THE EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM FERTILISATION ON THE GROWTH, YIELD AND QUALITY OF *Lachenalia*

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DECLARATION

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ABSTRACT

THE EFFECT OF NITROGEN, PHOSPHORUS AND POTASSIUM FERTILISATION ON THE GROWTH, YIELD AND QUALITY OF *Lachenalia*

Very little is known about the response of *Lachenalia* to fertilisation when cultivated in soil. The objective of this study was therefore to quantify the effect of fertilisation on the growth, yield and quality of *Lachenalia* in both the nursery and pot plant phases. In order to achieve this two pot trials for the nursery phase and one pot trial for the pot plant phase were conducted in the glasshouse.

For the first trial in the nursery phase the combined effect of nine nitrogen levels and three application times on the *Lachenalia* cultivars, Rupert and Ronina, were studied. The nitrogen was applied at levels equivalent to 0, 30, 70, 120, 180, 250, 330, 420 or 520 kg N ha^{-1}. Three different nitrogen application times were used namely: one third with planting and the rest 10 weeks after planting (T_1); one third with planting and the other two thirds after planting (T_2) or one quarter with planting and the other three quarters after planting (T_3). The leaf area of Ronina plants was larger than that of Rupert plants irrespective of nitrogen levels and application times. However, Ronina bulbs were larger and softer than Rupert bulbs. The nutrient (N, P, Ca and Mg) and carbohydrate (D-glucose, sucrose and starch) content of Rupert bulbs were higher than that of Ronina bulbs. Application of nitrogen had a positive influence on the leaf area, bulb fresh mass and circumference of both cultivars. Bulb firmness was negatively influenced by nitrogen application. The best results for most parameters were obtained when nitrogen was applied in four equal applications.

In the second trial for the nursery phase the response of Rupert and Ronina to five nitrogen (0, 70, 180, 330 or 520 kg N ha^{-1}) and five phosphorus (0, 10, 30, 50 or 80 kg N ha^{-1}) or five potassium (0, 70, 180, 330 or 520 kg N ha^{-1}) levels were studied. Neither the interaction between nitrogen and phosphorus levels nor the interaction between nitrogen and potassium levels had a large influenced on the growth and development of *Lachenalia*. Results obtained in this trial with respect to the effect of nitrogen levels on the different parameters mainly confirm with the results obtained with the first trial.

In the trial for the pot plant phase the effect of seven nitrogen levels (0, 30, 70, 120, 180, 250, 330, 420 or 520 kg N ha^{-1}) on *Lachenalia* grown from 7-8 cm bulbs, whereof the fertilisation history in the nursery phase differed, was investigated. The fertilisation history of the bulbs in the nursery phase consisted of three nitrogen levels (0, 70, 250 or 520 kg N ha^{-1}) combined with two nitrogen application times (T_1, T_2 or T_3 as described earlier). The leaf area of Ronina plants was larger than that of Rupert plants. Nitrogen applied in the nursery phase promoted the leaf area of both Rupert and Ronina. Application of nitrogen in the nursery phase and in the pot plant phase increased the number of inflorescence per plant and the number of florets per inflorescence. The peduncle length increased with higher nitrogen levels in the nursery phase whereas the peduncle diameter increased with higher nitrogen levels in the pot plant phase.

Keywords: Bulb quality, florets quality, inflorescence quality, leaf area, peduncle length

UITTREKSEL

DIE EFFEK VAN STIKSTOF-, FOSFOR- EN KALIUMBESTING OP DIE GROEI, OPBRENGS EN KWALITEIT VAN *Lachenalia*

Min inligting is bekend oor die reaksie van *Lachenalia* op bemesting wanneer dit in grond verbou word. Die doel van die studie was om die effek van bemesting op die groei, opbrengs en kwaliteit van *Lachenalia* in beide die kwekery- en potplantfase te kwantifiseer. Om dit te bereik is twee potproewe vir die kwekeryfase en een potproef vir die potplantfase in die glashuis uitgevoer.

Vir die eerste potproef in die kwekeryfase is die gekombineerde effek van nege stikstof peile en drie toedienings tye op die twee *Lachenalia* cultivars, Rupert en Ronina, ondersoek. Stikstof is toegedien teen peile ekwiwalent aan 0, 30, 70, 120, 180, 250, 330, 420 of 520 kg N ha^{-1}. Drie verskillende toedieningstye is gebruik naamlik: een derde met plant en die ander twee derdes tien weke na plant (T_1); een derde met plant en die ander twee derdes na plant deur die groeiseisoen (T_2) of een kwart met plant en die ander drie kwarte na plant deur die groeiseisoen (T_3). Die blaaroppervlak van Ronina plante was grootter as die van Rupert plante ongeag die stikstofpeile en toedieningstye. Ronina bolle was ook grootter en sagter as die bolle van Rupert. Die voedingstofinhoud (N, P, Ca en Mg) en koolhidraatinhoud (D-glukose, sukrose en stysel) van Rupert bolle was hoër as die van Ronina bolle. Stikstoftoediening het 'n positiewe invloed op die blaaroppervlak, bolmassa en -omtrek van beide cultivars gehad. Stikstoftoediening het die fermheid van bolle is negatief beïvloed deur stikstoftoediening. Die beste resultate vir die meeste parameters wat gemeet is, is verkry as stikstof in vier gelyke dele (T_3) deur die groeiseisoen toegedien is.

In die tweeede proef vir die kwekeryfase is die reaksie van Rupert en Ronina op vyf stikstof- (0, 70, 180, 330 or 520 kg N ha^{-1}) en vyf fosfor- (0, 10, 30, 50 or 80 kg N ha^{-1}) of vyf kaliumpeile (0, 70, 180, 330 or 520 kg N ha^{-1}) ondersoek. Die interaksie tussen stikstof- en fosforpeile asook die interaksie tussen stikstof- en kaliumpeile het nie 'n groot invloed op die groei en ontwikkeling van *Lachenalia* gehad nie. Resultate wat verkry is in die proef met betrekking tot die invloed van stikstofpeile op die die groei en ontwikkeling van *Lachenalia* het grootliks die resultate bevestig wat in die eerste proef verkry is.

In die proef vir die potplantfase is die invloed van sewe stikstofpeile (0, 30, 70, 120, 180, 250, 330, 420 of 520 kg N ha^{-1}) op *Lachenalia*, wat ontwikkel het uit 7-8 cm bolle en waarvan die bemestingsgeskiedenis verskil, ondersoek. Die bemestingsgeskiedenis van die bolle in die kwekeryfase het uit drie stikstofpeile (0, 70, 250 of 520 kg N ha^{-1}) bestaan wat met twee stikstof toedieningstye (T_1, T_2 of T_3 soos vroeër verduidelik) gekombineer is. Die blaaroppervlak van Ronina plante was groter as die van Rupert. Stikstof wat in die kwekeryfase toegedien is het die blaaroppervlak van beide Rupert en Ronina in die potplantfase positief beïnvloed. Die aantal bloeiwyses per plant en blommetjies per bloeiwyse het toegeneem soos die stikstofpeile verhoog het in die kwekery- asook die potplantfase. Die bloeisteellengte verleng met 'n toename in stikstofpeile in die kwekeryfase terwyl die deursnee van die bloeisteel toeneem met 'n toename in stikstofpeile in die potplantfase.

