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INTRODUCTION — In the US and Canada, the current utilization of tulips as cut flowers is less than that of potted tulips. We believe that this in part is due to a lack of information on the postharvest development of cut tulips. In a series of articles, Rogers (15, 16) emphasized the need for research on postharvest handling of cut flowers. Thus, we have endeavored to assem-

by Maarton Bonschop and A. A. Do Hortogh An analysis of the post-harvest characteristics of cut tulips

the second part of a study of tulips as cut flowers, including information on total growth, the growth of the last internode and changes in flower size.

ble pertinent information on the various postharvest characteristics of cut tulips.

In a preliminary study the emphasis was placed on flower life and flower shape (7). In this paper, we have expanded the information on those characteristics and have included information on the total growth of the cut tulip, growth of the last internode and the changes in flower size at various time intervals during their postharvest life.

STABY - OS

MATERIALS AND METHODS

CULTURAL PROCEDURES — The tulips (1968-69 season) used in these studies (tables 1 and 2) were forced following the procedures outlined in the "Bulb Forcers'

Table 1. Postharvest degrees Fahrenhelt.	flower life	and flo	wer sh	ape of tu	lips at 75					7	
	Average	Flowe	r shape	(degroes)	Classi-		Avergen	Flows	r shape	(degroes)	Classi-
Class, cultivar	flower life	24 hrs	72 hrs	Last day	Acation	Class, cultivar	flower life	24 hrs	72 hrs	Last day	Acation
•	(days)				at 72 hrs		(days)				at 72 hrs
	•••					Demeter	56	13	28	32	CUP
Single Early tullps						Dix' Favourite	5 to 6	23	34	44	semi-cup
Bellona	5 to 6	15	37	46	semi-cup	Gander	4 to 5	28	38	45	somi-cup
Thule	5 to 6	26	35	39	semi-cup	Golden Age	> 6	15	26	25*	cup
Tommy	5 to 6	20	38	54	semi-cup	Insurpassable	5 to 6	10	16	22	cup
						Mamasa	5 to 6	27	39	41	semi-cup
Mendel tulips				• •		Most Miles	4 to 5	21	41	45	semi-cup
Apricot Beauty	4 to 5	34	59	96	open	Paul Richter	5 to 6	23	34	49	semi-cup
Athleet	5 to 6	24	40	63	semi-cup	Pink Attraction	> 6	15	24	36	cup
Bing Crosby	4 to 5	16	25	32	cup	Pink Supreme	5 to 6	17	26	30	cup
Golden Olga	4 to 5	17	31	39	semi-cup	Queen of Bartigons	> 6	15	25	37	CUD
Golden Triumph	· > 6	15	28	53	cup	Queen of Night	5 to 6	12	17	17*	cup
Krelage's Triumph	4 to 5	15	33	46	semi-cup	Red Pitt	5 to 6	14	23	27	CUP
Pink Trophy	5 to 6	22	33	42	semi-cup	Reveil	5 to 6	18	29	36	CUD
Piquante	5 to 6	9	28	43	cup	Rose Copland	> 6	8	13	20	CUD
Van der Eerden	> 6	18	31	40	semi-cup	Vredehof	5 to 6	12	20	34	CUD
	-				•	Wim van Est	5 to 6	10	19	19*	CUP
Triumph tuline									•••		
Blondo	5 10 4	12	22	24		Single Late tulips					
Caston	5 10 0	20	24	40	cop	Golden Harvest	5 to 6	7	13	26	CU.D
Crorer December Mold	5 10 0	20	12	14	sem-cop						
Breaming Mara	5 10 0	27	13	10	cop	Darwin Hybrid tulios					
Emmy Peeck	5 10 0	2/	47	33	open	Apeldoorn	3 to 4	21	37	43	semi-cup
FIFST LODY	3 10 0	14	23	2/	cup	Beauty of Apeldoorn	3 to 4	15	33	79	somircup
Hibernia	5 10 0	15	25	2/	cup	/ Empire State	4 to 5	14	43	52	temi-cup
K & M's Iriumph	5 10 0	13	2/	41	eup	General Fisenhower	3 to 4	28	A 1	50	somi-cup
Kornetoros	5 to 6	8	21	35	cup	Golden Apeldoorn	3 to 4	23	A 1		iomi-cup
Levant	5 to 6	12	23	29	cup	Gudoshnik	4 10 5	21	34	48	temi-cup
Madame Spoor	5 to 6	9	16	14	cup	lewel of Spring	3 10 4	10	24	40	semi-cop
Merry Widow	5 to 6	8	17	23	cup	London	3 to 4	23	74	34	semi-cup
Mirjoran	5 to 6	16	27	31	cup	Oxford	3 10 4	22	34	40	somi-cup
Olaf	5 to 6	19	40	65	semi-cup	President Kennedy	4 to 5	18	21	51	sami-cup
Pox	2 6	15	22	27	cup	Stringd Apaldoorn	4 to 4	24	30	57	semi-cup
Peerless Pink	> 6	11	19	28	cup	Combon chergoon	- 10 5	~~	90		*******COD
Preludium	5 to 6	15	25	39	cup	Liby-flowering tuling					
Princess Beatrix	5 to 6	22	40	67	semi-cup	Aladdin		22	50	79	
Prominence	4 to 5	14	25	28	cup	Liloc Time	5	24	24	47	open emi-m-
Purple Stor	> 6	7	13	18	cup	Maziette	5 6 6	25	45	47+	зашнсль
Roland	5 to 6	15	27	23*	cup	Maytime		10	19		open
Sunray	5 to 6	12	40	52	semi-cup	Queen of Shehe		24	72	31	CUP
Topscore	5 to 6	22	39	66	semi-cup	Pad Shina	5100	11	73	63	
						White Triumahata	4 4 4	10	30 24	41	semi-cup
Darwin tulips						while momphotor	5 10 0	17	30	41	чөтч-сор
Atilia	> 6	12	19	28	CUD	Parrot tulips					
Cantor	5 to 6	14	20	22	ແມ່ນ	Comet	4 to 5	19	55	85	0000
Copland's Favourite	> 6	8	13	15	¢ub	Karel Doorman	5 to A	25	44	74	samicun
Cooland's Purple	ŚĂ	9	15	22	cup	"Indicates that the ne	tals of the	flower	reflex	ad lower	by during
Cooland's Record	<u>S</u> ā	B	15	22	cup	the final phase of som					.,

