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Auxin Induces Stem Elongation in Nonprecooled and Precooled Derooted and Rooted Tulip Bulbs

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Treatment with 0.1% indole-3-acetic acid (IAA, auxin) in lanolin paste to the cut surface of the top internode of nonprecooled and precooled derooted and rooted bulbs of tulip after decapitation promoted the entire stem elongation. Application of 0.5% 2, 3, 5-triiodobenzoic acid (TIBA) in lanolin paste at the middle of the last internode after IAA treatment promoted the elongation of the half top of the last internodes, but inhibited the elongation of the lower half of the last internode and other lower internodes. It is suggested that auxin controls the stem elongation in tulip and that neither flower bud nor roots are necessary for partial stem elongation in the presence of auxin.

INTRODUCTION

It is well known that tulip bulbs require a specific duration of low temperatures for optimal growth and flowering. Decapitation of flower buds during the growth after receiving cold temperature inhibits the elongation growth of the flower stalk and the reduction of the elongation is recovered by the application of auxin to the cut surface (Op den Kelder *et al.*, 1971; Hanks and Rees, 1977; etc.). Saniewski and De Munk (1981) found that application of IAA to the cut surface of the stem after decapitation and excision of the leaves of nonprecooled tulip bulbs 'Apeldoorn' also stimulated the elongation growth of all internodes, but the final length of the stem was about half that in precooled bulbs.

Since the roots may be another factor affecting flower stalk elongation in tulip (M. Saniewski and L. Kawa, unpublished data, cited by Kawa and De Hertogh, 1992), effects of application of auxin on stem elongation of nonprecooled or precooled and derooted or rooted tulip bulbs were compared in this study. The effect of TIBA, an auxin transport inhibitor, on stem elongation was also studied.

MATERIALS AND METHODS

Two cultivars of tulip (*Tulipa gesneriana* L.) bulbs, 'Apeldoorn' and 'Gudoshnik', a 1994 harvest in Poland, were used in this study.

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Effects of IAA and TIBA on stem elongation of nonprecooled derooted bulbs

Bulbs of 'Apeldoorn' and 'Gudoshnik', after flower bud formation, were kept at 17°C until 9 January 1995. On 9 January, the bulbs were derooted and upper part of scales together with flower bud was removed. Then the flower bud was replaced by plain lanolin (control) or 0.1% IAA containing lanolin. The bulbs were placed in water in plastic trays and incubated in a greenhouse at 17–20°C. On 16 January, when the total length of the stem treated with IAA was 44.0 mm (last internode; 26.3 mm) in 'Apeldoorn' and 34.5 mm (last internode; 20.1 mm) in 'Gudoshnik', additional treatment was made in the middle of last internode with plain lanolin or 0.5% TIBA containing lanolin. The bulbs were kept in the same conditions as before to incubate. Measurement took place on 25 January for 'Apeldoorn' and on 30 January for 'Gudoshnik'. Photographs were taken on 26 January for both cultivars.

Effects of IAA and TIBA on stem elongation of precooled derooted bulbs

Bulbs of 'Apeldoorn' and 'Gudoshnik', after flower bud formation, were cooled at 5°C from 25 October until use on 19 January 1995. On 19 January, after the bulbs were derooted and upper part of scales together with flower bud was removed, the flower bud was replaced by plain lanolin and 0.1% IAA-lanolin. The bulbs were incubated in the same manner as above. When the total length of the stem of IAA-treated 'Apeldoorn' and 'Gudoshnik' was 44.3 mm (last internode; 20.4 mm) and 39.5 mm (last internode 17.6 mm), respectively on 25 January additional treatment with plain lanolin or 0.5% TIBA was made in the middle of the last internode. On 3 February, the length of internodes was recorded and photographs were taken.

Effects of IAA on stem elongation of nonprecooled and precooled derooted 'Gudoshnik' bulbs

IAA treatment to precooled and nonprecooled derooted 'Gudoshnik' was given on 30 January. The result was recorded on 16 February and photographed on the next day.