Sleutelwoorde: Bol kwaliteit, bloeiwyse kwaliteit, blaaroppervlak, bloeisteellengte

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CHAPTER 1

MOTIVATION AND OBJECTIVES

1.1 MOTIVATION

South Africa is a country with a rich inheritance of indigenous flower bulbs species (Niederwieser, Kleynhans & Hancke, 2002). Despite this valuable natural resource, South Africa is still not one of the largest exporters of flower bulbs in the world (De Hertogh & Le Nard, 1993). The floriculture industry in South Africa is small compared to the Netherlands, France, United Kingdom and United States of America which are the major bulb producing countries.

International sanctions prior to 1991 influenced the flower bulb industry of South Africa negatively and caused the industry to grow mainly around the local market. Only a few commercial cultivars have been introduced to the international flower bulb market (Rees, 1992). Gladiolus and Freesias are two examples of flower bulbs indigenous to South Africa that are now cultivated in other countries over the world (Niederwieser *et al.*, 2002). The international orientation of growers as well as international networking by researchers was also influenced negatively by international sanctions (Department of Trade and Industry, 2000).

In general flower bulb production is very labour intensive and can therefore make an important contribution to employment creation in South Africa (Niederwieser *et al.*, 2002). The importance of novel products for the export market and South African's opportunity in this regard cannot be over emphasized.

The ARC Institute for Vegetables and Ornamental Plants started with research on a number of genera in the 1960's and one genus, *Lachenalia* J. Jacq. ex Murray (Hyacinthaceae), was selected as a flower bulb with very good potential to develop as a new crop (Ferreira & Hancke, 1985; Coertze & Louw, 1990; Coertze, Hancke, Louw, Niederwieser & Klesser 1992). This genus was evaluated for its excellent flower variation, excellent shelf live, average propagation and regular flowering.

Lachenalia is a bulbous plant with different varieties which can be used in the floriculture industry for garden bulbs, cut flowers and pot plants (Hancke, 1991; Coertze *et al.*, 1992). South Africa can increase its market share in the international flower bulb trade by increasing the production and export of *Lachenalia* bulbs. During the 2001 season 1 million and 2003 season 3 million *Lachenalia* bulbs were exported to Europe (Personal communication, 2002: F.L. Hancke, Pretoria and 2003: J.G. Niederwieser, Pretoria).

Lachenalia species are indigenous to the winter rainfall areas of South Africa (Duncan, 1988). There are currently 110 *Lachenalia* species. All of these *Lachenalia* species are deciduous (Duncan, 1992). *Lachenalia* are very widdy distributed from the south-western region of Namibia, south into South Africa where it is found throughout the Western Cape to as far inland as the south-western Free State, from where its probable boundary makes an arc to the south east down to Eastern Cape on the east coast. The genus therefore occurs in a very wide range of habitats such as semi-desert conditions in deep sand, rocky outcrops in humus-rich soil, seasonally inundated flats and marshes, and high rainfall mountain conditions (Duncan, 1992). *Lachenalia* occur in a wide range of soil types, however, soils must be well drained for best growth and production.

Several factors such as climatic conditions, soil properties and cultivation practices may have an influence on the growth of *Lachenalia* and hence yield of bulbs. South Africa has for example tremendous climate diversity that ranges from summer to winter rainfall regions, arid to humid zones and temperate to tropical areas (du Toit, Robbertse & Niederwieser, 2001). In addition a large range of soils, differing vastly in physical, chemical and biological properties, covered South Africa also (Land Type Survey Staff, 2001). More information is needed on the optimum growth conditions of *Lachenalia* to produce bulbs competitively for the export market.

There is much variation in the optimum growth conditions both in and between *Lachenalia* species. *Lachenalia* spp. follows the growth cycle of winter rainfall plants (Duncan, 1988; Roodbol, Louw & Niederwieser, 2002). In nature the bulbs start growing after the first winter rain with rapid vegetative growth in autumn (April to May), followed by flowering in winter and spring (June to September). Plants stop flowering when temperatures start to increase and the rainfall decrease. This is followed by a long

dormant period during the hot, dry summer months (November to March) (Duncan, 1988).

Before flowering, bulb growth is slow but after flowering bulb growth increase. Day length has no effect on the growth cycle of bulbs of the family Hyacinthaceae. However, temperature is the most important environmental factor which regulate the growth cycle of *Lachenalia* bulbs (Rees, 1992).

Lachenalia bulbs can be propagated in different ways. For example bulbs can be propagated *in vivo* where the mother bulbs can spontaneously form daughter bulbs. Apart from this method mature leaves can be placed in suitable medium whereafter bulblets will form on the cut surface of the leaves. Bulbs can also be propagated *in vitro* by means of adventitious bud formation on leaf segments (explants) (Coertze *et al.*, 1992; Niederwieser & Ndou, 2003). It is the young tissue from the proximal ends of leaves that will form the most bulblets and old tissue from the distal end the least (Coertze *et al.*, 1992; Ndou, Niederwieser & Robbertse, 2003; Niederwieser & Ndou, 2003; Suh, Lee & Roh, 1997).

The production of *Lachenalia* consists of four phases: firstly, the production of bulblets from leaf cuttings, followed by bulb enlargement, bulb preparation and lastly the pot plant production stage (Du Toit, 2001). Phase two and three can also be called the nursery phase which is very important in *Lachenalia* production. The objective of the nursery phase is to produce a high percentage export quality bulbs with a circumference of = 6 cm up to 9 cm in the shortest period possible (Louw, 1993; Roodbol *et al.*, 2002).

Usually, bulblets obtained from leaf cuttings are between 2-2.5 cm and 3-4 cm in diameter and too small for export. Further enlargement of these bulblets in the nursery for a year is therefore essential. However, after two years some bulbs will have only a diameter of between 4-5 cm and 5-6 cm and are still not large enough to export. These two year old bulbs will be planted in the nursery for another year whereafter it will be destroyed if still not = 6 cm in diameter. At present bulbs with a diameter of more than 10-12 cm are not been exported but it may change in future (Personal communication, 2002: F.L. Hancke, Pretoria and 2003: J.G. Niederwieser, Pretoria).

Bulblets are planted in beds in the nursery at 1.5 million bulblets per hectare. After one season in the nursery 600 000 bulbs with an average mass of 7 g (4.2 ton ha^{-1}), 600 000 bulbs with a average mass of 5 g (3 ton ha^{-1}) and 300 000 bulbs with a average mass of 3-4 g (0.9 ton ha^{-1}) are harvested. A total average yield of 8.1 ton ha^{-1} can be harvested in a nursery (Personal communication, 2002: F.L. Hancke, Pretoria and 2003: J.G. Niederwieser, Pretoria)..

