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# The influence of chlormequat on the flowering of the tulip[1]

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## Summary

Tulip bulbs cv. 'Apeldoorn' were dry stored at 5 °C during 12 or 18 weeks prior to planting on 9 November 1972, 15 December 1972 and 17 January 1973. Plants were forced at 15 °C or 19 °C under fluorescent light. Chlormequat was added to the soil after emergence of the terminal bud, and caused reduction of the length of stem, lowest and highest internode and perianth. The factors forcing temperature, chlormequat, date of planting and duration of 5 °C were of decreasing importance in their effect on the length of the different organs. Longer 5 °C treatment caused an increased effect of chlormequat on length of the highest internode.

## Introduction

Preliminary investigations by Van Bragt and Van 't Hof (1969) indicated that the growth of tulips is retarded when chlormequat is added to the soil. The tulips received a low temperature treatment when the bulbs were dry. They were planted and forced in a greenhouse. Further experiments during the following years indicated that the influence of chlormequat depended not only on the duration of the low temperature treatment but also responded to the temperature in the greenhouse, which was easily maintained at 15 °C during the growth of bulbs planted in November, but rose to higher values during the growth of bulbs forced later in the season.

To exclude the effect of increased solar irradiation and rising greenhouse temperatures following experiments were carried out under controlled environmental conditions. This also made it possible to test the assumption that the reaction of tulips to chlormequat treatment not only depends on the duration of the cold treatment and the forcing temperature but also on the date of planting.

This paper reports on the effect of chlormequat on tulips planted and forced under identical light conditions at 15 °C or 19 °C after 12 or 18 weeks dry storage at 5 °C which was concluded on three consecutive planting data.

## Material and methods

Tulip bulbs cv. 'Apeldoorn', harvested in 1972, circumference 12 cm or more, were dry stored at 20 °C followed by 12 or 18 weeks at 5 °C. The 5 °C treatments were concluded on 9 November 1972 (12 weeks only), 15 December 1972 and 17 January

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1973 (12 and 18 weeks), respectively. On these data the bulbs were planted in sandy soil in 5-litre plastic pots. Each pot contained 7 bulbs. The pots were placed in a growth chamber at 15 ± 0.5 °C or at 19 ±0.5 °C. Plants were illuminated, 24 hours per day, by fluorescent light from Philips TL type 57RS, giving 12.4 W $m^{-2}$ at 30 cm above soil level. Chlormequat treatments were given when the sprouts were about 3 cm above the soil. Each pot received 250 ml water containing 0 (control), 1, 4, 8, 10, 12 or 16 g chlormequat. Each treatment was given to 21 plants.

The following data were collected: number of days to flowering (average over 21 plants), length of the lowest internode (from the bulb to the first leaf), length of the highest internode (under the perianth), total stem length, length of the perianth leaves. The measurements were carried out at the time of flowering and at the time when the organs had reached their final length.

## Results

The data obtained from the January planting of bulbs previously dry stored at 5 °C during 18 weeks and then grown at 15 °C are given in detail in Table 1, which shows

Table 1. Influence of chlormequat (g/pot) on number of days to flowering, duration of flowering, stem length, length of lowest and highest internode and length of the perianth. Bulbs were dry stored at 5 °C during 18 weeks before planting on 17 January 1973. Forcing at 15 °C. Seven bulbs per pot, 21 bulbs per treatment. Fluorescent light 12.4 W $m^{-2}$ at 30 cm above soil level, 24 hours per day.

| Chlormequat (g/pot) | Number of days till flowering | Duration of flowering (days) | Stem length (cm) | |
|---|---|---|---|---|
| | | | at flowering time | final |
| 0 | 37.0 | 9.2 | 57.3±2.5 | 68,6±2.9 |
| 1 | 36.7 | 10.2 | 57.7±2.2 | 67.8±3.4 |
| 4 | 35.3 | 10.0 | 52.9±3.1 | 63.0±3.2 |
| 8 | 36.6 | 9.4 | 55.6±1.0 | 64.6±2.4 |
| 10 | 35.6 | 9.4 | 50.2±2.2 | 59.0±2.5 |
| 12 | 35.8 | 9.1 | 49.2±3.6 | 58.5±4.3 |
| 16 | 35.6 | 9.3 | 47.4±3.3 | 55.2±3.7 |

