Potato Res. 22 (1979) 319-332

The influence of growth regulators GA_3, ABA, kinetin and IAA* on sprout and root growth and plant development using excised potato buds

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Accepted for publication: 11 June 1979

Zusammenfassung, Résumé p. 330.

Additional keywords:

Summary

In a potato bud bioassay GA_3 appeared to stimulate sprout growth and to inhibit root development. The inhibition of root growth retarded the development of the sprouts into plants. Kinetin and IAA stimulated root development. ABA has an initially retarding effect on sprout growth. But during prolongation of the experiment this delay becomes less, and at low concentrations turns into a stimulating effect. During the subsequent development into plants, there is again a stimulating effect of ABA at the higher concentrations.

Introduction

It was assumed by Rappaport & Wolf (1969) that the growth regulators ABA and GA play an important role in dormancy and sprouting of potatoes. Application of GA was supposed to break the dormancy, which is contradictory to the statement made by Madec & Perennec (1969) that GA does not break dormancy, but promotes sprout growth after dormancy is broken.

According to Rappaport & Sachs (1967) injury of tubers leads to increased GA activity and break of dormancy. Several research workers have found an increased GA activity towards the end of dormancy (Smith & Rappaport, 1961; Bialek & Bielińska-Czarnecka, 1975).

The group of compounds isolated from dormant potatoes by Hemberg (1952, 1958) capable of inhibiting the growth of *Avena* coleoptiles and identical to the so-called inhibitor-β complex, appeared to contain the growth inhibiting compound ABA, discovered by Eagles & Wareing (1964). This was established by Milborrow in 1967.

El Antably et al. (1967) showed that ABA could prolong the dormancy of tubers and retard the growth of buds in a bioassay.

According to Bielińska-Czarnecka & Bialek (1976) and Thomas & Wurr (1976) there is an increased GA activity at the break of dormancy, accompanied by a decrease of the

*GA_3 = gibberellic acid; ABA = abscisic acid; IAA = indolacetic acid; kinetin = 6-furfuryl-amino-purine.

activity of inhibitors, and the latter authors concluded that the main inhibiting compound was not ABA, but a component still unknown.

Railton & Wareing (1973) observed an increase in GA activity after application of ABA to the leaves of *Solanum andigena*.

It is obvious that many questions remain to the answered with respect to the significance and the effect of ABA.

The cytokinin content, particularly in the tissue surrounding the eyes, is increasing at the break of dormancy (Engelbrecht & Bielińska-Czarnecka, 1972). Rappaport & Wolf (1969) do not consider IAA to be very important in this respect.

In the following experiments different concentrations of ABA, GA, kinetin and IAA were applied to potato buds in bioassays, to obtain more insight into the effect of these compounds on the sprouting, root formation and plant development.

Materials and methods

The experiments were carried out with potatoes of cv. Bintje, seed quality class E, stored at 2–4 C. The activity of the growth regulators was tested according to the excised bud assay method described by van Es & Hartmans (1969) with a few modifications. The experiments were carried out in the dark, at 18 C. GA and kinetin were obtained from Koch Light Laboratories, and IAA from Merck, Darmstadt.

The ABA was synthetized according to the method of Cornforth et al. (1965) with modifications of Nieuwenhuis & van Es (1973).

The growth regulators were dissolved in water. Water was used as a control.

The length of sprouts, shoots and roots was measured regularly at intervals determined by the growth rate in a particular experiment. All experiments were done in duplicate; 15 eye-pieces were used in each experiment. Approximately 100 ml of test solution was used per experiment; the solution was not replaced during an experiment. Sprouts and roots were weighed at the end of each experiment. In some cases the eye pieces including sprouts and roots were transferred to plastic trays (H × L × W ; 8 cm × 45 cm × 29 cm), filled with moist perlite containing 1 litre nutrient solution (2.0 g KNO_3; 0.8 g $Ca(NO_3)_2$; 0.6 g $MgSO_4$; 0.45 g KH_2PO_4 and minor elements).

Depending on the growth rate, new nutrient solution was supplied every 10–14 days. This material was grown at 18 C in the light for 12 hours per day, (TL 57 de Luxe, Philips, light intensity approx. 10000 lx) in trays containing 20 plants.

The data in this paper are representative for the trend in many experiments. Quantitative data varied with the physiological state of the potato material used for the bioassay method.