Very little is known about the response of *Lachenalia* bulblets planted in soil when fertilised with nitrogen, phosphorus and potassium. Nitrogen is needed for vegetative growth and is part of proteins, enzymes, vitamins, chlorophyll and plant regulators. Too much nitrogen can delay flowering and fruiting while deficiencies can reduce yields, cause yellowing of the leaves and stunt growth (Bergmann, 1992). Phosphorus is not only necessary for seed germination but also stimulates early growth and is important in flower and fruit formation. The vital role of phosphorus in fat, carbon, hydrogen and oxygen metabolism as well as in respiration and photosynthesis must be emphasised (Havlin, Beaton, Tisdale & Nelson, 1999). Potassium promotes vigor and disease resistance, supports root development, improves plant quality and increases winter hardiness due to carbohydrate storage in roots. In addition potassium increase protein production and is essential to starch, sugar and oil formation and transfer and in water relations (Mengel & Kirkby, 1978). It is also well known that there is an interaction between nitrogen and phosphorus and also between nitrogen and potassium. For example high phosphorus levels will inhibit the uptake of nitrogen by plants. Usually, high nitrogen and low potassium levels favour vegetative growth and low nitrogen and high potassium levels promote flowering (Mengel & Kirkby, 1978; Bergmann, 1992; Havlin *et al*., 1999).

1.2 OBJECTIVES

The general aim with this study was therefore to quantify the effect of nitrogen, phosphorus and potassium fertilisation on the growth, yield and quality of *Lachenalia* cultivars when cultivated in soil. Specific objectives were however as follow:

1. To determine the response of *Lachenalia* to nitrogen fertilisation in the nursery phase (Chapter 3).

2. To establish the response of *Lachenalia* to nitrogen and phosphorus or potassium fertilisation in the nursery phase (Chapter 4).
3. To ascertain the response of *Lachenalia* to nitrogen fertilisation in the pot plant phase (Chapter 5).

CHAPTER 2

MATERIALS AND METHODS

2.1 GENERAL

In order to achieve the objectives of this study several pot trials were conducted from 2001 until 2003 in the glasshouses of the Department of Soil, Crop and Climate Sciences at the University of the Free State in Bloemfontein. All the soil and plant analyses were done in the laboratories of this department. Staff of the ARC-Roodeplaat Institute for Vegetable and Ornamental Plants at Roodeplaat in Pretoria gave valuable hints on the proper conduction of *Lachenalia* pot trials.

2.2 SOIL COLLECTION AND PREPARATION

Topsoil of the fine sandy loam Bainsvlei form (Soil Classification Working Group, 1991) was collected from a commercial farm west of Bloemfontein for the pot trials. The soil was dried at room temperature, sieved through a 5 mm screen, mixed manually several times and stored until needed. Initially, insufficient soil was collected in 2001 for all the pot trials and additional soil was collected in 2003. As a result of crop rotation on the farm it was impossible to collect in both instances soil from the same field. The soil collected in 2001 and 2003 differed therefore somewhat with regard to their chemical properties (Table 2.1). However the fertility status of the 2001 and 2003 collected soil is in general excellent according to local guidelines (FSSA, 2003).

Table 2.1: Some physical and chemical properties of the topsoil collected in 2001 and 2003 for the pot trials

Property*	2001	2003
Particle size distribution (%)		
Sand (0.02-2 mm)	84	84
Silt (0.002 - 0.02 mm)	2	2
Clay (< 0.002 mm)	14	14
$pH_{(KCl)}$	7.3	5.1
EC (mSm^{-1})	17	14
Nutrients ($mg\ kg^{-1}$)		
P ($NaHCO_3$)	10	15
Ca (NH_4OAc)	802	641
Mg (NH_4OAc)	178	119
K (NH_4OAc)	148	166
Na (NH_4OAc)	49	32
Zn (HCl)	2	2

*** Determined with standard procedures (The Non-Affiliated Soil Analysis Working Committee, 1990)**

2.3 EXPERIMENTAL DESIGN AND TREATMENTS

A complete randomised block design was used for every pot trial conducted in this study. The treatments however differed between the trials in agreement with the study's objectives.

In the nursery phase the response of *Lachenalia* cultivars to nitrogen levels and application times was investigated firstly (Figure 2.1 and 2.2). The trials were conducted in 2001 and 2002 with soil collected in 2001 (Table 2.1). Two trials were run every year by planting bulblets of different circumferences in each *viz.* 2.5-3 cm and 3-4 cm. A total of 24 treatment combinations were applied per trial in 2001, including six nitrogen levels, two application times and two cultivars (Table 2.2). Based on results of this year the treatment combinations were increased to 54 per trial in 2002, comprising nine nitrogen levels, three application times and two cultivars.

Table 2.2: Summary of the treatments applied in 2001 and 2002 to investigate the response of *Lachenalia* cultivars in the nursery phase to nitrogen levels and application times. Bulblets (2.5-3 cm and 3-4 cm) without a fertilisation history were planted.

Nitrogen levels (kg ha^{-1})			
2001		**2002**	
N_0	0	**N_0**	0
N_1	30	**N_1**	30
N_2	70	**N_2**	70
N_3	120	**N_3**	120
N_4	180	**N_4**	180
N_5	250	**N_5**	250
		N_6	330
		N_7	420
		N_8	520
Application time			
T_1	$^1/_3$ N with planting $^2/_3$ N 10 weeks after planting	**T_1**	$^1/_3$ N with planting $^2/_3$ N 10 weeks after planting
T_2	$^1/_3$ N with planting $^1/_3$ N 10 weeks after planting $^1/_3$ N 18 weeks after planting	**T_2**	$^1/_3$ N with planting $^1/_3$ N 10 weeks after planting $^1/_3$ N 16 weeks after planting
		T_3	$^1/_4$ N with planting $^1/_4$ N 10 weeks after planting $^1/_4$ N 16 weeks after planting $^1/_4$ N 21 weeks after planting
Cultivar			
C_1	Rupert	**C_1**	Rupert
C_2	Ronina	**C_2**	Ronina

Figure 2.1: ***Lachenalia*** **plants grown from bulblets (2.5-3 cm) representing the nursery phase**

Figure 2.2: Five ***Lachenalia*** **plants per pot grown from (2.5-3 cm) bulblets representing the nursery phase**

Secondly the response of *Lachenalia* cultivars to nitrogen and phosphorus levels as well as to nitrogen and potassium levels was also investigated in the nursery phase. The two trials were conducted in 2003 with soil collected this year (Table 2.1). Only bulblets with

a circumference of 2.5-3 cm were planted. A total of 50 treatment combinations were applied per trial as shown in Table 2.3 (Five nitrogen levels, five phosphorus levels and two cultivars) and Table 2.4 (Five nitrogen levels, five potassium levels and two cultivars).

