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Effects of ionizing-radiation and post-radiation action of some plant growth regulators on the seed germination and seedling growth of Scotch pine *

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Abstract

The effects of small doses of gamma irradiation on the seed germination and seedling growth of Scotch pine and post-radiation action of water solutions of IAA, GA_3 and kinetin have been investigated. Changes in the destructive action of ionizing-radiation by gibberellic acid and its intensifying by IAA and kinetin has been found.

INTRODUCTION

It is known that pine seeds show a great sensitivity to ionizing-radiation (El-Lakany, 1971). Although the degree of action of radiation is closely dependent on the applied dose (Gustafsson and Simak, 1958; Ohba and Simak, 1961; Simak et al. 1961; Donini et al., 1967), provenience of material (Ohba and Simak, Lunden, 1964; Nalborczyk et al., 1970), individual marks of the mother material (Gustafsson and Simak, 1958; Mergen and Cummings, 1965) it is not yet sufficiently recognized. The ionizing-radiation exerts on seeds of conifers usually a negative effect. However, many authors maintain that depending upon the dose and quality of material the irradiation may even result in stimulation of growth and development of plants (Simak and Gustafsson, 1953; Ehrenberg and Ehrenberg, 1958; Kuzin, 1962). The results of these experiments are not, however, univocal. Up to new litlle is known about their character.

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Under the influence of ionizing-radiation deep changes take place in the metabolism of all the substances occurring in the plant organism. The irradiation influences the level of growth hormones (Mika, 1952; Gordon, 1957; Gunckel and Sparrow, 1961; Levinsky and Haunold, 1967; Michalski 1971, et al.). This phenomenon is generally connected with the growth inhibition, retardation of the hypocotyl and root growth and lowering the survival rate. According to Key and Wold (1961), Mathur (1961), Gaur and Notani (1969), post-radiation treatment with IAA, GA_3 or kinetin contributed to the revival of capabilities of growth and development of plants.

The aim of this work was to study the post-radiation action of 3-indoleacetic acid, gibberellic acid and kinetin on seed germination and seedling growth of Scotch pine.

METHODS

Seeds of Scotch pine (*Pinus silvestris* L.) of lowland provenience (humidity — 7.4 p.c., germination capacity of 96 p.c., were irradiated with gamma rays at doses of 0.5, 1.0, 2.5 and 5.0 kR from cobalt source (^{60}Co) mod. PXM-20 prod. USSR. Samples, containing 300 seeds, were placed on glass plates covered with Whatman's paper No. 3. All seeds were oriented in one direction with micropylar end. The plates were situated in horizontal position in moist chambers in controlled light (about 3.000 lux) and temperature (23—24° C.) conditions. For moistening the paper: water, 10^{-4} M water solution of gibberellic acid ("Gibrescol"-Polfa), 10^{-4} M water solution of kinetin (6-furfurylaminopurine-Permedia) and 10^{-4} water solution of 3-indoleacetic acid (Merck) were applied.

After 72 hr of germination the plates were put vertically in moist chambers securing constant moistening of breeding-ground by applying the solutions. At 24 hr intervals germinating seeds were conunted and the growth of roots and hypocotyls measured. The results were subjected to statistical analysis.

RESULTS

In the experimental conditions applied in this work distinct macroscopic effect of irradiation on Scotch pine seeds could be established already after 48 hr of germinating (Fig. 1). At small doses of radiation: 0.5, 1.0 and 2.5 kR, distinct differentiation in the number of germinating seeds in comparison to controls is noted. As the radiation dose increases, pine seeds germination in the water medium is inhibited, and in case of 5.0 kR dose it takes place 24 hrs later. The amount of germinating seeds is equalized with time so that after 120 hrs the number of germinating seeds

for smaller radiation doses (0.5 and 1.0 kR) is similar to those in controls. Increasing the dose to 2.5 and 5.0 kR clearly inhibits the germination. The germination of the seeds exposed to radiation dose of 5.0 kR after 120 hrs is about 20 p. c. in comparison to control seeds.

