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EVALUATION OF FLURPRIMIDOL EFFICIENCY IN POT CULTIVATION OF FORCED TULIPS

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Abstract. When producing bulb crops, height control is often required to obtain plants which are proportional to pot size. It regards particularly to forced tulips. An effective means of controlling plant height is the use of plant growth regulators. Research was conducted to define influence of flurprimidol on pot cultivation of forced tulips of 'Arma', 'Ile de France', 'Juan' and 'Yokohama' cultivars. Flurprimidol in concentrations of 7.5, 15.0, 22.5 and 30.0 mg·dm^{-3} was applied in the form of single and double spraying of the plants. The lowest plants with the shortest upper internodes resulted from double application of flurprimidol in concentrations of 22.5 mg·dm^{-3} 30.0 mg·dm^{-3}. The best effect in terms of inhibiting growth was achieved in case of 'Juan' and 'Arma' cultivars treated with a retardant in the above mentioned concentration. The applied dosage and frequency of application of flurprimidol are not sufficient to inhibit the growth of 'Ile de France' and 'Yokohama' tulips. It was noted that double spraying of tulips with flurprimidol in the concentration of 22.5 mg·dm^{-3} and both single and double spraying in concentration of 30.0 mg·dm^{-3} leads to the growth of the largest leaf with the smallest area index. It was also noticed that flurprimidol slows down slightly blooming of flowers and affects shortening of flower bud length.

Key words: potted tulips, plant growth retardants, Topflor

INTRODUCTION

In the past few years bulbous plants in pots have enjoyed an increasing interest from both producers and consumers. Already in December there is availability of *Tulipa*, *Narcissus* and *Hyacinthus* on the market, and the selection is completed with species such as *Crocus* and *Muscari* later in the year. Among the abovementioned species tulips are the most attractive as they are offered in variety of colors and flower forms, and their leaves often are decorative as well. Main advantage of tulips for the producers is a rather uncomplicated and short cultivation, and low requirements for warmth and

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space [Miller 2002]. The choice of tulips for pot cultivation is dependent mainly on the usefulness of the particular cultivar for this type of production, but also on the requirements of the market. Cultivars with low height, big flowers in attractive colors and decorative leaves are most wanted. Final quality of pot plants is also closely linked to the length of flowering shoots and leaves [Zalewska et al. 2010]. There have also been attempts to introduce valuable cultivars which are too high for this type of production [Startek 2003]. Growth retardants have been used for that purpose [De Hertogh 1996, Krug et al. 2003, Krug et al. 2005]. Their main function is to slow down growth of elongation cells, which is the result of gibberellins' synthesis blockage [Jankiewicz 1997].

The experiment was an attempt to adapt several interesting cultivars of tulips to pot cultivation by the application of growth retardant – flurprimidol (in preparation Topflor 015 SL) in the form of spraying the plants.

MATERIALS AND METHODS

The research which was conducted for 3 growing seasons (at the turn of 2002/2003, 2003/2004 and 2004/2005) in a greenhouse of Felin Experimental Station of University of Life Sciences in Lublin focused on four cultivars of tulips: 'Arma' (Fringed tulips), 'Ile de France' (Triumph tulips), 'Juan' (Foster's tulips) and 'Yokohama' (Single Early tulips). Tulip bulbs of circumference of 11–12 cm were used in this experiment. Prior to potting, tulip bulbs were dressed in the solution of fungicidal preparations Kaptan 50 WP in the concentration of 1.5% and Topsin M 70 WP in the concentration of 0.7%. Then they were planted at the beginning of November into pots of 7 cm diameter, top layer of plough soil collected from the field was used as medium. Average nutrient content of medium was (in $mg \cdot dm^{-3}$): $N\text{-}NO_3$ – 15, P – 95, K – 161, Ca – 520, Mg – 51. Pots with bulbs were placed in a room with air temperature of +9°C.

After 16 weeks of cooling and bulb rooting pots with tulips were taken to greenhouse and divided into two experimental groups. The first treatment of spraying with retardant – flurprimidol in concentrations of 7.5, 15.0, 22.5 and 30.0 $mg \cdot dm^{-3}$ was applied on both groups on the sixth day of forcing in the greenhouse. Second treatment, only on the second group, was applied in the same concentrations four days after the first treatment. Plants were spayed until foliage was thoroughly covered with the spray solution but the spray solution was not allowed to drop off. Plants that were not sprayed were used as control combination. During cultivation necessary treatments were conducted. Plant growth and flowering process were observed. In the moment flower buds were discolored duration of forcing period was determined, plant height was measured (along with flower bud) and length of flower bud. After the loss of decorative value the length of upper internode and length and width of leaf blade were measured (quotient of these amounts was taken as an index of largest leaf area).