Table 2.3: Summary of treatments applied in 2003 to investigate the response of *Lachenalia* cultivars in the nursery phase to nitrogen and phosphorus levels. Bulblets (2.5-3 cm) without a fertilisation history were planted.

Nitrogen level (kg ha^{-1})		Phosphorus level (kg ha^{-1})	
N_0	0	P_0	0
N_1	70	P_1	10
N_2	180	P_2	30
N_3	330	P_3	50
N_4	520	P_4	80
Application time			
T_1	$^1/_3$ N with planting $^2/_3$ N 10 weeks after planting	T_1	$^1/_3$ P with planting $^2/_3$ P10 weeks after planting
Cultivar			
C_1	Rupert		
C_2	Ronina		

Table 2.4: Summary of treatments applied in 2003 to investigate the response of *Lachenalia* cultivars in the nursery phase to nitrogen and potassium levels. Bulblets (2.5-3 cm) without a fertilisation history were planted.

Nitrogen level (kg ha^{-1})		Potassium level (kg ha^{-1})	
N_0	0	K_0	0
N_1	70	K_1	70
N_2	180	K_2	180
N_3	330	K_3	330
N_4	520	K_4	520
Application time			
T_1	$^1/_3$ N with planting $^2/_3$ N 10 weeks after planting	T_1	$^1/_3$ K with planting $^2/_3$ K 10 weeks after planting
Cultivar			
C_1	Rupert		
C_2	Ronina		

In the pot plant phase the response of *Lachenalia* cultivars to nitrogen levels was investigated in 2002 and 2003 (Figure 2.3-2.6). Only one year old bulbs with a 7-8 cm circumference that had a known fertilisation history were planted in the 2001 collected soil (Table 2.1). The fertilisation history of the bulbs that were planted in 2002 and 2003 are given in Table 2.5 and 2.6 respectively. In addition the treatment combinations for 2002 and 2003 are also presented.

Figure 2.3: Early growth stage of *Lachenalia* pot plants grown from (7-8 cm) bulbs

Figure 2.4: Ronina pot plant

Figure 2.5: Rupert pot plants showing the first signs of inflorescence

Figure 2.6 Rupert pot plants

Table 2.5: Summary of treatments applied in 2002 to investigate the response of *Lachenalia* cultivars in the pot plant phase to nitrogen levels. Bulbs (7-8 cm) with a fertilisation history from the 2001 nursery phase were planted.

Nitrogen level (kg ha^{-1})			
2001 (Nursery phase)		**2002 (Pot plant phase)**	
N_0	0	N_0	0
N_1	70	N_1	30
N_2	250	N_2	70
		N_3	120
		N_4	180
		N_5	250
Application time			
T_1	$^1/_3$ N with planting $^2/_3$ N 10 weeks after planting	T_1	$^1/_3$ N with planting $^2/_3$ N 10 weeks after planting
T_2	$^1/_3$ N with planting $^1/_3$ N 10 weeks after planting $^1/_3$ N 18 weeks after planting		
Cultivar			
C_1		Rupert	
C_2		Ronina	

Table 2.6: Summary of treatments applied in 2003 to investigate the response of *Lachenalia* cultivars in the pot plant phase to nitrogen levels. Bulbs (7-8 cm) with a fertilisation history from the nursery phase were planted.

Nitrogen level(kg ha^{-1})			
2002		**2003**	
N_0	0	N_0	0
N_1	250	N_1	70
N_2	520	N_2	180
		N_3	330
		N_4	520
Application time			
T_1	$^1/_3$ N with planting $^2/_3$ N 10 weeks after planting	T_1	$^1/_3$ N with planting $^2/_3$ N 10 weeks after planting
T_3	$^1/_4$ N with planting $^1/_4$ N 10 weeks after planting $^1/_4$ N 16 weeks after planting $^1/_4$ N 21 weeks after planting		
Cultivar			
C_1		Rupert	
C_2		Ronina	

All the bulblets planted in the nursery phase trials were kindly supplied by the ARC-Institute for Vegetable and Ornamental Plants. These bulblets had no fertilisation history as they were propagated from leaf cuttings. As mentioned the bulbs planted in the pot plant phase trials had a fertilisation history that must be kept in mind. These bulbs resulted from 2.5-3 cm circumference bulblets planted in the 2001 and 2002 nursery trials that were duplicated for this purpose. After harvesting the bulbs were graded according

to circumference, dipped in a solution (Table 2.7), dried in the shade, and stored in brown paper bags in a dark, well ventilated room at 20 to 25°C (Coertze *et al.*, 1992).

Table 2.7: Composition of solution for bulb treatment before storage

Chemical	Doses per 50 *l* H_2O
Kaptam	150 g
Omite	10 ml
Formalin (37 %)	250 ml
Benomil	50 g

For each treatment combination four 3 *l* plastic pots were filled with soil. The soil in the pots was wetted to field capacity before planting in April. In each pot of the nursery phase trials, six bulblets were planted and two weeks after emergence the plant were thinned to five per pot. One pot with the five bulblets represented one replication. Only two bulbs were planted per pot for the pot plant phase trials without thinning after emergence. All the pots were kept at field capacity using a drip irrigation system with a capacity of 4 $l\ h^{-1}$.

The fertilisation treatments were done by applying the appropriate amounts of nitrogen, phosphorus and potassium in solution to the pots. Ammonium nitrate, phosphoric acid and potassium chloride were used as sources of nitrogen, phosphorus and potassium respectively. The relevant nutrient solution was poured evenly on the soil surface of each pot whereafter the pots were irrigated.

In order to simulate the natural conditions in which *Lachenalia* plants grow the glasshouse temperatures were managed as follow: 22°C during day and 10°C during night from planting (April) to four weeks after full bloom (September). Thereafter the day and night temperatures were gradually increased to respectively 32°C and 15°C until harvest (November) to force the bulbs into a dormant phase.

2.4 COLLECTION OF DATA

2.4.1 PLANT GROWTH PARAMETERS

2.4.1.1 Leaf area

The leaf area per plant was calculated for all the pot trials using the following equation (Gardner, Pearce & Mitchell, 1985): Leaf area (cm^2) = ½ x Leaf blade length (cm) x Leaf blade width (cm). Thus in addition to the number of leaves the leaf blade length and width was measured also every second or third week until 23 weeks after planting.

2.4.1.2 Inflorescence

For the pot plant trials the total length of the peduncle was measured and the inflorescences per plant as well as florets per inflorescence were counted. The inflorescence stem diameter was measured in the pot plant phase trials in 2003.

2.4.2 BULB YIELD AND QUALITY

2.4.2.1 Bulb mass

At harvest the fresh mass of the bulbs were measured. The bulbs were then dried in an oven at 60°C for three to four weeks whereafter the dry mass was measured, also.