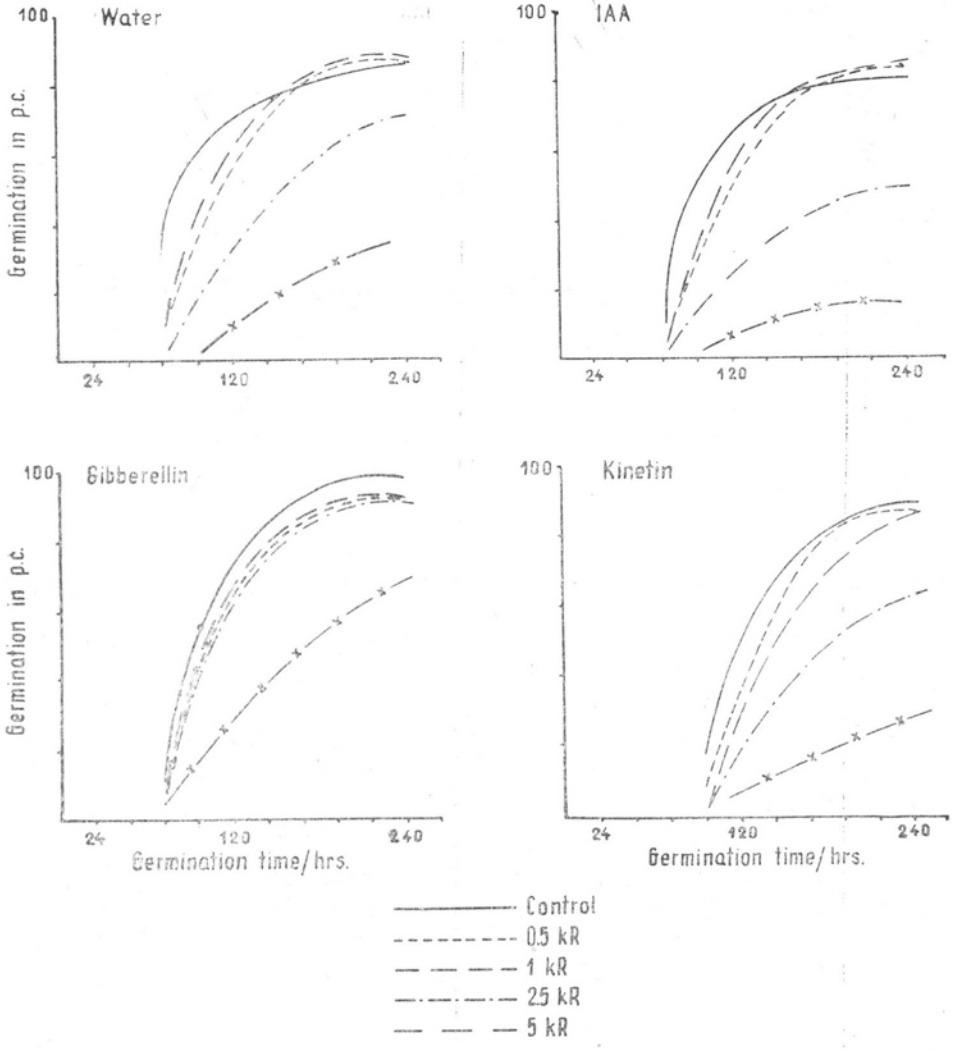

Fig. 1. Effects of ionizing-radiation and growth substances on pine seeds germination

The results presented on Fig. 1 show clear activation of germination of irradiated seeds under the influence of 10^{-4} M water solution of GA_3. Even the effects ot the highest radiation dose applied — 5.0 kR — are in a considerable degree leveled by the consequent action of gibberellin.

Differently from the stimulating effect of gibberellin solutions, 10^{-4} M solution of kinetin increases the inhibiting action of ionizing-radiation. In