Effects of IAA on stem elongation of nonprecooled rooted bulbs

Nonprecooled bulbs of the both cultivars were planted on 25 January. After rooting, they were treated as the same way as above with IAA on 1 February and grown until 24 February.

Effects of IAA on stem elongation of precooled rooted 'Gudoshnik' bulbs

Precooled 'Gudoshnik' bulbs were planted on 2 February. The rooted plants were treated in the same manner as above on 6 February. Measurement took place on 27 February.

RESULTS AND DISCUSSION

Effects of IAA and TIBA on stem elongation of nonprecooled derooted bulbs

Treatment with IAA in lanolin paste to the cut surface of nonprecooled, derooted and decapitated 'Apeldoorn' bulbs greatly promoted the flower stalk elongation (Table 1 and Fig. 1–A). This elongation response was made up from the top (fourth) internode 48%,

Table 1. Effects of IAA and TIBA on stem elongation of nonprecooled derooted 'Apeldoorn' bulbs.

Treatment	Length of internode (mm)					
	1st	2nd	3rd	4th	Total	above lanolin/TIBA in 4th internode
Control[z]	–	–	–	–	23.7	–
IAA	28.0	22.8	35.9	79.7	167.1	21.1
IAA+TIBA		17.5[y]		54.1	71.6	28.7

[z] Expressed as the length of leaves (plant height), because the length of each internode was too short to measure.

[y] Total length of lst, 2nd and 3rd internodes.

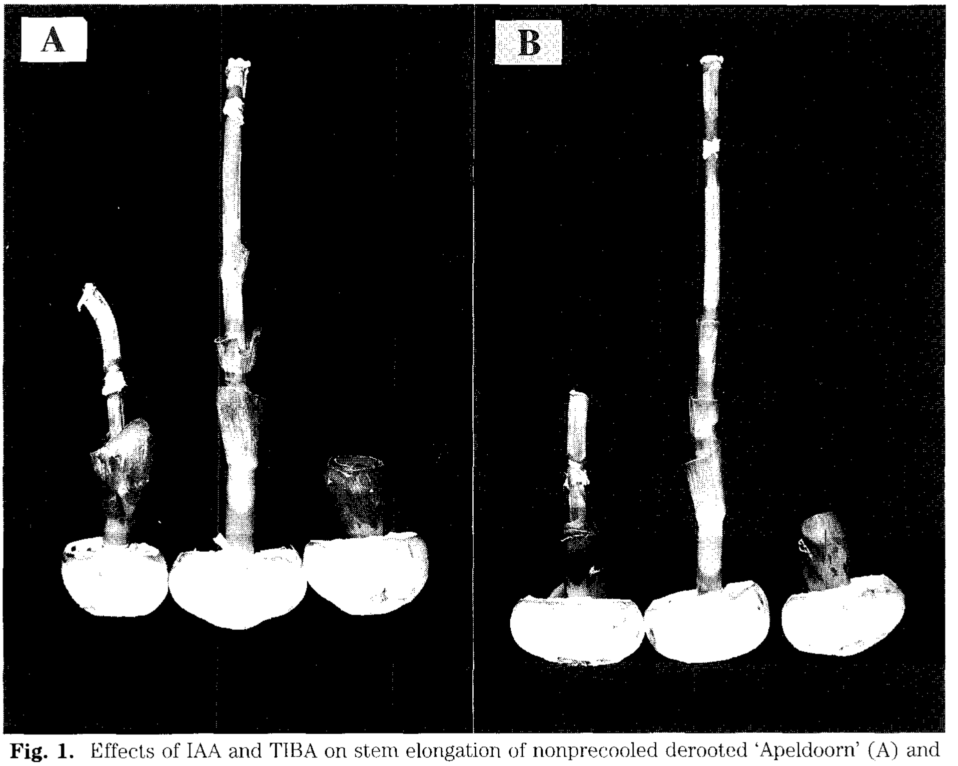

Fig. 1. Effects of IAA and TIBA on stem elongation of nonprecooled derooted 'Apeldoorn' (A) and 'Gudoshnik' (B) bulbs. Left to right in each photograph; IAA 0.1%+TIBA 0.5%, IAA 0.1% and control. Photographs were taken on 26 January 1995.