2.4.2.2 Bulb circumference

All bulbs were graded according to their circumference using perspex grading plates as shown in Figure 2.7. Eleven perspex plates with holes having the following circumferences were used for the grading: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 cm.

2.4.2.3 Bulb firmness

As shown in Figure 2.8 a constant load penetrometer (Stanhope Seta Limited, England, Model 1719) which is automatically controlled by a Seta-Matic penetrometer controller (Model 1720) was used to determine the firmness of the nursery phase bulbs. A constant load of 100 g was dropped automatically on the bulb allowing a needle to penetrate the bulb for 10 seconds whereafter the depth of penetration was recorded. The softer the bulb the deeper the needle will penetrate the bulb.

Figure 2.7: Some of the perspex plates that were used in the grading of the bulbs

Figure 2.8: The penetrometer used to determine the firmness of the bulbs

2.4.2.3 Bulb nutrient status

The dried bulbs were milled and analysed for several nutrients using standard procedures (Agrilasa, 2002). Steam distillation was used for the determination of N after digestion of the samples with sulphuric acid. Ashing of the samples with nitric acid was used to obtain the P, K, Ca and Mg in solution. The P was determined by colorimetry and the K, Ca and Mg by atomic absorption.

2.4.2.4 Bulb D-glucose, sucrose and starch content

The sucrose and D-glucose content of the bulbs harvested after the nursery phase trials were determined by the method outlined by Boehringer Mannheim (1997). Sucrose and D-glucose content were determined enzymatically using test kids (Boehringer Mannheim, 1997; cat. No. 716260). Calculations of sucrose and D-glucose levels were carried out according to the method of the suppliers of the test kids.

In addition, the starch content of these bulbs were also determined by using the Boehringer Mannheim starch test kits (Boehringer Mannheim, 1997; cat. No. 207748). Calculation of starch content was carried out according to the method of the suppliers of the starch test kits.

2.5 STATISTICAL ANALYSIS

As already mentioned all the pot trials were laid out as complete randomized block design. Analysis of variance was done on every measured parameter to determine the significance of differences between means of treatments using the NCSS 2000 program and Tukey's test for the LSD = 0.05.

CHAPTER 3

RESPONSE OF *Lachenalia* TO NITROGEN FERTILISATION IN THE NURSERY PHASE

3.1 INTRODUCTION

The aim of *Lachenalia* flower bulb producers is to produce a high yield of good quality bulbs in the shortest possible time. According to Brewster (1994) the yield of any crop is determined by: the quality of light absorbed by the leaves while harvestable dry matter is being produced; the efficiency with which the absorbed light is converted by photosynthesis into sucrose; the proportion of photosynthetic output transferred to the harvested part of the plant; the conversion coefficient between photosynthetic sucrose and the biochemical constituents of the harvested material; the weight losses due to respiration and decay after the above photosynthetic and biosynthetic processes have occurred.

Thus to achieve a high yield of marketable *Lachenalia* bulbs, *Lachenalia* bulblets should be planted at an appropriate time to develop sufficient leaf area for the interception of a high portion of incident light. Any factor which decreases the leaf area such as disease, pest or hail damage, low plant population, late planting, damage from herbicides or stress from lack of nutrients or water during the growth period could all contribute to low yields and poor quality bulbs (Brewster, 1994).

Lachenalia bulblets obtained from leaf cuttings are grown by producers for at least one season in a nursery till it reach the minimum marketable size of 6 cm in circumference. Roodbol & Niederwieser (1998) found that the bulb circumference of the *Lachenalia* cultivar Romelia increased shortly after planting due to uptake of water. The bulb circumference then started to decrease from approximately 8 weeks after planting and reached a minimum at full flowering. After flowering, the circumference of the bulbs increased markedly and reaching an average of 7.5 cm in circumference at harvest. However, fertilisation has a large influence on the number of bulbs reaching the minimum circumference of 6 cm in only one season (Louw, 1993).

Proper nutrition of *Lachenalia* plants in the nursery phase is therefore of utmost importance to ensuring a high yield of good quality bulbs (Louw, 1993). In this regard

nitrogen will play a vital role as was found with other bulbous flower plants such as *Hippeastrum* (Silberbush, Ephrath, Alekperov & Ben-Asher, 2003), *Leucocoryne coquimbensis* (Kim, Ohkawa & Nitta, 1998) and *Zantedeschia* (Clemens, Dennis, Butler, Thomas, Ingle & Welsh, 1998).

Nitrogen is absorbed by plants in both the ammonium and nitrate form. It is generally understood that ammonium is absorbed and utilised primary by young plants, whereas nitrate is the principal form utilised during the late growth stages. However, plants vary in their proportion of ammonium versus nitrate utilisation (Bennett, 1993).

Nitrogen has numerous functions in the plant. After absorption of ammonium or nitrate from soil these ions are transformed in the plant to the amine form. It is then utilised to form amino acids. Amino acids are essential for protein formation since they are considered as the building blocks. The amino acids are also part of the nucleic acids, DNA and RNA, that respectively hold the genetic information and direct protein synthesis (Bergmann, 1992). Nitrogen is also a constituent of other plant compounds such as chlorophyll and nucleotides. Many enzymes are proteinaceous and therefore nitrogen plays a key role in many metabolic processes. Nitrogen is also a structural constituent of cell walls (Havlin *et al.*, 1999).

From the foregoing discussion it is clear that any over or under fertilisation of nitrogen can be detrimental to the production *of Lachenalia* flower bulbs. Until now very little research was done on the nitrogen fertilisation requirement of *Lachenalia* plants that are cultivated in soil. However, research on other bulbous plants showed that deficiencies in nitrogen can lead to small plants and bulbs with early maturity. Conversely, excess nitrogen produce softer bulbs which are more susceptible to rotting, and delayed maturity (Sutcliffe, & Baker, 1974; Tsutsui, 1975; Laughlin, 1989; Maier, Dahlenburg, & Twigden, 1990; Bennett, 1993; Batal, Bondari, Granberry, & Mullinix, 1994; Ruamrungsri, Ruamrungsri, Ikarashi & Ohyama, 1997; Clemens *et al.*, 1998).

Proper management of nitrogen fertilisation for *Lachenalia* bulb production is critical, particularly on sandier soils that are very susceptible to nitrate leaching. Several studies showed that when bulbous plants are cultivated on sandier soils multiple applications of smaller amounts of nitrogen are the most efficient in reducing nitrate losses through leaching and hence preventing groundwater pollution. Usually it is recommended that a

third of the nitrogen is applied early in the growing season (1-8 weeks after planting) and the remaining two thirds of the nitrogen late in the growing season (16-24 weeks after planting). This approach ensures nitrogen availability during the vegetative and reproductive phase of most bulbous plants (Slangen, Krook, Hendriks & Hof, 1989; Batal *et al.*, 1994; Diaz-Perez, Purvis & Paulk, 2003).

