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Disinfection of *Lilium* Bulbs

The Effect of Disinfection with Prochloraz-Based Fungicides on the Quality of Cut Lilies.

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Date:	**09-06-2011**

PREFACE

Cost price efficiency is key in competing in the modern horticultural industry. Over the past four years I came to realize that bulb cultivation and the cultivation of bulb flowers is accompanied by major risks, as it is difficult to fine tune the product's quality. Seasonal influences affect bulb growth, and thereby the energy content and stress susceptibility of the bulbs. When a bulb grower sells its products he also sells the promise that the bulb will deliver a certain quality. However, this promise is not always met, resulting in an inferior product quality and eventually a lower selling price of the end product. Mostly, unexpected quality losses are caused by subsequent stress inducing conditions as well as seasonal factors. Within this research a potentially stress inducing factor has been addressed. It has given me the opportunity to address each aspect of lily production, superficially as well as in depth. Although follow up research is recommended this report gives a good basis for lily bulb disinfection and therewith production of lily flowers. Hopefully, readers will benefit from this report by being abled to tackle the issue of bulb disinfection in lily flower production. This report is of interest to lily breeders, lily bulb producers, lily bulb exporters and lily flower growers.

ABSTRACT

World Breeding B.V. is specialized in breeding, production, forcing and marketing of new lily varieties. For its promotion the company relies heavily on information generated in it is own cultivation program. However, in the year 2010 the company experienced unexpected major quality deviations in a large number of varieties during flower production in the first half of the year. Quality deviations expressed themselves in short stems, low flower bud quantities and extended production periods. These problems were suspected to be caused by the disinfection medium in which the bulbs were dipped for a period of 15 minutes before planting. Literature research pointed out that the active ingredient of Mirage Elan, Prochloraz, could be a stress-causing agent resulting in these specific quality deviations.

In this research nine treatments, including the currently applied disinfection treatment of World Breeding B.V. and eight alternatives to this treatment were tested on five *Lilium* cultivars. Treatments 1 to 8 included variations on the currently applied disinfection solution, furthermore a control treatment was applied. Whilst all treatments were applied at 1 to 5 min, the most likely alternatives to the currently applied disinfection treatment were also applied at 15 min on only two cultivars to examine the effect of an elongated dipping time.

Findings general for all *Lilium* cultivars cannot be drawn as a result of this research, because the cultivars used in this research reacted differently to the applied treatments. No significant differences were observed between the treatments. However, significant differences could be observed when results were compared with industry standards. The cultivars Massari®, White Cup® and Ice Dreamer® experienced a reduction in the amount of flower buds when treated with a dipping solution including Allure (Prochloraz (105 g/l) and Chloorthalonil (330 g/l)) at 1.00% and 2.00%. The cultivar Red Empire® experienced a reduction in the amount of flower buds when treated with a dipping solution including Allure at 1.00%. Mirage Elan (Prochloraz (450 g/l)) only caused quality deviations when applied in White Cup® at 0.02% and 15 min dipping time, 0.04% and 1 to 5 min dipping time and at 0.04% and 15 minutes dipping time. The cultivar Starfighter® did not experience any negative quality deviation at all.

Of the all round disinfection treatments, the currently applied disinfection treatment at World Breeding B.V. is least expensive. However, since no negative results where experienced when the bulbs were not disinfected this has to be considered to be the cheapest treatment.

As a result of this research it is recommended not to disinfect non-risk batches used for early forcing. Batches of lilies under threat of a fungal infection should be disinfected with 1.1% Captosan, 0.25% Shirlan, 1.00% Topsin M, 0.02% Mirage Elan and 0.04% Admire for a period of 1 to 5 min. For late forcing additional research is recommended.

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1. INTRODUCTION

1.1 Introduction to the genus *Lilium*

The genus *Lilium*, commonly named lily, is a member of the family Liliaceae and consists of approximately 100 species of bulbous perennials. Lilies originate mainly from woodland and scrub in Europe, Asia and North America and are grown for their showy, sometimes fragrant flowers. The bulbs are composed of overlapping fleshy scales and are sometimes rhizomatous with slender, horizontal stems that travel underground before becoming erect. The flower stems are unbranched and erect, ranging from 1 m to 3 m in length. Leaves are elliptic to lance shaped, glossy, usually mid to dark green leaves arranged in whorls or spirals or scattered alternately up the stems. Flowers are solitary or borne in racemes, panicles or umbels, and may be upward facing, horizontal or outward facing, nodding or pendent. They may be cup- to bowl- or bell shaped, trumpet shaped, funnel shaped, turkscap, or occasionally star shaped. Each has 6 stamens and 6 petals. The petals occur in most colours except blue and may be plain or marked with lines, spots or papillae (Brickell, 1996).

Lilies are classified into eight divisions or hybrid lines which are derived from different combinations of true species. Division 1, the Asiatic hybrids, are derived from various Asiatic species including *L. bulbiferum, L. cernuum, L. concolor, L. davidii, L. lancifolium* and *L. maculatum.* Division 2, the Martagon hybrids, are derived primarily from *L. hansonii* and *L. martagon.* Division 3, the Candidum hybrid is derived from *L. candidum* and other European species, except *L. martagon.* Division 4, the American hybrids, are derived from American species. Division 5, the Longiflorum hybrids are derived from *L. formosanum* and *L. longiflorum.* Division 6, the Trumpet and Aurelian hybrids are derived from Asiatic species including *L. regale, L. henryi* and *L. sargentiae.* Division 7, the Oriental hybrids, are derived from Eastern Asiatic species, such as *L. auratum* (See Figure 1)*, L japonicum* and *L. speciosum.* Division 8 includes hybrids, which have not been included in division 1 to 7. Lastly a ninth division includes all true species (Brickell, 1996).

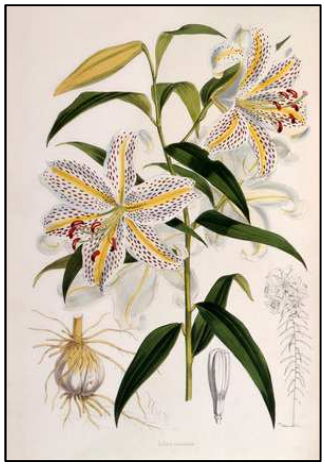

Figure 1 *Lilium auratum* represents some of the characteristics, which can be observed in Oriental hybrid lilies (RHS prints, 2011)

Although there is no accurate information available on the globally cultivated area of lily bulbs, it can be assumed that the Netherlands is the dominant producer. Production of lily bulbs in the

Netherlands has risen considerably from approximately 160 hectares in the year 1960 up to approximately 4200 hectares in 2010. Nowadays, within the Netherlands, the lily is responsible for 25% of the total value of exported flower bulbs. The increase in production was primarily due to the development of Asiatic hybrids and Oriental hybrids for the production of cut flowers (Bulbs online, 2011).

The first Asiatic hybrids were developed and introduced round the year 1950. The characteristics which make cultivars belonging to this division of particular interest for the production of cut flowers are: the wide variability of colours, relatively small-, upward facing-, star-shaped-, unscented flowers which are borne in racemes or umbels with short pedicels, easing the processing of flowers, the relatively short forcing period and the possibility to force flowers of this particular division year round, except for dark periods. Oriental hybrids were introduced round the year 1980. Cultivars belonging to this division characterize themselves by: flower colours limited to red-, pink- and white-tones, relatively large-, upward to outward facing-, star-shaped-, scented flowers which are borne in racemes or panicles, with a wide variability in pedicel length among cultivars, posing difficulties during the processing of flowers, the relatively long forcing period and the possibility to force flowers of this particular division during darker periods of the year (de Geus, 2006). It becomes evident that it is still possible to improve on certain characteristics of Asiatic hybrids and Oriental hybrids in order to create the ultimate cut lily. Recent breeding efforts have focused on eliminating negative characteristics from both hybrid lines by crossing them with other hybrids lines. These efforts have successfully resulted in four new hybrid lines belonging to division 8: Oriental hybrids * Trumpet hybrids (OT hybrids); Oriental hybrids * Asiatic hybrids (OA hybrids); Longiflorum hybrids * Oriental hybrids (LO hybrids) and Longiflorum hybrids * Asiatic hybrids (LA hybrids) (Bulbs online 2011).

1.2 Description of the Organization

In 1992 the breeding activities of World Flower B.V. in the Netherlands and World Bulbs B.V.B.A. in Belgium merged into World Breeding B.V. At present, the company is specialized in breeding and marketing of lilies. Breeding activities focus but do not limit themselves to Asiatic hybrids, Oriental hybrids, Longiflorum hybrids and the four new hybrid lines as stated in section 1.1. Some renowned cultivars resulting from the breeding program of World Breeding B.V. are: The Oriental hybrid Crystal Blanca, the LA hybrid Royal trinity, the OT hybrid Yelloween and the Longiflorum hybrid White Heaven (World Breeding B.V., 2011).

Before a newly selected cultivar is introduced on the market it is extensively tested on a wide range of quality traits relative to the division to which the specific cultivar belongs to (See Table 1). The first years of testing occur within the production facilities of World Breeding B.V. During this period the product is critically evaluated on its growing, blooming and forcing properties. In addition, the product is subjected to vase life and long-term storage tests. Only a handful of products passes-through this initial testing phase. In subsequent years commercial growers in various production areas test the remainder of the products. Only when a product passes all the selection criteria will it be commercialized and brought to the market (World Breeding B.V., 2011).

Table 1 General overview of quality traits of cut-lilies (World Breeding B.V., 2011)*

Quality trait		Least favourable	Most favourable
Cultivation Related	**Bulb cultivation characteristics**	Poor	Good
	Forcing period	Seasonal	Year round
	Forcing time	Long	Short
	Uniformity	Un uniform	Uniform
	Foliage life	Short	Long
	Vase life	Short	Long
Plant Related	**Flower bud colour**	Green	Coloured
	Flower bud length	Short	Tall
	Flower diameter	Small	Large
	Flower quantity	Low	High
	Flower direction	Outward facing	Upward facing
	Product length	Short	Tall
	Stem strength	Weak	Strong
	Foliage length	Short/Long	Medium
Disorder related	**Susceptibility to leaf scorch**	Susceptible	Not Susceptible
	Susceptibility to flower abortion	Susceptible	Not Susceptible
	Susceptibility to flower abscission	Susceptible	Not Susceptible
	Susceptibility to viruses	Susceptible	Not susceptible
	Susceptibility to fungal diseases	Susceptible	Not Susceptible

* **Each of the quality traits has to be specified on per division.**

The production processes within World Breeding B.V. are standardized, in order to weigh the genotypic characteristics of one product against that of others grown at the same time. Any deviating aspect in the production process will influence the phenotype of individual products to a certain extent and thereby influence the selection process.

1.3 Cultivation of Lilies as Cut Flowers

There is an extensive amount of information available on the basic requirements for the cultivation of cut lilies. Commercial growers build on this information with their experience and expertise thereby converting it to a production system, ideal according to their requirements.

Within conventional production systems lily bulbs are vegetative propagated through scales, bulbils and tissue culture. Bulbs will grow up to a size suitable for cut-flower production in two to three production cycles of one year each. During these cycles the bulbs are cultivated outdoors and harvested, processed and replanted between each cycle. Depending on the division, different bulb sizes are suitable for cut-flower production (See Table 2). The choice for a certain bulb size is dependent on three factors: firstly the end-product requirements, as an increasing bulb size will generally result in taller plants with a higher amount of flowers, secondly the growing period is of

major importance, smaller bulb sizes can only be used during periods with a relatively low temperature and low light intensities whereas larger bulb sizes are suitable for forcing under warmer conditions with high light intensities, finally it is important to note that larger bulb sizes are more susceptible to leaf scorch than smaller bulb sizes (de Geus, 2006).

Table 2 Bulb size suitable for cut-flower production according to the division (de Geus, 2006).

Division	**Bulb size suitable for cut-flower production** Measured by the bulb circumference taken in centimetres.					
	10/12	**12/14**	**14/16**	**16/18**	**18/20**	**20/+**
1) Asiatic hybrids	X	X	X	X		
5) Longiflorum hybrids		X	X	X	X	X
7) Oriental hybrids		X	X	X		
Flower bud quantity	Low	→	Medium		→	High
Product length	Short	→	Medium		→	Tall

Dutch-grown lily bulbs are harvested between August and December, with the optimal harvesting period depending on the cultivar and its division. Bulbs must receive a cold-moist treatment at 2°C for a minimum of eight weeks to break dormancy, after which they become available for cut-flower production. For later or year-round use the bulbs have to receive the cold-moist treatment after which they are packed in moist peat and are frozen at -1,5°C (Oriental hybrids and Longiflorum hybrids) or -2°C (Asiatic hybrids) for long-term storage (de Hertogh, 1996).

In general, flower initiation occurs when the shoots are 0,6 to 2,5 cm out of the bulbs. However, depending on the cultivar in combination with the storage treatment, flowers can also be initiated when the shoots are still inside the bulb. Stress caused by conditions other than the optimal can cause a loss in flower buds even before the product is planted (de Hertogh, 1996).

Before planting, frozen lily bulbs have to be defrosted at temperatures ranging between 10°C up to 15°C. Lilies require a sterile, well drained soil with a pH of 5,5 to 6,5 (Oriental hybrids) or 6 to 7 (Asiatic hybrids and Longiflorum hybrids) and an EC below 1,5 mS. The first 3 weeks of cultivation the lily will be dependent on its bulb roots, only after the sprout emerges from the soil the lily will develop its stem roots on which it will depend on for 90% of the uptake of water and nutrients. Therefore it is essential to plant lily bulbs with at least 6 to 8 cm of soil on top of the bulb, to allow for proper stem root development. The planting density is dependent on the cultivar, its division, the bulb size and the light intensity during cultivation (See Table 3)(de Geus, 2006).

Table 3 Quantity of bulbs planted on 1 m² according to the bulb size and product division (de Geus, 2006)

Division	Quantity of bulbs planted on 1 m² Dependant on the bulb size measured by the circumference taken in centimetres.					
	10/12	**12/14**	**14/16**	**16/18**	**18/20**	**20/+**
1) Asiatic hybrids	60 – 70	55 – 65	50 – 60	40 – 50		
5) Longiflorum hybrids		55 – 65	40 – 55	35 – 50	30 - 50	25 - 35
7) Oriental hybrids	55 – 65	45 – 55	40 – 50	35 – 45		

After planting lilies growing taller than 100 centimetres should be supported in growing upright. Supportive wire netting is therefore applied directly after planting and will be kept at approximately 5 centimetres below the lowest flower bud during cultivation. Soil nutrient levels should be maintained as shown in Table 4, with an EC of 0,75 mS/cm (Asiatic hybrids) or 0,90 mS/cm (Oriental hybrids).