Results and discussion

Influence of location of the eyes on sprout and root growth

Goodwin (1967b) demonstrated that the apical bud is dominant and that sprouting of the lateral buds is inhibited by the apical bud. This phenomenon cannot only be observed on intact tubers, but also after excision of the buds (Lallu & McWha, 1976).

Fig. 1 shows this effect also in the excised bud assay used here. This experiment was carried out with non-dormant tubers. The apical sprouts (A) grow fastest. Side sprouts (B and C) grow almost equally fast but less than the apical sprouts, and sprouts near the heel end (D) growing slowest. The apical sprout, which is the last to be developed during tuber formation and therefore physiologically the youngest bud, appeared to be the first to sprout. It is evident that this property remained even after separation from the tuber.

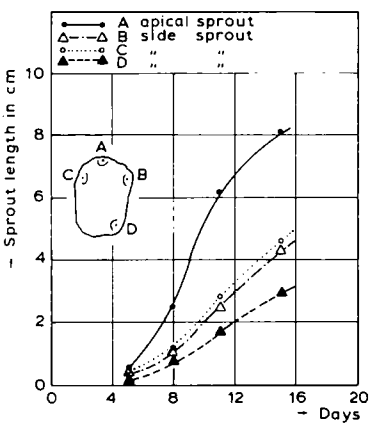


Fig. 1. Difference in sprout length between the apical sprout and side sprouts.

Apical sprout – *Apikaler Keim – Germe apical;* Sprout length in cm – *Keimlänge in cm – Longueur du germe en cm;* Days – *Tage – Jours*

Abb. 1. Unterschied in der Keimlänge zwischen dem apikalen Keim und den seitlichen Keimen.
Fig. 1. Différence d'élongation des germes entre le germe apical et les germes latéraux.

Table 1. Effect of the location of the eye upon root growth.

Apical sprout[1] A	Side sprout[2] B	Side sprout C	Sprout at heel end[3] D
27.7 mg*	4.6 mg*	3.9 mg*	0.2 mg*

* Root weight in mg per tuber piece after 10 days – *Gewicht der Wurzel in mg/Knollenstück nach 10 Tagen – Poids de racines en mg par tubercule après 10 jours*

[1] *Apikaler Keim – Bourgeon apical;* [2] *Seitlicher Keim – Bourgeon latéral;* [3] *Keim am Nabelende – Bourgeon terminal (talon)*

Tabelle 1. Einfluss der Lage des Auges auf das Wurzelwachstum.
Tableau 1. Effet de la localisation des yeux sur la croissance des racines.

Goodwin (1967a) could not find any morphological difference between the apical sprouts and the lateral sprouts. Therefore the difference must be attributed to differences in chemical composition of the excised buds.

Table 1 shows that root formation proceeds parallel with bud development. From the results of these tests it can be concluded that, because of their similarity, the pieces B and C were preferable for a study on the influence of growth regulators upon sprout and root growth.

Dormancy

Breaking of dormancy in seed potatoes – uninjured tissue – by GA is well-known (Holmes et al., 1970). Prolongation of dormancy of intact tubers by ABA was found by El Antably et al. (1967) and by application of high concentrations of IAA by Rappaport & Wolf (1969). It is also known that kinetin and zeatin break dormancy of potato tubers (Hemberg, 1970; Engelbrecht & Bielińska-Czarnecka, 1972).

None of the tested plant hormones GA, IAA, kinetin or ABA were capable of keeping the excised buds in the dormant state, or of bringing forward the moment of sprouting. This may be due to the increase in GA content as a consequence of injury, caused by preparation (Rappaport & Sachs, 1967).

However, Harkett (1976) found a break of dormancy in a bioassay where he applied GA to dormant tubers not long after harvest.