Based on dry mass, the growth of *Lachenalia* bulbs follows in general a sigmoidal pattern from planting up to flowering (Du Toit, 2001). Roodbol & Niederwieser (1998) found for example with the cultivar Ronina that the dry mass of the bulbs increased to approximately 3 weeks after planting, whereafter the dry mass of the bulbs remained almost constant for the next 10 to 12 weeks. From 13 to 15 weeks after planting the dry mass of the bulbs increased again until flowering, after which the dry mass remained constant until harvesting. However, Roodbol *et al.*, (2002) reported that the fresh mass of *Lachenalia* bulbs was significantly influenced by different quantities of the nutrient solution recommended by the Commissie Bemesting Glastuinbouw (1992).

The increase in the dry mass of *Lachenalia* bulbs during the latter sigmoidal phase resulted from the translocation of assimilates from the leaves that started with senescence then (Du Toit, 2001; Du Toit, Robbertse & Niederwieser, 2004). She found a continuous decrease of sugars in the leaves and increase of starch in the bulbs during full bloom. The starch and other carbohydrates found in the flower bulbs are very important for early growth of bulbous plants such as *Lachenalia* in the pot plant phase (Du Toit, Robbertse & Niederwieser, 2004; Miller, 1992). The amount and composition of the carbohydrates in bulbs are however influenced by nitrogen fertilisation (Brewster & Butler, 1989; Maier *et al.*, 1990; Woldetsadik, Gertsson & Ascard, 2002).

In addition to the carbohydrates the nutrients in flower bulbs are also very important in the early growth of bulbous plants. Studies in this regard showed that nitrogen fertilisation increased the nitrogen content in onions and shallot (Laughlin, 1989; Woldetsadik *et al.*, 2002) but not the content of P, K, Ca, Cu, Fe and Zn (Laughlin, 1989).

The objective with this study was to determine the response of two *Lachenalia* cultivars in the nursery phase to different combinations of nitrogen levels and application times.

3.2 RESULTS AND DISCUSSION

3.2.1 *LEAF AREA*

A summary on the analyses of variance that was done to determine the effects of different nitrogen levels and application times on the leaf area of Rupert and Ronina plants grown from 2.5-3 cm and 3-4 cm bulblets in 2001 and 2002 is given in Table 3.1.

Table 3.1: Summary on the analyses of variance showing the significant effects of nitrogen levels and application times on the leaf area of Rupert and Ronina plants grown from 2.5-3 cm and 3-4 cm bulblets in 2001 and 2002

Weeks after planting	Cultivar (C)	Nitrogen level (N)	Nitrogen application time (T)	C X N	C X T	N X T
2001: 2.5-3 cm bulblets						
8	*	ns	ns	ns	ns	ns
10	*	ns	ns	ns	ns	ns
12	*	ns	ns	ns	ns	ns
14	*	ns	ns	ns	ns	ns
16	*	*	ns	ns	ns	ns
18	*	*	ns	ns	ns	ns
20	*	*	ns	ns	ns	ns
23	*	*	ns	ns	ns	ns
2002: 2.5-3 cm bulblets						
7	*	*	ns	ns	*	ns
9	*	*	ns	ns	*	ns
11	*	*	ns	ns	*	ns
13	*	*	ns	*	*	ns
15	*	*	ns	*	*	ns
17	*	*	ns	*	*	ns
19	*	*	ns	*	*	ns
21	*	*	ns	ns	*	ns
23	*	*	ns	ns	*	ns
2001: 3-4 cm bulblets						
8	*	ns	ns	ns	*	ns
10	*	ns	ns	ns	*	ns
12	*	ns	ns	ns	*	ns
14	*	ns	ns	ns	*	ns
16	*	ns	ns	ns	ns	ns
18	*	ns	ns	ns	*	ns
20	*	ns	ns	ns	*	ns
23	*	ns	ns	ns	ns	ns
2002: 3-4 cm bulblets						
7	ns	ns	ns	ns	ns	ns
9	ns	*	ns	ns	ns	ns
11	ns	*	ns	ns	ns	ns
13	ns	*	ns	ns	ns	ns
15	*	*	ns	ns	ns	ns
17	*	*	ns	*	ns	ns
19	*	*	ns	*	ns	ns
21	*	*	ns	*	ns	ns
23	*	*	ns	*	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

Inspection of this table showed that the effects of neither the treatments nor their interactions were very consistent. On account of this inconsistency it was decided for the sake of convenience to present all the data in a graphical format (Figures 3.1 to 3.8). As expected the leaf area of *Lachenalia* plants grown from either 2.5-3 cm (Figures 3.1 to 3.4) or 3-4 cm (Figure 3.5 to 3.8) bulblets increased with increasing nitrogen levels, irrespective of cultivar or application time. Firstly, the leaf area of plants grown from 2.5-3 cm bulblets and secondly, the leaf area of plants grown from 3-4 cm bulblets will be addressed.