Table 4 Desired rates of soil nutrient levels (mmol/l) according to the product division (de Geus, 2006)

Division	Desired rates of soil nutrient levels (mmol/l)					
	Nitrogen (N)	**Phosphate (P)**	**Potassium (K)**	**Calcium (Ca)**	**Magnesium (Mg)**	**Sulphate (SO4)**
1) Asiatic hybrids	2,0	0,15	1,0	1,5	0,8	1,5
7) Oriental hybrids	3,0	0,15	1,3	1,8	1,0	1,5

To promote rooting it is advisable to start cultivation with a low temperature ranging from 12 to 13°C. This temperature should be maintained for at least one third of the cultivation period, during which the soil is kept moderately moist. During the remainder of the cultivation period different temperatures are maintained for the various divisions (See Table 5). Temperatures should not drop below the advised as this can cause leaf yellowing finally resulting in leaf abortion. However, high temperatures can cause flower abortion. It must therefore be concluded that it is important to maintain within the margins of the advised temperature ranges.

Table 5 Temperature requirements for the period after root development divided per product division (de Geus, 2006).

Division	Temperature range		
	Minimum	**Optimal**	**Maximum**
1) Asiatic hybrids	8°C - 10°C	14°C - 15°C	20°C - 25°C
5) Longiflorum hybrids	14°C	14°C - 16°C	20°C - 22°C
7) Oriental hybrids	15°C	15°C - 17°C	20°C - 22°C

During cultivation the relative humidity should be kept at 80 to 85%. Rapid fluctuations in the relative humidity as well as an extended period in which the relative humidity is too high or too low can cause stress resulting in leaf scorch (de Geus, 2006).

Approximately 85 days (Asiatic hybrids) or 100 days (Oriental hybrids and Longiflorum hybrids) after planting the lilies will be ready for harvesting. It is important to harvest lilies when they are ripe, but not overripe. As a rule of thumb, lilies with over ten buds should have three coloured flower buds, lilies with five to ten buds should have two coloured flower buds and lilies with less than ten buds should minimally have one coloured flower bud. Ripe lilies should be harvested by cutting them at soil level, after which they can remain un-cooled for a period of 30 minutes. To improve the product's shelf life it is important to remove the leaves from the lowest 10 centimetres of the flower stem. Finally the product can be placed on water and stored at 2 to 3°C (de Geus, 2006).

1.4 Physiological Disorders in Cut-Flower Production of Lilies

During the cultivation of cut-lilies, stress caused by conditions other than those considered to be optimal (See Section 1.3) can cause physiological disorders. Common physiological disorders include but are not limited to leaf scorch, flower abortion and flower abscission (See Table 6).

Table 6 Physiological disorders during cut-flower cultivation of lilies and their cause (Peeters, 2000).

Disorder	Stress causing factor						
	Cultivar choice	Bulb Size	Temperature	Light intensity	Water uptake	Nutrient Deficiency	Plant hormones
Leaf scorch	X	X	X	X	X	X	
Flower abortion (E)					X		
Flower abortion (L)	X	X		X		X	
Flower abscission			X				X

Leaf scorch can be caused by cultural as well as cultivar specific aspects. The chance of this disorder is increased when: a relatively large bulb size is used, water uptake is obstructed, plant growth cannot be supported by its root system, evaporation is promoted by heavy ventilation or high light intensities or when there is a calcium deficiency. The disorder occurs after approximately one third of the growing period. It is characterized by light green to yellow spots occurring in the centre of the leaf blade on the youngest leaves of the plant. These spots can become necrotic resulting in the wilting of the leaf tip. The plant will resume normal growth after the stress-causing factor is eliminated (Peeters, 2000).

Early flower abortion can be caused by an obstruction of the water uptake resulting in wilting of flower buds. Late flower abortion can be caused by cultural as well as cultivar specific aspects. The chance on the occurrence of this disorder is increased when: a relatively large bulb size is used, the plant is grown under low light intensities and with non-specific nutrient deficiencies. In contrast to early flower abortion, late flower abortion can be observed in plants, which are not obstructed in their growth. Initially, well-developed flower buds become pale and shrivel finally these buds will wilt. However, these wilted flower buds stay attached to the plant (Peeters, 2000).

Flower abscission can come into being when flower buds are exposed to high concentrations of ethylene or high temperatures. This disorder generally occurs when flower buds are between 2 and 3,5 cm in length. Buds will become pale, abscise and finally drop from the plant (Peeters, 2000).

Physiological disorders severely influence the quality of cut-lilies (See Section 1.2). The occurrence of these disorders will result in an unmarketable product, therefore World Breeding B.V. selects on cultivars, which are not susceptible to these disorders.

1.5 Pests and Diseases in Cut-Flower Production of Lilies

In addition to physiological deviations, the quality of cut-lilies can be severely influenced by a range of pests and diseases. Of high concern, are those pests and diseases able to develop and spread during storage and cultivation as batches selected for cut flower production initially have low pests and disease levels. Influential diseases able to develop and spread during storage and cultivation are primarily of fungal origin (de Geus, 2006).

Storage rot (See Figure 2) is a fungal disease caused by an infection with *Penicillium spp.* during the processing of lily bulbs. Spores of *Penicillium spp.* can only enter the bulbs through wounds originating from the processing process. The disease will develop during storage, resulting in brown, dry spots which can spread even at temperatures below 0°C. White mycelium can grow from the infected spots, on which blue to green spores can develop. An infection originating from the basal plate of the bulb will result in an obstruction of the water uptake, finally resulting in the symptoms of early flower abortion (See Section 1.4) (Peeters, 2000).

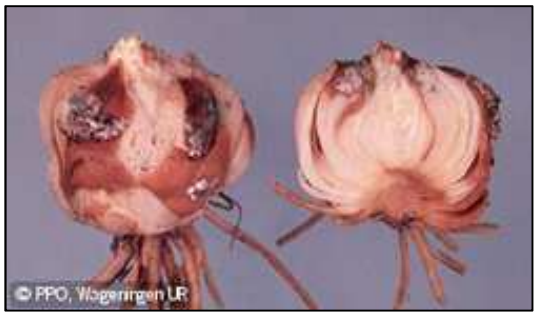

Figure 2 Storage rot in lily bulbs (Beeldbank, 2011)

Bulb rot and scale rot (See Figure 3) are fungal diseases, which can be caused by an infection with *Fusarium oxysporum* or *Cylindrocarpon destructans.* This disease will develop during bulb or flower cultivation, initially infecting the scales resulting in rotting of scale tissue (scale rot). When this infection spreads it can also infect the basal plate of the bulb (bulb rot) resulting in the eventual abortion of scales or an infection of the main sprout. Depending on the severity of the infection, the sprout will or will not develop after planting. When developing, water uptake is generally obstructed resulting in the symptoms of early flower abortion, flower abscission and/or leaf scorch (See Section 1.4). The disease will not develop nor spread during storage at temperatures below 0°C (Peeters, 2000).

Figure 3 Scale rot in lily bulbs (Beeldbank, 2011)

Botrytis rot is a fungal disease which can be caused by an infection with *Botritis cinerea,* it occurs when bulbs are packed in moist peat and stored at temperatures below 0°C. Tissue of infected bulbs colours brown and softens, mostly the infection affects the basal plate and sprout resulting in a bulb which is unfit for cut-flower production (Peeters, 2000).

During bulb or flower cultivation, lily plants can become infected with various species of aphids (See Figure 4). An infection with *Aulacortum circumflexum* or *Aphis gossypii* is most common in flower cultivation. The aphids live solely on the bottom of young foliage. Damage done by aphids can result in deformed leaves and flower buds, leaving an unmarketable product. Furthermore, flying aphids can be responsible for spreading of viruses such as lily mosaic virus, cucumber mosaic virus, lily symptomless virus and lily virus x (Peeters, 2000).

Figure 4 An aphid infection during the cultivation of *Lilium* as a cut flower (Beeldbank, 2011)

1.6 Disinfection of Lily Bulbs

An array of pests and diseases of various origins threaten lilies used for forcing. Spreading of fungal diseases in particular can be prevented by a range of cultural measures. Harvesting and processing of bulbs can result in superficial wounds in the scale tissue, through which the ever-present spores of various fungi can enter and infect the bulbs. It is therefore essential to minimize bulb damage during harvesting and processing. However, in practice it is impossible to eliminate bulb damage. Other cultural measures to prevent the initiation of a fungal infection are to dry and store bulbs at low temperatures (<5°C) (Brooijmans *et al*., 1994).

Although cultural measures can minimize fungal infections, they cannot completely take away the potential threat, nor can cultural measures be curative for already infected bulbs. In addition storage rot caused by *Penicillium spp.* can even spread re-infect and develop at temperatures below 0°C.

Therefore it is considered to be important to disinfect bulbs with preventive as well as curative fungicides shortly after processing (Brooijmans *et al*., 1994).

Lily bulbs used for the production of cut flowers can be disinfected by means of submerging them in a dipping solution, containing various pesticides dissolved in water. When these pesticides are arranged according to the group of pests or diseases against which they are applied, four groups can be identified (See Table 7).

Group 1 is active against a broad range of fungal diseases for a short period after disinfection; Group 2 is also active against a broad range of fungal diseases, but is affective for a longer time after disinfection; Group 3 is specifically active against *Fusarium oxysporum* and *Penicillium spp.*; Group 4 is active against various species of aphids (Fytostat, 2011).

Producers and users of lily bulbs each have their own dipping solution in which a pesticide of each group is applied. The choice between the different fungicides in group 2 and group 3 as well as the dipping time and the concentrations of individual pesticides is based on experience and varies between companies (Van der Meer, 2010).

Table 7 Pesticides used for the disinfection of lily bulbs used for the production of cut flowers and their specifications. (Fytostat, 2011).

Group	Active against	Pesticide	Active ingredient
1	Various fungal diseases (short term)	Captosan 500	Captan (500 g/l)
2	Various fungal diseases (long term)	Shirlan	Fluazinam (500 g/l)
		Securo	Folpet (300 g/l) Pyraclostrobine (100 g/l)
		Topsin M Vloeibaar	Thyofanaat-methyl (500 g/l)
3	*Fusarium oxysporum* & *Penicillium spp*.	Mirage Elan	Prochloraz (450 g/l)
		Allure Vloeibaar	Prochloraz (105 g/l) Chloorthalonil (330 g/l)
		Sportak EW	Prochloraz (450 g/l)
4	Various aphids	Admire	Imidacloprid (70%)

World Breeding B.V. disinfects the lilies used in its breeding, selection and promotional program in the dipping solution as shown in Table 8.

Table 8 Dipping solution used for the disinfection of lily bulbs by World Breeding B.V. (Kos, 2010)

Group	Active against	Pesticide	Active Ingredient	Application Rate
1	Various fungal diseases (short term)	Captosan 500	Captan (500 g/l)	1,10 %
2	Various fungal diseases (long term)	Shirlan	Fluazinam (500 g/l)	0,25 %
		Topsin M Vloeibaar	Thyofanaat-methyl (500 g/l)	1,00 %
3	*Fusarium oxysporum Penicillium spp*.	Mirage Elan	Prochloraz (450 g/l)	0,02 %
4	Various aphids	Admire	Imidacloprid (70%)	0,04 %

Until production season 2010 the bulbs were submerged in the dipping solution for a period of 15 minutes. From production season 2011 the total time in which the bulbs are submerged in the same solution is reduced to 1 to 5 minutes as a consequence of advice given by Van Gent & van der Meer B.V., the supplier of pesticides (Kos, 2010).

1.7 Problem Statement

World Breeding B.V. promotes cultivars based on a range of characteristics as generally stated in Table 1. Data required to describe these characteristics are collected from the initial selection of seedlings to the final testing phase. World Breeding B.V. relies on this data to be accurate in order to base recommendations specific to a cultivar. Furthermore, production indices such as the production time from planting to harvesting is an absolute necessity for the company to have in order to be able to conduct and implement an accurate production planning.

During the production season 2010 four quality indices were observed to be deviating from cultivar norms as set by World Breeding B.V. Bulbs of various cultivars which were planted to be ready for harvest in April and May: required a longer growing time than was expected for the particular period of the year, had a lower quantity of flower buds than was expected for flowers grown from a specific bulb size and/or were shorter than was expected from flowers grown from a specific bulb size during this particular period of the year. These irregularities were a general observation and occurred among cultivars grown from various bulb sizes belonging to the various divisions, which are used in the breeding program of World Breeding B.V.

Concept problem statement 1: During production season 2010 cultivars did not grow according to norms which are set as a result of years of data collection.

Cultivars known to be particularly susceptible to stress inducing conditions expressed these quality deviations to a great extent. Less sensitive cultivars seemed to deviate only marginally from this norm.

Concept problem statement 2: ***During production season 2010 stress susceptible cultivars did not grow according to norms which are set as a result of years of data collection.***

Furthermore it was observed that batches, which were not disinfected at all, did not express any of the quality deviations.

Concept problem statement 3: ***The currently applied disinfection treatment seems to cause stress susceptible cultivars not to grow according to norms which are set as a result of years of data collection.***

Research on the improvement of bulb disinfection treatments conducted in 1993 and 1994 by 'Laboratorium voor bloembollen onderzoek, Lisse' and 'Regionaal onderzoekscentrum, Breezand' supports the suspicion that an active ingredient used in the currently applied disinfection treatment is responsible for the deviations. During this research an increase in the percentage of plants with flower abortion (28 to 37%) was observed in the cultivar 'Connecticut King' an Asiatic hybrid as a consequence of an increase of the dipping time from 15 seconds to 60 seconds. The dipping solution contained 0,5% Captan and 0,4% Prochloraz (Schouten *et al.,* 1994). Various specialists within the flower bulb sector suspect the active ingredient Prochloraz to be the cause of the observed deviations.

<u>Final problem statement:</u>

Prochloraz based fungicides used in the currently applied disinfection treatment of world breeding B.V. are suspected to be the cause of stress susceptible cultivars not to grow according to norms, which are set as a result of years of data collection.

2. RESEARCH OBJECTIVE & RESEARCH QUESTIONS

World Breeding B.V. has collected an extensive amount of data on the performance of its cultivars. This data is used as a basis to promote cultivars on as well as to conduct an accurate production planning. However, during the production season 2010 three quality indices were observed to be deviating from the norms as set by World Breeding B.V. Deviations expressed themselves throughout the complete product range and were observed in four major quality/production indices:

1. *A relatively longer growing time than was expected for the specific period of the year;*

2. *A relatively lower quantity of flower buds than was expected for the specific flower bulb size;*

3. *A relatively shorter product length than was expected for the specific flower bulb size grown at that particular period of the year;*

As a consequence of these observations World Breeding B.V has set as an overall objective to eliminate these quality deviations and as a result to be able to fine-tune the data on product characteristics. This fine-tuned data on product characteristics will once again provide a basis to promote cultivars as well as to conduct an accurate production planning.

General objective: ***To identify and eliminate the cause of quality deviations observed in lilies planted to be ready for harvest between April and May.***

As quality deviations were only observed in batches of bulbs disinfected for 15 minutes in the dipping solution applied by World Breeding B.V., (See Section 1.7) the suspicion has risen that a specific pesticide, or combination of pesticides used in this dipping solution is responsible for the observed quality deviations.

