

The effect of potassium nutrition on growth and on plant hormones content in Scots pine (*Pinus silvestris* L.) seedlings

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Abstract

Pine seedlings were cultivated in Ingestad nutrient solution containing potassium as KCl on a 16-hr day, under light intensity of about 4000 lx and temperature of about 23°C. K⁺ used in a concentration of 50 ppm exerted a most pronounced positive effect on the growth of seedlings. After 4 months it was found that potassium used in this concentration increased elongation of hypocotyls, shoots, roots, primary and secondary needles as well as fresh weight and dry matter of tissues. In leafy shoots K⁺ increased the level of free gibberellins (GAs) and auxins and decreased the amount of bound GAs and an ABA-like inhibitor. In the roots K⁺ nutrition increased the amount of free GAs and of the growth inhibitor and decreased the level of bound GAs and auxins. No evident influence of K⁺ on the level of cytokinins in plant tissues was stated.

INTRODUCTION

Potassium is an important element necessary for plant growth and development. Its absorption is very quick being surpassed only by nitrogen. The role of potassium for growth and development of pines is not yet well known. According to Ingestad (1962/3) it is very important for the life of pines.

The present knowledge concerning the interrelations of K⁺ and plant hormones in physiological processes of plants is presented by Stopińska (1978). It is known for example that gibberellins (GAs) stimulate uptake and translocation of K⁺ in plants (Köhler, 1970; Cocucci, Cocucci, 1977). Moreover, in experiments with wheat, synergism of GAs and K⁺ in the elongation of internodes was observed (Chaussat, 1968).

Similarly, in experiments with sunflower it was found that kinetin stimulated absorption of K^+ by decapitated cotyledons and simultaneously their growth (Ilan et al., 1971). It was found that this hormone promoted transport and accumulation of potassium in hypocotyls of sunflower (Šonka, 1975) as well as the accumulation of this element in the roots of maize (Collins, Kerrigan, 1973).

Potassium stimulates translocation of auxins (Rice, Rohrbach, 1958; Anisimov, Bulatova, 1975), on the other hand auxins stimulate the absorption of potassium (Ilan et al., 1971; Ilan, Shapira, 1976). A synergistic effect of auxin and K^+ in the growth of wheat coleoptiles was observed (Haschke, Lüttge, 1975). Higinbotham et al. (1953) have also found that auxins stimulate the uptake of ions and water in excised tissues of different plant organs. The intensive absorption of K^+ as an effect of auxin treatment causes probably an accumulation of this ion in guard cells increasing their turgor. This leads in consequence to the opening of stomata (Marrè et al., 1975).

Contrary to GAs, cytokinins and auxins, abscisic acid (ABA) inhibits the absorption of K^+ (Dörffling et al., 1973; Reed, Bonner, 1974). According to Shaner and coworkers (1975) ABA inhibited the growth of maize roots and this was correlated with the decrease of K^+ influx into the plant tissues. There are also many data showing that ABA by decreasing K^+ accumulation in guard cells caused the closure of stomata (Mansfield, Jones, 1971).

It should be stressed that we have not found in the literature any data concerning the influence of K^+ nutrition on the level of plant hormones in plant tissues.

MATERIAL AND METHODS

Seedlings of pine (*Pinus silvestris* L.) were cultivated for 2 weeks in sawdust soaked with distilled water, under a 16-hr day, at light intensity of about 4000 lx and at temperature of about 23°C. When the seedlings reached the stage "free from the seed coat", they were transferred to the Ingstad (1962/63) nutrient solution containing potassium as KCl in different concentrations of K^+ : 0, 25, 50, 100 and 150 ppm for the first experiment and 0 and 50 ppm in the second experiment. Further cultivation of seedlings was performed under the same conditions of light and temperature. The solution was continuously aerated and renewed every 10 days.

The measurements of seedlings and the determination of activities of plant hormones: gibberellins, cytokinins, auxins and an ABA-like inhibitor in leafy shoots and in roots were performed 4 months after

sowing, by the methods described earlier (Michniewicz et al., 1976; Michniewicz, Stopińska, 1980).

