Defining Safe Ethylene Levels for Long Term Storage of Tulip Bulbs

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Abstract

The maximum ethylene level that can be permitted in storage rooms, without causing damage to tulip bulbs, is not exactly known. Therefore, a zero-tolerance for the presence of ethylene during storage of tulip bulbs is common practice. This results in excessive ventilation and coherent large energy costs. It is questioned whether this is always necessary. In different phases of the storage period the critical levels of ethylene were determined. Bulbs of eight economically important cultivars ('Apeldoorn', 'Christmas Marvel', 'Leen van der Mark', 'Monte Carlo', 'Negrita', 'Prominence', 'White Dream' and 'Yokohama') were exposed to various ethylene levels. In the first experiment bulbs were exposed to ethylene for two days shortly after harvest. Only in the cultivar 'Apeldoorn' this resulted in gummosis. In two subsequent experiments later during storage, bulbs were exposed to various ethylene levels during five weeks. Bulbs were investigated on visible internal damage, flower quality and bulb production. Damage depended on applied ethylene level, cultivar and period of storage. Research will be continued to define tolerable ethylene levels, taking into account the cultivar and the developmental stage of the bulb.

INTRODUCTION

The presence of ethylene in storage rooms can cause serious damage to tulip (*Tulipa gesneriana*) bulbs. Important sources of ethylene are bulbs infected with *Fusarium oxysporum f.*sp. *tulipae* (Kamerbeek et al. 1976). Ethylene can have various effects on tulip bulbs including gummosis (Kamerbeek et al. 1971), bud necrosis (De Munk 1972), flower bud blasting (De Munk 1973) and excessive splitting (De Munk et al. 1992). Gummosis (secretion of polysaccharides) can occur shortly after lifting if bulbs are exposed to ethylene (Kamerbeek et al. 1971). Bud necrosis is often associated with mites that penetrate the flower bud, if the buds are open at their tips. Open buds can be caused by ethylene shortly after lifting. In contrast to gummosis and bud necrosis, the susceptibility for flower bud blasting and excessive splitting is largest later during storage.

To avoid damage in commercial storage, the presence of ethylene is not tolerated. Therefore accumulation of ethylene is prevented by excessive ventilation. Consequently there are large energy costs for ventilating and controlling temperature. Low levels of ethylene don't always lead to damage. However, the maximum ethylene level that could be permitted in storage rooms without causing damage to tulip bulbs, is not exactly known.

Experiments have been started to define the critical ethylene levels during different phases of bulb development in storage. This could lead to a reduction in energy costs during the storage of tulip bulbs.

MATERIALS AND METHODS

Plant Material

Tulip bulbs from commercial stocks were stored at 20 °C after harvesting in July 1999. Eight economically important cultivars were selected: 'Apeldoorn', 'Leen van der Mark', 'Monte Carlo', 'Negrita', 'Prominence', 'White Dream', 'Yokohama' (bulbs of these cultivars with circumference 11-12 cm) and 'Christmas Marvel' (circumference 10-11 cm).

Gummosis

To study ethylene effects on gummosis, an experiment was done in August 3-5th 1999 shortly after harvest. During these two days, samples of twenty bulbs were placed in 65 L containers in a dark temperature controlled room at 20 °C.

These containers were connected to a flow through system in which N_2, O_2 and CO_2 (pure gases) and ethylene (N_2 as balance gas) were mixed using mass flow controllers. Total flow rate was 400 mL.min^{-1}. The applied O_2 and CO_2 partial pressures were comparable to normal air (respectively 21 kPa and 0 kPa). The relative humidity inside the containers was 60-70%. Four ethylene levels were applied: 0.003 Pa (30 ppb), 0.03 Pa (300 ppb), 0.1 Pa (1000 ppb) and 0.3 Pa (3000 ppb). Three replicates were used per ethylene level. The ethylene levels were checked regularly by gas chromatography. After the period of two days the number of bulbs with gummosis (gum blisters or extruded gum) were counted. Subsequently bulbs were stored for 19 days under ethylene free conditions at 20 °C (humidity not controlled).

Flower Bud Blasting and Excessive Splitting

To study ethylene effects on flower bud blasting, bulbs were exposed to various ethylene levels during five weeks from August 25th till September 28th 1999. Other bulbs from the same stock were exposed to various ethylene levels from October 15th till November 18th 1999. During the ethylene treatments, bulbs were placed in containers at 20 °C and connected to the flow through system as described for the gummosis experiment. Bulbs of the cultivars 'Apeldoorn', 'Leen van der Mark' and 'Monte Carlo' were exposed to four ethylene levels (0.003, 0.03, 0.1 and 0.3 Pa). Bulbs of the cultivars 'Negrita', 'Prominence', 'White Dream' and 'Yokohama' were exposed to two ethylene levels (0.03 and 0.1 Pa). Samples consisted of 60 bulbs. Three replicates were used per ethylene level. Controls bulbs were left outside the flow through system.

To compare the effect of ethylene on flower bud blasting between the two periods, 20 bulbs from each sample of 60 bulbs were used to study internal damage (first week of December 1999). Bulbs were cut into halves and floral buds were visually checked for damage. The remaining 40 bulbs of each sample of the first treatment period were used to study flower quality in the greenhouse after forcing. The remaining 40 bulbs of each sample from the second treatment period were planted on the field (experimental garden of the Bulb Research Centre in Lisse) to study bulb production.

Statistical Analysis

Analyses of significant differences were done by analysis of variance (ANOVA) with the statistical package Genstat. When significant differences were found, comparisons between pairs of data were made using the least significant differences between means (LSD) at a significance level of 95%.

