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Review

The Impact of Auxin and Cytokinin on the Growth and Development of Selected Crops

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Abstract: With a very diverse structure and small molecules, phytohormones are regulators of plant growth and development. Despite the fact that they are synthesized by plants in small quantities, they are highly active physiologically. According to their action, phytohormones can be divided into two categories, as either activators of plant growth and development or as inhibitors, with auxins and cytokinins belonging to the former group. Auxins are synthesized by plants in the apical meristems of shoots, but also in young leaves, seeds, and fruits. They stimulate the elongation growth of shoots and initiate the production of adventitious and lateral roots. Cytokinins, in turn, are formed in root tips and in unripe fruits and seeds. These hormones are responsible for stimulating the growth of lateral shoots, they also stimulate cytokinesis and, consequently, cell division. The aim of this review paper is to present the progress of the research on the effect of selected auxins and cytokinins on crops, considering the prospect of using them in plant growing methods.

Keywords: hormones; indole-3-butyric acid; naphthyl-1-acetic acid; 6-benzylaminopurine

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1. Development of the Research on Plant Growth and Development Regulators

In recent years, great attention has been paid to growth substances that can contribute to increasing the yield potential of crops and their biological value, in particular in unfavorable climatic conditions [1]. Regulators of plant growth and development are most often organic substances that even in small amounts modify plant physiology. This modification is based on supporting or inhibiting chemical reactions regulating such processes as germination, root formation, fruit setting, or plant senescence (Figure 1). Today, natural plant hormones are rarely applied to crops since their synthetic counterparts are mostly used i.e., 2,4-dichloro-phenoxyacetic acid (2,4-D), benzyladenine (BA), kinetin, tetrahydropyranyl-benzyladenine (PBA) [2–5]. Synthetic and natural hormones differ in the method of obtaining the substance. In the case of natural hormones, they come from the part of the plant where they are produced. On the other hand, synthetic hormones are usually salts obtained as a result of chemical reactions. Generally, Flasiński and Hąc-Wydro [6] showed that the natural plant hormone (IAA) interacts with the investigated lipid monolayers stronger than its synthetic derivative (NAA). The reason of these differences connects with the steric properties of both auxins. The naphthalene ring of a NAA molecule occupies a larger space than the indole system of an IAA, making it less well absorbed.

In Poland, there are about two hundred products/preparations that perform regulatory and stimulating functions in relation to plants or soil. In the countries of the European Community, there are over a thousand such products. In Poland, there are officially four categories, distinguished in the relevant legal acts: plant growth regulators, plant growth stimulants, agents improving soil properties, and organic and organic-mineral fertilizers. The above preparations are commercialized on the basis of Article 5 of the Act of 10 July 2007 on Fertilizers and Fertilization [7]. This article states that "Fertilizers and plant conditioners authorized for marketing in another Member State of the European Union or the Republic of Turkey, which have been produced in another Member State of the European Union or the Republic of Turkey, or in a country that is a member of the European Free Trade Association (EFTA), may also be placed on the market—a party to the agreement on the European Economic Area, if the national regulations under which they are manufactured and placed on the market ensure the protection of human and animal health and the protection of the environment and suitability for use". "Stimulator", as an official term, is not mentioned in the Regulation (EC) No. 1107/2009 [8]. This document defines the term "growth regulators"—these are mainly substances known as plant hormones (IAA, NAA, and gibberellins), ethylene precursors (ethephon, ethyl trinexapac), the well-known and popular CCC, i.e., chlormequat chloride retardant, inhibiting germination (chlorpropham and maleic hydrazide) and several other less popular ones. This group also includes a product that is a mixture of nitrophenols, stimulating the processes of plant resistance to (abiotic) stresses and inhibiting the aging and cell breakdown processes. The company that commercializes this product in Poland, and globally002C uses the term "biostimulator" when referring to it. Plant growth regulators are products that are registered in a similar way to pesticides. The procedure is regulated very precisely by Regulation (EC) No. 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market [8].