The experiment was set up in the system of complete randomization. There were 20 plants in each combination and one plant was a repetition. The results were processed statistically with variation analysis for 3-factor experiments. Significant differences were marked with Tukey's test, where $p = 0.05$. Due to high repetitiveness throughout the years results were processed as 3-year average.

RESULTS AND DISCUSSION

Flurprimidol applied in this experiment did not have significant effect on the length of forcing period of examined cultivars (tab. 1). However, it was observed that the forcing period of 'Juan' cultivar lengthened along with the increase of flurprimidol concentration and spray frequency. Tulips 'Juan' treated with flurprimidol solution in concentration of 7.5 mg·dm^{-3} were forced for 20.8 days but those which were sprayed twice with retardant solution in the concentration of 30.0 mg·dm^{-3} were forced for 22 days. The lengthening of tulip forcing period after application of growth retardants was also observed by Mc Daniel [1990]. In his research the time of forcing 'Paul Richter' cultivar in a greenhouse was longer when concentration of paclobutrazol was greater. Flurprimidol applied in the concentration of 30 mg·dm^{-3} resulted in flowering of 'Prima' lilly two days later [Pobudkiewicz and Nowak 1992]. Zalewska et al. [2010] observed that treating bulbs of narcissus with retardant prior to cooling slightly delayed the flowering of the following narcissus cultivars: 'Tête-à-Tête', 'Jumbile' and 'Geranium'. According to many authors growth retardants do not influence flowering of bulbous plants. As research conducted by Startek [2003] shows, ancymidol (in the concentration of 230, 460 and 920 mg·dm^{-3}), daminozyd (4250, 8500 and 7000 mg·dm^{-3}), flurprimidol (7.5, 15.0 and 30.0 mg·dm^{-3}) and paclobutrazol (4, 8, and 16 mg·dm^{-3}) used for soaking bulbs did not affect the number of days that tulips cultivated in pots were forced. Stajszczak and Szlachetka [1990] had similar conclusions in their research on the effect of flurprimidol on the growth and flowering of 'Gander' and 'Apeldoorn' tulips. Based on own research it should be noted that maximum lengthening of forcing period of tulips in greenhouse treated with flurprimidol in comparison with control plants was a little over 1 day and applied to 'Juan' cultivar treated with flurprimidol in the concentration of 30.0 mg·dm^{-3}. Therefore, taking into account the effect of growth retardants and reaction of particular cultivar to that retardant, flowering date can be planned.

Table 1. Effect of flurprimidol on the examined tulip cultivar forcing longevity (days)

Cultivar (A)	Flurprimidol concentration (B) (mg·dm^{-3})								
	control	7.5		15.0		22.5		30.0	
		spray frequency (C)							
		1×	2×	1×	2×	1×	2×	1×	2×
'Arma'	22.0	22.9	21.8	22.2	21.9	21.9	22.2	22.0	22.4
'Ile de France'	21.0	21.0	21.0	21.3	21.8	21.4	21.9	21.4	21.8
'Juan'	20.7	20.8	21.3	21.1	21.4	21.1	21.5	21.4	22.0
'Yokohama'	19.2	19.6	20.1	19.5	20.2	19.8	20.2	19.8	20.3

$LSD_{0.05}$: A = 0.25, B = 0.29, C = 0.13, A/B = 0.76, A/C = 0.41, B/C = 0.48, A/B/C = 1.07
1× – sprayed once
2× – sprayed twice

Table 2. Effect of flurprimidol on the examined tulip cultivar height (cm)

Cultivar (A)	Flurprimidol concentration (B) ($mg \cdot dm^{-3}$)								
	control	7,5		15,0		22,5		30,0	
		spray frequency (C)							
		1×	2×	1×	2×	1×	2×	1×	2×
'Arma'	31.8 fg*	29.1 e	25.5 cd	26.8 d	25.3 cd	26.5 d	23.4 b	24.2 bc	21.0 a
'Ile de France'	42.7 r	41.3 pr	37.1 l–n	38.3 no	35.8 j–l	36.4 k–m	34.7 i–k	35.8 j–l	33.3 g–i
'Juan'	40.6 p	39.5 op	32.4 gh	34.1 h–j	29.1 e	32.2 fg	27.1 d	30.5 ef	25.8 cd
'Yokohama'	42.7 r	40.4 p	38.0 m–o	38.0 m–o	35.7 j–l	35.5 j–l	33.4 g–i	34.1 h–j	31.8 fg