Influence of growth regulators on sprout growth

Influence of GA_3. The results of GA application on sprout growth are summarized in Fig. 2, showing it to have a strongly stimulating effect on the growth rate of the sprouts. At higher concentrations the increase of growth in length is often accompanied by a decrease of radial growth, resulting in thin shoots. This is in agreement with the results of Holmes et al. (1970), who found that application of higher GA concentrations

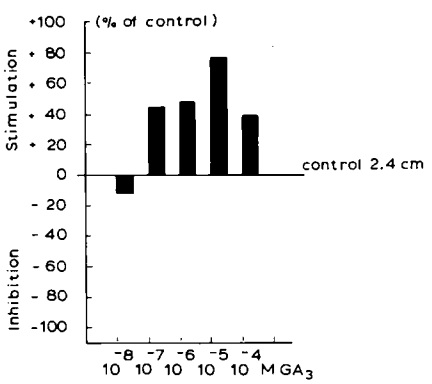


Fig. 2. Influence of GA_3 on the sprout length measured after 7 days.

Inhibition – *Hemmung – Inhibition;* Stimulation – *Forderung – Stimulation;* Control – *Kontrolle – Contrôle*

Abb. 2. Einfluss der GA_3 auf die Keimlänge, gemessen nach 7 Tagen.
Fig. 2. Influence de l'acide gibberellique sur la longueur des germes mesurée après 7 jours.

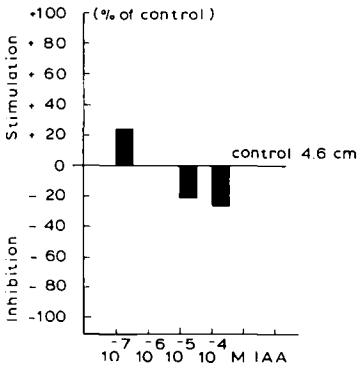


Fig. 3. Influence of IAA on the sprout length measured after 13 days.

Inhibition, Stimulation, Control: *siehe Abb. 2 voir fig. 2*

Abb. 3. Einfluss der IES auf die Keimlänge, gemessen nach 13 Tagen.

Fig. 3. Influence de l'acide indol-acétique sur la longueur des germes mesurée après 13 jours.

resulted in the development of plants with thin stems and chlorotic leaves.

The increase in sprout weight related to the increase in sprout length is up to 30% lower for the highest GA concentrations (10^{-4} *M*) due to decrease in radial growth. In some experiments with GA conc. 10^{-4}, 10^{-5} *M* there can be a decrease in sprout weight, although there is an increase in sprout length.

Influence of IAA. The results from the experiments with IAA, presented in Fig. 3, show that concentrations lower than 10^{-6} *M* stimulate sprout growth, whereas concentrations higher than 10^{-6} *M* have an inhibiting effect, possibly due to toxicity. This is confirmed by the work of Hemberg (1949, 1970) and Engelbrecht & Bielińska-Czarnecka (1972). They too found an inhibition of longitudinal growth at higher concentrations of IAA, which in our case, however, was not accompanied by an increase of lateral growth of the sprouts, as appears from Table 2.

Influence of kinetin. Kinetin was used because it is a compound with a cytokinin-like effect. The results are given in Fig. 4. The concentrations of 10^{-6} *M* and 10^{-7} *M* have a stimulating effect, whereas lower concentrations, 10^{-8} *M*, do not have any effect.

Table 2. Influence of IAA on lateral growth of the sprouts.

Treatment[1]	Sprout weight sprout length[2] (mg mm)
10^{-7} *M* IAA	1.9
10^{-6} *M* IAA	1.9
10^{-5} *M* IAA	1.8
10^{-4} *M* IAA	1.7
Control[3]	2.0

[1] *Behandlung – Traitement;* [2] *Keimgewicht: Keimlänge – Poids de germe: longueur des germes*

Tabelle 2. Einfluss von IES auf das Dickenwachstum der Keime.
Tableau 2. Influence de l'acide indol-acétique sur la croissance latérale des germes.

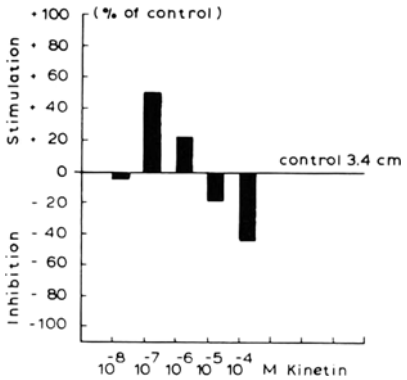


Fig. 4. Influence of kinetin on the sprout length measured after 11 days.

Inhibition, Stimulation, Control: *siehe Abb. 2 – voir fig. 2*

Abb. 4. Einfluss von Kinetin auf die Keimlänge, gemessen nach 11 Tagen.
Fig. 4. Influence de la kinétine sur la longueur des germes mesurée après 11 jours.