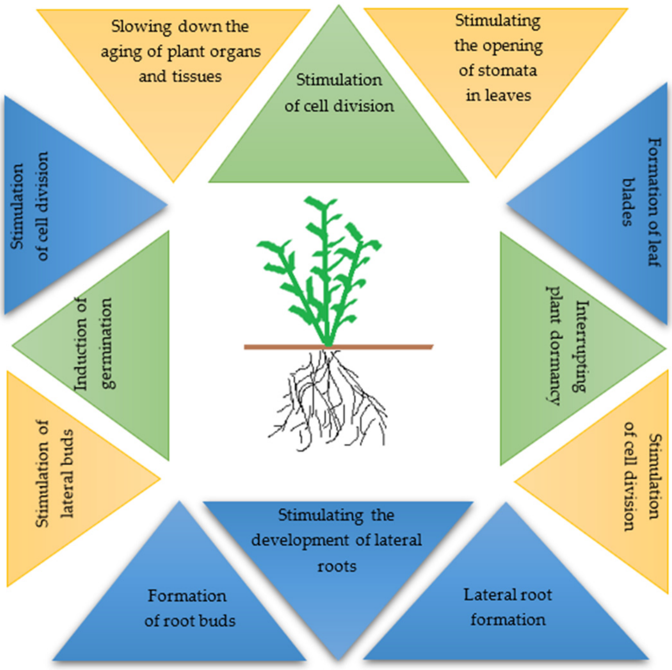

Figure 1. Functions of phytohormones. Auxins (blue); cytokinins (yellow); and gibberellins (green).

In a plant, there are about five key growth hormones that interact with each other: auxins, cytokinins, gibberellins, ethylene, and abscisic acid. They are effective if the relationship between them is balanced, but any imbalance affects the action of one of the hormones, triggering or deactivating another. Auxins are the most important because they are involved in all plant physiological processes. They form root buds, participate in cell division, and take part in tropisms. Cytokinins affect cell division, which in turn affects plant growth, but they also stimulate lateral buds and inhibit the aging of organs and plant tissues. In turn, gibberellins induce germination, interrupt plant dormancy, and stimulate cell division [5,9–13]. Ethylene and abscisic acid have the opposite effect to the three above-mentioned groups. They inhibit the growth and development of plants and accelerate their senescence. When the plant is under stress, the activity of abscisic acid increases, which is why it is called a stress hormone [3,4,14]. Hormones commonly found in plants primarily include auxins and cytokinins, whose role seems to be crucial in plant growth and development [4,15–22].

Research on growth regulators has practical applications, for example, in slowing down the growth of lawns in urban areas; they can be used to lower grass growth after mowing [23]. According to American studies [24], such retardants can have an effect on other features of lawn grass, for example, on an increase in its tolerance to shading.

In potato production, growth regulators may be of great importance, increasing dry matter and starch yields and the share of the required size of tubers. Other growth regulators may contribute to increasing plant resistance to adverse conditions, such as drought, low temperatures, or disease infestation [25,26]. The effect of such synthetic growth regulators as Mival (1-(chloromethyl)silatrane) or Poteitin (a mixture of 2,6 dimethylpyridine-N-oxide and succinic acid) on the growth and yield of 37 potato cultivars was studied by Sawicka [25–27] and Mikos-Bielak [28], who found that they stimulated tuber setting processes, increasing the share of marketable tubers in the total yield.

Growth regulators can also be used in the nursery of ornamental plants [29], where the aim is to produce well developed seedlings in the shortest possible time. Plants growing for a long time in small pots are prone to distortion of the root system. By the deformation of the roots of trees and shrubs grown in containers, the growth of their aboveground part may be inhibited because of insufficient amounts of water and minerals. Tangled roots in large quantities limit longer retention of water and mineral salts in the rhizosphere, which in turn may lead to a reduction in plant growth, as well as to a decrease in plant resistance to drought, heat, diseases, and pests [30]. According to Balušek et al. [3] and Abas et al. [29], auxins positively affect the regeneration of the root system of transplanted plants. In nurseries, the most commonly used auxins are indole-3-butyric acid (IBA) and naphthyl-1-acetic acid (NAA).