Research objective 1: ***To identify the pesticide or combination of pesticides which is responsible for quality deviations observed in lilies which are planted to be ready to harvest between April and May.***

It is an absolute necessity to disinfect lily bulbs planted to be ready for harvest after May to prevent pests and diseases as described in section 1.5. Therefore it is important to identify the best alternative to the currently applied disinfection treatment, if it is found that the current disinfection treatment is causing quality deviations. Pesticides of all groups as stated in section 1.6, Table 7 should be included in this alternative to be able to provide an all-round disinfection treatment.

Research objective 2: ***To identify the alternatives to the currently applied disinfection treatment, taking into account all the pesticide groups which are necessary for an all-round disinfection treatment.***

By combining research objective 1 and research objective 2 a final research objective can be formulated.

Final research objective:

To identify if a pesticide or combination of pesticides is responsible for quality deviations observed in lilies planted to be harvested between April and May, and as a result to formulate an alternative to the currently applied disinfection treatment, taking into account all the pesticide groups, which are necessary for an all-round disinfection treatment.

The suspicion has risen that Prochloraz, an active ingredient of the pesticides in group 3 (See Section 1.6, Table 7) is responsible for the deviations, which were observed in production season 2010 (See Section 1.8). Therefore, Prochloraz based pesticides and the effect of disinfection with Prochloraz based fungicides will be the main focus of this research. This is reflected in the research questions and the design of this research.

Main Research Question (MRQ):

Does the bulb disinfection treatment currently applied by World Breeding B.V. cause deviations in cultivar specific quality and/or production indices as described by World Breeding B.V.?

Sub Research Question (SRQ) 1:

To what extent do cultivars with different quality and/or production characteristics react to the applied disinfection treatments?

- *Can a difference in the products growing time from planting to harvesting be observed?*
- *Can a difference in the quantity of flower buds be observed?*
- *Can a difference in product length be observed?*

Sub Research Question (SRQ) 2:

Can the active ingredient Prochloraz be identified as the main cause for deviations in cultivar specific quality and/or production indices as described by World Breeding B.V.

- *Do deviations occur when Prochloraz based fungicides are applied at the advised concentration rates and dipping time?*
- *Do deviations occur when Prochloraz based fungicides are applied at double the advised concentrations but the advised dipping time?*
- *Do deviations occur when Prochloraz based fungicides are applied at the advised concentration rates but an increased dipping time?*
- *Do deviations occur when Prochloraz based fungicides are applied at double the advised concentrations and an increased dipping time?*

<u>Sub Research Question (SRQ) 3:</u>

Can the disinfection with a Prochloraz based fungicide in combination with another fungicide, which is currently used in the disinfection treatment of World Breeding B.V., be identified as the main cause for deviations in cultivar specific quality and/or production indices as described by World Breeding B.V.

- *Do deviations occur when a Prochloraz based fungicide is combined with a Captan based fungicide?*
- *Do deviations occur when a Prochloraz based fungicide is combined with a Fluazinam based fungicide?*
- *Do deviations occur when a Prochloraz based fungicide is combined with a Thyofanaat-methyl based fungicide?*

3. MATERIALS & METHODS

3.1 Cultivars & Pesticides: a general overview.

It has been stated in section 1.8 that deviations were expressed to a greater extent by cultivars requiring a longer production time, have a relatively low quantity of flower buds, stay genetically short and/or are particularly susceptible to stress inducing conditions. Therefore, cultivar selection has been made according to these four factors (See Table 9). In addition, the cultivar Starfighter® is described to be highly susceptible to stress inducing conditions whilst the cultivar White Cup® is described to be not susceptible to stress inducing conditions (Sun Valley, 2011).

Table 9 Selected cultivars and their evaluated characteristics (World Breeding B.V., 2011; Onings B.V., 2011)

Cultivar	Division	Size	Length (cm)	Flower bud quantity	Forcing time (days)
Massari®	OT hybrid	16/18	150	6	110
Red Empire®	Oriental hybrid	16/18	100	5	100
Ice Dreamer®	Oriental hybrid	16/18	90	7	125
Starfighter®	Oriental hybrid	16/18	95	8	127
White Cup®	Oriental hybrid	16/18	90	7	124

The pesticides used in this research include those applied in the disinfection treatment of World Breeding B.V. In addition an extra Prochloraz based fungicide has been made available to provide a potentially better alternative for the currently used Prochloraz based fungicide (See Table 10).

Table 10 Pesticides used in this research and the advised application rates (Kos, 2010).

Group	Active against	Pesticide	Active Ingredient	Advised application rate
1	Various fungal diseases (short term)	Captosan 500	Captan (500 g/l)	1,10 %
2	Various fungal diseases (long term)	Shirlan	Fluazinam (500 g/l)	0,25 %
		Topsin M Vloeibaar	Thyofanaat-methyl (500 g/l)	1,00 %
3	*Fusarium oxysporum Penicillium spp*.	Mirage Elan	Prochloraz (450 g/l)	0,02 %
		Allure Vloeibaar	Prochloraz (105 g/l) Chloorthalonil (330 g/l)	1,00 %
4	Various aphids	Admire	Imidacloprid (70%)	0,04 %

3.2 Research phases: a general overview.

This research has been subdivided into three major phases, each phase presenting a crucial step. Phase one was implemented between December and January and includes bulb collection, the application of the disinfection treatments, bulb packing and intermediate storage. Phase 2 has been implemented between February and May and includes bulb planting, cultivation, data collection and

harvest. Finally, phase three has been implemented at the end of this research in May and included the data processing. Section 3.3 to 3.5 of this proposal specify on the processes during each of these phases, the materials required and if applicable, the data which needs to be collected.

3.3 Phase 1: The pre-planting phase

3.3.1 Materials and Methods

Table 11 shows the materials necessary to conduct phase 1.

Table 11 Material requirements for phase 1

Material	Quantity
Bulbs	Specified on in section 3.3.1 – 3.3.9
Pesticides	Specified on in section 3.3.1 – 3.3.9
Netlon bags (20*20 cm)	54
Plastic label (10 *120 mm)	54
Permanent Marker (red & black)	2
Industrial bucket (12 L)	8
Syringe (27 ml)	8
Plastic crate (40*60*80 cm)	16
Perforated bag	8
Peat	0,0552 m3

The bulbs were collected in December after which they temporarily have been stored at 2°C to 5°C. The bulbs were disinfected in January according to the treatments as specified on in sections 3.3.1 to 3.3.9.

The procedure for each of the disinfection treatments as carried out during phase 1 was as follows:

1. Batches of the different cultivars were separated and packed in small netlon bags each containing eight bulbs;

Figure 5 Bulb preparation (Step 1 and 2)

2. Each of these bags was labelled specifying on the cultivar, bulb size and the disinfection treatment;

3. A plastic bag was folded in a crate after which it is filled for 1/4th with peat;

Figure 6 Prepared crate (Step 3)

4. A second crate was placed on top of the crate;

5. An industrial bucket was placed in the top crate;

Figure 7 Mini disinfection station (Step 4, 5, 6, 7, 8 and 9)

6. The industrial bucket was filled with 5 l of water;

7. The pesticides were mixed into the water using a separate syringe for each of the pesticides;

Figure 8 Packing of bulbs (Step 10)

8. The netlon bags containing the bulbs were submerged in the bucket with the disinfection solution for the required disinfection time;

9. The netlon bags were removed from the disinfection solution and placed next to the bucket in the top crate to dry;

Figure 9 Packing of bulbs (Step 11)

10. After the bulbs have been dried the top crate was removed and bags in the top crate were placed on top of the peat in the bottom crate;

11. The bottom crate was filled with peat after which the plastic bag was closed tight.

Figure 10 Packing of bulbs (Step 11)

After disinfection the bulbs were frozen at 0°C to -1°C for a period of 21 days.

3.3.2 Disinfection Treatments

This research has been subdivided into 8 different treatments, each being a different disinfection solution (See Table 12 and Table 13). Treatments 1 to 5 are given to each of the cultivars used in this research to compare the effects of two different Prochloraz based fungicides, Allure and Mirage Elan with each other and disinfection without a Prochloraz based fungicide and therefore to answer SRQ 1 and 2. Treatments 6 to 8 were applied on the cultivar Starfighter® to examine if other active ingredients used in the current disinfection treatment of World Breeding B.V. have a negative effect on the end product quality when combined with the active ingredient Prochloraz. Each of the treatment applications is given to two replications of eight bulbs at the normal disinfection time of 1 to 5 minutes. Additional treatments each of two replications of eight bulbs whereby the disinfection time was increased up to 15 minutes were given to White Cup® and Starfighter® in treatments 1 to 4. Starfighter® is particularly susceptible for stress inducing conditions whilst White Cup® is not susceptible to stress inducing conditions. The 15 minutes disinfection was done to test the effect of an increase of the disinfection time on the product quality.

Treatment 0 was the control treatment whereby the bulbs were not disinfected at all (See Table 12). This treatment was applied on all cultivars as specified on in section 3.1. Therefore, the treatment is of relevance to each of the sub research questions. Treatment 1 simulated the disinfection treatment currently applied by World Breeding B.V. (See Table 12). The disinfection solution contained each of the pesticides in advised levels (See section 3.1). The treatment is of relevance to sub research questions 1 and 2. Within treatment 2 the concentration of Mirage Elan was doubled to 0,04% (See Table 12). The treatment is of relevance to sub research question 1 and 2. Within the disinfection solution of treatment 3 Mirage Elan was replaced by Allure applied at the advised rate of 1% (See Table 12). The treatment is of relevance to sub research question 1 and 2. Within the disinfection solution of treatment 4 Mirage Elan was replaced by Allure applied at double the advised rate (See Table 12). The treatment is of relevance to sub research question 1 and 2. Treatment 5 does not include Prochloraz based fungicides (See Table 12). Treatment 5 was the second of the two control treatments allowed to establish a baseline quality. Therefore, the treatment is of relevance to each of the sub research questions.

Table 12 Specifications treatments 0 to 5.

Treatment	0	1	2	3	4	5
SRQ:	1,2,3	1,2	1,2	1,2	1,2	1,2,3
Cultivars:	Massari® Starfighter® Red Empire® White Cup® Ice Dreamer®	Massari® Starfighter® Starfighter® (15 minutes) Red Empire® White Cup® White Cup® (15 minutes) Ice Dreamer®	Massari® Starfighter® Starfighter® (15 minutes) Red Empire® White Cup® White Cup® (15 minutes) Ice Dreamer®	Massari® Starfighter® Starfighter® (15 minutes) Red Empire® White Cup® White Cup® (15 minutes) Ice Dreamer®	Massari® Starfighter® Starfighter® (15 minutes) Red Empire® White Cup® White Cup® (15 minutes) Ice Dreamer®	Massari® Starfighter® Red Empire® White Cup® Ice Dreamer®
Replications per cultivar	2	2	2	2	2	2
Bulbs per replication	8	8	8	8	8	8
Disinfection treatment	Captosan 500 (0%) Shirlan (0%) Topsin M vloeibaar (0%) Mirage Elan (0%) Allure (0%) Admire (0%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0,02%) Allure (0%) Admire (0,04%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0,04%) Allure (0%) Admire (0,04%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0%) Allure (1,00%) Admire (0,04%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0%) Allure (2,00%) Admire (0,04%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0%) Allure (0%) Admire (0,04%)
Standard Disinfection Time:		1 minute	1 minute	1 minute	1 minute	1 minute

The disinfection solution of treatment 6 did not include Fluazinam based fungicides (See Table 13). The treatment was of relevance to sub research question 1, 2 and 3 as it tested the effect of Prochloraz in combination with Fluazinam. Within the disinfection solution of treatment 7 the Captan based fungicides were not included (See Table 13). The treatment is of relevance to sub research question 1, 2 and 3 as it tests the effect of Prochloraz in combination with Captan. Within the disinfection solution of treatment 8 the Thiofanaat-methyl based fungicides were not included (See Table 13). The treatment is of relevance to sub research question 1, 2 and 3 as it tests the effect of Prochloraz in combination with Thiofanaat-methyl.

Table 13 Specifications treatment 6 to 8.

Treatment:	6	7	8
SRQ:	1,2,3	1,2,3	1,2,3
Cultivars:	Starfighter®	Starfighter®	Starfighter®
Replications per cultivar	2	2	2
Bulbs per replication	8	8	8
Disinfection treatment	Captosan 500 (1,10%) Shirlan (0%) Topsin M vloeibaar (1,00%) Mirage Elan (0,02%) Allure (0%) Admire (0,04%)	Captosan 500 (0%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0,02%) Allure (0%) Admire (0,04%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (0%) Mirage Elan (0,02%) Allure (0%) Admire (0,04%)
Standard disinfection time	1 minute	1 minute	1 minute

3.4 Phase 2: The Cultivation Phase

Table 14 shows the material requirements for phase 2. Phase 2 was the cultivation stage wherein the lilies were cultivated from bulb to flower. During this phase the product was monitored on a weekly basis to register data on growth, quantity of flower buds, diseases and physiological disorders.

Table 14 Material requirements for phase 2

Material	Quantity
Supportive wire netting	24 m2
Supportive poles	16
Measuring tape	1
Weighing scale	1

3.4.1 Planting

Before planting the packed bulbs were defrosted for five days at 5°C. To prepare the soil for planting it was cultivated to create sufficient macro-pores after which it was sterilized by steaming and finally the soil was levelled. The treatments were planted in a random order. However, the cultivars were be grouped together as the genetic height difference between cultivars could have caused deviations in product length (See Appendices 1,2,3,4 and 5).

Each of the cultivars used in this research was planted on the 2nd of February 2011 (See Figure 11). The treatments were planted in beds of 1m wide, in which 24 bulbs (Massari®) or 32 bulbs (Starfighter®, White Cup®, Red Empire® and Ice Dreamer®) were planted per 1m². Each treatment

was planted in two rows, with four bulbs planted per row. Bulbs were planted with 5 to 8 cm of soil on top, which provided sufficient space for stem-roots to develop. Furthermore, the cultivars were planted with 12,5 cm of additional spacing between the cultivars in order to avoid confusion in measurements.

Figure 11 Overview of the planting bed (2nd of February 2011)(Rooijakkers, 2011).

3.4.2 Cultivation

During cultivation phase all cultivars used in this research were subjected to the same, uniform climatic conditions (See Table 15). The pre-set cultivation temperature was steadily increased from 12°C in February to 17°C in May. Water was given overhead or through sprinklers placed in between the crop. Irrigation was applied once or twice a week depending on the radiation influence, and the crop growth stage. The amount of water given per application was steadily increased from 5 litres per square meter in February to 7 litres per square meter in May. The EC of the irrigation water remained at 1.4 throughout the complete cultivation phase. The company's policy prescribes that it is not permitted to give detailed information about crop nutrition or integrated pest management programs. For general information about crop nutrition and integrated pest management refer back to section 1.3.

