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Studies on the interaction of growth regulators with potassium ions in some physiological processes in the bean (*Phaseolus vulgaris* L.). I. The effect of growth regulators on the growth of leaves and on the potassium level in leaves and roots

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Abstract

Bean plants were cultured on Hoagland's water solution for one or eight days. The following growth regulators: kinetin (10^{-7} M), GA_3 (10^{-6} M), IAA (10^{-6} M) or ABA (5×10^{-5} M) were introduced into solutions for 24h. The regulators were found to have a different effect on the potassium level in leaves and roots depending on whether it was assessed 1 or 8 days after treatment. The mechanism by which growth regulators affect the processes of ion uptake and transport and their relation to growth are discussed.

Key words: Phaseolus, leaf growth, growth regulators, potassium level

INTRODUCTION

A number of recent publications point to the interaction of phytohormones with mineral salts in plant physiological processes (Stopińska 1978). It has been pointed out that plant hormones can regulate the uptake and transport of mineral salts in plants and, on the other hand, that mineral elements can affect the activity and level of endogenous growth regulators. The interaction of plant hormones with potassium ions is of particular importance. Studies on the mechanism of action of plant hormones point to their part in the processes of uptake and transport of K^+ ions and in controlling the properties of cell embranes through their effect on the electropotential, ion pump and the activity of membrane enzymes (Stopińska

1978, Starck 1980, Kaldewey 1984). Most papers concerning these processes point to the stimulating role of auxin (Kholdebarin 1981) as well as gibberellin (Benlloch et al. 1983). The data concerning cytokinin are contradictory; some of them indicate stimulation of K^+ uptake (Abutalybov et al. 1975), others point to its inhibition (Bittner and Buschmann 1983). Some authors think that cytokinins exert a specific influence on ion transport, including K^+, into xylem (Hong and Sucoff 1976). The results of studies on abscisic acid show clearly that it inhibits K^+ uptake (Karmoker and Steveninck 1979) while the problem of ion transport remains controversial (Collins and Kerrigan 1973).

The various effects of hormones on the processes of uptake and transport result in a modification of the potassium content in plants (Shaner et al. 1975, Kholdebarin 1981, Bittner and Buschmann 1983). In these types of experiments, however, the interaction of regulators with K^+ ions in growth has been given little attention and the effect of regulators has been reduced to a short-duration influence, often lasting only several hours, on the uptake and transport of ions in isolated organs of various species. It was therefore thought necessary to study the effect of growth regulators, such as auxin, gibberellins, cytokinins and abscisic acid on the growth and potassium level in the organs of an intact plant of a given species.

MATERIAL AND METHODS

The material for study was the bean (*Phaseolus vulgaris* L.) var. Saxa aurea. Five-day-old selected seedlings which had been grown in darkness at 25°C on pearlite watered, were transferred into dishes with distilled water. On the tenth day of culture the plants, which were in the stage of developed primary leaves, were stripped of the assimilating cotyledons and transferred to a medium whose basic macroelement solution was Hoagland's medium supplemented with microelements from Arnon's medium and with ferric citrate (Hewitt 1966). The composition of the medium is presented in Table 1. The medium, pH 5.6 was diluted with bidistilled water at a ratio of 1:2, the K^+ concentration was 3 mM. On the following day, growth regulators in the following concentrations, chosen in the preliminary experiment: kinetin (10^{-7} M), GA_3 (10^{-6} M), IAA (10^{-6} M) and ABA (5×10^{-5} M) were introduced into the medium for 24 hours. The control was the medium alone. The culture was conducted in a thermostat room at 25 ± 1°C, 50% humidity, in 6000 lx intensity light at 16-h photoperiod. After 19 days of culture from the moment of seed planting, each plant had a pair of primary leaves and one trifoliate leaf. The effect of regulators on the growth of both kinds of leaves was assessed by determining their

areas by the method of Shimski (1970), their fresh and dry matter and H_2O contents. The potassium level in the leaves and roots was determined twice. For the first time K^+ was assayed 24 hours after introducing the regulators into the medium. At that time the plants had only primary leaves and showed no morphological differences between those treated with regulators and controls. Potassium was assayed again 8 days after applying regulators, when both kinds of leaves showed morphological differences compared with controls. The level of potassium was calculated in two ways: per dry matter unit in order to find out the distribution of this

Table 1

The composition of the nutrient solution

Macroelements,	$g \cdot dm^{-3}$	Microelements,	$mg \cdot dm^{-3}$
$Ca(NO_3)_2 \times 4\ H_2O$	0.95	H_3BO_3	2.86
$MgSO_4 \times 7\ H_2O$	0.49	$MnCl_2 \times 4\ H_2O$	1.81
$NH_4H_2PO_4$	0.12	$CuSO_4 \times 5\ H_2O$	0.08
KNO_3	0.61	$ZnSO_4 \times 7H_2O$	0.22
		$H_2MoO_4 \times H_2O$	0.09
		ferric citrate	5.60 (Fe)

element in the plant, and per given organ to eliminate the dilution effect. K^+ content was determined using a flame spectrophotometer by Schillak's method (1967). Each variant consisting of 30 roots or leaf blades was analysed in three replications, 0.2 g dry matter samples were studied.