* means followed by the same letter are not significantly different
$LSD_{0.05}$: A = 0.43, B = 0.51, C = 0.23, A/B = 1.33, A/C = 0.72, B/C = 0.84, A/B/C = 1.88
1× – sprayed once
2× – sprayed twice

The most important role of retardants is limiting plant growth. According to De Hertogh [1996] esthetically looking tulips offered in pots should have the height of 25–30 cm. In the research that was conducted, the lowest tulips were obtained as a result of double spraying of plant with flurprimidol in the concentration of 30 $mg \cdot dm^{-3}$ and various cultivars reacted differently to the applied retardant (tab. 2). The greatest growth inhibition was noted in case of 'Juan' cultivar (plants sprayed twice with retardant solution in the concentration of 30.0 $mg \cdot dm^{-3}$ were lower than control plants by 36.5%) and 'Arma' (reduction of height by 34%). For comparison it is worth mentioning that 'Ile de France' and 'Yokohama' tulips in the same combination were lower than non-sprayed plants by 22% and 25.5% respectively. This could be accounted for by the fact that last two cultivars were the highest among all researched and have very specific construction. 'Yokohama' is characterized by long and rolled leaves that are tightly attached to the stem, which can make it difficult to cover them well with retardant solution. The leaves of 'Ile de France' on the other hand are covered with rather strong wax deposit, which probably leads to lesser absorption of the solution. In order to evaluate usefulness of the abovementioned cultivars for pot cultivation, their reaction to the application of retardant into soil should be checked as in such cases it could be more efficient than foliar application in the form of spraying [Farnham and Hasek 1971 after Nelson and Niedziela 1998] or higher doses should be applied. Results of research conducted by Mroczko and Szlachetka [1999] show that best results in dwarfing 'Gander' and 'Apeldoorn' tulips were obtained from double application of flurprimidol in concentrations of 30 $mg \cdot dm^{-3}$ and 40 $mg \cdot dm^{-3}$.

It was noted that the applied retardant affected length of flower bud length in the phase of commercial maturity (tab. 3). Plants which were not sprayed with retardants had the longest flower buds (average 5.6 cm), whereas those that were sprayed with

flurprimidol in concentration of 15.0 mg·dm^{-3} had the shortest flower buds (5.3 cm). However, the analysis of interaction between cultivar, retardant concentration and frequency of spraying revealed that 'Juan' reacted to all examined concentrations with the strongest shortening of flower bud length (they were shorter by 0.3–0.4 cm in comparison with that of control plants) but only in case of single application. Single spraying of 'Arma' tulip with flurprimidol in the concentration of 22.5 mg·dm^{-3} resulted in the greatest shortening of flower bud length. Also 'Yokohama' sprayed once with retardant solution in the concentration of 22.5 mg·dm^{-3} and 30.0 mg·dm^{-3} had the shortest flower buds. Nonetheless, despite the negative influence of flurprimidol on this feature, the differences are so insignificant that they do not lower decorative value of the examined tulip cultivars. Weryszko-Chmielewska et al. [2005] had similar conclusions and in addition they noticed that in 'Carlton' tulips, which are characterized by a great number of perianth segments, the retardant caused even greater number of perianth segments. Laskowska et al. [1998] state that chlorocholine chloride applied in high concentration (1% and 1.5%) in the form of spraying resulted in increased length of 'Lustige Witwe' tulips' flower bud. Similar influence of paclobutrazol in concentration of 100 mg·dm^{-3} on the lengthening of 'Lustige Witwe' tulip's flower bud was observed by Laskowska and Durlak [1995]. Flurprimidol applied in concentrations of 10–40 mg·dm^{-3} had no effect on the length of perianth leaves of 'Gander' and 'Apeldoorn' tulips cultivated in pots [Mroczko and Szlachetka 1999].