2. The Function and Role of Hormones in Plant Growth and Development Regulation

2.1. The Importance of Cytokinins in Plant Growth and Development Processes

The most important role of cytokinins is that they stimulate cell division, but their functions are much more complex and depend on interaction with other plant hormones [31–33]. Regulating root differentiation, cytokinins and auxins can have antagonistic effects, with, for example, auxin stimulating the development of lateral roots and cytokinins inhibiting it [32,34]. Cytokinins have a role in the transport and accumulation of photosynthesis products and affecting the activity of other enzymes, and also a huge impact on physiological and biochemical processes [35]. Cytokinin concentration in the plant depends on many factors, e.g., on the current stage of the development of cells, tissues, and the whole plant. Environmental factors, such as the amount and intensity of light, the occurrence of stress, or even access to nutrients, may also have a big impact [36,37]. Cytokinins are mainly synthesized in root apical meristems, but they can be also produced in fruits and young leaves [36,38]. Their levels are controlled by other phytohormones, which significantly affect not only their biosynthesis but also their degradation. Auxins play an important role lowering endogenous cytokinin levels, being also rapid and potent suppressors of cytokinin biosynthesis [39,40]. When cytokinins are synthesized, they are transported to other tissues, entering cells through diffusion and active transport involving transport protein, PUP (purine permease), and ENT (equilibrative nucleoside transporters) [41]. Cytokinins are key compounds regulating the development and function of chloroplasts [38]. The highest cytokinin concentrations are recorded at the initial stage of leaf development, which is attributed to cytokinesis stimulation, membrane formation, plastid division, and, occurring at that time, intensive protein synthesis [39,42].

The literature also deals with the effect of cytokinins on leaf anatomical structure. Microscopic observations conducted on wheat and sugar beet leaves showed that the effects of cytokinins led to mesophyll cell enlargement and intensive lignification of leaf-strengthening tissues. The formation of larger amounts of leaf vascular bundles was also observed. Cytokinins also affect the intensification of photosynthesis, regulating it at many levels [43]. They stimulate the opening of stomata, mainly in mature and aging leaves, affecting the regulation of CO_2 diffusion necessary in carboxylation. In this case, cytokinin is antagonistic to abscisic acid, which causes stomatal closure [31]. Cytokinins affect photosynthesis by regulating chloroplast biogenesis and function, but the main factor regulating the work of chloroplasts is light. Phytohormones from the cytokinin group stimulate the division and formation of chloroplast ultrastructure [41,44,45]. Studies have also shown the effect of cytokinins on increasing the level of photosynthetic proteins. An example is chlorophyll-binding proteins that are part of chlorophyll-protein complexes, whose task is to collect light energy. Chloroplast proteins are divided into three groups. The first group consists of proteins whose level increases slightly after the action of cytokinins. Secondly, there are proteins whose accumulation is dependent on light, with cytokinins affecting the speed of the process. The third group comprises of proteins whose levels increase in response to cytokinins regardless of the action of light [20,46,47]. It is worth noting that the positive effect of cytokinins on photosynthesis is also attributed to their delaying of leaf senescence. This phenomenon has been observed in many species treated with exogenously applied phytohormones and in genetically modified plants with increased endogenous cytokinin concentrations [48–50]. With leaf age, the natural concentration of cytokinins decreases, which is associated with their degradation. Cytokinins block or slow down plant aging process by stopping chlorophyll loss and, consequently, by maintaining the green color of the leaves. This situation occurs as a result of an inhibitory effect of phytohormones on the degradation of green pigment. It has also been proven that cytokinins have a great influence on the vital functions of the plant and are perhaps its indispensable element [51,52].

2.2. The Importance of Auxins in Plant Growth and Development Processes

Auxins, the second group of phytohormones, are organic compounds that can lengthen stem cells in a manner similar to cytokinins. The initial research on auxins dates back to the nineteenth century. It turned that the coleoptile of *Elymus canadensis* was sensitive to light, bending towards its source [53–55]. Researchers [3,56] concluded that there must be some substance that penetrated into an agar block and that it was produced by the tip of the plant and then transported to the coleoptile, causing this organ to bend towards light. The above conclusions were confirmed by other studies in which oat coleoptile tips were placed on agar blocks for several days. After this time, it turned out that both coleoptile tips and the agar exhibited growth-stimulating properties. Based on the above findings, the first quantitative bioassay for the detection of auxins was developed [54,57]. The name auxin comes from Greek auxein 'to grow', which reflects the role of this group of hormones. The substance behind this name is indole-3-acetic acid (IAA) [9,58]. Many years of research on phytohormones have made it possible to identify a number of substances constituting the group of auxins. It is known now that in addition to IAA, natural auxins include indole-3-butyric acid (IBA) and 4-chloroindole-3-acetic acid (4-CL-IAA). These substances contain an indole ring in their molecule [59,60].