Table 15 Climatic conditions during the cultivation phase.

Factor	February	March	April	May
Heating temperature	12	15	17	17
Ventilation temperature	15	15	17	17
Irrigation	5 L/m2/week	5 – 7 L/m2/week	5 – 7 L/m2/week	7 L/m2/week
EC	1.4	1.4	1.4	1.4

During cultivation the development of individual plants was monitored and registered. There are two major production indices which were measured and observed during cultivation: growth measured

by the length in centimetres from soil level up to the top flower bud, and the occurrence of physiological disorders measured by their presence (See Table 16).

Table 16 Production indices measured during cultivation.

Production indices	Measurement	Frequency
Stem growth	Length in cm	Weekly
Occurrence of physiological disorders	Leaf scorch Flower abortion Flower abscission	Daily

3.4.3 Harvest & Post-Harvest

At the end of cultivation the products were harvested by cutting the stem with a sharp knife at soil level, after which the final measurements were conducted. The measurements included: a final measurement of product length, the quantity of flower buds per stem crop development stage and the presence of physiological disorders (See Table 17). The length of the lowest flower bud on a branch is taken as the objective measurement value for the crop development stage. Plants having a longer flower bud will mature earlier than those with a shorter flower bud.

Table 17 Quality indices measured after harvest.

Quality indices	Measurement
Plant length	Length in cm
Number of flower buds	Quantity of flower buds/stem
Crop development stage	Flower Bud Length in cm
Presence of physiological disorders	Leaf scorch Flower abortion Flower abscission

3.5 Phase 3: Data Processing

Data collected during phase 1 and phase 2 will be processed and analysed in phase 3, with Excel. The aim of data processing is to assess differences in quality and production indices between the different treatments applied on the individual cultivars, finally resulting in the answers to the questions as specified in Chapter 2.

4. RESULTS

4.1 General Observations During Cultivation.

After planting it took several weeks until the sprouts emerged through the soil surface. Red Empire® broke through the soil after 14 days on the 16th of February 2011. Massari® and White Cup® broke through the soil surface after 21 days on the 23rd of February 2011. Starfighter® and Ice Dreamer® broke through the soil surface after 28 days on the 2nd of March.

During the cultivation phase abnormalities were observed in the cultivars White Cup® and Starfighter®. Both cultivars had a number of plants growing remarkably slower than the rest (See Figure 14). The smaller plants seemed to be spread evenly over the different treatments. Only in the second week of April they could be identified as virus infected plants. Most likely this virus was the lily mosaic virus (See Figure 15). However, it is possible that other diseases such as Fusarium oxysporum also affected plants. On the 20th of April it was decided to remove the virus-infected plants from the trials in order to prevent spreading of this particular virus throughout the various products grown in the same greenhouse. In total 11% of the Starfighter® plants and 13.3% of the White Cup® plants were visually identified to be infected.

Figure 12 A normal growing plant (left) versus an abnormally growing plant (right) in Starfighter® (Rooijakkers, 2011)

Figure 13 A plant infected with the lily mosaic virus in White Cup® (Rooijakkers, 2011)

4.2 Responses of Individual Cultivars to Different Treatments.

4.2.1 Influence of dipping treatments 0 to 5 applied for 1 – 5 minutes on production time.

The length of the lowest flower bud on a branch is taken as the objective measurement value for the crop development stage. Plants having a longer flower bud will mature earlier than those with a shorter flower bud. The influences of treatment 0 to 5 applied for a period of 1 to 5 minutes on the final flower bud length of each of the cultivars used in this research are compared with each other in table 18. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to compare treatments between cultivars. The results show that there are no significant differences between the treatments within each of the cultivars ($P > 0.05$).

Table 18 Differences between average flower bud length per dipping treatment, applied for 1 - 5 minutes on individual cultivars*.

Treatment		Average Flower Bud Length (cm)				
		Massari®	White Cup®	Ice Dreamer®	Starfighter®	Red Empire®
0	No disinfection	6.5 a	5.3 a	4.8 a	3.4 a	6.3 a
1	Mirage Elan 0.02%	6.9 a	5.6 a	5.2 a	4.1 a	6.6 a
2	Mirage Elan 0.04%	6.9 a	5.8 a	5.2 a	3.8 a	6.6 a
3	Allure 1.00%	6.4 a	5.5 a	5.2 a	4.0 a	6.4 a
4	Allure 2.00%	6.9 a	5.1 a	5.2 a	4.0 a	6.7 a
5	No Prochloraz	6.7 a	5.3 a	5.0 a	4.0 a	6.7 a

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$.**

4.2.2 Influence of dipping treatments 1 to 4 applied for 15 minutes on production time.

The length of the lowest flower bud on a branch is taken as the objective measurement value for the crop development stage. Plants having a longer flower bud will mature earlier than those with a shorter flower bud. The influences of treatment 1 to 4 applied for a period of 15 minutes on the final flower bud length of the cultivars Starfighter® and White Cup® are compared with each other in table 19. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to compare treatments between cultivars. The results show that there are no significant differences between the treatments within each of the cultivars. ($P > 0.05$)

Table 19 Differences between average flower bud lengths per dipping treatment, applied for 15 minutes on individual cultivars*.

Treatment		Average Flower Bud Length (cm)	
		White Cup®	Starfighter®
1	Mirage Elan 0.02%, 1 - 5 minutes	5.6 a	4.1 a
1	Mirage Elan 0.02%, 15 minutes	5.1 a	3.8 a
2	Mirage Elan 0.04% 1 - 5 minutes	5.8 a	3.8 a
2	Mirage Elan 0.04%, 15 minutes	5.3 a	4.0 a
3	Allure 1.00%, 1 - 5 minutes	5.5 a	4.0 a
3	Allure 1.00%, 15 minutes	5.0 a	3.7 a
4	Allure 2.00%, 1 - 5 minutes	5.1 a	4.0 a
4	Allure 2.00%, 15 minutes	4.9 a	3.8 a

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$.**

4.2.3 Influence of dipping treatments 0 to 5 applied for 1 – 5 minutes on flower bud quantities.

The influences of treatment 0 to 5 applied for a period of 1 to 5 minutes on the flower bud quantities of each of the cultivars used in this research are presented in table 20. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to compare treatments between cultivars. The results show that there are no significant differences between the treatments within each of the cultivars ($P > 0.05$).

Table 20 Differences between average flower bud quantities per dipping treatment, applied for 1 to 5 minutes on individual cultivars*.

Treatment		Average Flower Bud Quantity				
		Massari®	White Cup®	Ice Dreamer®	Starfighter®	Red Empire®
0	No disinfection	3.4_{a}	4.4_{a}	5.3_{a}	5.7_{a}	3.6_{a}
1	Mirage Elan 0.02%	3.3_{a}	4.5_{a}	5.8_{a}	5.9_{a}	3.8_{a}
2	Mirage Elan 0.04%	3.1_{a}	4.5_{a}	5.8_{a}	5.5_{a}	3.6_{a}
3	Allure 1.00%	3.0_{a}	4.3_{a}	5.7_{a}	6.3_{a}	3.8_{a}
4	Allure 2.00%	3.1_{a}	4.1_{a}	5.6_{a}	6.4_{a}	3.9_{a}
5	No Prochloraz	3.1_{a}	4.5_{a}	5.9_{a}	6.1_{a}	4.0_{a}

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$.**

4.2.4 Influence of dipping treatments 1 to 4 applied for 15 minutes on flower bud quantities.

The influences of treatment 1 to 4 applied for a period of 15 minutes on the flower bud quantities of the cultivars Starfighter® and White Cup® are compared with each other in table 21. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to compare treatments between cultivars. The results show that there are no significant differences between the treatments within each of the cultivars ($P > 0.05$).

Table 21 Differences between average flower bud quantities per dipping treatment, applied for 15 minutes on individual cultivars*.

Treatment		Average Flower Bud quantity	
		White Cup®	Starfighter®
1	Mirage Elan 0.02, 1 – 5 minutes	4.5 $_a$	5.9 $_a$
1	Mirage Elan 0.02%, 15 minutes	4.8 $_a$	6.1 $_a$
2	Mirage Elan 0.04%, 1 – 5 minutes	4.5 $_a$	5.5 $_a$
2	Mirage Elan 0.04%, 15 minutes	4.6 $_a$	5.9 $_a$
3	Allure 1.00%, 1 – 5 minutes	4.3 $_a$	6.3 $_a$
3	Allure 1.00%, 15 minutes	4.8 $_a$	6.4 $_a$
4	Allure 2.00%, 1 – 5 minutes	4.1 $_a$	6.4 $_a$
4	Allure 2.00%, 15 minutes	4.5 $_a$	6.4 $_a$

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$.**

4.2.5 Influence of dipping treatments 0 to 5 applied for 1 – 5 minutes on plant length.

The influences of treatment 0 to 5 applied for a period of 1 to 5 minutes on the final plant length of each of the cultivars used in this research are compared with each other in table 22. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to compare treatments between cultivars. The results show that there are no significant differences between the treatments within each of the cultivars ($P > 0.05$).

Table 22 Differences between average plant lengths per dipping treatment, applied for 1 - 5 minutes on individual cultivars*.

Treatment		Average Plant Length (cm)				
		Massari®	White Cup®	Ice Dreamer®	Starfighter®	Red Empire®
0	No disinfection	150.1 $_a$	99.5 $_a$	96.6 $_a$	84.7 $_a$	100.5 $_a$
1	Mirage Elan 0.02%	147.6 $_a$	103.6 $_a$	98.1 $_a$	92.4 $_a$	102.8 $_a$
2	Mirage Elan 0.04%	153.1 $_a$	103.1 $_a$	98.6 $_a$	88.5 $_a$	104.8 $_a$
3	Allure 1.00%	151.3 $_a$	100.2 $_a$	99.2 $_a$	95.3 $_a$	104.4 $_a$
4	Allure 2.00%	143.7 $_a$	94.1 $_a$	98.2 $_a$	93.1 $_a$	105.8 $_a$
5	No Prochloraz	150.4 $_a$	95.8 $_a$	96.3 $_a$	89.9 $_a$	103.0 $_a$

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$.**

4.2.6 Influence of dipping treatments 1 to 4 applied for 15 minutes on plant length.

The influences of treatment 1 to 4 applied for a period of 15 minutes on the final plant length of the cultivars Starfighter® and White Cup® are compared with each other in table 23. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to

compare treatments between cultivars. The results show that there are no significant differences between the treatments within each of the cultivars (P > 0.05).

Table 23 Differences between average plant lengths per dipping treatment. Applied for 15 minutes on individual cultivars*.

Treatment		Average Plant Length (cm)	
		White Cup®	Starfighter®
1	Mirage Elan 0.02%, 1 – 5 minutes	103.6 $_a$	92.4 $_a$
1	Mirage Elan 0.02%, 15 minutes	101.7 $_a$	89.6 $_a$
2	Mirage Elan 0.04%, 1 – 5 minutes	103.1 $_a$	88.5 $_a$
2	Mirage Elan 0.04%, 15 minutes	101.4 $_a$	89.4 $_a$
3	Allure 1.00%, 1 – 5 minutes	100.2 $_a$	95.3 $_a$
3	Allure 1.00%, 15 minutes	99.2 $_a$	90.8 $_a$
4	Allure 2.00% 1 – 5 minutes	94.1 $_a$	93.1 $_a$
4	Allure 2.00%, 15 minutes	89.8 $_a$	90.8 $_a$

- **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$.**

4.3 Crop Performance Compared to Set Standards

4.3.1 Influence of dipping treatments 0 to 5 applied for 1 – 5 minutes on flower bud quantities.

Performance of individual cultivars compared to industry standards after applying dipping treatments 0 to 5 for a period of 1 to 5 minutes is shown in table 24. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to compare treatments between cultivars. It could not be proven statistically that Massari® produced less flower buds than expected as a result of any of the treatments (P > 0.05). White Cup® produced less flower buds than expected when dipped in treatment 2 (P < 0.05), dipped in treatment 3 (P < 0.05) and dipped in treatment 4 (P < 0.05). Ice Dreamer® produced less flower buds than expected when treatment 0 was applied (P < 0.05) and when dipped in treatment 4 (P < 0.05). Red Empire® only produced less flower buds than expected when dipped in treatment 3 (P < 0.05).

Table 24 Differences from expected flower bud quantities per dipping treatment, applied for 1 to 5 minutes on individual cultivars*.

Treatment		Flower Bud Quantity				
		Massari®	White Cup®	Ice Dreamer®	Starfighter®	Red Empire®
Expected Quantity		6 $_a$	7 $_a$	7 $_a$	8 $_a$	5 $_a$
0	No disinfection	3.4 $_a$	4.4 $_a$	5.3 $_b$	5.7 $_a$	3.6 $_a$
1	Mirage Elan 0.02%	3.3 $_a$	4.5 $_a$	5.8 $_a$	5.9 $_a$	3.8 $_a$
2	Mirage Elan 0.04%	3.1 $_a$	4.5 $_b$	5.8 $_a$	5.5 $_a$	3.6 $_a$
3	Allure 1.00%	3.0 $_a$	4.3 $_b$	5.7 $_a$	6.3 $_a$	3.8 $_b$
4	Allure 2.00%	3.1 $_a$	4.1 $_b$	5.6 $_b$	6.4 $_a$	3.9 $_a$
5	No Prochloraz	3.1 $_a$	4.5 $_a$	5.9 $_a$	6.1 $_a$	4.0 $_a$

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$ from the expected value.**

4.3.2 Highlight Massari®

Other than the other cultivars used in this research Massari® had losses in flower buds which were presented by petioles without a flower bud. The expected number of petioles without a flower bud is 0 (See Table 25). Differences to the expected quantity were experienced when bulbs were dipped in treatment 3 for 1 to 5 minutes ($P < 0.05$), and in treatment 4 for 1 to 5 minutes ($P < 0.05$).

Table 25 Differences from expected flower bud losses per dipping treatment, applied for 1 to 5 minutes on Massari®*.

Treatment		Flower Bud Loss on Massari®
Expected quantity		0 $_a$
0	No disinfection	0.5 $_a$
1	Mirage Elan 0.02%	0.6 $_a$
2	Mirage Elan 0.04%	0.8 $_a$
3	Allure 1.00%	0.9 $_b$
4	Allure 2.00%	0.9 $_b$
5	No Prochloraz	0.6 $_a$

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$ from the expected value.**

4.3.3 Influence of dipping treatments 1 to 4 applied for 15 minutes on flower bud quantities.

Performance of the cultivars White Cup® and Starfighter® compared to industry standards after applying dipping treatments 0 to 5 for a period of 15 minutes is shown in table 26. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to compare treatments between cultivars. White Cup® produced less flower buds than

expected when dipped in treatment 1 ($P < 0.05$) and when dipped in treatment 2 ($P < 0.05$). Starfighter® did not produce significantly less flower buds at all

Table 26 Differences from expected flower bud quantities per dipping treatment, applied for 15 minutes on White Cup® and Starfighter®*.