| Chlormequat (g/pot) | Length lowest internode (cm) | | Length highest internode (cm) | | Length of perianth (cm) | |
|---|---|---|---|---|---|---|
| | at flowering time | final | at flowering time | final | at flowering time | final |
| 1 | 13.4±0.9 | 13.8±0.8 | 21.2±1.4 | 32.1±2.2 | 5.6±0.4 | 7.9±0.5 |
| 2 | 14.2±1.2 | 14.3±0.4 | 21.0±3.2 | 31.2±3.6 | 5.6±0.3 | 8.2±0.8 |
| 4 | 12.8±1.0 | 13.1±1.0 | 17.7±2.8 | 27.3±2.9 | 5.2±0.2 | 7.4±0.4 |
| 8 | 13.5±1.1 | 13.7±1.0 | 19.1±3.2 | 28.0±2.8 | 5.4±0.2 | 7.3±0.4 |
| 10 | 11.6±1.3 | 11.9±1.2 | 17.4±2.1 | 25.8±2.2 | 5.3±0.2 | 7.2±0.3 |
| 12 | 11.9±1.4 | 12.3±1.5 | 16.6±3.4 | 25.3±3.5 | 5.1±0.2 | 6.9±0.6 |
| 16 | 10.3±1.9 | 10.7±1.3 | 17.3±2.2 | 25.0±2.4 | 5.1±0.2 | 6.8±0.5 |

Effect chlormequat 0 → 16 at $P < 00.1$

Table 2. Effect of duration of 5 °C treatment, date of planting (72-11-09, 72-12-15 and 73-01-17), forcing temperature and chlormequat (+ with, — without chlormequat), on number of days till flowering and length of stem at flowering time.

| Period of 5 °C treatment before planting (weeks) | Forcing temp. (°C) | Number of days till flowering | | | Stem length (cm) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 72-11-09 | 72-12-15 | 73-01-17 | 72-11-09 | | 72-12-15 | | 73-01-17 | |
| | | | | | — | + | — | + | — | + |
| 12 | 15 | 67 | 54 | 44 | 57 | 51 | 57 | 50 | 48 | 43 |
| 12 | 19 | 46 | 34 | 28 | 48 | 40 | 49 | 39 | 40 | 33 |
| 18 | 15 | | 43 | 37 | | | 60 | 58 | 57 | 47 |
| 18 | 19 | | 28 | 24 | | | 52 | 43 | 48 | 41 |

For length of stem: Effects of 5 °C treatment, date of planting, forcing temperature, chlormequat, significant at $P < 0.01$.

that there is no effect of chlormequat on the number of days till flowering and on the duration of the flowering. Increasing quantities of chlormequat reduce the length of the stem, the lowest and highest internode and the perianth, both at the time of flowering and at the time they have reached their final length.

The results obtained with this plant material and these treatments were similar to all others. Therefore only the data obtained with the chlormequat treatments 0 (control) and 16 g per pot will be considered below. Also, further considerations are restricted to the observations made at the time of flowering, since most of the data concerning the final lengths of the plant organs did not provide additional information on the influence of chlormequat. The only exception was found in the influence of chlormequat on the final length of the highest internode.

Table 2 gives a survey of the relation between 5 °C treatment, forcing temperature, chlormequat treatment, and the number of days till flowering and the length of the stem at the time of flowering. This table shows that the later the bulbs are planted, the sooner they flower. The stem length decreases with a later planting date. A treatment at 5 °C during 18 weeks before planting results in a shorter period until flowering while the plants have a longer stem as compared with 5 °C during 12 weeks. Compared with 15 °C, the forcing temperature of 19 °C also reduces the number of days till flowering and the stem length at flowering time. In all cases chlormequat reduces the length of the stem.

Table 3 gives the data about the relation between the 5 °C treatment, date of planting, forcing temperature and the effect of chlormequat on the length of the lowest and the highest internode and on the length of the perianth at the time of flowering. From this table and from the data in Table 2, which refer to the total length of the plants, the following conclusions are drawn.