Engelbrecht & Bielińska-Czarnecka (1972) found an increase in the cytokinin level in the tissue surrounding the buds at the time of sprouting.

Fig. 4 clearly shows that concentrations of 10^{-4} *M* and 10^{-5} *M* have an inhibiting effect, probably because these concentrations are toxic.

It was noted that there was an increase of almost 40 % in the number of axillary buds at all concentrations. Such a phenomenon was not found with any of the other growth regulators.

Influence of ABA. ABA is a major component of the inhibitor-β complex (Milborrow, 1967). In the bioassay (Fig. 5) ABA, although inhibiting in most concentrations, appeared to act as a stimulant in some concentrations, depending on the duration of the experiment. This becomes particularly manifest at concentrations of approx. 10^{-8} *M*. After some time the inhibition turns into a stimulating effect. This effect might be explained by the hypothesis that application of ABA induces an increase in the

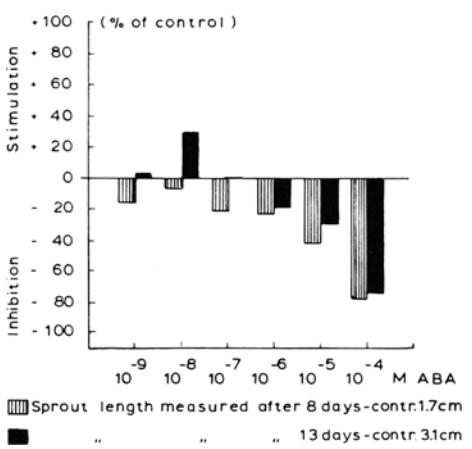


Fig. 5. Influence of ABA on the sprout length.

Sprout length measured after .. days – *Keimlänge gemessen nach .. Tagen – Longueur des germes mesurée après .. jours;* Inhibition, Stimulation, Control: *siehe Abb. 2 – voir fig. 2*

Abb. 5. Einfluss von ABA auf die Keimlänge.
Fig. 5. Influence de l'acide abscissique sur la longueur des germes.

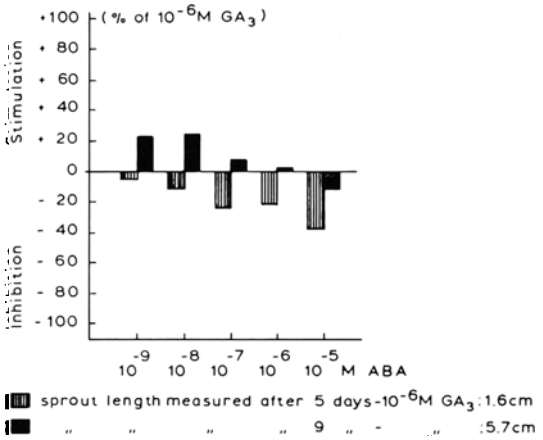


Fig. 6. Influence of ABA + 10^{-6} *M* GA_3 on the sprout length.

Stimulation, Inhibition: *siehe Abb. 2 – voir fig. 2;* Sprouth length measured after .. days: *siehe Abb. 5 – voir fig. 5*

Abb. 6. Einfluss von ABA + 10^{-6} M GA_3 auf die Keimlänge.
Fig. 6. Influence de l'acide abscissique + 10^{-6} M d'acide gibberellique sur la longueur des germes.

concentration of GA-like substances in the tuber tissue. The moment of manifestation of this secondary GA effect seems to be related to the concentration of ABA. Railton & Wareing (1973) found that application of ABA to excised leafs of *Solanum andigena* resulted in an increase of gibberellin activity. ABA was assumed to convert an inactive GA precursor into a biologically active form. Fries et al. (1971) also found this stimulating effect, related to the concentration and time, in the development of the hypocotyls in *Lens culinaris*.

Influence of ABA + GA. ABA inhibits the synthesis of DNA and RNA (Shih & Rappaport, 1970). Application of GA can reverse this inhibition, as the activity of GA dominates. This becomes also apparent in the experiment where ABA and GA are applied simultaneously (Fig. 6). All concentrations of ABA in combination with 10^{-6} *M* GA caused inhibition after 5 days. This effect declined after 9 days, and at the lowest concentrations of ABA a stimulating effect was observed. There is also in this case the possibility of inducing GA-like substances by ABA. The concentration of 10^{-6} *M* GA gave a stimulation of approx. 55 % compared to the control (application of water).