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Handbook" (6) and "The Dutch Bulb Manual" (9). A complete description of the cultivars can be found elsewhere (4, 14). The flowers were used at their period of maximum availability (9).

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Flowers were removed from the forcing flats at the bud stage (first sign of color) with the bulb left attached and stored dry in an upright position at 35 degrees Fahrenheit (5). When 12 to 14 flowers of a given cultivar were accumulated, the bulbs were removed, and the tulips were bunched, wrapped in paper and stored dry in a horizontal position at 35 degrees (8) for 72 to 120 hours. This length of time was used to simulate a time of transport.

When a study was initiated, the flowers were removed from the refrigerator and taken to a 75-degree



Figure 1. Schematic diagram showing representative shapes of cup, semi-cup and open tulip flowers.

room, approximating that of an average American home. Because the tulip is unaffected by the source of light (1), the flowers received no natural light. They were subjected to continuous artificial light supplied by standard 40-watt, coolwhite fluorescent tubes.

The blooms were divided into three replications of four flowers each. The flowers were subsequently recut, and the initial data were recorded (tables 1 and 2). The tulips were then placed in a vase containing 71-degree tap water. During the study the water was never replaced, only refilled as necessary. DEVELOPMENTAL CHARACTERISTICS OBSERVED AND RECORDED

