Beside these effects, 2,4-D is a very potent herbicide.

Cytokinins: The natural cytokinins isopentenyladenine, zeatin and similar compounds are seldom used because of their rapid metabolism. Kinetin and benzylaminopurine (BAP) and its o- and m- hydroxy derivatives, topolins induce callus growth and shoot initiation in tissue cultures and they increase sink strength and thus grain yield in some cereals, especially at low nitrogen. They prevent senescence and regulate chloroplast development and function. (Arteca 1996, Kamínek 1997, Kamínek et al. 1997). Some urea derivatives also have cytokinin-like effects – the best example is thidiazuron.

Gibberellins: In this case, the natural substances are often used, predominantly gibberellic acid GA_3. Its application can increase number of male flowers (e.g. in cucumber), to induce germination and specifically starch degradation in barley grains during malt production and increase fruit set (and sometimes also size), e.g. in grapes. Gibberellins also induce parthenocarpy. In citrus trees, they delay senescence. Gibberellins induce flowering in rosette-type long-day plants and they are also used for reduction of the duration of juvenility in forest trees (Arteca 1996, Macháčková 1997, Ross et al. 1997).

Ethylene: As ethylene is the hormone of senescence, ripening and abscission, it is mainly used, usually in the form of the regulator Ethrel (Camposan – 2-chloroethyl phosphonic acid) to enhance and synchronize ripening of fruits and to synchronize leaf and fruit abscission. It is also often used to reduce growth and increase tillering in winter cereals (Arteca 1996, Macháčková 1997, Morgan and Drew 1997). Regulator Ethrel is an example of an "ideal" regulator, because it decomposes to natural components: ethylene, chloride, and phosphate anions. Inhibitors of ethylene synthesis or action are used in horticulture to prolong the shelf-life of cut flowers and some fruits (Sisler and Serek 1997).

2. Substances interfering with hormone metabolism and/or mode of action

The most important group of these substances are plant growth retardants, which are inhibitors of gibberellin biosynthesis. They reduce unwanted longitudinal shoot growth without lowering plant productivity. We know of 4 groups of these substances: (a) onium compounds like chlorcholine chloride (CCC), blocking the cyclisation of the gibberellin skeleton, (b) N- heterocyclic compounds, e.g. ancymidol or paclobutrazol, blocking the first oxidation steps in gibberellin biosynthesis (c) acylcyclohexane diones (prohexadione-Ca), inhibiting late oxidation steps in gibberellin biosynthesis and (d) 16,17-dihydro-gibberellin A5 and related substances, which block late steps of biosynthesis (Rademacher 1995, 2000). These substances are widely used to shorten the stalks of cereals, namely wheat and thus prevent lodging (in our country a mixture of CCC and Ethrel is often used for this purpose – Retacel Super). The retardants reduce growth and affect habitus and quality of some ornamental plants like *Poinsettia* or *Chrysanthemum* and are often used in gardens to improve compactness and uniform growth of bedding plants like *Zinnia, Geranium, Impatiens* or *Dianthus* and to control turf growth. Retardants (in recent years especially prohexadione-Ca) are widely used in fruit tress, mainly apples and pears, for reduction of growth and increase of flower set. In vineyards and citrus orchards they are used to reduce the vegetative growth. Plants treated with retardants often have more vigour and higher resistance to different stress factors (Rademacher 2000).

3. Miscellaneous synthetic compounds

There are numerous compounds found by an extensive screening which are used on individual crops for specific purposes, like enhanced germination and initial growth, ripening, defoliation etc. In this group of substances we can find defoliants (ammonium nitrate, endothall, paraquat, sodium chlorate) - these substances usually act as dessicants as well. Diaminozide (Alar) was extensively used for control of height of ornamental plants and for increasing flower setting and limiting preharvest drop in fruit trees. But the use of this substance is now limited because of its potential toxicity (the same holds true for maleic hydrazide). Dikegulac sodium is used to suppress apical dominance and increase branching and maleic hydrazide to control turf growth. This group of substances also includes, in a broader sense, herbicides (Arteca 1996, Rademacher 2000).

According to the statistics, the world market with plant protecting chemicals amounted in 1999 to 28 billion USD. But growth regulators represent only a small percentage out of this total. Why is it so, when in the sixties a much higher use of these substances was expected? There are numerous reasons, but the most important are economical, environmental and, last but not least, high variability of the final effect (depends on the state of plants, wheather etc.).

In the last two decades a novel approach appeared, which can be used to manipulate plant growth and development: transgenosis. The first transgenic plants were those carrying genes for auxin and cytokinin biosynthesis of *Agrobacterium tumefaciens* and until now, *Agrobacterium* is used as a very potent tool in plant transformation. Today, we have plants (mainly soybean and maize) carrying the δ-endotoxin gene of *Bacillus thuringiensis* and being resistant against insects, we have tomatoes, in which the process of ripening is controlled by means of antisense RNA for ACC synthase or by expression of bacterial ACC deaminase (Klee et al. 1991, Theologis et al. 1993), we have the "golden" rice carrying gene for vitamin A synthesis. By manipulating ethylene synthesis or perception, other processes like senescence and abscission can be regulated. Expression of the *ipt* gene coding for the main enzyme of cytokinin biosynthesis under specific promoters can help to manipulate sink strength and assimilate distribution and also delay senescence. Plants to which appropriate genes were transferred are also able to produce vaccines and other important proteins. Of course, also this approach has its drawbacks. As this approach is relatively new and not fully understood, the new transgenic lines must be thoroughly tested for the eventual presence of allergenic or toxic substances and for their potential impact on the environment.

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