Influence of growth regulators on root growth

Influence of GA. Fig. 7 shows that root formation is inhibited by GA; the inhibition increases with increasing concentration of GA.

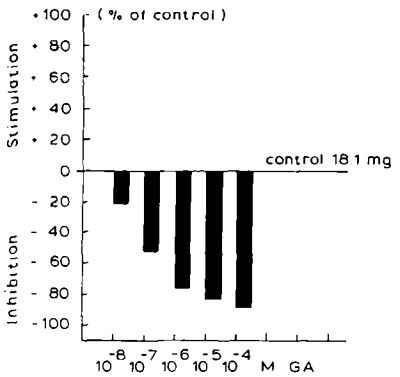


Fig. 7. Influence of GA_3 on the root weight after 7 days.

Inhibition, Stimulation, Control: *siehe Abb. 2 – voir fig. 2*

Abb. 7. Einfluss von GA_3 auf das Wurzelgewicht nach 7 Tagen.
Fig. 7. Influence de l'acide gibberellique sur le poids des racines après 7 jours.

Influence of IAA. Fig. 8 presents the influence of IAA on the root formation as measured after 13 days. The lower concentrations of IAA have a positive effect and the higher concentrations have a negative effect on root growth. Repeated tests with tuber material from different origin showed that factors such as age, year of harvest and physiological state play a role with respect to the concentration at which inhibition turns into activation.

Influence of kinetin. Kinetin concentrations of 10^{-7} *M* and 10^{-8} *M* have strong stimulating effects on root growth (Fig. 9). In fact the stimulation is greater than in any other test carried out. The root weight in these cases is 3.5 times as high as in the controls. There appeared to be twice as many roots while their length showed also a significant increase. The (too) high concentrations 10^{-4} and 10^{-5} *M* have a negative effect.

Influence of ABA. It is noteworthy that ABA has an inhibiting effect on root growth (Fig. 10) in the range of 'higher' concentrations, 10^{-5} and 10^{-6} *M* and also at the 'low' concentration, 10^{-9} *M*, while there was hardly any effect at all at concentrations of 10^{-5} and 10^{-8}*M*. There seems to exist a sort of optimum concentration for ABA, at which root growth is least delayed. This may also indicate that at low concentrations of ABA, induction of GA finally leads to a dominance of GA activity, and as appears from our experiments this will cause a negative influence on root development.

Fries et al. (1971) also found a stimulating effect related to ABA concentration in the development of roots in *Lens culinaris*.

The development of excised potato buds into plants after treatment of the buds with growth regulators during sprout growth

Plant development was observed after application of some regulators at a few concentrations.

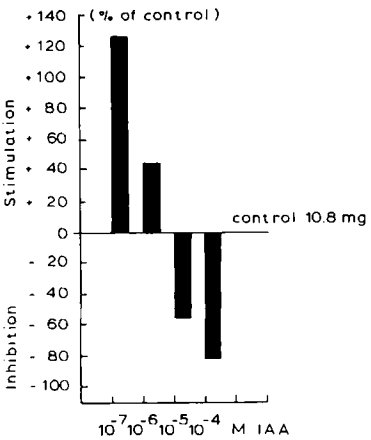


Fig. 8. Influence of IAA on the root weight after 13 days.

Stimulation, Inhibition, Control: *siehe Abb. 2 – voir fig. 2*

Abb. 8. Einfluss von IES auf das Wurzelgewicht nach 13 Tagen.
Fig. 8. Influence de l'acide indol-acétique sur le poids des racines après 13 jours.

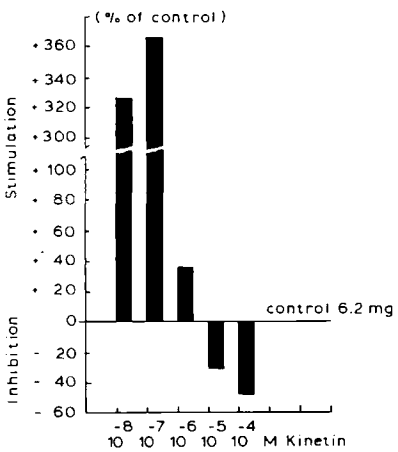


Fig. 9. Influence of kinetin on root weight after 11 days.