Compared to IAA (indole-3-acetic acid), IBA (indole-3-butyric acid) is much more effective in inducing plant lateral and adventitious roots [61]. In addition, it stimulates elongation growth of the stem much faster [62]. Auxin in the form of 4-CL-IAA, containing an additional chlorine atom, occurs only in leguminous plants [2]. Scientists have discovered two other non-indole compounds, i.e., phenylacetic acid and p-hydroxyphenylacetic acid, with auxin properties [59]. Auxins are found in two forms, free and bound. The free form is a small fraction of the total amount of auxins in plants and is biologically active [63]. However, most auxins found in plants are bound [62]. Auxin synthesis occurs in young, developing parts of plants, such as the tips of shoots, developing leaves, or seeds [64–67]. Auxins are also synthesized in roots, namely in the meristem of the main root and in developing lateral roots [64,68–70]. Despite its relatively simple structure, auxin coordinates a whole range of processes occurring during plant life [71–73]. The hormone is transported through plant organs from the place of its synthesis to specific cells and tissues. For many years, the mechanism of its transport has been the subject of research by scientists from various fields, by biochemists, physiologists and molecular biologists, and the results indicate two transport pathways, which are different physiologically and spatially. The first pathway is rapid transport through the elements of phloem, and the other one is polar transport, from cell to cell, involving various tissues [59,74,75]. The accumulation of auxins in specific plant tissues depends on the polar transport of this hormone.

Auxins also support a large number of development processes in the plant. Such processes include, among others, the formation of lateral roots, leaves and flowers, tropisms, differentiation of vascular tissues, as well as the formation of the apical-basal axis during the process of embryogenesis [29,30,53,54,76]. Despite research and great progress in understanding the mechanisms of their effect on plants, auxins still constitute a large field of studies for researchers [5,77].

2.3. Effect of Auxins and Cytokinins on Selected Physiological Parameters of Plants

Growth and development of plants and, consequently, their yields are primarily dependent on the activity of basic physiological processes, such as photosynthesis and transpiration (Table 1) [78,79]. According to studies on soybean cultivars, their physiological activity, expressed as photosynthetic and transpiration intensity, was the highest during the flowering stage. However, during the stage of seed development the intensity of both processes decreased significantly, almost 3–4 times. A radical decrease with age in gas exchange parameters of two soybean cultivars was reported by Fu et al. [80], who also found that their photosynthetic efficiency was the highest between the 10th and 17th day of flowering, after which leaf senescence followed. During the stage of seed development, 30–40 days after flowering began, leaves reduced their photosynthetic activity up to five times. Contrary to that, Subrahmanyam [81] noted the highest photosynthetic and transpiration efficiency of soybean plants during the stage of seed formation. He also pointed out that the intensity of these processes could vary greatly, and, consequently, demand for photosynthetic products also varied, depending on plant variety, genetic properties, and development stage, as well as on the external environment and habitat conditions. Similar changes in photosynthetic activity were observed by Luquez, Starck, and Wróbel [82–84].

A rapid decrease in the intensity of photosynthetic and transpiration processes during the stage of seed development was also observed by the present authors in 2008. However, it was caused not only by natural senescence processes, but also by long-lasting high air temperature and low precipitation. In such conditions, plants close their stomata to cope with water loss, at the same time limiting CO_2 cellular access, necessary for the photosynthetic process [85–87]. Indole-3-butyric acid (IBA) and 6-Benzylaminopurine (BAP) applied separately also significantly affected this process, either intensifying or decreasing it, depending on the year of research and the development stage (Table 1). This was also confirmed by Ashraf et al. [88], who treated barley plants with indole-3-acetic acid (IAA) at a concentration of 30 mg per L and found a significant increase in CO_2 photosynthetic assimilation. Similar results were obtained by Aldesque [89], who treated young barley seedlings with IAA at a concentration of 25 mg kg^{-1} per grain soaked in a solution of this hormone. He also used higher doses of synthetic auxin (50 mg kg^{-1}), after which he found a substantial reduction in plant gas exchange processes. The same reaction of plants was observed by Pospišilova [90], who observed modification of gas exchange parameters depending on the concentration of a given growth regulator. Some authors [91–94] report an increase in CO_2 photosynthetic assimilation in soybean and cotton leaves after the use of synthetic auxins and cytokinins, probably caused by an increase in the activity of the photosynthetic enzyme. A significant increase in the activity of this enzyme was found in plants treated with synthetic auxin and cytokinin (Figure 2). In his research, Subrahmanyam [81] found a significant positive correlation between the intensity of photosynthetic processes and transpiration processes, but also between the intensity of those processes and stomatal conduction. However, the correlation between photosynthetic and transpiration intensity and CO_2 concentration in intercellular spaces was either positive or negative depending on the type of the phytohormone used. A positive correlation between photosynthetic and transpiration intensity and stomatal conductivity indicates efficient gas exchange between the leaf and atmosphere. The above author also found a significantly positive correlation between photosynthetic and transpiration processes and stomatal conductivity of soybean leaves. Chaves et al. [87] explain that an increase in CO_2 concentration in intercellular spaces may cause a decrease in the access of substrates needed for photosynthesis processes.