The results were analysed statistically, LSD at $P = 0.05$ being calculated for the leaf areas and the standard error for the dry matter and potassium levels in plants.

RESULTS AND DISCUSSION

Eight days after being introduced into the medium, kinetin as well as GA_3 significantly stimulated growth of laminae of both primary and trifoliate leaves by simultaneously increasing their fresh and dry matter, as compared with the control (Figs. 1 and 2). The reports from literature concerning the effect of cytokinins and gibberellins on leaf growth are not always consistent, unlike data on IAA, whose lack of significant effect on leaf growth has been confirmed (see Goodwin 1978). It has also been found that ABA inhibited growth in both types of leaves, which is in line with the reports of other authors (Quarrie and Jones 1977). The effect on trifoliate leaves of the regulators under study was stronger than on primary leaves (Fig. 1), which testifies to the greater sensitivity of

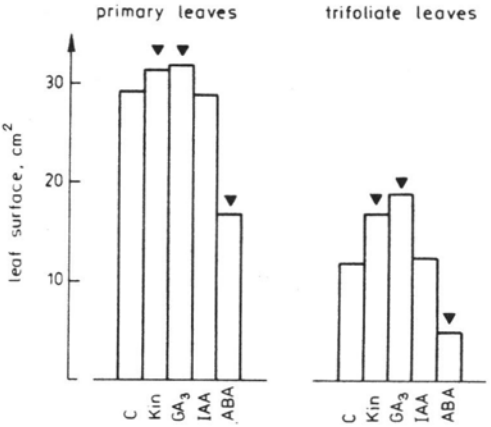

Fig. 1. The effect of growth regulators on growth of bean leaves (average of 20 plants). C — control, Kin — kinetin (10^{-7} M), GA_3 — gibberellic acid (10^{-6} M), IAA — indole 3-acetic acid (10^{-6} M), ABA — abscisic acid (5×10^{-5} M), ▲ — significant differences in relation to control at $P = 0.05$

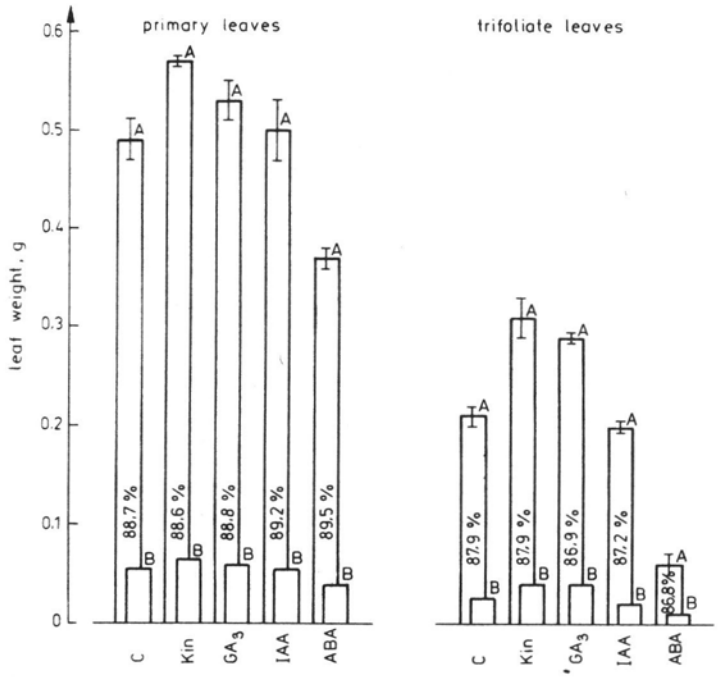

Fig. 2. The effect of growth regulators on fresh and dry matter content in bean leaves (numbers in columns show $H_2O\%$). C, Kin, GA_3, IAA, ABA — as on Fig. 1. A — fresh matter, B — dry matter, vertical lines — standard errors