Stimulation, Inhibition, Control: *siehe Abb. 2 – voir fig. 2*

Abb. 9. Einfluss von Kinetin auf das Wurzelgewicht nach 11 Tagen.
Fig. 9. Influence de la kinétine sur le poids des racines après 11 jours.

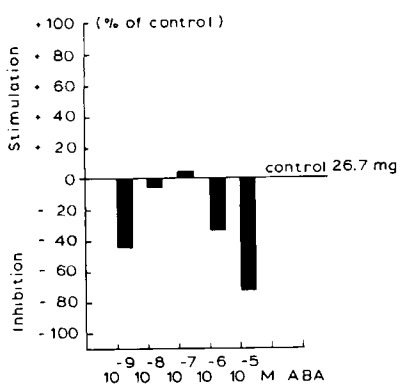


Fig. 10. Influence of ABA on root weight after 15 days.

Stimulation, Inhibition, Control: *siehe Abb. 2 – voir fig. 2*

Abb. 10. Einfluss von ABA auf das Wurzelgewicht nach 15 Tagen.
Fig. 10. Influence de l'acide abscissique sur le poids des racines après 15 jours.

Influence of GA and IAA. The growth rates of the sprouts of buds treated with either IAA 10^{-5} *M*, GA 10^{-5} *M* or GA 10^{-7} *M* are presented in Fig. 11a. The activating effect of GA is apparent, but IAA has practically no effect (see also Figs. 2 and 3). A change in effect takes place during growth of the material treated with GA. The initial stimulating effect of GA on sprout growth appears to result in an inhibition at further development of the plants (Fig. 11b), probably due to the negative influence of GA on root formation (Fig. 7). No effect was seen in the test with IAA; it should be noted that only limited material was available, since only one concentration was tested.

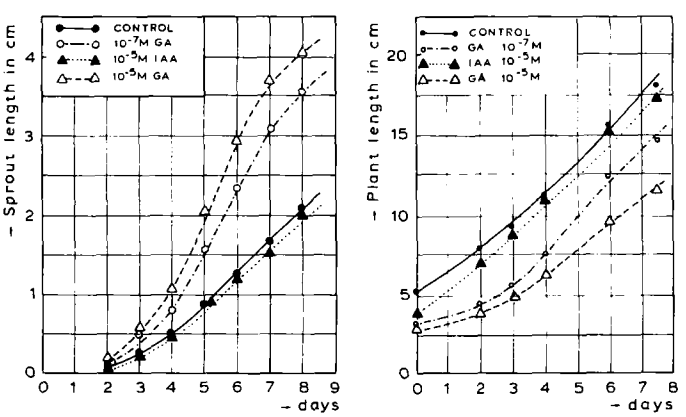
Influence of ABA. From Fig. 12a it can be seen that the initial inhibition of 10^{-6} *M* of ABA compared with the control, changes into a stimulating effect after some days. Both 10^{-5} *M* and 10^{-6} *M* of ABA appear to have a stimulating effect on the development into plants (Fig. 12b).

The initial inhibition of approx. 15 % during sprouting, which was caused by 10^{-5} *M*, turned into an activation of approx. 55 % during the development into plants. This was not only reflected in the length of the plants but also in the fresh weight.

One may come to the question whether a certain ratio of the growth regulators is prerogatory in order to obtain a well-balanced plant development, so that sprout growth as well as root growth take place in an optimum way.

It seems that too high a concentration of GA results in the development of smaller plants, whereas the effect of ABA at high concentration may be compensated by