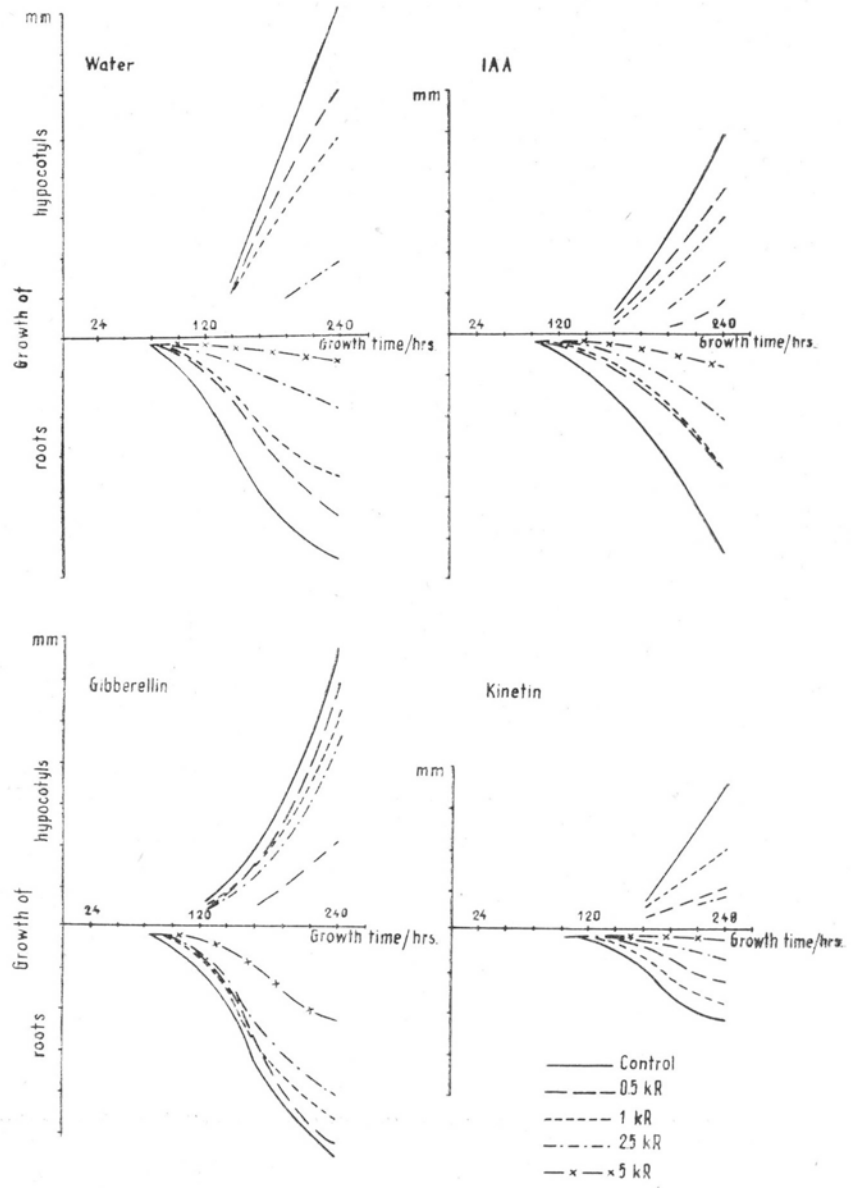

Fig. 2. Effects of ionizing-radiation and growth subtances on hypocotyls and roots growth in pine seedlings

reference to control kinetin retards pine seed germination for 24 hrs. Significant differences in the rate of seed germination in kinetin solution are observed in seeds exposed to radiation action of 1.0, 2.5 and 5.0 kR doses. The first effects on germinating were observed here only after 120 hrs. The seeds iradiated with 5.0 kR dose germinated in kinetin solution especially slowly.

IAA similarly to kinetin, inhibited pine seed germination and increased the inhibitory action of ionizing-radiation. The number of germinated seeds was very small. This was mostly marked with regard to material irradiated with 2.5—5.0 kR doses.

It appears from the data contained in Fig. 2 that the elongation increase of seedling hypocotyls and roots was dependent upon the applied ionizing-radiation doses and on the growth substances applied. The inhibitory effect of radiation on growth of pine seedlings was marked as the exposure dose increased. The dose of 2.5 kR was the highest one causing the delay of hypocotyl emergence and a considerable shortening of its growth. In this experimental variant an inhibition of daily root increment was noted. The strongest action was exerted by 5.0 kR dose. During the experimental period the hypocotyl did not appear and the root was markedly shortened.

In the described experimental conditions the stimulating effect of gibberellin on the growth of root and hypocotyl developing from irradiated seeds was obserwed. They emerged 24 hrs earlier than in control. The stimulating action revealed itself especially at doses of 2.5 and 5.0 kR. Post-radiation treatment with gibberellin activated the emergence of hypocotyl already after 7 days of seed germination.