All analyses were replicated 3 times and the results were elaborated by analysis of variance. The differences were estimated with LSD at $P = 0.05$.

RESULTS AND DISCUSSION

Potassium stimulated significantly the elongation of hypocotyls, shoots, primary and secondary needles and roots and increased the number of lateral roots and both kinds of needles (Table 1). It also increased fresh and dry matter of shoots and roots (Table 1). The most pronounced positive effect on growth of pine seedlings was obtained by potassium used in a concentration of 50 ppm. Basing on this fact in further experiments K^+ concentration in the nutrient solution was limited to 50 ppm.

The data concerning the influence of K^+ on the level of plant hormones are shown in Figs 1-5.

Gibberellins were localized in 3 active zones: free GAs corresponding to R_f values 0.1-0.2, 0.4-0.7 and 0.8-1.0 and bound GAs at R_f 0.1-0.3, 0.4-0.7 and 0.8-0.9 (Fig. 1). From these data as well as from those presented in Fig. 2 it is evident that potassium increased the level of free and decreased the amount of bound GAs in both tested plant organs. Thus, the growth stimulation of shoots and roots as an effect of K^+ nutrition was correlated with the increase of free gibberellins and with the decrease of bound ones. It is also evident that shoots in comparison to roots were characterized by a higher level of both kinds of gibberellins. Such a correlation between the growth intensity of pine seedlings and the content of GAs is in accordance with the results of our earlier experiments with Scots pine (Michniewicz et al. 1974, 1976).

Potassium only slightly increased the amount of cytokinins in the shoots and did not significantly influence the level of these hormones in the roots of seedlings (Fig. 3). Taking into consideration all our earlier results with pine seedlings (Michniewicz et al., 1974, 1976) it may be concluded that there is no evident correlation between the rate of elongation of shoots and the level of cytokinins in tissues. However, stimulation of growth of shoots as an effect of potassium nutrition (Fig. 3) was correlated with a slight increase in these hormones.

Stimulation of root elongation and initiation of lateral roots as an effect of K^+ nutrition does not seem to be correlated with the level of cytokinins (Table 1, Fig. 3).

Table 1

Effect of different concentrations of potassium on growth of pine seedlings after 4 months (averages from 10 seedlings in 1-st experiment and from 20 seedlings in 2-nd)

Concentration of K ⁺ in ppm	S t e m			N e e d l e s			R o o t s	
	length of hypocotyl (cm)	length of shoot (cm)	length of pri- mary needles (cm)	number of primary needles ^a	length of se- condary needles ^b (cm)	number of secondary needles	length of root (cm)	number of first order lateral roots
I — 0	2.3	1.1	2.2	31.0	0.0	0.0	12.8	25.2
I — 25	3.0	1.9	4.8	44.0	1.4	2.2	16.9	31.0
I — 50	4.4	2.2	6.4	67.0	3.8	6.6	22.8	44.0
I — 100	2.7	1.8	4.5	57.0	2.3	3.4	19.4	33.2
I — 150	2.3	1.6	3.1	48.0	1.2	1.8	15.1	28.4
II — 0	4.4	1.6	4.3	69.5	0.5	1.4	9.4	41.4
II — 50	5.0	2.8	6.4	95.0	1.8	4.7	12.5	86.2
	0.2	0.2	0.9	10.4	0.8	2.0	0.7	9.3

a — primary needles (juvenile needles)

b — secondary needles (dwarf shoot needles)