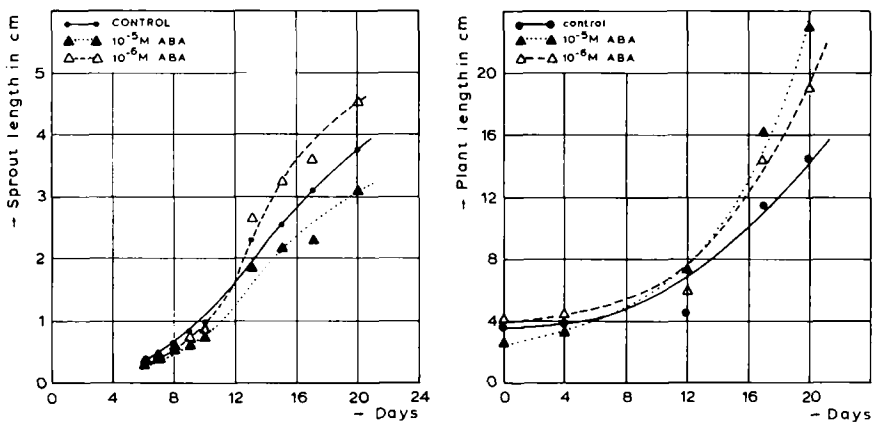
Fig. 11. Influence of GA_3 and IAA on sprout length (a, left) and plant growth (b, right).



Sprout length – *Keimlänge – Longueur des germes;* Plant length – *Länge der Pflanzen – Longueur des plants;* Days – *Tage – Jours*

Abb. 11. Einfluss von GA_3 und IES auf die Keimlänge (a, links) und das Pflanzenwachstum (b, rechts).
Fig. 11. Influence de l'acide gibberellique et de l'acide indol-acétique sur la longueur des germes (a, à gauche) et sur la croissance des plants (b, à droite).

Fig. 12. Influence of ABA on sprout growth (a, left) and plant growth (b, right).



Sprout length, Plant length, Days: *siehe Abb. 11 – voir fig. 11*

Abb. 12. Einfluss von ABA auf das Keimwachstum (a, links) und das Pflanzenwachstum (b, rechts).
Fig. 12. Influence de l'acide abscissique sur la croissance des germes (a, à gauche) et des plants (b, à droite).

activation or induction of GA. More research is needed to support this hypothesis. In view of this, the findings of Bielińska-Czarnecka & Bialek (1976) are of importance. They established two peaks of ABA and GA during the period of growth and storage of the tubers.

The first peak of ABA occurs in June-July, after which ABA disappears and GA increases. The ABA level in the tubers increases again during maturation and wilting, to be followed by a decline during the period of storage, November-December. GA is supposed to increase in the latter period, coinciding with the break of dormancy. The GA level would decrease after break of dormancy.

More work will have to be done to investigate the final influence of IAA and kinetin upon the development of the plant; both compounds have a positive effect on both sprout and root growth within certain concentration limits.

It is not the effect of a single growth hormone that needs attention, but rather the ratio of the various growth hormones which influence the plant system. When the growth regulator balance present in a tuber is changed, the reaction of the tuber depends on this balance.

The effects of applying growth regulators, or unknown substances isolated from potatoes in a potato bud bioassay must therefore be interpreted very carefully. Dependent on the physiological state of the tuber, the concentration used and the duration of the experiment, the effect on sprout, root and plant growth can vary from stimulation to inhibition.

Zusammenfassung

Untersuchungen über den Einfluss von (Wachstumsregulatoren) GA_3, ABA, Kinetin und IES auf das Spross- und Wurzelwachstum und die Pflanzenentwicklung mit Hilfe von Augenstecklingen

Pflanzenhormone spielen eine wichtige Rolle in dem Phänomen der Keimruhe und der Keimung. Der Einfluss dieser Stoffe auf die Keimung, die Wurzelbildung und die Pflanzenentwicklung wurde mit Hilfe eines bereits früher beschriebenen Biotests mit ausgeschnittenen Augen untersucht (van Es & Hartmans, 1969).

In diesem Versuch wurden nur die Seitenknospen nahe des apikalen Auges benutzt, da die Keimfähigkeit von der Lage der Augen auf der Kartoffelknolle abhängig ist (Abb. 1). Das wiederum ist eine Folge der unterschiedlichen chemischen Zusammensetzung des die Augen umgebenden Knollengewebes.

Während der Keimungsversuche lagen die ausgeschnittenen Augen ständig in der Testlösung. Mit Ausnahme in den Abb. 1, 11 und 12 wurde der Prozentsatz Hemmung oder Förderung auf die Wasserkontrolle berechnet.

Die Keimruhe schien von keiner der getesteten Substanzen beeinflusst zu sein, was durch das Brechen der Keimruhe durch den nach dem Schneiden erhöhten GA-Gehalt verursacht sein kann.