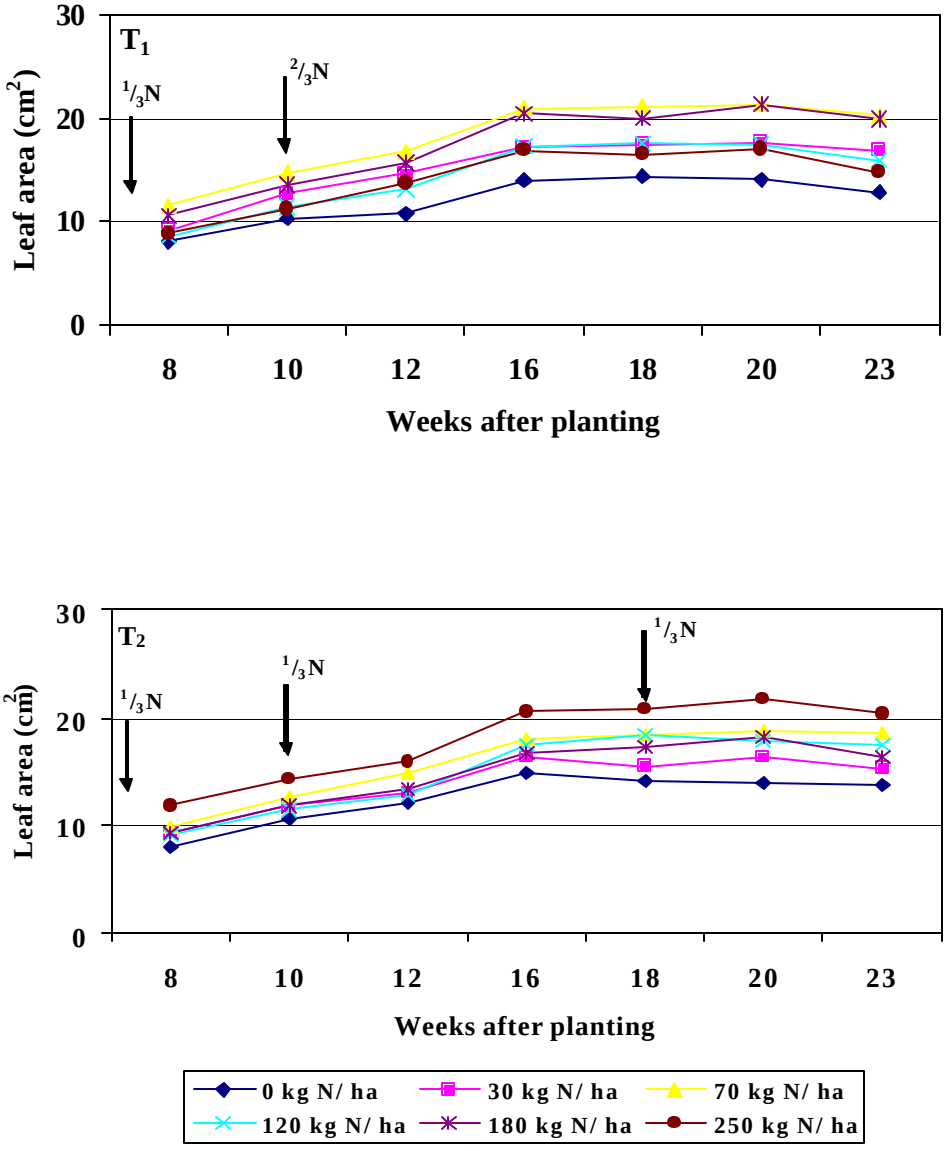

Figure 3.1: Effect of nitrogen levels and application times on the leaf area of Rupert plants grown from 2.5-3 cm bulblets in 2001

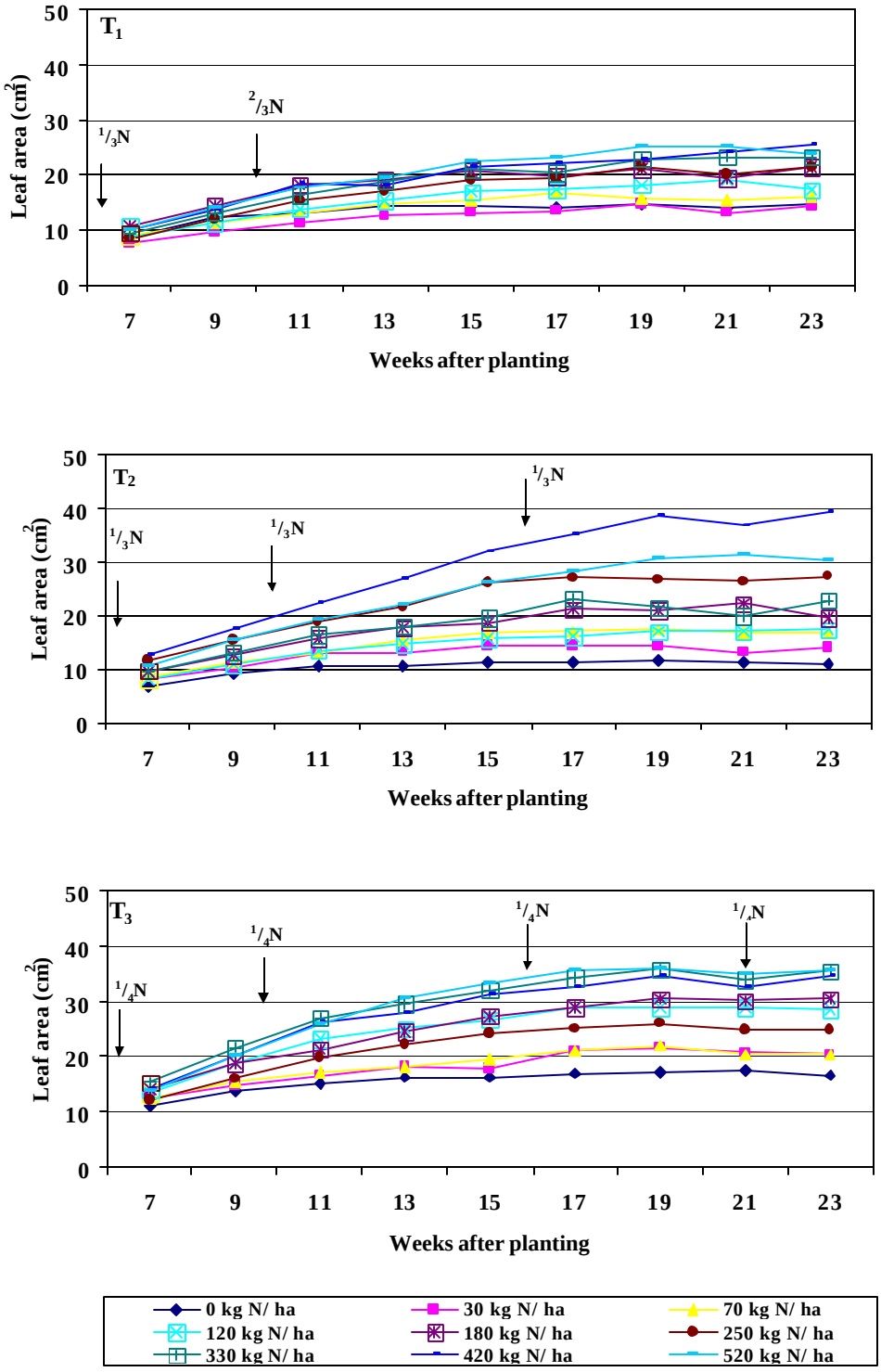

Figure 3.2: Effect of nitrogen levels and application times on the leaf area of Rupert plants grown from 2.5-3 cm bulblets in 2002