Linkin Arrive Less Totrai Opposite Opposite <thopposite< th=""> <thopposite< th=""> <thopposit< th=""><th rowspan="2">Class, cuttivor</th><th rowspan="2">Total plant growth (cm)</th><th rowspan="2">Growth last internode (cm)</th><th colspan="3">Growth of flower</th><th>(cm)*</th><th>Closs, cultiver</th><th>Total plant</th><th>Growth last</th><th colspan="3">Growth of Rower (cm)</th><th>(08)*</th></thopposit<></thopposite<></thopposite<>	Class, cuttivor	Total plant growth (cm)	Growth last internode (cm)	Growth of flower			(cm)*	Closs, cultiver	Total plant	Growth last	Growth of Rower (cm)			(08)*	
Single Early fullps Demeter 20 9 5.0 6.0 7.5 2.3 Bellon 17 9 5.5 6.0 7.0 1.5 Dirk' favorite 13 6 5.0 6.0 7.5 2.3 Thule 14 11 6.5 7.0 0.5 1.5 Gander 17 11 6.0 6.5 7.3 1.5 Anded Milps Imarposcible 16 10 5.0 6.0 7.0 8.0 2.0 Pluk Miles 17 12 6.0 7.0 8.0 2.0 Pluk Miles 17 12 6.0 7.0 8.0 2.0 Pluk Miles 17 13 6.0 7.0 2.0 Pluk Miles 17 14 3.0 6.0 7.0 2.0 Golden Triumph 14 12 5.0 6.0 7.0 2.0 Reserval 13 8 3.0 5.3 7.0 2.0 Golden Triumph 11 <t< th=""><th>longth</th><th>24 hrs</th><th>day</th><th>growth</th><th></th><th>growm (cm)</th><th>internocie (cm)</th><th>length</th><th>24 hrs</th><th>day</th><th>growth</th></t<>				longth	24 hrs	day	growth		growm (cm)	internocie (cm)	length	24 hrs	day	growth	
Bellenci 17 9 5.5 6.0 7.0 1.5 Dirk Favorite 13 6 5.5 6.0 7.0 1.5 Thule 14 11 6.5 7.0 8.0 1.5 Gender 17 11 6.0 6.5 7.3 1.5 Tommy 15 10 5.0 6.0 7.0 2.0 Gelden Age 21 11 5.0 6.0 7.0 2.5 Arriset Beauty 12 7 6.0 7.0 9 3.0 Mamese 10 8 6.0 7.0 2.5 Golden Flumph 14 12 5.5 6.0 7.5 2.0 Pluk Krinctinn 19 14 5.0 5.5 7.5 2.0 Queen of Night 15 15 5.0 7.5 2.0 Queen of Reight 15 15 5.0 7.5 2.0 Queen of Reight 15 15 5.0 7.5 1.5 Reight 15 15	Single Early tulips							Demeter	20	9	5.0	6.0	7.5	2.5	
	Bellona	17	9	5.5	6.0	7.0	1.5	Dix' Favorite	13	6	5.5	6.0	7.0	1.5	
Tommy 15 10 5.0 6.0 7.0 2.0 Colden Age 21 11 5.3 5.7 5.2 5.0 Apricet Beachy 12 7 6.0 7.0 9.0 3.0 Marmens 10 8 6.0 7.0 2.0 Arbiest Beachy 13 6 6.0 6.5 8.0 2.0 Marmens 10 8 6.0 7.0 8.5 2.3 Golden Olge 15 11 5.5 6.0 7.5 2.0 Pink Atrication 19 14 5.0 6.0 7.0 2.0 Golden Triumph 14 12 5.5 6.0 7.0 1.3 Queen of Karijons 18 13 5.0 6.0 7.0 2.0 Friquente 11 2.5 6.0 7.0 2.0 Red Pirit 15 13 5.0 6.0 7.0 2.0 Friquente 12 12 6.0 5.0 7.0	Thule	14	11	6.5	7.0	8.0	1.5	Gander	17	11	6.0	6.5	7.5	1.5	
Insurportable 16 10 5.0 6.0 7.0 7.2 7.3 Apricot Beouty 12 7 6.0 7.0 9.0 3.0 Marmans 10 8.0 7.0 8.2 Bing Crasby 13 6 6.0 7.0 1.5 6.0 7.5 2.0 Plink Attraction 19 14 5.0 6.0 7.0 2.2 Golden Trumph 14 12 5.5 6.0 7.5 2.0 Plink Attraction 19 14 5.0 6.5 7.0 2.1 Golden Trumph 14 10 5.0 6.0 7.0 2.0 Rule at Trigons 18 15 5.0 5.7 2.0 Finu Trophy 16 10 5.0 6.0 7.0 2.0 Rule at Trigons 18 15 5.0 7.0 2.0 Figurents 12 6.0 7.0 8.0 2.0 Rese Capland 12 6.0 7.0 2.0 <td>Tommy</td> <td>15</td> <td>10</td> <td>5.0</td> <td>6.0</td> <td>7.0</td> <td>2.0</td> <td>Golden Age</td> <td>21</td> <td>11</td> <td>5.5</td> <td>6.5</td> <td>7.5</td> <td>2.0</td>	Tommy	15	10	5.0	6.0	7.0	2.0	Golden Age	21	11	5.5	6.5	7.5	2.0	
	Mandal Milton							Insurpassable	16	10	5.0	6.0	7.5	2.5	
	Aminat Tonps	19	-	4.0	7.0	~ ~	2.0	Mamasa	10	8	6.0	7.0	8.0	2.0	
Ammeer 18 13 5.2 0.0 7.0 1.3 Paul Richer 14 11 5.0 6.0 7.0 2.0 Golden Oiga 15 11 5.5 6.0 7.5 2.0 Pink Attraction 19 14 5.0 6.0 7.0 2.0 Golden Tiumph 15 11 5.5 6.0 7.5 2.0 Pink target at the stand at the stan	Apricor becury	14		0.0	7.0	70	3.0	Most Miles	17	12	6.0	7.0	8.5	2.5	
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	Copland's Record	12	6	5.0	6.0	7.0	2.0	*2.5 cm oquals 1 Inch.			- • -				