Table 3. Effect of flurprimidol on the examined tulip cultivar flower bud length (cm)

Cultivar (A)	Flurprimidol concentration (B) (mg·dm^{-3})								
	control	7.5		15.0		22.5		30.0	
		spray frequency (C)							
		1×	2×	1×	2×	1×	2×	1×	2×
'Arma'	5,2 c–e*	5.1 b–d	5.0 a–c	5.0 a–c	5.0 a–c	4.9 ab	5.0 a–c	5.0 a–c	5.0 a–c
'Ile de France'	4,9 ab	4.9 ab	5.0 a–c	4.8 a	4.8 a	4.9 ab	5.0 a–c	4.9 ab	4.9 ab
'Juan'	6,4 ij	6.1 h	6.5 j	6.0 h	6.2 hi	6.1 h	6.2 hi	6.1 h	6.2 hi
'Yokohama'	5,7 g	5.4 ef	5.6 fg	5.4 ef	5.4 ef	5.3 de	5.4 ef	5.3 de	5.6 fg

* means followed by the same letter are not significantly different
$LSD_{0.05}$: A = 0.06, B = 0.07, C = 0.03, A/B = 0.17, A/C = 0.09, B/C = 0.11, A/B/C = 0.25
1× – sprayed once
2× – sprayed twice

Tulips in pots should have short internodes. Especially the upper internode should be shortened [Mroczko and Szlachetka 1999]. In the research, the shortest upper internode (tab. 4) was noted in combinations, where retardant was applied twice in concentration of 22.5 mg·dm^{-3} and 30.0 mg·dm^{-3} (by 29.2% and 33% in comparison with control plants). The influence of flurprimidol on this trait depended also on the cultivar.

Table 4. Effect of flurprimidol on the examined tulip cultivar upper internode length (cm)

Cultivar (A)	Flurprimidol concentration (B) (mg·dm^{-3})								
	control	7.5		15.0		22.5		30.0	
		spray frequency (C)							
		1×	2×	1×	2×	1×	2×	1×	2×
'Arma'	15,7 j–m*	16.3 k–n	14.1 f–j	14.6 f–k	13.4 e–i	14.5 f–k	11.8 b–e	13.1 e–g	10.9 b–d
'Ile de France'	21,7 s	19.9 rs	18.7 pr	18.3 o–r	17.4 m–p	17.8 n–p	16.6 l–o	16.6 l–o	15.3 i–l
'Juan'	13,2 e–h	12.8 d–f	10.0 b	12.0 c–e	7.6 a	10.9 b–d	6.6 a	10.4 bc	6.3 a
'Yokohama'	16,6 l–o	15.3 i–l	14.8 g–l	15.1 h–l	14.6 f–k	13.7 e–i	12.7 d–f	14.6 f–k	11.8 b–e

* means followed by the same letter are not significantly different
$LSD_{0.05}$: A = 0.44, B = 0.52, C = 0.24, A/B = 1.34, A/C = 0.73, B/C = 0.86, A/B/C = 1.92
1× – sprayed once
2× – sprayed twice

Table 5. Effect of flurprimidol on the examined tulip biggest leaf area index (cm^2)

Cultivar (A)	Flurprimidol concentration (B) (mg·dm^{-3})								
	control	7.5		15.0		22.5		30.0	
		spray frequency (C)							
		1×	2×	1×	2×	1×	2×	1×	2×
'Arma'	159.8	156.8	142.6	147.1	137.0	145.8	134.6	134.7	129.3
'Ile de France'	175.0	174.0	171.8	168.9	160.8	161.7	158.8	157.4	155.0
'Juan'	168.2	168.6	162.2	163.1	156.5	157.1	151.7	152.3	145.4
'Yokohama'	210.1	198.2	184.8	192.2	187.4	177.7	170.9	170.0	166.1

$LSD_{0.05}$: A = 3.48, B = 4.13, C = 1.88, A/B = 10.73, A/C = 5.81, B/C = 6.77, A/B/C = 15.18
1× – sprayed once
2× – sprayed twice

'Juan' reacted with the strongest shortening of top internode, and value of the trait was lower compared to control by respectively 42.4%, 50% and 52.3% in case of plants double-sprayed with flurprimidol in concentration of 15.0 mg·dm^{-3}, 22.5 mg·dm^{-3} and 30.0 mg·dm^{-3}. The influence of retardants on the internode length was emphasized in other scientific studies. Weryszko-Chmielewska et al. [2005] in their study of tulip reaction to flurprimidol application obtained greatest length reduction in case of bottom internodes. Test results of Mroczko and Szlachetka [1999] indicate that tulips treated with flurprimidol had clearly shorter internodes. They obtained most shortened inter-

nodes in combination where plants were sprayed once with retardant in concentration of 40 mg·dm^{-3}.