I — first experiment

II — second experiment

LSD at P=0.05

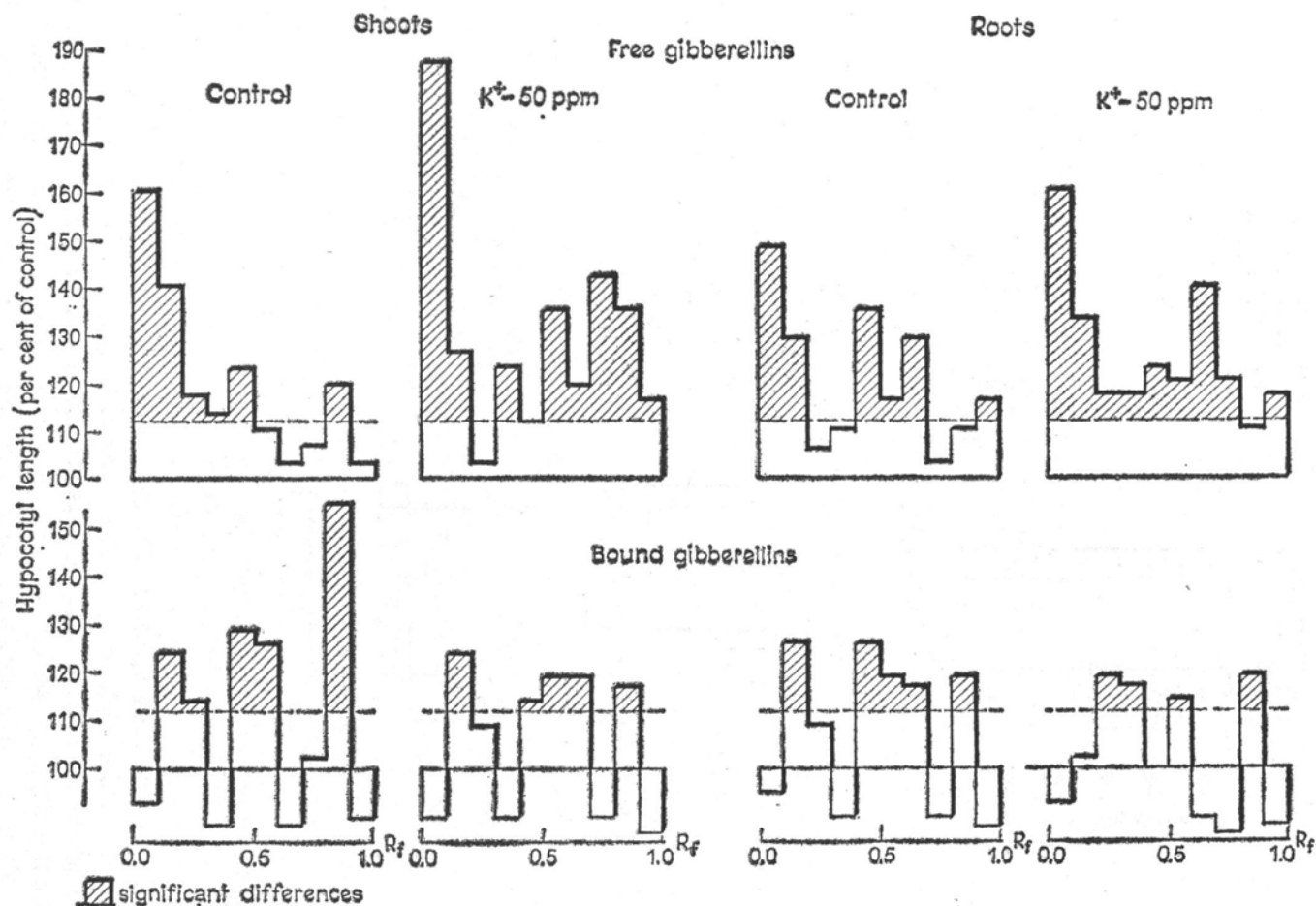


Fig. 1 Chromatographic analyses of gibberellins in shoots and roots of pine seedlings.

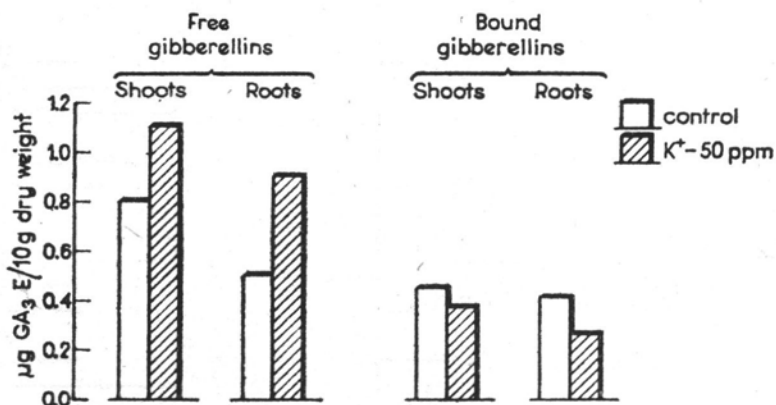


Fig. 2. Total amount of gibberellins in shoots and roots of pine seedlings.