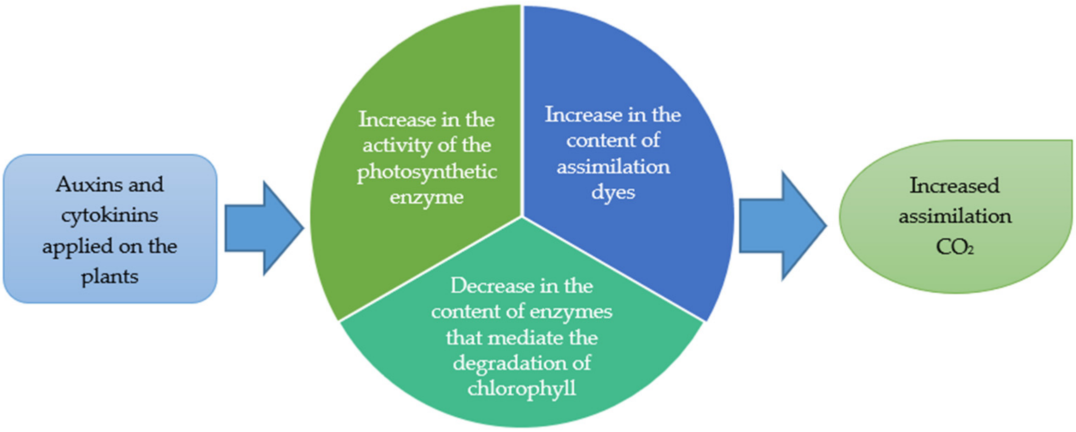

Figure 2. Influence of auxins and cytokinins on the process of CO_2 assimilation in plants.

Table 1. Influence of auxin and cytokinin on plant physiological processes in various crops.

Plant Physiological Precesses	**Crops**					
	Barley Leaves and Seedlings	**Soybean Leaves**	**Cotton Leaves**	**Wheat Leaves**	**Alfalfa Leaves**	**Cabbage Leaves**
Increased assimilation CO_2	x [88,89]	x [81] o [81]	x [91,93] o [91,93]			
Increase in total chlorophyll content		x [95]		x [89]		o [17]
Increase in the content of chlorophyll "a"					o [94,96]	

Auxin (x); cytokinin (o).

Plant productivity depends, to a large extent, on the content of photosynthetic pigments, which is the most important factor affecting photosynthesis (Figure 2). Some studies report that the content of total chlorophyll and carotenoids increased in plants sprayed with indole-3-butyric acid. Aldesuqe [89] applied indole-3-acetic acid (IAA), belonging to the auxin class, at a concentration of 25 mg kg^{-1}, to wheat and noted a significant increase in total chlorophyll content. Using a slightly lower concentration of IAA (10 mg L^{-1}), Galdallah [95] reported a clear increase in chlorophyll content of soybean leaves. In contrast, Pandey et al. [94] and Skalska [96] applied BAP to alfalfa at various concentrations, from 0.025 to 0.20%, and found a significant increase in chlorophyll a content, while spraying these plants with IAA did not affect it. Fu et al. [80] report that as soybean plants age, the chlorophyll content of carotenoids decreases. Exogenously applied cytokinin may increase chlorophyll content in aging leaf tissues by slowing the breakdown of this pigment and by delaying the senescence process [15]. In their research on the effect of BAP on cabbage, Costa et al. [17] observed a slower degradation rate of total chlorophyll compared to control plants. At the same time, the authors determined the activity of enzymes mediating chlorophyll degradation, such as chlorophyllase and magnesium dechelatase. It turns out that in plants sprayed with BAP, there is a significant decrease in the activity of these enzymes compared to control plants.