Treatment		Flower Bud Quantity	
		White Cup®	Starfighter®
Expected Quantity		7_{a}	8_{a}
1	Mirage Elan 0.02%, 1 – 5 minutes	4.5_{a}	5.9_{a}
1	Mirage Elan 0.02%, 15 minutes	4.8_{b}	6.1_{a}
2	Mirage Elan 0.04%, 1 – 5 minutes	4.5_{b}	5.5_{a}
2	Mirage Elan 0.04%, 15 minutes	4.6_{b}	5.9_{a}
3	Allure 1.00%, 1 – 5 minutes	4.3_{b}	6.3_{a}
3	Allure 1.00%, 15 minutes	4.8_{a}	6.4_{a}
4	Allure 2.00%, 1 – 5 minutes	4.1_{b}	6.4_{a}
4	Allure 2.00%, 15 minutes	4.5_{a}	6.4_{a}

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$ from the expected value.**

4.3.4 Influence of dipping treatments 0 to 5 applied for 1 - 5 minutes on plant length.

Performance of individual cultivars compared to industry standards after applying dipping treatments 0 to 5 for a period of 1 to 5 minutes is shown in table 27. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to compare treatments between cultivars. It could not be proven significantly that Massari®, White Cup®, Starfighter® and Red Empire® produced less plant length than expected as a result of any of the treatments. Only the cultivar Ice Dreamer® produced less plant length when dipped in treatment 0 ($P < 0.05$), treatment 1 ($P < 0.05$), treatment 2 ($P < 0.05$), treatment 4 ($P < 0.05$) and treatment 5 ($P < 0.05$). Treatment 3 could not be proven to be significantly different from the expected plant length of 150 centimetres ($P > 0.05$).

Table 27 Differences from the expected plant length per dipping treatment, applied for 1 to 5 minutes on each of the cultivars used in this research*.

Treatment		Average Plant Length (cm)				
		Massari®	White Cup®	Ice Dreamer®	Starfighter®	Red Empire®
Expected Length		150 $_{a}$	95 $_{a}$	110 $_{a}$	95 $_{a}$	100 $_{a}$
0	No disinfection	150.1 $_{a}$	99.5 $_{a}$	96.6 $_{b}$	84.7 $_{a}$	100.5 $_{a}$
1	Mirage Elan 0.02%	147.6 $_{a}$	103.6 $_{a}$	98.1 $_{b}$	92.4 $_{a}$	102.8 $_{a}$
2	Mirage Elan 0.04%	153.1 $_{a}$	103.1 $_{a}$	98.6 $_{b}$	88.5 $_{a}$	104.8 $_{a}$
3	Allure 1.00%	151.3 $_{a}$	100.2 $_{a}$	99.2 $_{a}$	95.3 $_{a}$	104.4 $_{a}$
4	Allure 2.00%	143.7 $_{a}$	94.1 $_{a}$	98.2 $_{b}$	93.1 $_{a}$	105.8 $_{a}$
5	No Prochloraz	150.4 $_{a}$	95.8 $_{a}$	96.3 $_{b}$	89.9 $_{a}$	103.0 $_{a}$

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at $P \leq 0.05$ from the expected value.**

4.3.5 Influence of dipping treatments 1 to 4 applied for 15 minutes on plant length.

Performance of the cultivars Starfighter® and White Cup® compared to industry standards after applying dipping treatments 0 to 5 for a period of 15 minutes is shown in table 28. Only the treatments within a cultivar are compared as genetic differences between cultivars make it impossible to compare treatments between cultivars. It could not be proven significantly that either White Cup® or Starfigther® produced less plant length than expected as a result of any of the treatments ($P > 0.05$).

Table 28 Differences from the expected plant length per dipping treatment, applied for 15 minutes on White Cup® and Starfighter®*.

Treatment		Average Plant Length (cm)	
		White Cup®	Starfighter®
Expected Length		95 $_a$	95 $_a$
1	Mirage Elan 0.02%, 1 – 5 minutes	103.6 $_a$	92.4 $_a$
1	Mirage Elan 0.02%, 15 minutes	101.7 $_a$	89.6 $_a$
2	Mirage Elan 0.04%, 1 – 5 minutes	103.1 $_a$	88.5 $_a$
2	Mirage Elan 0.04%, 15 minutes	101.4 $_a$	89.4 $_a$
3	Allure 1.00%, 1 – 5 minutes	100.2 $_a$	95.3 $_a$
3	Allure 1.00%, 15 minutes	99.2 $_a$	90.8 $_a$
4	Allure 2.00%, 1 – 5 minutes	94.1 $_a$	93.1 $_a$
4	Allure 2.00%, 15 minutes	89.8 $_a$	90.8 $_a$

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at P ≤ 0.05**

4.4 Effects of fungicide combinations.

4.4.1 Influence of dipping treatment 6 to 8 applied for 1 to 5 minutes on production time

The length of the lowest flower bud on a branch is taken as the objective measurement value for the crop development stage. Plants having a longer flower bud will mature earlier than those with a shorter flower bud. The influences of dipping treatment 0, 5, 6, 7 and 8 applied for a period of 1 to 5 minutes on production time of the cultivar Starfighter® are compared with each other in table 31. The results show that there are no significant differences between the treatments within each of the cultivar (P > 0.05).

Table 29 Differences from the expected flower bud quantity per dipping treatment, applied for 1 to 5 minutes on Starfighter®*.

Treatment		Average flower bud Length (cm)
		Starfighter®
0	No disinfection	3.4 $_a$
6	No Fluazinam	3.8 $_a$
7	No Captan	4.0 $_a$
8	No Thiofanaat-methyl	3.8 $_a$
5	No Prochloraz	4.0 $_a$

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at P ≤ 0.05.**

4.4.2 Influence of dipping treatment 6 to 8 applied for 1 to 5 minutes on plant length

The influences of dipping treatment 0, 5, 6, 7 and 8 applied for a period of 1 to 5 minutes on the plant length of the cultivar Starfighter® are compared with each other in table 29. The results show that there are no significant differences between the treatments within each of the cultivars (P > 0.05).

Table 30 Differences from the expected plant length per dipping treatment, applied for 1 to 5 minutes on Starfighter®*.

Treatment		Average Plant Length (cm)
		Starfighter®
0	No disinfection	84.7 $_a$
6	No Fluazinam	88.1 $_a$
7	No Captan	88.6 $_a$
8	No Thyofanaat-methyl	90.8 $_a$
5	No Prochloraz	89.9 $_a$

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at P ≤ 0.05.**

4.4.3 Influence of dipping treatment 6 to 8 applied for 1 to 5 minutes on flower bud quantity

The influences of dipping treatment 0, 5, 6, 7 and 8 applied for a period of 1 to 5 minutes on the flower bud quantity of the cultivar Starfighter® are compared with each other in table 30. The results show that there are no significant differences between the treatments within each of the cultivars (P > 0.05).

Table 31 Differences from the expected flower bud quantity per dipping treatment, applied for 1 to 5 minutes on Starfighter®*.

Treatment		Average Number of Flower Buds
		Starfighter®
0	No disinfection	5.7 $_a$
6	No Fluazinam	6.1 $_a$
7	No Captan	5.9 $_a$
8	No Thiofanaat-methyl	5.4 $_a$
5	No Prochloraz	6.1 $_a$

* **Data represents mean values of sixteen replications per treatment. Mean values followed by the same subscript letters indicate that treatments are not significantly different at P ≤ 0.05.**

4.5 Pesticide Cost Prices of the Disinfection Treatments

For the commercial perspective it is important to weigh costs of activities against their potential benefits or drawbacks. Table 32 highlights the pesticide costs for treatment 0 to 5.

Table 32 Cost price comparisons treatment 0 to 5 (Van der Meer, 2011)

Pesticide	Normal Application Rate	Price 1000L	Cost price per Treatment					
			0	1*	2	3	4	5
Captosan	1.10%	€6.90	€0.00	€6.90	€6.90	€6.90	€6.90	€6.90
Shirlan	0.25%	€13.21	€0.00	€13.21	€13.21	€13.21	€13.21	€13.21
Topsin M	1.00%	€16.96	€0.00	€16.96	€16.96	€16.96	€16.96	€16.96
Admire	0.04%	€0.16	€0.00	€0.16	€0.16	€0.16	€0.16	€0.16
Mirage Elan	0.02%	€1.72	€0.00	€1.72	€3.44	€0.00	€0.00	€0.00
Allure	1.00%	€20.75	€0.00	€0.00	€0.00	€20.75	€41.50	€0.00
Total Cost price			€-	€38.95	€40.67	€57.98	€78.73	€37.23
Comparison			0%	100%	104%	149%	202%	96%

* **Standard disinfection treatment.**

When treatment 1 and treatment 3 are compared with each other, it becomes evident that using Allure instead of Mirage Elan increases the cost price with 49%. Furthermore, the cost price is reduced by 4% when no Prochloraz based fungicide is applied. The cost prices of treatment 6 to 7 are shown in Table 33. It becomes evident that besides Allure, Captosan and Topsin M are major cost building pesticides. By removing Shirlan from the current disinfection program as in treatment 6 the cost price is reduced with 34 % and when Topsin M is removed the cost price is even reduced by 44 %.

Table 33 Cost price comparisons treatment 6 to 8 (Van der Meer 2011)

Pesticide	Normal Application Rate	Price 1000L	Cost price per Treatment		
			6	7	8
Captosan	1.10%	€6.90	€6.90	€0.00	€6.90
Shirlan	0.25%	€13.21	€0.00	€13.21	€13.21
Topsin M	1.00%	€16.96	€16.96	€16.96	€0.00
Admire	0.04%	€0.16	€0.16	€0.16	€0.16
Mirage Elan	0.02%	€1.72	€1.72	€1.72	€1.72
Allure	1.00%	€20.75	€0.00	€0.00	€0.00
Total Cost price			€25.74	€32.05	€21.99
Comparison			66%	82%	56%

5. DISCUSSION

'Stress' is the main factor for quality loss in lilies and can be caused by conditions different from those considered to be optimal. When conditions deviating from those considered to be optimal can cause stress, it can be assumed that conditions which are closer related to the optimal conditions can reduce stress (See Table 34).

Table 34 Growing conditions versus product quality illustrated in percentages.

Conditions	0%	25%	50%	75%	100%
Quality	0%	25%	50%	75%	100%

This indicates that when bulbs have been subjected to specific conditions other than optimal, they are 'stressed'. Subsequent stress inducing conditions adds on to the previous. It could be concluded that the final product quality is a result of the potential product quality minus the sum of the stress inducing conditions.

Statement 1: Final product quality = potential product quality – ($\sum$ stress inducing conditions)

Furthermore the effect of the stress inducing conditions depends on the susceptibility of the bulbs to stress. For example a prematurely harvested bulb is not only stressed but also still active, whilst a fully ripened bulb can be considered to be dormant. These active bulbs are still developing and ripening and will therefore be affected in their development by the stress inducing condition. From this it can be concluded that the effect of stress inducing conditions depends on the resistance of the bulbs to these conditions, they therefore might have effects varying on a seasonal basis.

Statement 2: Effect of stress inducing conditions depends on the susceptibility of bulbs to stress. Certain seasonal factors can make bulbs more susceptible to stress inducing conditions.

The previous is best illustrated when comparing bulb production season 2009 with bulb production season 2010. World Breeding B.V. has considered the year 2010 to be a very stable bulb growing season wherein the lily bulbs grew steadily and were allowed to ripen before harvest. In contrast, in season 2009 bulbs grew explosively and did not ripen fully before harvest, resulting in stress as well as greater susceptibility to stress inducing conditions (Kos, 2010). Bubs originating from production season 2009 were used for forcing in the year 2010 whilst bulbs originating from production season 2010 were used for forcing in the year 2011.

In the year 2010 the results of the bulb forcing program were other than expected, with less flower buds per stem, a shorter flower stem and a longer growing time from planting to harvesting. Whilst this was thought to be a result of the disinfection with Prochloraz based fungicides, it might well have been a result of prematurely harvested bulbs, which were highly susceptible to stress and afterwards were disinfected with Prochloraz based fungicides. This supports the previous statement that the final product quality is a result of the sum of stress inducing conditions.

The second statement is supported by the observation that the different treatments applied on the five cultivars used in this research did not give significantly different results in any of the measured parameters when compared with one another. Although trends in average measurements could be observed, these cannot be proven significantly. An explanation for this observation can be that the bulbs were less affected by the disinfection treatments because they were less susceptible to stress than the bulbs used in the previous year.

Significant differences only could be observed when the flower bud quantities of each of the treatments were compared with industry standards specifically set for the individual cultivars. Table 35 summarizes on the treatments resulting in a loss in flower buds for each of the cultivars.

Table 35 Treatments resulting in a loss of flower buds when compared to the expected quantity of flower buds. *

Treatment		Application time	Massari®	White Cup®	Ice Dreamer®	Starfighter®	Red Empire®
0	No disinfection	NA*			X		
1	Mirage Elan normal concentration	1 – 5 min					
		15 min	NA	X	NA		NA
2	Mirage Elan double concentration	1 – 5 min		X			
		15 min	NA	X	NA		NA
3	Allure normal concentration	1 – 5 min	X	X	X		X
		15 min	NA		NA		NA
4	Allure double concentration	1 – 5 min	X	X	X		
		15 min	NA		NA		NA
5	No Prochloraz	1 – 5 min					

- **Treatments resulting in significantly different flower bud quantities from the expected are marked with X.**
- **NA means not applicable.**

The results indicate that cultivars react differently to the treatments. This can be a consequence of the susceptibility of individual cultivars to stress or the effects of Prochloraz disinfections.

Statement 3: Individual cultivars have different stress tolerance levels.

Deviating results can be observed in the cultivars White Cup® and Starfighter®, whereby the increase of the dipping time in treatment 3 and 4 does not affect the final product quality as well as the growing time at all. Furthermore the cultivar Starfighter® is not influenced by any of the disinfection treatments (See Table 36). Both cultivars were affected by a viral as well as a fungal infection. It is possible that they did not show significant quality deviations because Allure applied at 15 minutes dipping time supressed the fungal infection, and as such influenced the end product quality positively. The stress caused by the fungal infection could have been higher than that of the disinfection treatments.

The negative reaction of the cultivar White Cup® on the disinfection treatment can be explained by the dipping time. White Cup® has been disinfected sooner after harvest than each of the other cultivars, as it was harvested only one week before disinfection. At the time of disinfection the surface wounds on the bulbs of White Cup® were not dried yet, creating a greater surface area for absorption of fungicides, and more effective adsorption. It is likely that individual bulbs of White Cup® have taken up more of the active ingredient Prochloraz than those of other cultivars. Therefore the potential negative effects of disinfection with Prochloraz based fungicides were increased on White Cup®.

When the two other quality parameters are compared, only Ice Dreamer® deviates from the expected plant length in all treatments except for treatment 3. Most likely explanation is that Ice Dreamer® is a relatively new cultivar from which only little information has been available. In this case it can be assumed that the product length standards need to be fine tuned more. For the total production time no significant differences could be found.