rigerator and taken to a 75-degree three rep

Keeping quality. Various senescent characteristics were observed.

(a) Flaring of the petals. Flowers were discarded when the petals flared or reflexed downward to the extent that light could be seen along the entire length of the individual petals.

(b) Discoloration. This characteristic included such things as drying up or browning of the petals or a large deviation from their normal color. Deviations from the normal color range were measured using a color reflectance meter.

(c) Petal drop. Some cultivars exhibit no obvious characteristics of senescence, but ultimately their petals drop during the process of senescence.

(d) Shaking test. The unnatural petal drop produced by shaking the flower stem. This simulates movement in the home.

(e) Bending of the stem. A natural, stiff, upright stem is a definite attribute to any cut flower. When an individual flower bent below the horizontal plane, it was discarded.

The keeping quality of cut tulips was classified as follows: (a) Keepin quality three to four days: Poor. (b) Keeping quality four to five days: Fair. (c) Keeping quality five to six days: Good. (d) Keeping quality greater than six days: Excellent.

Flower shape. The shapes of the flowers were recorded daily. A schematic diagram of the shapes is presented in figure 1. They were classified as follows: (a) Cup: Flower has the petals remaining in an upright position parallel to the flower stalk (less than 30-degree angle). (b) Semi-cup: Flower has the petals open at 31 to 45-degree angle to flower stalk. (c) Open: Flower has the petals open at an angle greater than 45 degrees.

Flower size. Each flower was measured daily, from the bud stage until discarded. The outer petal surface, from its tip to the point of attachment to the floral stalk, was measured.

The growth of the last internode and whole plant. The tulip continues to grow after cutting. The last internode, which is that part of the stem between the upper leaf and the flower, was measured daily.

The growth of the total plant included the growth of the flower as well as the stem.

Water uptake. Six flowers of each tulip variety were chosen randomly, and each was placed in a graduated cylinder. The rate and amount of water uptake were recorded during the development of each flower. The water in the cylinders was never changed, only refilled as necessary.

Other data. In addition to the characteristics mentioned, a record was kept of the time and the weather conditions which prevailed when the tulip flowers were harvested. In the laboratory, a record was kept of the type of cut used for recutting the stems. Namely, whether the stem was cut at an angle or square.

RESULTS

Tulips, with few exceptions, will last at least five days when placed in a room at 75 degrees (table 1). The notable exception is the Darwin Hybrid class, which averaged only three to four days and thus has limited potential in our homes. It is interesting that this class of tulips is popular in Europe at the present time, but, as Hekstra (12) has reported, the life of the tulip is temperature dependent. He found that the lower the temperature, the longer the flower life. Thus in Europe, where central heating is not widespread and the homes are naturally cool, these cultivars are acceptable.

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Within a given class of tulips, we observed considerable variability in flower shape (table 1). After 24 hours, the tulip flower undergoes a transformation from the bud stage of development to full flower. We noted that most tulips become cup-shaped in this time period. On the other hand, after 72 hours considerable change was observed in many cultivars. As the flowers progressed toward senescence, we again saw varying changes. In some cases such as Athleet, a complete transition from cup to open was observed. Sometimes the petals reflexed inward during the last stages of senescence, eg, Roland. For practical purposes, the 72-hour stage of development can be used as the expected flower shape.