An important trait for the decorative value of tulips is size of leaves. The lowest value of the biggest leaf area index (tab. 5) was noted in combinations where flurprimidol was applied twice in concentrations of 22.5 mg·dm^{-3} and once and twice in concentration of 30.0 mg·dm^{-3}. However, the examined cultivars differed significantly in the size of the biggest leaf. 'Arma' had the smallest one and in control combination the biggest leaf area index equaled 159.8 cm^2. As the result of double application of retardant in concentration of 22.5 mg·dm^{-3} and 30.0 mg dm^{-3} it shrank down to 134.6 cm^2 and 129.3 cm^2 respectively. In case of 'Yokohama' which was characterized by the greatest index of examined tulips' biggest leaf area, its greatest reduction was observed as the result of spraying with retardant. In combinations where flurprimidol was used in concentrations of 22.5 mg·dm^{-3} biggest leaf area index was decreased by 17%, whereas in concentration of 30.0 mg·dm^{-3} by 20%. Available literature lacks information concerning changes in leaf area of bulbous plants as effect of retardants application, but there is some data about their effect on the length of leaf blade. Mroczko and Szlachetka [1999] obtained significantly shortened leaves of 'Gander' and 'Apeldoorn' tulips as a result of foliar application of flurprimidol in concentration of 40 mg·dm^{-3} and application to soil in the dose of 2 mg/pot. Length of leaves determines height of Narcissus cultivated in pots. As Zalewska and Leszczyńska [2002] inform, in case of plants from bulbs soaked in solution of flurprimidol, shortening of the longest leaf length equaled, depending on concentration, from 9.5% to 26%. Flurprimidol had significant effect on the shortening of leaf length of 'Flower Drift' Narcissus [Startek and Zawadzińska 2001] and 'Tete a Tete' and 'Carlton' [Krzymińska 2001] cultivated in pots.

CONCLUSIONS

1. The lowest plants with the shortest upper internodes were obtained as a result of double application of flurprimidol in the concentrations of 22.5 mg·dm^{-3} and 30.0 mg·dm^{-3}. The best result of growth inhibition was obtained in case of cultivars 'Juan' and 'Arma'. The applied doses as well as frequency of flurprimidol application are not sufficient to inhibit growth of 'Ile de France' and 'Yokohama' tulips.

2. Flurprimidol does not lower decorative value of tulip flowers, it does not significantly lengthen the forcing period in greenhouse, therefore it can be used to inhibit potted tulip growth. Plant reaction to the retardant depends on the cultivar.

3. Double spraying of forced potted tulips with flurprimidol in the concentration of 22.5 mg·dm^{-3} and single and double in the concentration of 30.0 mg·dm^{-3} results in production of the biggest leaf with the lowest area index.

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OCENA SKUTECZNOŚCI FLUROPRIMIDOLU W UPRAWIE DONICZKOWEJ PĘDZONYCH TULIPANÓW

Streszczenie. W przypadku produkcji gatunków cebulowych kontrolowanie wysokości roślin jest często niezbędne do uzyskania okazów proporcjonalnych do wielkości doniczki. Dotyczy to zwłaszcza tulipanów. Skutecznym sposobem regulowania wysokości roślin

jest stosowanie regulatorów wzrostu. W doświadczeniu badano wpływ fluroprimidolu w uprawie doniczkowej pędzonych tulipanów odmian ‘Arma’, ‘Ile de France’, ‘Juan’ oraz ‘Yokohama’. Fluroprimidol w stężeniach 7,5; 15,0; 22,5 oraz 30,0 mg·dm^{-3} zastosowano w formie jedno- i dwukrotnego opryskiwania roślin. Najniższe rośliny o najkrótszych szczytowych międzywęźlach uzyskano w wyniku dwukrotnej aplikacji fluroprimidolu w stężeniach 22,5 mg·dm^{-3} oraz 30,0 mg·dm^{-3}. Najlepszy efekt zahamowania wzrostu uzyskano w przypadku odmian ‘Juan’ oraz ‘Arma’ traktowanych retardantem w wyżej wymienionych stężeniach. Zastosowane dawki i częstotliwość aplikacji fluroprimidolu nie są wystarczające do ograniczenia wzrostu tulipanów ‘Ile de France’ i ‘Yokohama’. Zaobserwowano, że dwukrotne opryskiwanie tulipanów fluroprimidolem w stężeniu 22,5 mg·dm^{-3} oraz jedno- i dwukrotne w stężeniu 30,0 mg·dm^{-3} powoduje wytworzenie największego liścia o najniższym wskaźniku powierzchni. Stwierdzono także, że fluroprimidol opóźnia nieznacznie kwitnienie roślin oraz wpływa na skrócenie długości pąka kwiatowego.

Słowa kluczowe: tulipany w doniczkach, retardanty, Topflor

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