third internode 21%, second internode 14% and the first internode 17%. Application of TIBA lanolin after IAA treatment (IAA+TIBA) inhibited the flower stalk growth by 43% of the IAA treated plants, whereas the length of the top (last) internode above the position of TIBA treatment was longer with IAA+TIBA than with IAA only. The top internode length with IAA+TIBA was 68% of that with IAA only, whereas the growth of the lower internodes (the first, second and the third internodes) with IAA+TIBA was

Table 2. Effects of IAA and TIBA on stem elongation of nonprecooled derooted 'Gudoshnik' bulbs.

Treatment	Length of internode (mm)					
	1st	2nd	3rd	4th	Total	above lanolin/TIBA in 4th internode
Control[z]	–	–	–	–	37.8	–
IAA	33.4	32.2	36.2	79.3	181.1	25.5
IAA+TIBA		31.9[y]		64.1	96.0	28.8

[z] Expressed as the length of leaves (plant height), because the length of each internode was too short to measure.
[y] Total length of lst, 2nd and 3rd internodes.

only 20% of that of IAA treated plants.

Quite similar results were obtained in 'Gudoshnik', although each response to IAA and IAA+TIBA was a little different from that in 'Apeldoorn' (Table 2 and Fig. 1–B).

Effects of IAA and TIBA on stem elongation of precooled derooted bulbs

Application of IAA promoted flower stalk elongation of the precooled and derooted 'Apeldoorn' bulbs (Table 3 and Fig. 2–A). The response to IAA application in total internode length is considered to be less in the precooled than in nonprecooled bulbs without roots. The last internode was 37% of the total length of the flower stalk, the third was 20%, the second 16% and the first 27%. The lower internodes seemed to be more affected by low temperature than by IAA. TIBA application, however, inhibited the elongation of internodes suggesting the role of IAA to controlling the elongation of all internodes. The response of top internode and half top internode elongation to TIBA was similar both in precooled and nonprecooled bulbs without roots. McKay *et al.* (1994) showed that TIBA reduced both IAA level and internode elongation below the site of application in wild-type garden pea (*Pisum sativum*). In the short mutant (*lkb*) which contained 2- to 3-fold less free IAA than those of the wild type of garden pea, TIBA strongly promoted the elongation of internodes and also raised IAA level above the application site. The authors concluded that the level of IAA in wild-type garden pea internodes is necessary for normal elongation and that when the level of IAA is reduced (*lkb* mutant) normal elongation is affected. TIBA application at the node between the

Table 3. Effects of IAA and TIBA on stem elongation of precooled derooted 'Apeldoorn' bulbs.

Treatment	Length of internode (mm)					
	1st	2nd	3rd	4th	Total	above lanolin/TIBA in 4th internode
Control[z]	–	–	–	–	34.2	–
IAA	50.2	30.4	36.6	67.4	184.6	28.8
IAA+TIBA	18.4	10.5	16.8	52.8	98.5	31.4

[z] Expressed as the length of leaves (plant height), because the length of each internode was too short to measure.

first and second internodes of tulip flower stalk reduced both the elongation of the first internode and the levels of diffusible auxin from the upper internodes to the first internode (Okubo and Uemoto, 1984).

The total internode length of IAA treated 'Gudoshnik' was almost the same as that of 'Apeldoorn', whereas the lower internodes were longer in 'Gudoshnik' than in 'Apeldoorn' (Table 4 and Fig. 2–B). This also indicates that the lower internodes are more affected by low temperature than upper internodes.