It should be noted that the shape of the tulip flower is a function of temperature (2, 3, 10, 11, 13, 17). It has been found that the lower the temperature the more cup-shapedthe flower will become (11). In addition, fully developed tulip flowers will reflex when moved from a lower to a higher temperature (10). Many florists have observed this



Figure 2. The 24-hour water uptake patterns for Apeldoorn and Gudoshnik tulip cultivars.



Figure 3. Cumulative 96-hour water uptake patterns for Apeldoorn and Gudoshnik tulip cultivars.

when they moved a design piece from a refrigerator to a warm room. Remember that the tulip flower will assume its normal flower shape (table 1) after about two to four hours of conditioning at room temperature.

An important point to note in table 2 is that tulip flower stems of all cultivars continue to grow after cutting. In particular, we found that considerable variation exists in the elongation of the last internode. With some cultivars, like Apeldoorn, almost all the growth can be accounted for by the last internode. On the other hand, Dreaming Maid grew little in this region. This is important for retail florists to consider, because it points out the need for wiring many tulips if a fixed design is desired. It also tells why designs with tulips change daily. It should be pointed out that the maximum growth of the last internode occurs during the first 24 hours.

We also found that the first 24 hours was the greatest period of growth for the tulip flower (table 2). In most cases, the flower petals elongated as much in the first 24 hours as in the remaining three to five days. This is important, because florists wish to have large flowers. By buying in the bud stage they can obtain a long-lasting flower and one which also will produce a larger flower after it is placed in the design.

Although no data are presented on the changes in flower colors, it was found that the red cultivars undergo the greatest change. Normally, they become much darker in color as they age. They are followed by the deep pinks, pinks, lavenders and then yellows and whites. Thus, the greater the pigmentation, the greater the changes.

The water uptake patterns (figures 2 and 3) were the same for all tulip cultivars tested. The greatest amount of water uptake occurred during the first 24 hours, and within this period of time the initial hour had the greatest rate. This explains why arrangements with tulips need to be refilled after they are sent to the customer. It was interesting to note that there was

always a decline in the rate of water uptake 24 hours prior to the death of the flower. Also, the amount of water taken up can vary between cultivars (figure 3). Perhaps in the development of new cultivars it would be desirable to select for low water uptake cultivars with long vase lives.

Lastly, measurements were made on the effect of the time of harvest (am, noon, pm), the prevailing weather conditions and the angle at which the stems are recut. None of these factors influenced the development of the tulips. The most important aspect was the stage of flower development when cut (8).

CONCLUSIONS

The information presented in this paper is given to serve as a guide for the American florists' industry. From our studies we have concluded that specific findings can be adopted by the industry.

First and foremost, it is necessary to market cut tuling in the hud stage and by cultivar name. If this is done, the information presented in tables 1 and 2 can be of value. It is obvious that each cultivar has its own desirable and undesirable characteristics. It is impossible to predict either the flower shape or life unless one knows the cultivar name.

Figures 2 and 3 show that tulips should be recut, remain wrapped and conditioned in water for at least two hours (preferably three to four)-at-room temperature to harden the flowers and to initiate the transition from the bud stage of development to full flower. Also, because cut tulips continue to take up water, they demonstrate the need for refilling the containers after the design has been created.

Lastly, we found that there is no specific need to recut the stem of a tulip in any particular manner. Stems should, however, be recut prior to hardening.

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EDITOR'S NOTE: The first portion of this study was presented in the January 16, 1969, issue of the Review, pp 41-43, 91 and 92. The article published in this issue is Michigan Agricultural Experiment Station Journal Article No. 4903. The research was supported in part by a grant from the Netherlands Flower-bulb Institute, New York, N.Y., and the Ornamental Marketing Board of The Hague, The Nethcrlands. Maarten Benschop is a student at the Agricultural University, Wageningen, The Netherlands, and A. A. De Hertogh is an associate professor, department of horticulture, Michigan State University, East Lansing.

Reprinted from The Florists' Review, Vol. 145, No. 3758 (12-11-69): 24-26, 62-65.