Kinetin increased the inhibitory action of ionizing-radiation on the growth of hypocotyls and roots. Contrary to gibberellins, kinetin retarded the growth of hypocotyls for 24 hrs.

Although IAA exhibited a stronger inhibitory action on seed germination than kinetin, its influence on growth of hypocotyls and roots of pine seedlings was much smaller. At a dose of 5.0 kR some activation of hypocotyls and roots growth as compared to controls was observed.

DISCUSSION

It follows from the data presented in this paper that ionizing-radiation exerts a considerable influence on germination of Scotch pine seeds. This is in agreenement with the data of other authors (Simak and Gustafsson, 1953; Gustafsson and Simak, 1958, Vidaković, 1960; Kamra and Simak, 1965; Karaban 1966, et al.). Rudolph and Miksche 1970 examined nine different species of conifers and among them — *Pinus silvestris* — and stated the influence of some doses of ionizing-radiation on seed germination, on elongation of cotylendons, on

the increase in dry weight of plants and also on the elongation of hypocotyls and roots. The above findings are confirmed in the works of Vidaković (1962). The investigations of this author and other workers (Ohba and Simak, 1961; Mergen and Staire, 1970) stress that germination rate and growth intensity of seedlings are species features dependent on many factors.

The elimination of negative action of ionizing-radiation on pine seed germination as well as on the growth hypocotyls by exogenous gibberellins must be connected with the deficiency of these growth substances brought about by ionizing-radiation action (Gaur and Notani, 1960; Mathur, 1961; Levinsky and Haunold, 1967). Increased levels of these substances in the plant may induce the general growth of seedlings. The opinion of different authors on the influence of gibberellins on pine seed germination and seedling growth are divergent. Many of them maintain that gibberellin has no effect on pine seed germination (Pfnur, 1957; Westing, 1959), does not stimulate growth of hypocotyls (Brown and Gifford, 1958) although other authors are of different opinion (Jenkins 1961; Grower 1962). On the other hand the results of our experiments allow to conclude that gibberellins stimulate germination and growth of pine seedlings, levelling at the same time the damages caused by ionizing-radiation. Post-radiation revival of the growth abilities caused by gibberellins does not have, up to now, any theoretical grounds.

The results of our experiments confirm also the data of other authors pointing out to the fact that kinetin intensifies the destructive action of ionizing-radiation on germination and growth of pine seedlings (Mathur, 1961).

According to Gordon (1957) ionizing-radiation lowers the level of auxins in plants. However, post-radiation treatment with auxins increases the level of endogenous stimulators, inducing according to Key and Wold (1961) the general growth of plants. This was observed also with IAA not with kinetin in some variants of our experiments.

CONCLUSION

1. A dependence between the exposure dose of gamma rays and the capacity of seed germination of Scotch pine has been established. Higher radiation doses delayed germination of seeds.

2. A dependence between the gamma radiation dose and the growth of pine seedlings has been established. Increasing exposure doses have generally retarded growth.

3. Post-radiation application of gibberellin, activated depending on the radiation dose, the seed germination and growth of pine hypocotyls in control as well as in irradiated material. Gibberellin reduced the inhibitory

action of ionizing-radiation on seed germination and the growth of hypocotyls and roots of pine seedlings.

4. Kinetin increased the inhibitory action ionizing-radiation on germination and growth of pine seedlings.

5. IAA applied after radiation, inhibits depending on the radiation dose, the pine seed germination as well as the growth of hypocotyls and roots of seedlings.

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Wpływ promieniowania jonizującego i poradiacyjne działanie niektórych regulatorów wzrostu roślin na kiełkowanie nasion i wzrost siewek sosny zwyczajnej

Streszczenie

Badano wpływ małych dawek promieniowania gamma na kiełkowanie nasion i wzrost siewek sosny zwyczajnej oraz poradiacyjne działanie roztworów wodnych IAA, GA_3 i kinetyny. Stwierdzono niwelowanie destrukcyjnego działania promieniowania jonizującego przez kwas giberelowy oraz pogłębiania go przez IAA i kinetynę.