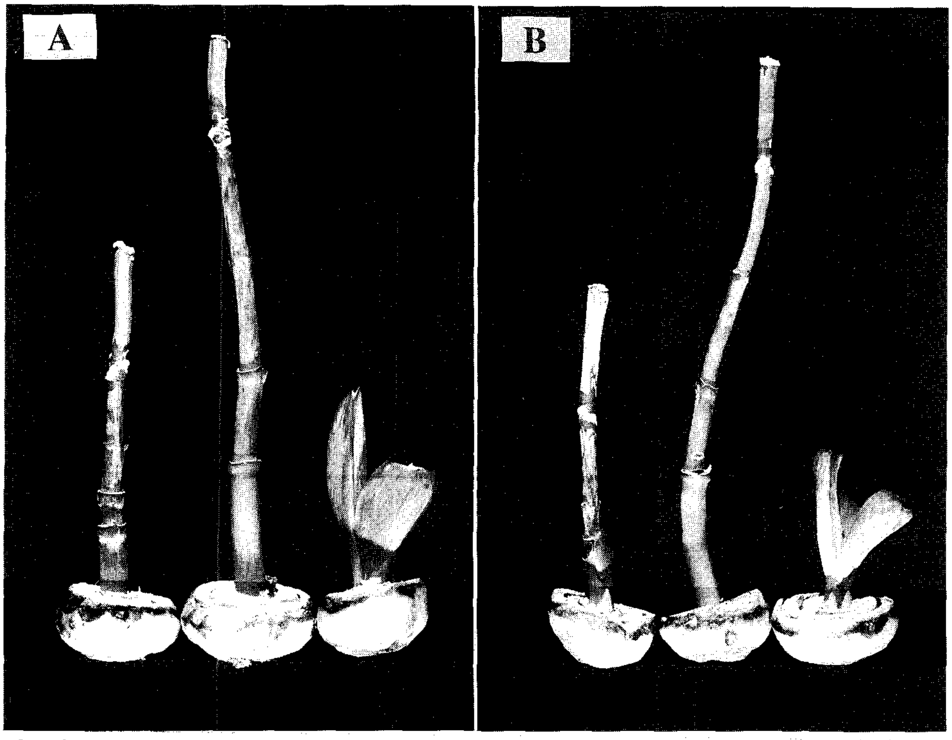

Fig. 2. Effects of IAA and TIBA on stem elongation of precooled derooted 'Apeldoorn' (A) and 'Gudoshnik' (B) bulbs. Left to right in each photograph; IAA 0.1%+TIBA 0.5%, IAA 0.1% and control. Photographs were taken on 3 February 1995.

Table 4. Effects of IAA and TIBA on stem elongation of precooled derooted 'Gudoshnik' bulbs.

Treatment	Length of internode (mm)					
	1st	2nd	3rd	4th	Total	above lanolin/TIBA in 4th internode
Control[z]	–	–	–	–	45.6	–
IAA	57.1	34.1	35.1	57.5	183.8	21.1
IAA+TIBA	20.5	13.8	19.8	68.4	122.5	33.2

[z] Expressed as the length of leaves (plant height), because the length of each internode was too short to measure.

Effects of IAA on stem elongation of nonprecooled and precooled derooted 'Gudoshnik' bulbs

More detailed comparison of the response of 'Gudoshnik' to IAA treatment between nonprecooled and precooled bulbs without roots clarified that the treatment was more effective in lower internodes of cooled bulbs (Table 5 and Fig. 3).

Table 5. Effects of IAA on stem elongation of nonprecooled and precooled derooted 'Gudoshnik' bulbs.