The forcing temperature is the major factor which determines the difference in the length of stem, internodes and perianth. The next most influential factor is chlormequat, which clearly affects total length, length of the lowest internode and length of perianth. The effect of chlormequat on the length of the highest internode is also significant, but smaller than the effect of the factors duration of the 5 °C treatment and date of planting. These latter factors are of less importance than the former two for the growth of the plants. They are significant for the total length and for the length of the highest internode, but they barely affect the length of the lowest internode, while the 5 °C

Table 3. Effect of the duration of the 5 °C treatment (A, in weeks), date of planting (72-11-09, 72-12-15 and 73-01-17), forcing temperature (B, in °C) and chlormequat (C, + = with, — = without) on length of lowest and highest internode and perianth at flowering time.

| A | B | C | Length (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lowest internode | | | highest internode | | | perianth | | |
| | | | 72-11-09 | 72-12-15 | 73-01-17 | 72-11-09 | 72-12-15 | 73-01-17 | 72-11-09 | 72-12-15 | 73-01-17 |
| 12 | 15 | — | 10.4 | 13.5 | 11.0 | 22.0 | 23.2 | 16.6 | 5.9 | 6.3 | 5.6 |
| 12 | 15 | + | 8.6 | 12.1 | 9.2 | 21.5 | 18.1 | 14.0 | 5.5 | 5.6 | 5.4 |
| 12 | 19 | — | 6.7 | 10.0 | 9.7 | 20.3 | 16.8 | 12.1 | 5.3 | 5.7 | 4.9 |
| 12 | 19 | + | 5.4 | 6.8 | 7.2 | 16.6 | 14.2 | 9.4 | 5.3 | 5.1 | 4.6 |
| 18 | 15 | — | | 12.3 | 13.4 | | 23.8 | 21.2 | | 5.4 | 5.6 |
| 18 | 15 | + | | 10.9 | 10.3 | | 21.2 | 17.3 | | 5.1 | 5.1 |
| 18 | 19 | — | | 8.4 | 10.9 | | 21.5 | 15.6 | | 4.9 | 5.2 |
| 18 | 19 | + | | 6.8 | 8.2 | | 15.5 | 12.6 | | 4.6 | 4.8 |

For length of lowest internode: no effect of 5 °C treatment and date of planting. Effect of forcing temperature at $P < 0.05$, chlormequat at $P < 0.10$.
For length of highest internode: effect of 5 °C treatment, data of planting, forcing temperature at $P < 0.01$, chlormequat at $P < 0.10$.
For length of perianth: no effect of date of planting, 5 °C treatment at $P < 0.10$, forcing temperature and chlormequat at $P < 0.01$.
Interaction 5 °C treatment and chlormequat at $P < 0.10$.

treatment has some influence on the length of the perianth. An interesting factor is the interaction between the duration of the 5 °C treatment and the effect of chlormequat on the length of the highest internode. The growth-inhibiting effect of chlormequat was the greatest on plants from bulbs treated at 5 °C during 18 weeks before planting.

Thus in the sequence forcing temperature (15 versus 19 °C), chlormequat treatment (control versus 16 g per pot), date of planting (November, December, January) and duration of the 15 °C treatment (12 versus 18 weeks before planting) these four factors are of a decreasing importance in their contribution to the length of stem, internodes and perianth.

The above-mentioned factors have the following effects:

*Effect of the forcing temperature*
At 15 °C the stem, the lowest and the highest internode and the perianth are longer than at 19 °C.

*Effect of chlormequat*
Chlormequat reduces the length of the stem and the perianth, and, to a lower extent, the length of the lowest and the highest internode. This part of the plant is stronger reduced by chlormequat when the 5 °C treatment was 18 weeks instead of 12. At the forcing temperature of 15 °C the effect of chlormequat seems to be smaller than at 19 °C but this difference just falls short of statistical significance.