3. The Use of Phytohormones as Growth Regulators in Plant Production

3.1. Effect of Auxins and Cytokinins on Crop Yield and Morphometry

According to Nowak and Wróbel [97], fertilizers and plant protection products can no longer increase plant yields significantly, so more attention is paid to the use of various growth substances. According to the above authors, the purpose of such products is to increase plant yield potential in adverse weather or in any other unfavorable conditions not suitable for a given plant. In particular, according to von Richthofen [98] and Ulmasov et al. [99], growth-promoting substances are of great importance in the cultivation of leguminous plants, with their unstable yield and high sensitivity to weather conditions. Such substances include exogenously applied phytohormonal growth regulators used on crops and vegetables [9,97,100–104].

In their studies on the effect of synthetic auxin and cytokinin and of their mixture on soybean, Nowak and Wróbel [97,103] reported a significant yield increase. According to the authors, auxin was the most effective, followed by cytokinin and their mixture, with an increase, compared to control plants, of 34, 32, and 29%, respectively.

Reinecke et al. [105] reported an increase in pea yield in response to a hormonal regulator containing, indole-3-butyric acid. Furthermore, beneficial effects of synthetic auxins and cytokinins on the yield of some plants were presented by Czapla et al. [9], Barcley and McDavid [106], and Nowak et al. [107]. At the same time, in response to auxin application Nowak et al. [107] reported a significant increase in field bean seed weight, on average by 10%. Kertikov and Vasileva [108] reported higher grain yield and better chemical composition in vetch. Treating soybean with auxin (IBA) and cytokinin (NAA) and their mixtures, Czapla et al. [9] found that auxin was the most effective in increasing the number of pods and seed yield. However, some other researchers did not observe significant effects of synthetic growth hormones on crops.

According to some authors [78], the rate of plant growth and development and the yield are primarily determined by the intensity of basic physiological processes, such as photosynthesis and transpiration. According to Reinecke et al. [105], auxins, as exogenously applied growth hormones, can increase the physiological activity of plants and thus affect their productivity.

Kuang et al. [109] and Peterson et al. [110] suggest that plants respond positively to synthetic hormones because they affect physiological processes, especially an earlier increase in tissue vascularization, which manifests itself in the thickening of such morphological organs as stems, leaves, and inflorescences. According to Rylott and Smith [111], synthetic auxin and cytokinin increase plant yield and make generative organs competitive over vegetative ones. This was confirmed by Pandey et al. [94], who using synthetic auxin on cotton plants found a significant increase in the number and weight of flowers. A similar trend was observed by Qifu et al. [112] and Kuang et al. [109,113]. Using cytokinin, they reported better vascularization of plant tissues and an increase in the transport of photosynthesis products from vegetative to generative parts, which increased their concentration in generative organs, and consequently resulted in higher yield and better seed filling. Moreover, according to the literature [106,114], exogenously used phytohormones stimulate phloem transport of photosynthesis products, improving the level of nutrition of plant tissues, which improves plant condition and resistance to stress, increasing the yield and its quality.

The literature reports about positive effects of synthetic hormones on the growth of leaves. According to Aldesuquy [89], an auxin (indole-3-acetic acid) increased the number and area of barley leaf blades. In contrast, Khan et al. [115], applying auxin in the form of indole-3-butyric acid (IBA) and a-naphthylacetic acid (NAA) to lily and Pal and Das [116] to cabbage, at concentrations of 100 mg·kg^{-1} also observed an increase relative to control in the number and area of leaves.

Jamil et al. [117] found that synthetic IAA auxin was more effective than GA3 (gibberellin) in such morphometric characteristics as the number and size of flowers of *Hippeastrum* Herb. of the *Amaryllidaceae* family. A positive effect of exogenously applied auxin on long-flowered lily (*Lilium longiflorum*) inflorescence biometrics was also observed by Karaguzel et al. [118], Pal and Das [116] and Prakash and Jha [119]. Clifford et al. [120] and Baylis and Clifford [121] argue that the levels of plant hormones, such as auxin and cytokinin, rise when the inflorescences are formed, which promotes the process. Contrary to that, their content often decreases during flowering, which, according to Reese et al. [114] and Nagel et al. [122], may be the reason for premature flower shedding.