The third aspect, which has been studied in this research, is the effect of the combination of Prochloraz based fungicides with other fungicides used in the current disinfection solution of World Breeding B.V. No significant differences could be observed when Topsin m vloeibaar, Shirlan and Captosan 500 were excluded from the disinfection solution.

In general no extreme measurement values were observed. Whilst results in 2010 clearly pointed towards the active ingredient Prochloraz as the cause for major quality deviations in a range of lily cultivars. For future research it is important to increase the 'stress factor' thereby promoting quality deviations and therewith differences between treatments.

From a cost price perspective it is most interesting not to disinfect flower bulbs at all. However, this option has to be weighed against the threats of fungal infections. It can be assumed that a fungal disease develops during storage and further affects the quality of the bulbs used for forcing. In addition a batch of bulbs having been infected with a fungal disease can be considered to be a risk batch whereby disinfection is absolutely necessary. Therefore the option of disinfection should be weighed against the use of the respective batch of bulbs.

6. CONCLUSIONS

6.1 Do lilies react differently to the range of disinfection treatments?

From this research it cannot be proven significantly that lilies react differently to the range of disinfection treatments applied in this research. There were no significant differences in the products growing time, flower bud quantity and product length, irrespective of the cultivar or treatment. It can be concluded that there is no difference between completely leaving out the disinfection, disinfecting with Mirage Elan at the normal concentration and the double concentration, disinfection with Allure at the normal concentration and the double concentration and disinfection without a Prochloraz based fungicide. Finally significant differences could not be found when the bulbs were disinfected for a period of 15 minutes instead of 1 to 5 minutes.

Conclusion 1.1: **No difference in the products growing time from planting to harvesting could be observed.**

Conclusion 1.2: **No difference in the quantity of flower buds could be observed.**

Conclusion 1.3: **No difference in the product length could be observed.**

6.2 Can disinfection with Prochloraz be identified as the main cause for quality deviations?

When the measured quality parameters which result from the different disinfection treatments are compared to the expected quality parameters set by the industry, significant differences can be found. However, these are cultivar dependant and cannot be taken as a general result of the treatment.

Conclusion 2.1: **Deviations do occur in Massari®, White Cup® Red Empire® and Ice dreamer® when Allure is applied at the advised concentration and dipping time.**

Conclusion 2.2: **Deviations do occur in Massari®, White Cup® and Ice Dreamer® when Allure is applied at double the advised concentration but the advised dipping time. Deviations also occur in White Cup® when Mirage Elan is applied at double the advised concentration but the advised dipping time.**

Conclusion 2.3: **Deviations do occur in White Cup® when Mirage Elan is applied at the normal concentration but an increased dipping time.**

Conclusion 2.4: **Deviations do occur in White Cup® when Mirage Elan is applied at double the advised concentration and an increased dipping time.**

6.3 Does Prochloraz combined with another active ingredient cause quality deviations?

From this research it cannot be proven that the active ingredient Prochloraz causes quality deviations when combined with other fungicides. There were no significant differences in the products growing time, flower bud quantity and product length, irrespective of the cultivar or treatment. It can be concluded that there is no difference between not disinfecting the bulbs at all, the normal

disinfection treatment, a Prochloraz based fungicide combined with a Captan based fungicide, a Prochloraz based fungicide combined with a Fluazinam based fungicide and a Prochloraz based fungicide and a Thiofanaat-methyl based fungicide.

Conclusion 3.1: **Deviations do not occur when a Prochloraz based fungicide is combined with a Captan based fungicide.**

Conclusion 3.2: **Deviations do not occur when a Prochloraz based fungicide is combined with a Fluazinam based fungicide.**

Conclusion 3.3 **Deviations do not occur when a Prochloraz based fungicide is combined with a Thiofanaat-methyl based fungicide.**

6.4 The bulbs disinfection treatment, which is currently applied by World Breeding B.V.

Main Conclusion: **From this research it cannot be confirmed that the disinfection treatment, which is currently applied by World Breeding B.V., causes deviations in cultivar specific quality and/or production indices as described by world Breeding B.V.**

7. RECOMMENDATIONS

7.1 Practical Use of the Research Results

From a cost perspective it is most interesting not to disinfect bulbs at all. As treatment 0 did not generate negative results at all this would be an option for non-risk batches used for early forcing. Since this research was conducted early in the year, and it can be assumed that a fungal infection, especially infections with *Penicillium* spp. spread during storage it is recommendable to disinfect bulbs used for later forcing and risk batches. Only two all round disinfection treatments were used in this research. Disinfection treatments including Mirage Elan at normal concentration rates and dipping times did not result in quality reductions whatsoever. Disinfection treatments including Allure even caused quality reductions when applied at normal concentrations and dipping times. Furthermore, the treatments including Allure were at least 49 % more expensive than the treatment currently applied at World Breeding B.V. Recommendations are presented in Table 36. For late forcing additional research is recommended.

Table 36 Recommended disinfection treatments based on forcing time and fungal infection risk.

	Early Forcing	**Late Forcing**
Low Risk	Treatment 0	Research recommended
High Risk	Treatment 1	Research recommended

7.2 Additional Research

Disinfection treatments used within this research have been within the normal range of what is currently being applied in the sector. Although double concentrations of Allure and Mirage Elan have been used, there have been no 'extreme' treatments to magnify the effect of Prochloraz based fungicides. For this reason follow up research is recommendable whereby the extremes are taken into account. The follow up research should only include Red Empire® and Massari®, as these are cultivars which are representable for the currently commercially available material from World Breeding B.V. By limiting the amount of cultivars, more replications per treatments can be used without increasing the inputs required as compared to this research, giving a better overview of the variations among the treatments. Table 37 shows the set up of this follow up research.

The follow up research should be carried out with plantings in January and plantings in September. In this way the variation between early and late forcing can be included in the research results. Furthermore, potential development of fungal infections, and the stress factor caused by early forcing can be incorporated, by using early and late plantings.

Table 37 Recommended follow up research set up.

Treatment	0	1	2	3	4	5
Cultivars:	Red Empire® Massari®	Red Empire® Massari®	Red Empire® Massari®	Red Empire® Massari®	Red Empire® Massari®	Red Empire® Massari®
Replications:	20	20	20	20	20	20
Disinfection treatment	Captosan 500 (0%) Shirlan (0%) Topsin M vloeibaar (0%) Mirage Elan (0%) Allure (0%) Admire (0%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0,02%) Allure (0%) Admire (0,04%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0,10%) Allure (0%) Admire (0,04%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0%) Allure (1,00%) Admire (0,04%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0%) Allure (5,00%) Admire (0,04%)	Captosan 500 (1,10%) Shirlan (0,25%) Topsin M vloeibaar (1,00%) Mirage Elan (0%) Allure (0%) Admire (0,04%)
Disinfection time		1 minute	1 minute	1 minute	1 minute	1 minute

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APPENDICES

Appendix 1: Planting Map Massari®

Cultivar	Treatment	Replication	Planting row	Bulb number			
Massari®	4	1	1	1	2	3	4
			2	5	6	7	8
	2	1	3	1	2	3	4
			4	5	6	7	8
	4	2	5	1	2	3	4
			6	5	6	7	8
	2	2	7	1	2	3	4
			8	5	6	7	8
	5	2	9	1	2	3	4
			10	5	6	7	8
	0	1	11	1	2	3	4
			12	5	6	7	8
	3	1	13	1	2	3	4
			14	5	6	7	8
	1	2	15	1	2	3	4
			16	5	6	7	8
	1	1	17	1	2	3	4
			18	5	6	7	8
	0	2	19	1	2	3	4
			20	5	6	7	8
	3	2	21	1	2	3	4
			22	5	6	7	8
	5	1	23	1	2	3	4
			24	5	6	7	8

Appendix 2: Planting Map White Cup®[*]

Cultivar	Treatment	Replication	Planting Row	Bulb number			
White Cup®	0	2	25	1	2	3	4
			26	5	6	7	8
	1	3	27	1	2	3	4
			28	5	6	7	8
	5	2	29	1	2	3	4
			30	5	6	7	8
	4	4	31	1	2	3	4
			32	5	6	7	8
	4	3	33	1	2	3	4
			34	5	6	7	8
	3	1	35	1	2	3	4
			36	5	6	7	8
	4	1	37	1	2	3	4
			38	5	6	7	8
	2	1	39	1	2	3	4
			40	5	6	7	8
	3	4	41	1	2	3	4
			42	5	6	7	8
	3	2	43	1	2	3	4
			44	5	6	7	8
	1	4	45	1	2	3	4
			46	5	6	7	8
	3	3	47	1	2	3	4
			48	5	6	7	8
	2	2	49	1	2	3	4
			50	5	6	7	8
	4	2	51	1	2	3	4
			52	5	6	7	8
	2	4	53	1	2	3	4
			54	5	6	7	8
	1	2	55	1	2	3	4
			56	5	6	7	8
	1	1	57	1	2	3	4
			58	5	6	7	8
	0	1	59	1	2	3	4
			60	5	6	7	8
	5	1	61	1	2	3	4
			62	5	6	7	8
	2	3	63	1	2	3	4
			64	5	6	7	8

[*] Replications 3 and 4 were applied for a period of 15 minutes.

Appendix 3: Planting Map Ice Dreamer®

Cultivar	Treatment	Replication	Planting row	Bulb number			
Ice Dreamer®	4	2	65	1	2	3	4
			66	5	6	7	8
	3	2	67	1	2	3	4
			68	5	6	7	8
	2	2	69	1	2	3	4
			70	5	6	7	8
	3	1	71	1	2	3	4
			72	5	6	7	8
	4	1	73	1	2	3	4
			74	5	6	7	8
	5	2	75	1	2	3	4
			76	5	6	7	8
	2	1	77	1	2	3	4
			78	5	6	7	8
	0	1	79	1	2	3	4
			80	5	6	7	8
	5	1	81	1	2	3	4
			82	5	6	7	8
	1	2	83	1	2	3	4
			84	5	6	7	8
	0	2	85	1	2	3	4
			86	5	6	7	8
	1	1	87	1	2	3	4
			88	5	6	7	8

Appendix 4: Planting Map Starfighter®*

Cultivar	Treatment	Replication	Planting Row	Bulb number			
Starfighter®	3	2	89	1	2	3	4
			90	5	6	7	8
	2	4	91	1	2	3	4
			92	5	6	7	8
	4	1	93	1	2	3	4
			94	5	6	7	8
	3	4	95	1	2	3	4
			96	5	6	7	8
	5	1	97	1	2	3	4
			98	5	6	7	8
	1	2	99	1	2	3	4
			100	5	6	7	8
	2	3	101	1	2	3	4
			102	5	6	7	8
	4	4	103	1	2	3	4
			104	5	6	7	8
	7	1	105	1	2	3	4
			106	5	6	7	8
	6	1	107	1	2	3	4
			108	5	6	7	8
	8	1	109	1	2	3	4
			110	5	6	7	8
	5	2	111	1	2	3	4
			112	5	6	7	8
	2	2	113	1	2	3	4
			114	5	6	7	8
	7	2	115	1	2	3	4
			116	5	6	7	8
	4	2	117	1	2	3	4
			118	5	6	7	8
	4	3	119	1	2	3	4
			120	5	6	7	8
	6	2	121	1	2	3	4
			122	5	6	7	8
	1	1	123	1	2	3	4
			124	5	6	7	8
	2	1	125	1	2	3	4
			126	5	6	7	8
	3	1	127	1	2	3	4
			128	5	6	7	8
	1	3	129	1	2	3	4
			130	5	6	7	8
	8	2	131	1	2	3	4
			132	5	6	7	8

* Replications 3 and 4 were applied for a period of 15 minutes.

	3	3	133	1	2	3	4
			134	5	6	7	8
	0	1	135	1	2	3	4
			136	5	6	7	8
	1	4	137	1	2	3	4
			138	5	6	7	8

Appendix 5: Planting Map Red Empire®

Cultivar	Treatment	Replication	Planting row	Bulb number			
Red Empire®	5	1	139	1	2	3	4
			140	5	6	7	8
	3	1	141	1	2	3	4
			142	5	6	7	8
	1	2	143	1	2	3	4
			144	5	6	7	8
	4	1	145	1	2	3	4
			146	5	6	7	8
	0	1	147	1	2	3	4
			148	5	6	7	8
	4	2	149	1	2	3	4
			150	5	6	7	8
	3	2	151	1	2	3	4
			152	5	6	7	8
	2	1	153	1	2	3	4
			154	5	6	7	8
	5	2	155	1	2	3	4
			156	5	6	7	8
	0	2	157	1	2	3	4
			158	5	6	7	8
	1	1	159	1	2	3	4
			160	5	6	7	8
	2	2	161	1	2	3	4
			162	5	6	7	8

Appendix 6: T-tests Flower Bud quantity Massari®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.62, p > 0.05	A
0 versus 2	Two-sample t(15)=-1.41, p > 0.05	A
0 versus 3	Two-sample t(15)=-2.42, p > 0.05	A
0 versus 4	Two-sample t(15)=-2.57, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.70, p > 0.05	A
1 versus 2	Two-sample t(15)=-0.65, p > 0.05	A
1 versus 3	Two-sample t(15)=-1.62, p > 0.05	A
1 versus 4	Two-sample t(15)=-1.64, p > 0.05	A
2 versus 3	Two-sample t(15)=-0.89, p > 0.05	A
2 versus 4	Two-sample t(15)=-1.19, p > 0.05	A
3 versus 4	Two-sample t(15)=-0.45, p > 0.05	A
5 versus 1	Two-sample t(15)=0.00, p > 0.05	A
5 versus 2	Two-sample t(15)=-0.75, p > 0.05	A
5 versus 3	Two-sample t(15)=-1.65, p > 0.05	A
5 versus 4	Two-sample t(15)=-1.87, p > 0.05	A

Appendix 7: T-tests Flower Bud Quantity White Cup®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.17, p > 0.05	A
0 versus 2	Two-sample t(15)=-0.23, p > 0.05	A
0 versus 3	Two-sample t(15)=0.19, p > 0.05	A
0 versus 4	Two-sample t(15)=0.66, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.19, p > 0.05	A
1 versus 2	Two-sample t(15)=0.00, p > 0.05	A
1 versus 3	Two-sample t(15)=0.36, p > 0.05	A
1 versus 4	Two-sample t(15)=0.76, p > 0.05	A
2 versus 3	Two-sample t(15)=0,54, p > 0.05	A
2 versus 4	Two-sample t(15)=1.04, p > 0.05	A
3 versus 4	Two-sample t(15)=0.58, p > 0.05	A
5 versus 1	Two-sample t(15)=0.06, p > 0.05	A
5 versus 2	Two-sample t(15)=0.06, p > 0.05	A
5 versus 3	Two-sample t(15)=0.32, p > 0.05	A
5 versus 4	Two-sample t(15)=0.63, p > 0.05	A
1 versus 1 (15 min.)	Two-sample t(15)=-0.51, p > 0.05	A
2 versus 2 (15 min.)	Two-sample t(15)=-0.37, p > 0.05	A
3 versus 3 (15 min.)	Two-sample t(15)=-1.15, p > 0.05	A
4 versus 4 (15 min.)	Two-sample t(15)=-0.76, p > 0.05	A
1 (15 min.) versus 2 (15 min.)	Two-sample t(15)=0.43, p > 0.05	A
1 (15 min.) versus 3 (15 min.)	Two-sample t(15)=-0.13, p > 0.05	A
1 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.51, p > 0.05	A
2 (15 min.) versus 3 (15 min.)	Two-sample t(15)=-0.42, p > 0.05	A
2 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.24, p > 0.05	A
3 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.52, p > 0.05	A