Wir fanden, dass der Einfluss auf das Keim- und das Wurzelwachstum entweder hemmend oder fördernd war, abhängig vom physiologischen Zustand des Materials, der Konzentration der zugesetzen Chemikalien und der Versuchsdauer. Hohe Konzentrationen hemmten das Wachstum, wahrscheinlich ein toxischer Effekt.

GA_3, IES und Kinetin förderten das Längenwachstum der Keime während ABA hemmte (Abb. 2, 3, 4). Die Hemmung durch ABA nahm jedoch nach wenigen Tagen ab und in geringen Konzentrationen trat sogar eine fördernde Wirkung auf (Abb. 5), vielleicht verursacht durch eine Induktion der GA-Synthese durch ABA.

Die Wurzelbildung wurde durch GA_3 gehemmt (Abb. 7) und stark gefördert durch IES und Kinetin in geringen Konzentrationen (Abb. 8 und 9).

ABA hemmte die Wurzelbildung bei hohen und niedrigen Konzentrationen (Abb. 10).

Der letztere Effekt kann durch einen Anstieg des GA-Gehaltes verursacht sein, induziert durch ABA, der über die ABA letztlich dominiert.

Pflanzen, entstanden aus mit GA_3 behandelten Augen, wuchsen langsam (Abb. 11b), eine Folge der verzögerten Wurzelentwicklung. Andererseits zeigte mit ABA behandeltes Material ein beschleunigtes Wachstum, das mit den zugeführten Konzentrationen positiv korreliert war (Abb. 12b). Dieser Effekt ist auch durch eine von ABA induzierte Aktivität der GA verursacht und ist offensichtlich ein indirekter Effekt.

Résumé

L'influence de régulateurs de croissance (GAZ, ABA, kinetin et IAA) appliqués sur des bourgeons de pommes de terre excisés, sur la germination, la croissance des racines et le développement des plantes

Les hormones des plants jouent un rôle important en ce qui concerne les phénomènes de dormance et de germination. Les effets de ces composés sur la germination, la formation des racines et le développement des plantes ont été examinés au préalable par bio-essai sur des bourgeons excisés (van Es & Hartmans, 1969).

Dans cette expérimentation, seuls les bourgeons latéraux situés près du bourgeon apical ont été utilisés, puisque la capacité de germination est dépendante de la localisation des bourgeons sur le tubercule (fig. 1). Ceci est une conséquence de la différence de composition chimique des tissus environnant les bourgeons.

Durant les essais sur la germination, les bourgeons excisés étaient continuellement en contact avec la solution test. Les pourcentages d'inhibition ou de stimulation, (sauf pour les fig. 1, 11 et 12) ont

été calculés par rapport au témoin eau.

Aucun des composés expérimentés n'a semblé avoir une influence quelconque sur la dormance, laquelle pouvait être due à la rupture de dormance occasionnée par exemple par l'augmentation du taux d'acide gibberellique après blessure.

Dépendamment de l'état physiologique du matériel, de la concentration des produits chimiques appliqués et de la durée de l'expérimentation, nous avons trouvé que l'effet sur la croissance des germes et celle des racines était soit inhibiteur, soit stimulateur. De hautes concentrations ont inhibé la croissance, probablement est-ce le résultat des effets toxiques.

L'acide gibberellique, l'acide indol-acétique et la kinétine ont favorisé l'élongation des germes tandis que l'acide abscissique l'a inhibé (fig. 2, 3 et 4).

Cependant, l'inhibition due à l'acide abscissique déclinait après quelques jours et pouvait même se transformer en stimulation à basse concentration (fig. 5); peut-être était-ce dû à la synthèse de l'acide gibberellique induite par l'acide abscissique.

La formation des racines était inhibée par l'acide gibberellique (fig. 7) et fortement stimulée par l'acide indol-acétique et la kinétine à basse concentration (fig. 8 et 9).

Les plantes issues de bourgeons excisés traités à l'acide gibberellique poussaient lentement (fig. 11b) en conséquence du développement retardé des racines.

Le matériel traité à l'acide abscissique présentait une croissance accélérée qui était positivement en corrélation avec les concentrations appliquées (fig. 12b). Cet effet est aussi attribué à l'acide abscissique induit, à l'activité de l'acide gibberellique et est manifestement un effet indirect.

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