3.2. Effect of Auxins and Cytokinins on Chemical Composition of Plant Biomass

The content of macroelements in plant dry matter depends, among others, on the species, the level of nitrogen fertilizer, the intensity of use and harvest time [9]. An increase in potassium content in plants treated with synthetic hormones was observed by Wierzbowska and Nowak (Figure 3) [123,124]. Using growth regulators on wheat plants, the authors found that kinetin and auxin significantly increased potassium content in wheat grains by 16.73% and 10.33%, respectively. Opposite results were presented by Czapla et al. [9], who reported a reduction in potassium content by an average of 9% in soybean after spraying plants with two synthetic auxins, i.e., IBA and NAA, separately and together. Additionally, when applying IBA, BAP, and IBA + BAP to lupine, they observed a decrease in potassium content, especially in seeds, in response to all treatments. In the experiment of Wierzbowska et al. [125], growth regulators applied in the form of gibberellin and auxin increased calcium content in wheat grains, blades, chaff, and in the oldest leaves by 28% compared to control. According to Wierzbowska and Bowszys [126], hormones also affect an increase in the accumulation of magnesium in spring wheat. They reported that gibberellin increased the magnesium content of stalks, chaff and the oldest leaves, and auxin increased it in most of those organs.

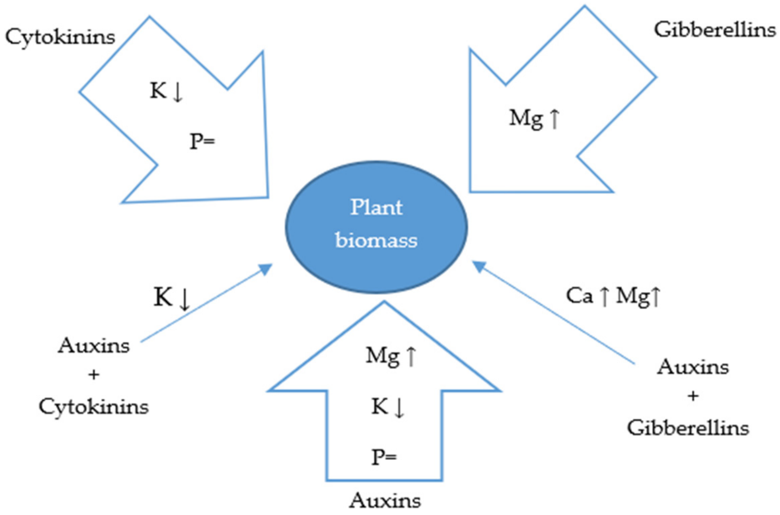

Figure 3. The influence of phytohormones on the chemical composition of biomass: increase ↑, decrease ↓, no change =.

Exogenously used auxin and cytokinin do not affect plant phosphorus content. This tendency was confirmed by the results obtained by Czapla et al. [9] and Nowak et al. [107], who found no change in its concentration in field bean, soybean, and lupine after the use of synthetic auxins and cytokinins. However, the literature [127,128] suggests that an increase in the content of certain minerals in the aboveground parts of plants in response to synthetic growth hormones occurs because of a better developed root system, in particular, because of the elongation of capillary roots. As a consequence, this leads to more intensive nutrient uptake from soil. Zhao [21] and Weijers et al. [129] report that auxins are the most effective here, sending signals informing about the course of physiological processes in acceptor organs of photosynthesis products and about increasing demand for nutrients. In addition, cytokinins together with auxins stimulate cambium activity and the formation of vascular tissues that facilitate the penetration of various types of nutrients in plants [130].

4. Conclusions

Research on plant hormones as growth regulators proves that hormones can have practical applications in the cultivation of many plant species. Auxins and cytokinins can be used to stimulate the rhizosphere regeneration process. Exogenous use of auxins and cytokinins in appropriate concentrations increases the dry matter yield of plants and also improves its stability. It also reduces the occurrence of diseases. Adverse effects of auxin and cytokinin include a decrease in the content of vitamin C and an increase in the content of phenolic compounds. These hormones contribute to better tillering, growth of foliage, and improvement of induction, mass, and intensity of flowering. Auxins and cytokinins in foliar applications affect the chemical composition of the dry matter of plants in different ways. Most often, they increase the content of potassium and calcium, but do not change the concentration of phosphorus in plants.

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