Appendix 8: T-test Flower Bud Quantity Ice Dreamer®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-1.58, p > 0.05	A
0 versus 2	Two-sample t(15)=-1.78, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.78, p > 0.05	A
0 versus 4	Two-sample t(15)=-1.06, p > 0.05	A
0 versus 5	Two-sample t(15)=-2.24, p > 0.05	A
1 versus 2	Two-sample t(15)=0.00, p > 0.05	A
1 versus 3	Two-sample t(15)=0.18, p > 0.05	A
1 versus 4	Two-sample t(15)=0.70, p > 0.05	A
2 versus 3	Two-sample t(15)=0.19, p > 0.05	A
2 versus 4	Two-sample t(15)=0.81, p > 0.05	A
3 versus 4	Two-sample t(15)=0.23, p > 0.05	A
5 versus 1	Two-sample t(15)=0.45, p > 0.05	A
5 versus 2	Two-sample t(15)=0.50, p > 0.05	A
5 versus 3	Two-sample t(15)=0.46, p > 0.05	A
5 versus 4	Two-sample t(15)=1.31, p > 0.05	A

Appendix 9: T-test Flower Bud Quantity Starfighter®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.22, p > 0.05	A
0 versus 2	Two-sample t(15)=0.25, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.53, p > 0.05	A
0 versus 4	Two-sample t(15)=-0.59, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.33, p > 0.05	A
0 versus 6	Two-sample t(15)=-0.41, p > 0.05	A
0 versus 7	Two-sample t(15)=-0.15, p > 0.05	A
0 versus 8	Two-sample t(15)=0.27, p > 0.05	A
1 versus 2	Two-sample t(15)=0.70, p > 0.05	A
1 versus 3	Two-sample t(15)=-0.45 p > 0.05	A
1 versus 4	Two-sample t(15)=-0.54, p > 0.05	A
1 versus 6	Two-sample t(15)=-0.28, p > 0.05	A
1 versus 7	Two-sample t(15)=0.10, p > 0.05	A
1 versus 8	Two-sample t(15)=0.68, p > 0.05	A
2 versus 3	Two-sample t(15)=-1.06, p > 0.05	A
2 versus 4	Two-sample t(15)=-1.14, p > 0.05	A
3 versus 4	Two-sample t(15)=-0.08, p > 0.05	A
5 versus 1	Two-sample t(15)=0.17, p > 0.05	A
5 versus 2	Two-sample t(15)=0.76, p > 0.05	A
5 versus 3	Two-sample t(15)=-0.24, p > 0.05	A
5 versus 4	Two-sample t(15)=-0.32, p > 0.05	A
5 versus 6	Two-sample t(15)=-0.07, p > 0.05	A
5 versus 7	Two-sample t(15)=0.26, p > 0.05	A
5 versus 8	Two-sample t(15)=0.75, p > 0.05	A
1 versus 1 (15 min.)	Two-sample t(15)=-0.29, p > 0.05	A
2 versus 2 (15 min.)	Two-sample t(15)=-0.52, p > 0.05	A
3 versus 3 (15 min.)	Two-sample t(15)=-0.10, p > 0.05	A
4 versus 4 (15 min.)	Two-sample t(15)=-0.03, p > 0.05	A
1 (15 min.) versus 2 (15 min.)	Two-sample t(15)=0.35, p > 0.05	A
1 (15 min.) versus 3 (15 min.)	Two-sample t(15)=-0.27, p > 0.05	A
1 (15 min.) versus 4 (15 min.)	Two-sample t(15)=-0.43, p > 0.05	A
2 (15 min.) versus 3 (15 min.)	Two-sample t(15)=-0.55, p > 0.05	A
2 (15 min.) versus 4 (15 min.)	Two-sample t(15)=-0.82, p > 0.05	A
3 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.01, p > 0.05	A

Appendix 10: T-test Flower Bud Quantity Red Empire®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.63, p > 0.05	A
0 versus 2	Two-sample t(15)=-0.23, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.75, p > 0.05	A
0 versus 4	Two-sample t(15)=-1.27, p > 0.05	A
0 versus 5	Two-sample t(15)=-1.52, p > 0.05	A
1 versus 2	Two-sample t(15)=0.45, p > 0.05	A
1 versus 3	Two-sample t(15)=0.00, p > 0.05	A
1 versus 4	Two-sample t(15)=-0.62, p > 0.05	A
2 versus 3	Two-sample t(15)=-0.54, p > 0.05	A
2 versus 4	Two-sample t(15)=-1.12, p > 0.05	A
3 versus 4	Two-sample t(15)=-0.73, p > 0.05	A
5 versus 1	Two-sample t(15)=0.85, p > 0.05	A
5 versus 2	Two-sample t(15)=1.38, p > 0.05	A
5 versus 3	Two-sample t(15)=1.00, p > 0.05	A
5 versus 4	Two-sample t(15)=0.21, p > 0.05	A

Appendix 11: T-test Plant Length Massari®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=0.34, p > 0.05	A
0 versus 2	Two-sample t(15)=-0.48, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.27, p > 0.05	A
0 versus 4	Two-sample t(15)=0.74, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.07, p > 0.05	A
1 versus 2	Two-sample t(15)=-0.88, p > 0.05	A
1 versus 3	Two-sample t(15)=-0.85, p > 0.05	A
1 versus 4	Two-sample t(15)=0.39, p > 0.05	A
2 versus 3	Two-sample t(15)=0.76, p > 0.05	A
2 versus 4	Two-sample t(15)=1.20, p > 0.05	A
3 versus 4	Two-sample t(15)=0.96, p > 0.05	A
5 versus 1	Two-sample t(15)=0.43, p > 0.05	A
5 versus 2	Two-sample t(15)=-0.96, p > 0.05	A
5 versus 3	Two-sample t(15)=-0.30, p > 0.05	A
5 versus 4	Two-sample t(15)=0.84, p > 0.05	A

Appendix 12: T-test Plant Length White Cup®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.35, p > 0.05	A
0 versus 2	Two-sample t(15)=-0.53, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.11, p > 0.05	A
0 versus 4	Two-sample t(15)=0.59, p > 0.05	A
0 versus 5	Two-sample t(15)=0.34, p > 0.05	A
1 versus 2	Two-sample t(15)=0.05, p > 0.05	A
1 versus 3	Two-sample t(15)=0.35, p > 0.05	A
1 versus 4	Two-sample t(15)=0.83, p > 0.05	A
2 versus 3	Two-sample t(15)=1.06, p > 0.05	A
2 versus 4	Two-sample t(15)=1.33, p > 0.05	A
3 versus 4	Two-sample t(15)=0.92, p > 0.05	A
5 versus 1	Two-sample t(15)=-0.57, p > 0.05	A
5 versus 2	Two-sample t(15)=-0.67, p > 0.05	A
5 versus 3	Two-sample t(15)=-0.44, p > 0.05	A
5 versus 4	Two-sample t(15)=0.05, p > 0.05	A
1 versus 1 (15 min.)	Two-sample t(15)=0.20, p > 0.05	A
2 versus 2 (15 min.)	Two-sample t(15)=0.65, p > 0.05	A
3 versus 3 (15 min.)	Two-sample t(15)=-0.14, p > 0.05	A
4 versus 4 (15 min.)	Two-sample t(15)=0.40, p > 0.05	A
1 (15 min.) versus 2 (15 min.)	Two-sample t(15)=0.14, p > 0.05	A
1 (15 min.) versus 3 (15 min.)	Two-sample t(15)=0.37, p > 0.05	A
1 (15 min.) versus 4 (15 min.)	Two-sample t(15)=1.38, p > 0.05	A
2 (15 min.) versus 3 (15 min.)	Two-sample t(15)=0.33, p > 0.05	A
2 (15 min.) versus 4 (15 min.)	Two-sample t(15)=1.35, p > 0.05	A
3 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.87, p > 0.05	A

Appendix 13: T-test Plant Length Ice Dreamer®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.93, p > 0.05	A
0 versus 2	Two-sample t(15)=-1.12, p > 0.05	A
0 versus 3	Two-sample t(15)=-1.12, p > 0.05	A
0 versus 4	Two-sample t(15)=-0.85, p > 0.05	A
0 versus 5	Two-sample t(15)=0.18, p > 0.05	A
1 versus 2	Two-sample t(15)=-0.32, p > 0.05	A
1 versus 3	Two-sample t(15)=-0.51, p > 0.05	A
1 versus 4	Two-sample t(15)=-0.04, p > 0.05	A
2 versus 3	Two-sample t(15)=-0.25, p > 0.05	A
2 versus 4	Two-sample t(15)=0.25, p > 0.05	A
3 versus 4	Two-sample t(15)=0.44, p > 0.05	A
5 versus 1	Two-sample t(15)=-1.25, p > 0.05	A
5 versus 2	Two-sample t(15)=-1.42, p > 0.05	A
5 versus 3	Two-sample t(15)=-1.33, p > 0.05	A
5 versus 4	Two-sample t(15)=-1.12, p > 0.05	A

Appendix 14: T-test Plant Length Starfighter®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.53, p > 0.05	A
0 versus 2	Two-sample t(15)=-0.26, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.79, p > 0.05	A
0 versus 4	Two-sample t(15)=-0.58, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.36, p > 0.05	A
0 versus 6	Two-sample t(15)=-0.25, p > 0.05	A
0 versus 7	Two-sample t(15)=-0.30, p > 0.05	A
0 versus 8	Two-sample t(15)=-0.39, p > 0.05	A
1 versus 2	Two-sample t(15)=0.32, p > 0.05	A
1 versus 3	Two-sample t(15)=-0.27, p > 0.05	A
1 versus 4	Two-sample t(15)=-0.06, p > 0.05	A
1 versus 6	Two-sample t(15)=0.41, p > 0.05	A
1 versus 7	Two-sample t(15)=0.36, p > 0.05	A
1 versus 8	Two-sample t(15)=0.12, p > 0.05	A
2 versus 3	Two-sample t(15)=-0.64, p > 0.05	A
2 versus 4	Two-sample t(15)=-0.38, p > 0.05	A
3 versus 4	Two-sample t(15)=0.20, p > 0.05	A
5 versus 1	Two-sample t(15)=-0.21, p > 0.05	A
5 versus 2	Two-sample t(15)=0.11, p > 0.05	A
5 versus 3	Two-sample t(15)=-0.51, p > 0.05	A
5 versus 4	Two-sample t(15)=-0.27, p > 0.05	A
5 versus 6	Two-sample t(15)=0.17, p > 0.05	A
5 versus 7	Two-sample t(15)=0.12, p > 0.05	A
5 versus 8	Two-sample t(15)=-0.07, p > 0.05	A
1 versus 1 (15 min.)	Two-sample t(15)=0.26, p > 0.05	A
2 versus 2 (15 min.)	Two-sample t(15)=-0.08, p > 0.05	A
3 versus 3 (15 min.)	Two-sample t(15)=0.37, p > 0.05	A
4 versus 4 (15 min.)	Two-sample t(15)=0.22, p > 0.05	A
1 (15 min.) versus 2 (15 min.)	Two-sample t(15)=0.02, p > 0.05	A
1 (15 min.) versus 3 (15 min.)	Two-sample t(15)=-0.10, p > 0.05	A
1 (15 min.) versus 4 (15 min.)	Two-sample t(15)=-0.14, p > 0.05	A
2 (15 min.) versus 3 (15 min.)	Two-sample t(15)=-0.11, p > 0.05	A
2 (15 min.) versus 4 (15 min.)	Two-sample t(15)=-0.13, p > 0.05	A
3 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.00, p > 0.05	A

Appendix 15: T-test Plant Length Red Empire®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.33, p > 0.05	A
0 versus 2	Two-sample t(15)=-0.59, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.56, p > 0.05	A
0 versus 4	Two-sample t(15)=-0.77, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.35, p > 0.05	A
1 versus 2	Two-sample t(15)=-0.68, p > 0.05	A
1 versus 3	Two-sample t(15)=-0.73, p > 0.05	A
1 versus 4	Two-sample t(15)=-1.45, p > 0.05	A
2 versus 3	Two-sample t(15)=-0.15, p > 0.05	A
2 versus 4	Two-sample t(15)=-0.42, p > 0.05	A
3 versus 4	Two-sample t(15)=-0.86, p > 0.05	A
5 versus 1	Two-sample t(15)=0.07, p > 0.05	A
5 versus 2	Two-sample t(15)=-0.58, p > 0.05	A
5 versus 3	Two-sample t(15)=-0.59, p > 0.05	A
5 versus 4	Two-sample t(15)=-1.23, p > 0.05	A

Appendix 16: T-test Flower Bud Length Massari®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.68, p > 0.05	A
0 versus 2	Two-sample t(15)=-0.83, p > 0.05	A
0 versus 3	Two-sample t(15)=0.06, p > 0.05	A
0 versus 4	Two-sample t(15)=-0.62, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.47, p > 0.05	A
1 versus 2	Two-sample t(15)=0.05, p > 0.05	A
1 versus 3	Two-sample t(15)=0.97, p > 0.05	A
1 versus 4	Two-sample t(15)=0.05, p > 0.05	A
2 versus 3	Two-sample t(15)=2.12, p > 0.05	A
2 versus 4	Two-sample t(15)=0.02, p > 0.05	A
3 versus 4	Two-sample t(15)=-0.87, p > 0.05	A
5 versus 1	Two-sample t(15)=-0.44, p > 0.05	A
5 versus 2	Two-sample t(15)=-0.96, p > 0.05	A
5 versus 3	Two-sample t(15)=1.04, p > 0.05	A
5 versus 4	Two-sample t(15)=-0.37, p > 0.05	A