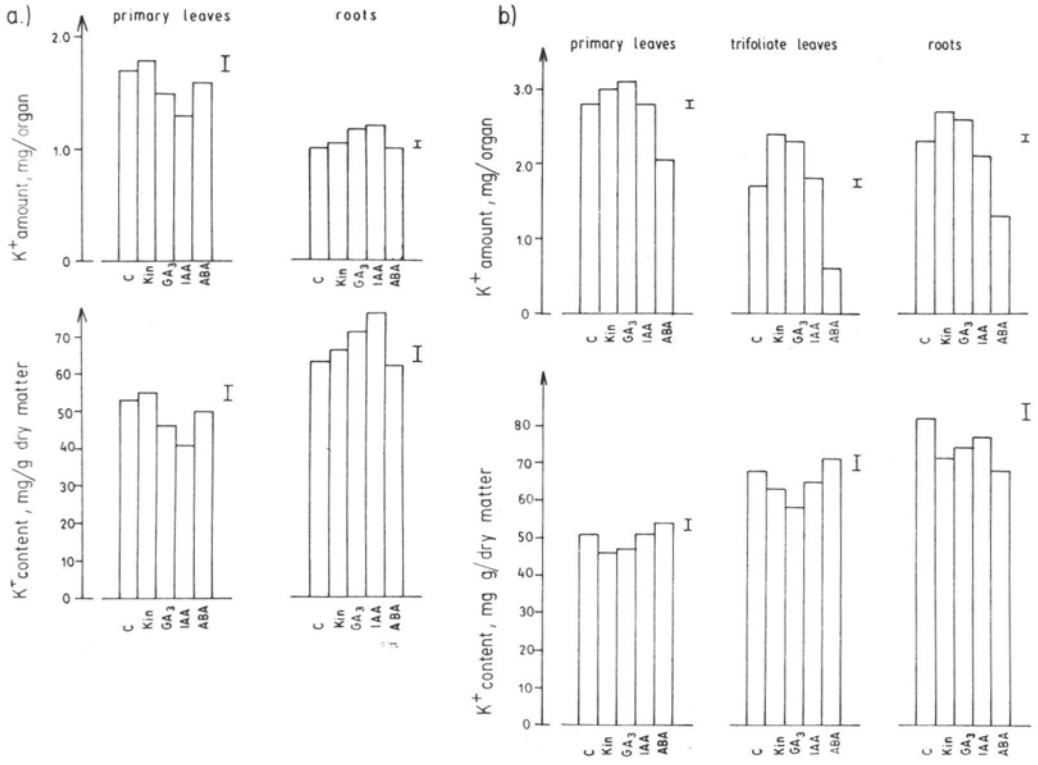

Fig. 3. The effect of growth regulators on potassium amount and content in bean leaves and roots. a — 24 hours after treatment, b — 8 days after treatment. C, Kin, GA_3, IAA, ABA — as on Fig. 1., vertical lines — standard errors

younger organs than of older ones. The numbers in the diagrams in Fig. 2 indicate that the growth regulators do not significantly affect the water content in the tissues of the organs, since the differences in relation to the controls do not exceed 1%. Figure 3 demonstrates that the 24-h treatment with IAA and GA_3 resulted in a pronounced increase of the K^+ content and K^+ amount in roots and in their simultaneous decrease in the primary leaves, which also showed no morphological differences compared with controls. Some of the experiments done on whole plants testify to the stimulation of basipetal transport of potassium by auxin already by 24 hours after introducing the regulator (Halevy and Wittwer 1965, Kannan 1978). The data on GA_3, however, are not so consistent; some of them point to a stimulating effect on basipetal transport (Kannan 1978), others on acropetal transport (Halevy and Wittwer 1965). With regard to kinetin and ABA, no significant changes in K^+ content and amount compared with controls were observed during the first 24 hours, which is inconsistent with the results of other authors (Abutalybov et al. 1975).

Somewhat different results were obtained when the measurements were taken eight days after introducing the regulators into the medium, at the moment when morphological differences had become evident. As follows from the data presented on Fig. 3, kinetin and GA_3 increased the amount of K^+ in the roots as well as in both kinds of leaves, whereas ABA decreased the amount, and IAA had no significant effect whatsoever. The effect of the regulators was most pronounced in the trifoliate leaves, less so in the roots, and the least in primary leaves. The effect of regulators on the amount of K^+ in bean leaves was analogous with their effect on growth.