Treatment	Length of internode (mm)				
	1st	2nd	3rd	4th	Total
Nonprecooled	25.9	27.1	31.5	61.8	146.3
Precooled	61.7	38.2	39.4	61.8	201.1

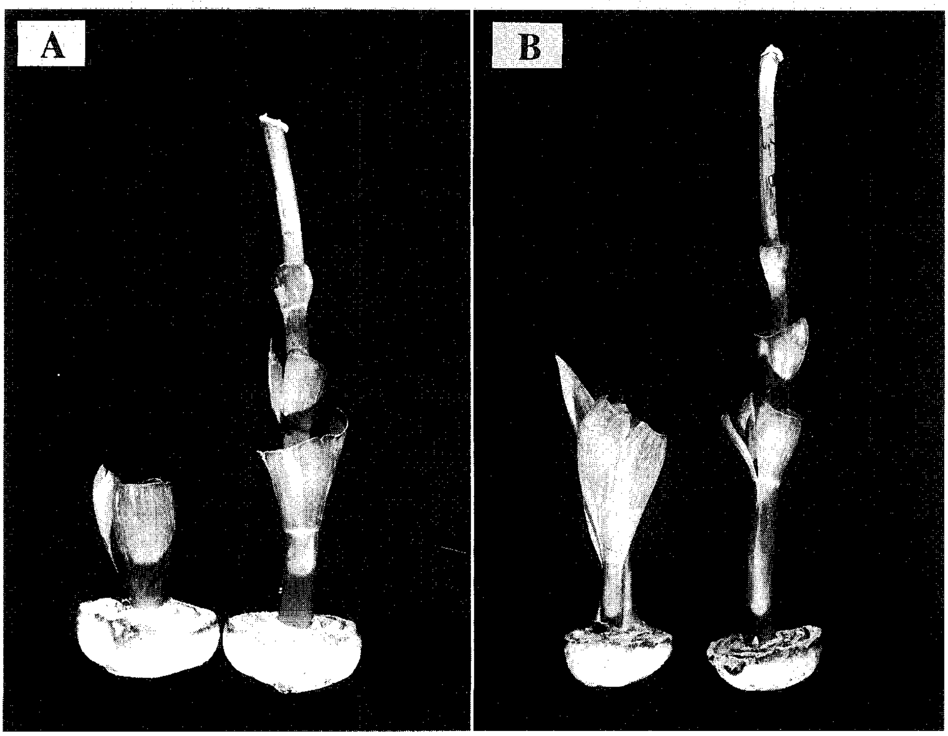

Fig. 3. Effects of IAA on stem elongation of nonprecooled (A) and precooled (B) derooted 'Gudoshnik' bulbs. Left; control, right; IAA 0.1% in each photograph. Photographs were taken on 17 February 1995.

Effects of IAA on stem elongation of nonprecooled rooted bulbs

Promoting effect of IAA application on stem elongation was confirmed in nonprecooled rooted bulbs of the both cultivars as well as in nonprecooled derooted bulbs (Table 6 and Fig. 4).

Effects of IAA on stem elongation of precooled rooted 'Gudoshnik' bulbs

Earlier treatment with IAA to precooled and rooted 'Gudoshnik' bulbs after decapitation than the treatments done by others (Op den Kelder *et al.*, 1971; Hanks and Rees, 1977; etc.) was also effective to restoring the inhibited growth of flower stalk (Table

Table 6. Effects of IAA on stem elongation of *nonprecooled rooted bulbs.*

Cultivar	Length of internode (mm)	
	Total	4th
Apeldoorn	105.1	82.7
Gudoshnik	111.3	74.0