Appendix 17: T-test Flower Bud Length White Cup®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.53, p > 0.05	A
0 versus 2	Two-sample t(15)=-1.30, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.67, p > 0.05	A
0 versus 4	Two-sample t(15)=0.39, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.14, p > 0.05	A
1 versus 2	Two-sample t(15)=-0.27, p > 0.05	A
1 versus 3	Two-sample t(15)=0.14, p > 0.05	A
1 versus 4	Two-sample t(15)=0.85, p > 0.05	A
2 versus 3	Two-sample t(15)=1.18, p > 0.05	A
2 versus 4	Two-sample t(15)=1.85, p > 0.05	A
3 versus 4	Two-sample t(15)=1.19, p > 0.05	A
5 versus 1	Two-sample t(15)=-0.26, p > 0.05	A
5 versus 2	Two-sample t(15)=-0.53, p > 0.05	A
5 versus 3	Two-sample t(15)=-0.22, p > 0.05	A
5 versus 4	Two-sample t(15)=0.39, p > 0.05	A
1 versus 1 (15 min.)	Two-sample t(15)=0.90, p > 0.05	A
2 versus 2 (15 min.)	Two-sample t(15)=2.83, p > 0.05	A
3 versus 3 (15 min.)	Two-sample t(15)=1.25, p > 0.05	A
4 versus 4 (15 min.)	Two-sample t(15)=0.36, p > 0.05	A
1 (15 min.) versus 2 (15 min.)	Two-sample t(15)=-0.67, p > 0.05	A
1 (15 min.) versus 3 (15 min.)	Two-sample t(15)=0.24, p > 0.05	A
1 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.57, p > 0.05	A
2 (15 min.) versus 3 (15 min.)	Two-sample t(15)=0.55, p > 0.05	A
2 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.82, p > 0.05	A
3 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.30, p > 0.05	A

Appendix 18: T-test Flower Bud Length Ice Dreamer®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-1.75, p > 0.05	A
0 versus 2	Two-sample t(15)=-1.51, p > 0.05	A
0 versus 3	Two-sample t(15)=-1.66, p > 0.05	A
0 versus 4	Two-sample t(15)=-1,81, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.77, p > 0.05	A
1 versus 2	Two-sample t(15)=0.20, p > 0.05	A
1 versus 3	Two-sample t(15)=0.00, p > 0.05	A
1 versus 4	Two-sample t(15)=-0.20, p > 0.05	A
2 versus 3	Two-sample t(15)=-0.19, p > 0.05	A
2 versus 4	Two-sample t(15)=-0.37, p > 0.05	A
3 versus 4	Two-sample t(15)=-0.18, p > 0.05	A
5 versus 1	Two-sample t(15)=-1.25, p > 0.05	A
5 versus 2	Two-sample t(15)=-0.96, p > 0.05	A
5 versus 3	Two-sample t(15)=-1.14, p > 0.05	A
5 versus 4	Two-sample t(15)=-1.33, p > 0.05	A

Appendix 19: T-test Flower Bud Length Starfighter®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-0.99, p > 0.05	A
0 versus 2	Two-sample t(15)=-0.52, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.93, p > 0.05	A
0 versus 4	Two-sample t(15)=-0.86, p > 0.05	A
0 versus 5	Two-sample t(15)=-0.79, p > 0.05	A
0 versus 6	Two-sample t(15)=-0.71, p > 0.05	A
0 versus 7	Two-sample t(15)=-0.98, p > 0.05	A
0 versus 8	Two-sample t(15)=-0.51, p > 0.05	A
1 versus 2	Two-sample t(15)=0.59, p > 0.05	A
1 versus 3	Two-sample t(15)=0.19, p > 0.05	A
1 versus 4	Two-sample t(15)=0.18, p > 0.05	A
1 versus 6	Two-sample t(15)=0.49, p > 0.05	A
1 versus 7	Two-sample t(15)=0.12, p > 0.05	A
1 versus 8	Two-sample t(15)=0.49, p > 0.05	A
2 versus 3	Two-sample t(15)=-0.48, p > 0.05	A
2 versus 4	Two-sample t(15)=-0.42, p > 0.05	A
3 versus 4	Two-sample t(15)=0.01, p > 0.05	A
5 versus 1	Two-sample t(15)=-0.16, p > 0.05	A
5 versus 2	Two-sample t(15)=0.37, p > 0.05	A
5 versus 3	Two-sample t(15)=-0.01, p > 0.05	A
5 versus 4	Two-sample t(15)=0.00, p > 0.05	A
5 versus 6	Two-sample t(15)=0.25, p > 0.05	A
5 versus 7	Two-sample t(15)=-0.07, p > 0.05	A
5 versus 8	Two-sample t(15)=0.31, p > 0.05	A
1 versus 1 (15 min.)	Two-sample t(15)=0.63, p > 0.05	A
2 versus 2 (15 min.)	Two-sample t(15)=-0.56, p > 0.05	A
3 versus 3 (15 min.)	Two-sample t(15)=0.54, p > 0.05	A
4 versus 4 (15 min.)	Two-sample t(15)=0.35, p > 0.05	A
1 (15 min.) versus 2 (15 min.)	Two-sample t(15)=-0.63, p > 0.05	A
1 (15 min.) versus 3 (15 min.)	Two-sample t(15)=0.15, p > 0.05	A
1 (15 min.) versus 4 (15 min.)	Two-sample t(15)=-0.04, p > 0.05	A
2 (15 min.) versus 3 (15 min.)	Two-sample t(15)=0.61, p > 0.05	A
2 (15 min.) versus 4 (15 min.)	Two-sample t(15)=0.48, p > 0.05	A
3 (15 min.) versus 4 (15 min.)	Two-sample t(15)=-0.17, p > 0.05	A

Appendix 20: T-test Flower Bud Length Red Empire®

Treatment	T-test output	Group
0 versus 1	Two-sample t(15)=-1.64, p > 0.05	A
0 versus 2	Two-sample t(15)=-1.64, p > 0.05	A
0 versus 3	Two-sample t(15)=-0.65, p > 0.05	A
0 versus 4	Two-sample t(15)=-2.22, p > 0.05	B
0 versus 5	Two-sample t(15)=-1.91, p > 0.05	A
1 versus 2	Two-sample t(15)=0.00, p > 0.05	A
1 versus 3	Two-sample t(15)=0.80, p > 0.05	A
1 versus 4	Two-sample t(15)=-0.55, p > 0.05	A
2 versus 3	Two-sample t(15)=0.80, p > 0.05	A
2 versus 4	Two-sample t(15)=-0.55, p > 0.05	A
3 versus 4	Two-sample t(15)=-1.30, p > 0.05	A
5 versus 1	Two-sample t(15)=0.34, p > 0.05	A
5 versus 2	Two-sample t(15)=0.34, p > 0.05	A
5 versus 3	Two-sample t(15)=1.08, p > 0.05	A
5 versus 4	Two-sample t(15)=-0.17, p > 0.05	A

Appendix 21: One sample T-test Flower Bud Quantity Massari®

Treatment	T-test Output	Group
0 versus expected value (5)	One-sample t(15)=-1.24, p > 0.05	A
1 versus expected value (5)	One-sample t(15)=-0.76, p > 0.05	A
2 versus expected value (5)	One-sample t(15)=-1.58, p > 0.05	A
3 versus expected value (5)	One-sample t(15)=-1.56, p > 0.05	A
4 versus expected value (5)	One-sample t(15)=-0.67, p > 0.05	A
5 versus expected value (5)	One-sample t(15)=-1.61, p > 0.05	A

Appendix 22: One sample T-test Flower Bud Quantity White Cup®

Treatment	T-test Output	Group
0 versus expected value (7)	One-sample t(15)=-1.75, p > 0.05	A
1 versus expected value (7)	One-sample t(15)=-1.36, p > 0.05	A
2 versus expected value (7)	One-sample t(15)=-2.58, p < 0.05	B
3 versus expected value (7)	One-sample t(15)=-2.64, p < 0.05	B
4 versus expected value (7)	One-sample t(15)=-2.16, p < 0.05	B
5 versus expected value (7)	One-sample t(15)=-1.61, p > 0.05	A
1 (15 min.) versus expected value (7)	One-sample t(15)=-3.29, p < 0.05	B
2 (15 min.) versus expected value (7)	One-sample t(15)=-2.48, p < 0.05	B
3 (15 min.) versus expected value (7)	One-sample t(15)=-1.62, p > 0.05	A
4 (15 min.) versus expected value (7)	One-sample t(15)=-1.36, p > 0.05	A

Appendix 23: One sample T-test Flower Bud Quantity Ice Dreamer®

Treatment	T-test Output	Group
0 versus expected value (7)	One-sample t(15)=-2.40, p < 0.05	B
1 versus expected value (7)	One-sample t(15)=-1.45, p > 0.05	A
2 versus expected value (7)	One-sample t(15)=-1.83, p > 0.05	A
3 versus expected value (7)	One-sample t(15)=-0.80, p > 0.05	A
4 versus expected value (7)	One-sample t(15)=-2.28, p < 0.05	B
5 versus expected value (7)	One-sample t(15)=-1.57, p > 0.05	A

Appendix 24: One sample T-test Flower Bud Quantity Starfighter®

Treatment	T-test Output	Group
0 versus expected value (8)	One-sample t(15)=-0.91, p > 0.05	A
1 versus expected value (8)	One-sample t(15)=-0.56, p > 0.05	A
2 versus expected value (8)	One-sample t(15)=-0.83, p > 0.05	A
3 versus expected value (8)	One-sample t(15)=-0.28, p > 0.05	A
4 versus expected value (8)	One-sample t(15)=-0.26, p > 0.05	A
5 versus expected value (8)	One-sample t(15)=-0.36, p > 0.05	A
6 versus expected value (8)	One-sample t(15)=-0.42, p > 0.05	A
7 versus expected value (8)	One-sample t(15)=-0.61, p > 0.05	A
8 versus expected value (8)	One-sample t(15)=-0.70, p > 0.05	A
1 (15 min.) versus expected value (8)	One-sample t(15)=-0.43, p > 0.05	A
2 (15 min.) versus expected value (8)	One-sample t(15)=-0.49, p > 0.05	A
3 (15 min.) versus expected value (8)	One-sample t(15)=-0.20, p > 0.05	A
4 (15 min.) versus expected value (8)	One-sample t(15)=-0.65, p > 0.05	A

Appendix 25: One sample T-test Flower Bud Quantity Red Empire®

Treatment	T-test Output	Group
0 versus expected value (6)	One-sample t(15)=-1,77, p > 0.05	A
1 versus expected value (6)	One-sample t(15)=-1,46, p > 0.05	A
2 versus expected value (6)	One-sample t(15)=-1.91, p > 0.05	A
3 versus expected value (6)	One-sample t(15)=-2.17, p < 0.05	B
4 versus expected value (6)	One-sample t(15)=-1.24, p > 0.05	A
5 versus expected value (6)	One-sample t(15)=-1.22, p > 0.05	A

Appendix 26: One sample T-test Plant Length Massari®

Treatment	T-test Output	Group
0 versus expected value (150)	One-sample t(15)=0.00, p > 0.05	A
1 versus expected value (150)	One-sample t(15)=-0.09, p > 0.05	A
2 versus expected value (150)	One-sample t(15)=0.44, p > 0.05	A
3 versus expected value (150)	One-sample t(15)=0.17, p > 0.05	A
4 versus expected value (150)	One-sample t(15)=-0.20, p > 0.05	A
5 versus expected value (150)	One-sample t(15)=0.04, p > 0.05	A

Appendix 27: One sample T-test Plant Length White Cup®

Treatment	T-test Output	Group
0 versus expected value (95)	One-sample t(15)=0.16, p > 0.05	A
1 versus expected value (95)	One-sample t(15)=0.22, p > 0.05	A
2 versus expected value (95)	One-sample t(15)=0.92, p > 0.05	A
3 versus expected value (95)	One-sample t(15)=0.77, p > 0.05	A
4 versus expected value (95)	One-sample t(15)=-0.03, p > 0.05	A
5 versus expected value (95)	One-sample t(15)=-0.01, p > 0.05	A
1 (15 min.) versus expected value (95)	One-sample t(15)=1.41, p > 0.05	A
2 (15 min.) versus expected value (95)	One-sample t(15)=1.17, p > 0.05	A
3 (15 min.) versus expected value (95)	One-sample t(15)=1.15, p > 0.05	A
4 (15 min.) versus expected value (95)	One-sample t(15)=-0.15, p > 0.05	A

Appendix 28: One sample T-test Plant Length Ice Dreamer®

Treatment	T-test Output	Group
0 versus expected value (110)	One-sample t(15)=-2.55, p < 0.05	B
1 versus expected value (110)	One-sample t(15)=-3.10, p < 0.05	B
2 versus expected value (110)	One-sample t(15)=-2.34, p < 0.05	B
3 versus expected value (110)	One-sample t(15)=-1.44, p > 0.05	A
4 versus expected value (110)	One-sample t(15)=-2.31, p < 0.05	B
5 versus expected value (110)	One-sample t(15)=-3.13, p < 0.05	B

Appendix 29: One sample T-test Plant Length Starfighter®

Treatment	T-test Output	Group
0 versus expected value (95)	One-sample t(15)=-0.31, p > 0.05	A
1 versus expected value (95)	One-sample t(15)=-0.08, p > 0.05	A
2 versus expected value (95)	One-sample t(15)=-0.19, p > 0.05	A
3 versus expected value (95)	One-sample t(15)=-0.01, p > 0.05	A
4 versus expected value (95)	One-sample t(15)=-0.05, p > 0.05	A
5 versus expected value (95)	One-sample t(15)=-0.15, p > 0.05	A
6 versus expected value (95)	One-sample t(15)=-0.28, p > 0.05	A
7 versus expected value (95)	One-sample t(15)=-0.27, p > 0.05	A
8 versus expected value (95)	One-sample t(15)=-0.10, p > 0.05	A
1 (15 min.) versus expected value (95)	One-sample t(15)=-0.22, p > 0.05	A
2 (15 min.) versus expected value (95)	One-sample t(15)=-0.17, p > 0.05	A
3 (15 min.) versus expected value (95)	One-sample t(15)=-0.10, p > 0.05	A
4 (15 min.) versus expected value (95)	One-sample t(15)=-0.17, p > 0.05	A

Appendix 30: One sample T-test Plant Length Red Empire®

Treatment	T-test Output	Group
0 versus expected value (100)	One-sample t(15)=0.02, p > 0.05	A
1 versus expected value (100)	One-sample t(15)=0.40, p > 0.05	A
2 versus expected value (100)	One-sample t(15)=0.52, p > 0.05	A
3 versus expected value (100)	One-sample t(15)=0.88, p > 0.05	A
4 versus expected value (100)	One-sample t(15)=1.27, p > 0.05	A
5 versus expected value (100)	One-sample t(15)=0.38, p > 0.05	A

Appendix 31: One sample T-test Flower Bud Loss Massari®

Treatment	T-test Output	Group
0 versus expected value (0)	One-sample t(15)=0.97, p > 0.05	A
1 versus expected value (0)	One-sample t(15)=1.01, p > 0.05	A
2 versus expected value (0)	One-sample t(15)=1.68, p > 0.05	A
3 versus expected value (0)	One-sample t(15)=2.56, p < 0.05	B
4 versus expected value (0)	One-sample t(15)=2.11, p < 0.05	B
5 versus expected value (0)	One-sample t(15)=1.25, p > 0.05	A