RESULTS

Gummosis

Only bulbs of cultivar 'Apeldoorn' significantly developed gummosis as a reaction to ethylene (Table 1). Severe excretions of gum were observed. The percentage of bulbs with gummosis depended on the applied ethylene level. No damage occurred at

0.003 Pa ethylene. The percentage of bulbs with gummosis increased during subsequent storage under ethylene free conditions. At none of the cultivars, internal damage was found.

Flower Bud Blasting

During the two periods of ethylene treatment later during storage, no gummosis occurred any more.

After treatment with various ethylene levels during the first period, only bulbs of the cultivar 'White Dream' showed clear visible symptoms of flower bud blasting. In this cultivar, the 0.1 Pa ethylene treatment led to flower bud blasting in 18% of the total number of bulbs (Table 2, period 1). The susceptibility to flower bud blasting was larger in period 2 (Table 2, period 2). There were large differences between cultivars. Bulbs of the cultivars 'Apeldoorn', 'Christmas Marvel' and 'Yokohama' were most susceptible. Bulbs of the cultivar 'Leen van der Mark' showed very little damage. These differences were confirmed by the development of flowers after planting (data not shown).

Some ethylene effects only appeared after forcing. Ethylene treatment of bulbs of 'Apeldoorn' during period 1 significantly ($P<0.05$) induced blasted stamens (Table 3). No damage was found at 0.003 Pa while a level of 0.03 Pa showed a significant increase in blasted stamens.

Excessive Splitting

There were clear differences between cultivars regarding the effect of ethylene on splitting (Table 4). Only bulbs of the cultivars 'Christmas Marvel' and 'Yokohama' were affected by the ethylene concentration of 0.03 Pa. Bulbs of 'Apeldoorn' and 'Monte Carlo' were affected by 0.1 Pa. Total cluster weight was never positively influenced by ethylene treatment.

DISCUSSION

In the past, research on critical ethylene levels was often done on bulbs of the cultivar 'Apeldoorn' (for instance De Munk et al. 1992). Currently other cultivars are economically more important. In the presents experiments it was shown that 'Apeldoorn' was most susceptible for ethylene effects in comparison with the other cultivars. Practically, during storage of bulbs of relatively tolerant cultivars a higher ethylene level can be permitted than during storage of a more susceptible cultivar like 'Apeldoorn'.

Current advice for ventilation of tulip storage rooms is based on a critical ethylene level of 0.01 Pa (0.1 ppm) (De Munk and Duineveld 1986). In the present experiments it was shown that under certain circumstances levels above 0.01 Pa could be tolerated. Besides on cultivar, this depended on the developmental stage of the bulb as was shown by the big difference in damage after different periods of ethylene treatment (Table 2). This clearly demonstrated that there are good opportunities for reducing ventilation during some periods of storage. This requires accurate measurement of ethylene, which is possible with modern equipment.

Conclusions for practical situations cannot be drawn based on one-year results. However, the present results indicated that there are good opportunities for reducing ventilation and coherent storage costs. Research will be continued to define safe ethylene levels, taking into account the cultivar, the developmental stage of the bulb and the duration of exposure to ethylene.

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Tables

Table 1. The mean percentage of bulbs with gummosis.

Ethylene (Pa)	Apel-doorn	Christmas Marvel	Leen vd Mark	Monte Carlo	Negrita	Promi-nence	White Dream	Yoko hama
after 2 days of gas treatment:								
0.003	0	0	0	0	0	0	0	0
0.03	7	0	0	0	0	2	0	0
0.1	2	0	0	0	2	0	0	0
0.3	35	0	0	0	0	0	2	0
after 2 days of gas treatment + 19 days under ethylene free conditions:								
0.003	0	0	0	0	0	0	0	0
0.03	8	0	0	0	0	2	0	2
0.1	18	0	0	0	2	0	0	0
0.3	50	0	0	0	0	0	2	2

Table 2. The mean percentage of bulbs with visible symptoms of flower bud blasting in bulbs.

Ethylene (Pa)	Apel-doorn	Christmas Marvel	Leen vd Mark	Monte Carlo	Negrita	Promi-nence	White Dream	Yoko hama
period 1 (August 25th - September 28th):								
0.03	0	0	*	0	0	0	0	0
0.1	0	0	*	0	0	0	18	0
period 2 (October 15th - November 18th):								
0.03	7	17	0	16	0	0	0	8
0.1	97	88	3	65	21	52	58	98

* Bulbs of the cultivar 'Leen van de Mark' were removed from the experiment due to large number of fusarium infected bulbs.

Table 3. The mean percentage of flowers with blasted stamens after forcing of 'Apeldoorn' bulbs, treated with various ethylene concentrations during period 1 (August 25th - September 28th). Means within the column followed by different letters are significantly different (P<0.05).

Ethylene (Pa)	% flowers with blasted stamens
Control	1 a
0.003	2 a
0.03	26 b
0.1	62 c
0.3	73 c

Table 4. The mean percentage of bulb clusters with excessive splitting (main bulb < 50% of total cluster weight). Means within each column followed by different letters are significantly different (P<0.05).

Ethylene (Pa)	Apel-doorn	Christmas Marvel	Leen vd Mark	Monte Carlo	Negrita	Promi-nence	White Dream	Yoko hama
0	65 a	13 a	3 a	20 a	36 a	50 a	62 a	35 a
0.03	68 a	52 b	14 a	16 a	32 a	55 a	56 a	60 b
0.1	83 b	80 c	16 a	46 b	47 a	68 a	74 a	73 c