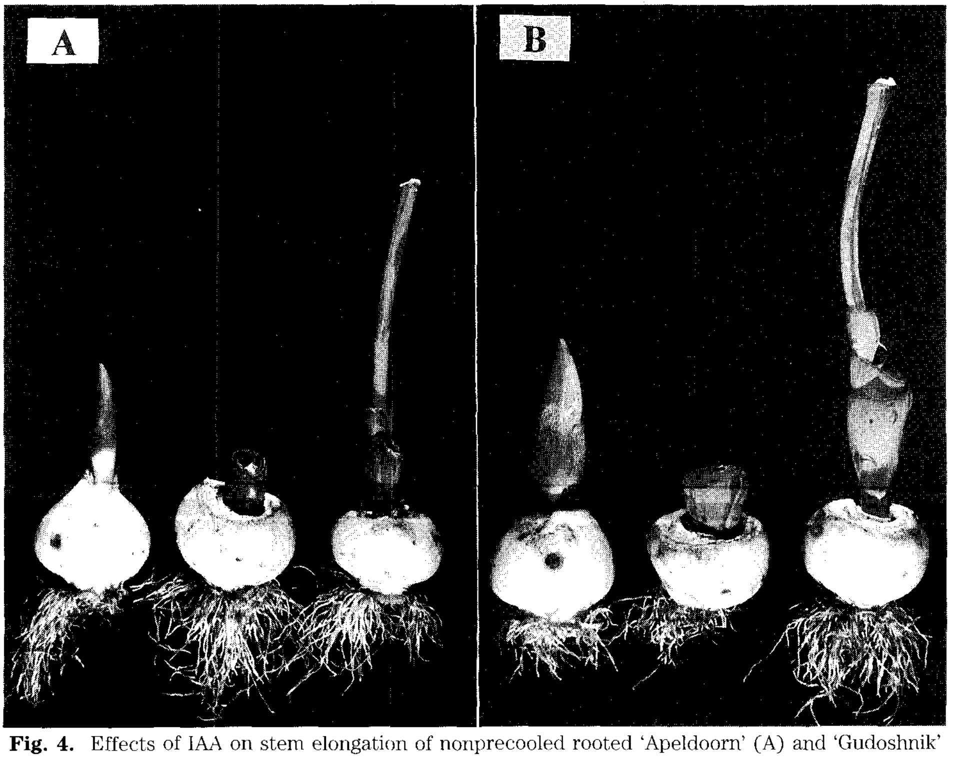

Fig. 4. Effects of IAA on stem elongation of nonprecooled rooted 'Apeldoorn' (A) and 'Gudoshnik' (B) bulbs. Left to right in each photograph; intact control, decapitated control and IAA 0.1%. Photographs were taken on 24 February 1995.

Table 7. Effects of IAA on stem elongation of precooled rooted 'Gudoshnik' bulbs.

Treatment	Length of internode (mm)				
	1st	2nd	3rd	4th	Total
Intact control	68.3	62.0	70.8	187.5	388.6
Decapitated+IAA	110.3	79.9	83.2	166.5	439.9

Fig. 5. Effects of IAA on stem elongation of precooled rooted 'Gudoshnik' bulbs. Left to right; intact control, decapitated control and IAA 0.1%. Photograph was taken on 27 February 1995.

7 and Fig. 5).

These results indicate that auxin controls the elongation of all internodes, and irrespective of the existence of roots and flower buds, and irrespective of being received low temperature or not, tulip flower stalk can elongate to some degree in the existence of IAA.

Another factors than auxin should also be considered in controlling system of stem elongation in tulip, because the response of elongation to IAA application in each internode was different in precooled and nonprecooled bulbs, particularly in lower internodes. It has already been reported that gibberellin can partly substitute for cold requirement in tulip bulbs (Rudnicki *et al.*, 1976; Hanks, 1982, 1984; Rebers *et al.*, 1994). It is, however, clear in this study that auxin can also substitute cold requirement of tulip bulbs, although it does not completely. Role of gibberellins as well as auxin in controlling tulip stem elongation has been reported (Hanks and Rees, 1977; Okubo and Uemoto, 1985; Okubo *et al.*, 1986; Saniewski, 1989), but the experiments were done with cold treated bulbs. The important role of auxin in stem elongation of nonprecooled bulbs as well as of precooled bulbs was confirmed in this study.

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