*Effect of the date of planting*
The later the bulbs are planted, the shorter the length of the stem and the highest internode. The length of the lowest internode and the flower petals are affected to a

Table 4. Effect of 5 °C treatment, forcing temperature and chlormequat on elongation of the highest internode during flowering.

| Duration of 5 °C treatment in weeks | Forcing temperature (°C) | With (+) or without (—) chlormequat | Length of highest internode (cm) | | |
|---|---|---|---|---|---|
| | | | 72-11-09 | 72-12-15 | 73-01-17 |
| 12 | 15 | — | 9.5 | 7.2 | 10.4 |
| 12 | 15 | + | 7.0 | 6.8 | 12.3 |
| 12 | 19 | — | 9.6 | 12.8 | 15.1 |
| 12 | 19 | + | 10.9 | 10.8 | 14.5 |
| 18 | 15 | — | | 8.4 | 10.9 |
| 18 | 15 | + | | 5.8 | 7.7 |
| 18 | 19 | — | | 10.4 | 13.8 |
| 18 | 19 | + | | 7.2 | 9.9 |

Effect of 5 °C treatment, forcing temperature, chlormequat and date of planting at $P < 0.01$. Interaction 5 °C treatment and chlormequat at $P < 0.01$.

lesser extent. An exception is found in the bulbs planted in November, which do not differ in length with the December planting, although differences between the lengths of the highest internodes were found.

*Effect of the duration of the 5 °C treatment*

The duration of the 5 °C treatment does not appreciably affect the length of the lowest internode, but after 18 weeks at 5 °C the plants have a longer stem and longer highest internode when in flower. At that time, their perianths are shorter.

As mentioned before, the influence of chlormequat as recorded at the time of flowering does not essentially differ from its influence in case the final length of the plants is considered. Plants continue to grow from the time of flowering and this growth is mainly due to the elongation of the highest internode. Its growth during flowering is given in Table 4, which shows that a shorter 5 °C treatment gives a greater elongation of the highest internode, that this part of the stem elongates more at 19 °C than at 15 °C and that the January planting gives more elongation than earlier plantings. Finally, it appears that the elongation of the highest internode is the more inhibited by chlormequat when the 5 °C treatment of the bulbs was longer. This conclusion was also made for the observations at the time of flowering, but at that time the interaction was at $P < 0.1$, while Table 4 shows that it is at $P < 0.01$ when calculated from the data recorded at the end of the flowering period.

## Discussion

The effect on plant growth and flowering of the factors duration of the 5 °C treatment before planting, time of forcing and forcing temperature are in general accordance with the findings of Slootweg & Hoogeterp (1965), Rees (1969) and Moe & Wickstrøm (1973). The experiments presented in this paper show that the effects of these three factors on growth and flowering of tulip increase in importance in the order in which they are given here.

Apparently chlormequat is taken up by the roots. In the plant it may exert its effect through its inhibitory action on the biosynthesis of gibberellins. These substances were

found in tulip bulbs. It was supposed that increased duration of the 5 °C treatment increased their gibberellin level which was the cause of the more rapid growth after extended 5 °C treatment. Support for this hypothesis was found by Aung & de Hertog (1968) who worked with the cv. 'Ralph', but not by van Bragt (1971) who worked with 'Apeldoorn'. Gibberellins promote the growth of tulips when added to the bulb at the time of planting (van Bragt and Zijlstra, 1970), and their effect can be antagonized by chlormequat when given simultaneously (van Bragt, unpublished).

The possibility remains that chlormequat acts through its inhibitory effect on the gibberellin biosynthesis in the stage when green parts and the roots are present. As was shown in this paper, the effect of chlormequat becomes more distinct when the plant, and the highest internode in particular, has reached its final length. At that time there is a clear interaction between the growth-reducing effect of chlormequat and the duration of the 5 °C treatment. Most probably this is due to the fact that 18 weeks at 5 °C promote the growth of the highest internode more than 12 weeks at 5 °C, as can be seen in Table 3. The highest internode is the part of the stem which is the latest to continue its elongation. Its growth almost entirely depends on the presence of the flower (op den Kelder et al., 1971). Compared to the scales and the stem, the floral parts have a highly active terpene biosynthesizing system. In bulbs, the activity of this system increases with an increased duration of the low temperature treatment (Staby et al., 1972). Terpenes are gibberellin precursors, and it may be that it is the action of chlormequat on this system which contributed to the growth reduction of the highest internode.

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