Data on K^+ content in dry matter indicate that both in leaves and roots it is reduced after kinetin and gibberellin treatment (Fig. 3). A reduction in K^+ content effected by ABA was observed only in roots. IAA did not affect the potassium content in any of the organs studied. The above results contradict those of other authors. The few studies of that problem carried out on intact plants showed that treatment with GA raised the K^+ content in various organs (Starck et al. 1984) while at the same time stimulating their growth (Stojanov 1974, Saimbhi et al. 1975). The data obtained in this study concerning the effect of kinetin also are not confirmed by the results of other authors (Bittner and Buschmann 1983) pointing to reduction of K^+ content going on with the reduction in growth of plants organs. The effect of kinetin and gibberellin on K^+ content in leaves may be due to the extended surface area of these organs and the subsequent dilution of potassium in dry matter. The reducing effect of ABA on K^+ content was revealed only in roots, whereas in leaves, while their growth was inhibited, no such effect was observed. The data concerning the leaves are inconsistent with the results of Dekock et al. (1978) studying other plants as well as bean (Karmoker and Steveninck 1979) where the reducing effect of ABA on growth was accompanied with a decrease in K^+ content. The lowering of the potassium content in intact roots has been confirmed by other authors in such plants as maize (Shaner et al. 1975) and bean (Karmoker and Steveninck 1979). The latter authors have found that this effect was due to inhibition of uptake and transport of K^+ ions. Some authors suggest that these processes are affected by ABA concentration or by quick change in the ABA-cytokinin balance in roots (Erlandson et al. 1978).

All of the data presented above, based on a study of non-labelled potassium in only some parts of the plant, do not allow conclusions on the uptake and transport of potassium. However, the changes in K^+ content in the plant affected by regulators probably resulted from regulation of these processes.

The data illustrating the distribution of K^+ in particular organs of bean plants demonstrate that the highest content of this element per dry matter

unit was found in roots, a lower one in the trifoliate leaves, and the lowest in primary leaves, in all variants except ABA, in which K^+ content in the youngest leaves and in roots was alike. Similar results have been obtained by Cline and Hungate (1960) in their study on bean; they demonstrated a dependence of inter-leaf transport on the availability of K^+ from the roots. The variant with ABA treatment exemplifies a case when probably low K^+ uptake by the root resulted in maximum transport of K^+ to young trifoliate leaves which show the greatest demand for this ion.

Study of the effect of growth regulators on ion content in intact plants is complicated by other factors, such as transpiration. It is known that long-distance ion transport is affected, among other things by the transpiration current (Russell and Barber 1960). The intensity of this process depends to a large extent on the opening of stomata, which is stimulated by cytokinins and gibberellins (Livne and Vaadia 1965), and inhibited by auxin and ABA (Mansfield 1967, Mansfield and Jones 1971). The action of regulators on K^+ content should also be considered in the aspect of their effect on growth, photosynthesis and transport of assimilates (see Starck 1980).

To sum up, it can be concluded that the short-term effect of regulators was different from the effect obtained after a longer time. The inability to distinguish the processes of ion uptake and transport from growth processes is justified by the difficulty of establishing which was the primary and which was the secondary effect of the action of growth regulators. Thus the level and distribution of K^+ in bean among its particular organs depends on hormonal factors as well as on their age and position in the plant.

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Studia nad współdziałaniem regulatorów wzrostu z jonami potasowymi w niektórych procesach fizjologicznych u fasoli (Phaseolus vulgaris L.). I. Wpływ regulatorów wzrostu na wzrost i na poziom potasu w liściach i korzeniach fasoli

Streszczenie

Siewki fasoli hodowano na pożywce wodnej Hoaglanda zawierającej KNO_3 w stężeniu 3 mM, przy fotoperiodzie L:D = 16:8, intensywności światła ok. 6000 lx i w temp. $25 \pm 1°C$. Wprowadzenie na 24 godz. do pożywki regulatorów wzrostu (kinetyny — 10^{-7} M, GA_3 — 10^{-6} M, IAA — 10^{-6} M i ABA — 5×10^{-5} M) spowodowało istotne zmiany we wzroście liści w stosunku do kontroli. Pod wpływem kinetyny i GA_3 obserwowano stymulację, natomiast pod wpływem ABA hamowanie wzrostu zarówno liści juvenilnych jak i trójdzielnych; IAA nie wywarł istotnego wpływu. Ponadto stwierdzono odmienny wpływ regulatorów na ilość i na zawartość potasu w roślinie w zależności od tego, czy określano go po 24 godz., czy po dłuższym czasie. Pod wpływem IAA i GA_3 po 24 godz. od momentu wprowadzenia regulatorów do pożywki nastąpił wzrost ilości i zawartości potasu w korzeniach i obniżenie w liściach; kinetyna i ABA nie wywarły istotnego wpływu. Po 8 dniach od momentu wprowadzenia do pożywki, wpływ regulatorów na ilość potasu w badanych organach był analogiczny do efektów wzrostowych, natomiast wpływ na zawartość był odwrotny i prawdopodobnie wynikał z efektu rozcieńczenia tego pierwiastka w jednostce suchej masy.