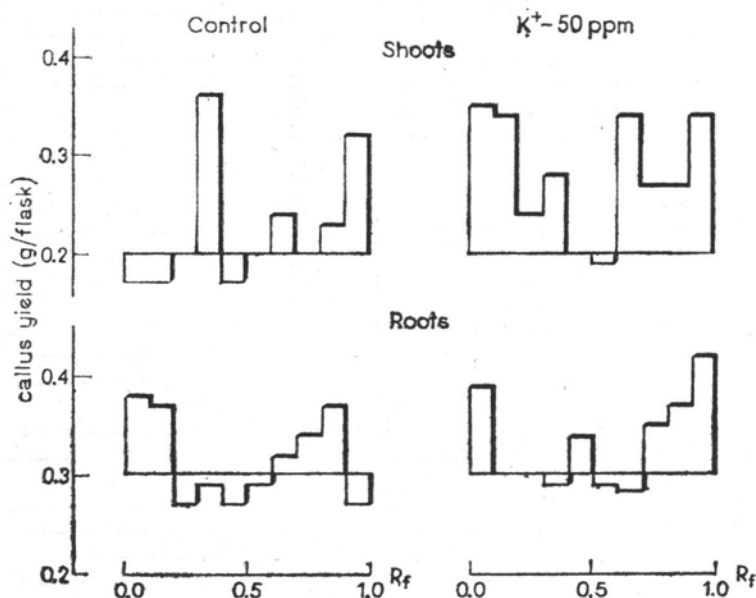


Fig. 3 Chromatographic analyses of cytokinins in shoots and roots of pine seedlings.

The stimulative effect of K^+ on the growth of pine shoots is correlated with the high level of auxins (Fig. 4) and low level of an ABA-like inhibitor in plant tissues (Fig. 5). Such a correlation between the growth intensity of shoots and the content of auxins and growth inhibitors is in accordance with our earlier experiments with Scots pine (Michniewicz et al., 1974, 1976).

A different picture was obtained in the case of roots. Potassium stimulated the growth of roots and increased the number of lateral

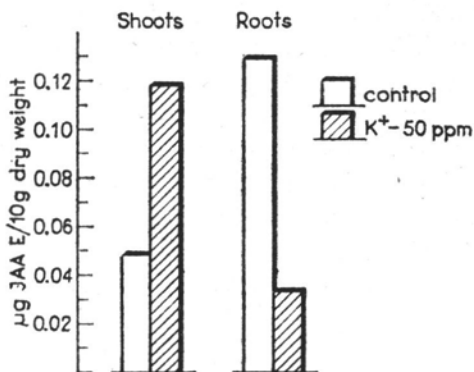


Fig. 4. Total amount of auxins in shoots and roots of pine seedlings.

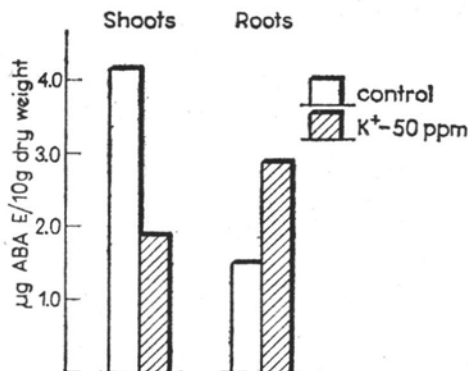


Fig. 5. Total amount of ABA-like inhibitor in shoots and roots of pine seedlings.

roots but this stimulation was correlated with the decrease of the auxins level and increase of the level of the ABA-like inhibitor in tissues.

The differences in the content of auxins in shoots and in roots, despite the same stimulative effect of K^+ nutrition on the growth of both these organs, will be clear when we consider the well known fact that roots are more sensitive to auxins than shoots. Thus, growth stimulation of roots takes place at lower concentration of auxins in plant tissues than stimulation of shoots.

The decrease of the level of auxins in roots may be explained either by the consumption of these hormones during the process of lateral root initiation or by the increase of translocation of auxins from roots to shoots what would be in accordance with the data from the literature showing that K^+ stimulates translocation of auxins in plants Rice, Rohrbauh, 1958; Anisimov, Bulatova, 1975).

The statement that growth stimulation of roots was correlated with an increase of the ABA-like inhibitor is difficult to explain. Probably these hormones are not involved in the growth processes of pine seedlings.

As known, potassium increases the water content in plant tissues. Also in our experiments K^+ significantly increased the water content in roots (Table 2). This agrees with the results of Ingested (1960) and Jakušev (1965) who found that K^+ absorbed by Scots pine is accumulated mainly in the roots of these plants.

Table 2

Effect of K^+ nutrition on fresh and dry weight of pine seedlings after 4 months. Average from 30 seedlings, in g/100 seedlings (data from experiment II)

Concentration of K^+ in ppm	Plant organ	Fresh weight	Dry weight	Dry weight %	H ₂ O %
0	shoots	22.93	5.42	23.65	76.35
	hypocotyls	3.44	1.02	29.69	70.31
	roots	5.35	0.90	16.79	83.21
50	shoots	39.37*	9.08*	23.06	76.94
	hypocotyls	4.81*	1.41*	29.36	70.64
	roots	12.55*	1.58*	12.56*	87.44*

* — differences between nutrient combinations significant at $P=0.05$

It is difficult to explain why the increase of water content in roots as the effect of K^+ nutrition is correlated with the decrease of the auxins level and with an increase in the level of free gibberellins and the ABA-like inhibitor.

The role of plant hormones in physiological processes in conifers is not well known as yet. There may be some differences in the mechanisms of hormone action between Gymno- and Angiosperms. Some differences are also known in the mechanism of water absorption between pines and broadleaved trees. Thus, the "root pressure" which in broadleaved trees plays some significant role in water absorption and translocation does not operate in pines.

As mentioned in the introduction plant hormones influence the absorption of K^+ . On the other hand, from the results of our experiments it is evident that K^+ affects the metabolism of plant hormones in pine seedlings. The mechanisms of this interaction are not known yet. Possibly, as suggested by Poovaiah and Leopold (1976) the ions may influence the binding of hormones with the cytoplasmatic complex in plant cells. However, the effect of hormones on the absorption of K^+

is connected with their influence on the ATP-ase lipoprotein complex which, as Erdei and coworkers (1979) suggest, possesses a receptor site for auxins.

The influence of K^+ on the growth and level of plant hormones in the shoots and roots of pine seedlings is very similar to the effect of N nutrition (Michniewicz et al., 1976). However these results were obtained in separate experiments performed in different environmental conditions. Thus, they are not fully comparable. The comparison of the effect of both elements on growth and metabolism of plant hormones in Scots pine seedlings will be the subject of a separate publication.

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Wpływ potasu na wzrost siewek sosny zwyczajnej (*Pinus silvestris* L.) i zawartość w nich hormonów roślinnych

Streszczenie

Siewki sosny hodowano na pożywce Ingestada zawierającej K^+ jako KCl przy 16 godzinnyim dniu, intensywności światła około 4000 lx i w temperaturze $\pm 23^\circ C$. Optymalnym dla wzrostu okazało się stężenie K^+ — 50 ppm. Po czterech miesiącach hodowli stwierdzono, że K^+ użyty w tym stężeniu stymulował wydłużanie hypokotyli, pędów, korzeni, igieł młodocianych i krótkopędowych oraz świeżą i suchą masę tkanek. W pędach ulistnionych K^+ zwiększał poziom wolnej GA i auksyn, zmniejszał natomiast ilość związanej GA i inhibitora o właściwościach ABA. W korzeniach, pod wpływem nawożenia K^+ zwiększała się ilość wolnej GA i inhibitora natomiast zmniejszał się poziom związanej GA i auksyn. Nie stwierdzono istotnego oddziaływania K^+ na poziom cytokinin w tkankach siewek.