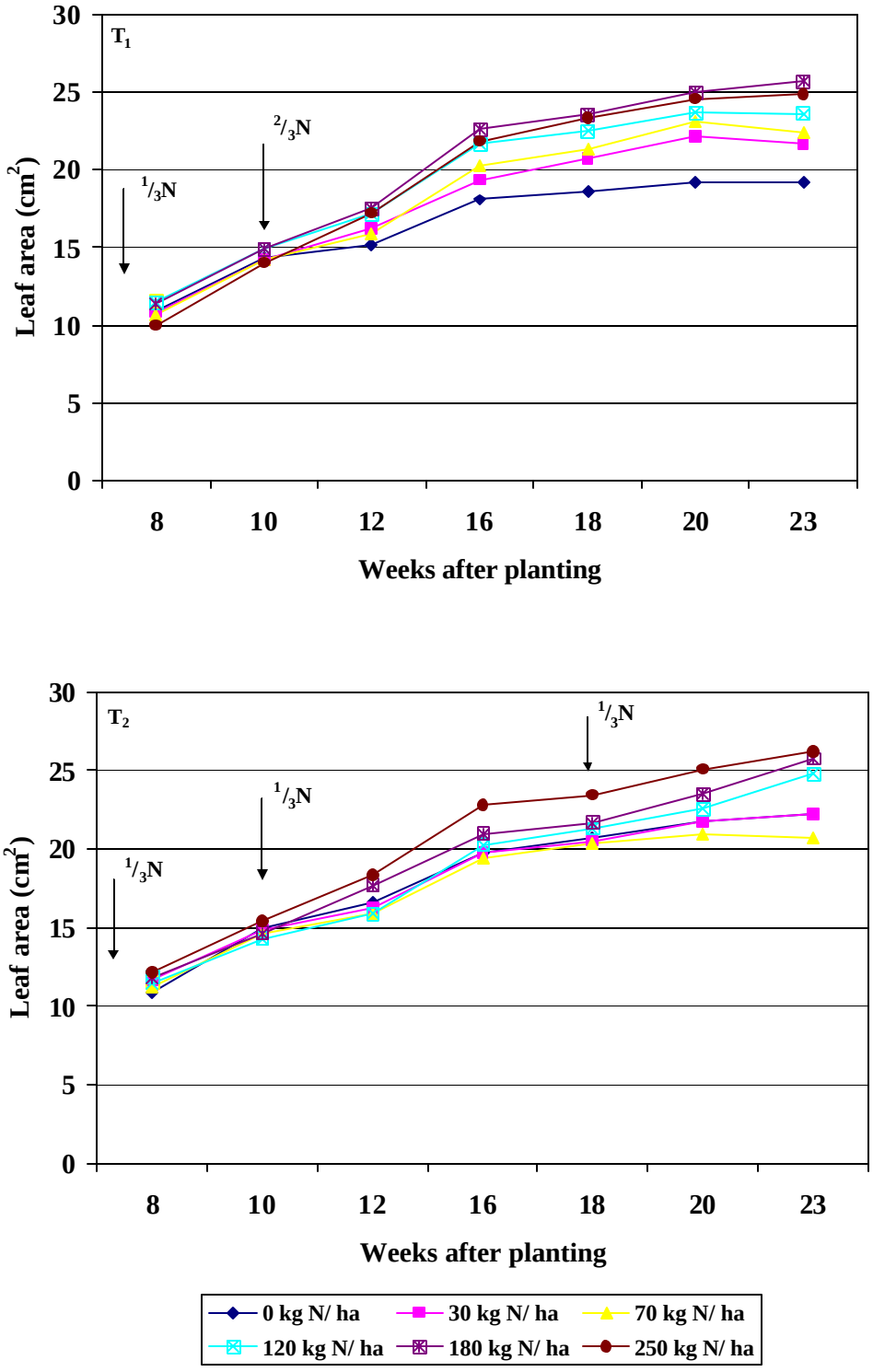

Figure 3.3: Effect of nitrogen levels and application times on the leaf area of Ronina plants grown from 2.5-3 cm bulblets in 2001

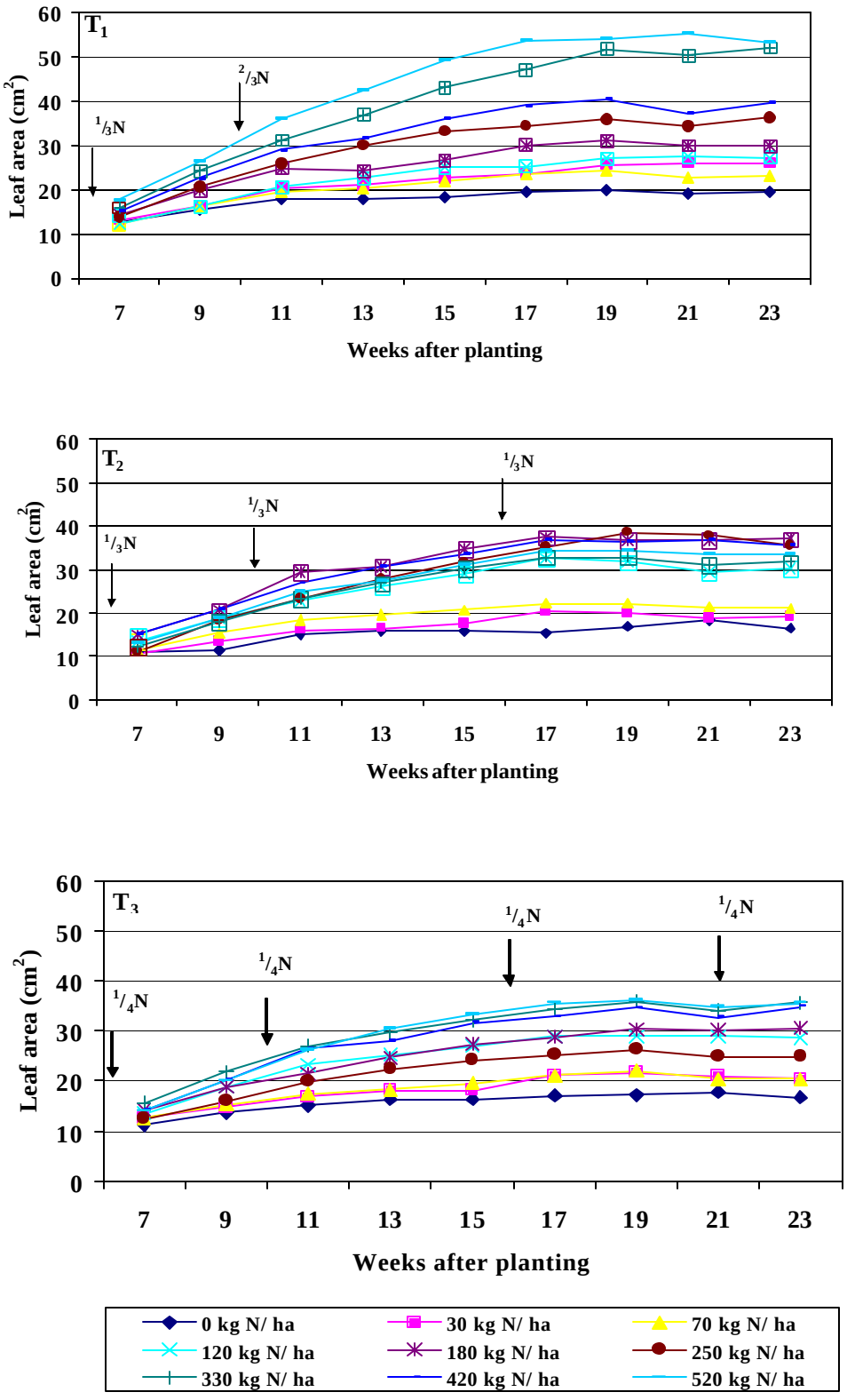

Figure 3.4: Effect of nitrogen levels and application times on the leaf area of Ronina plants grown from 2.5-3 cm bulblets in 2002

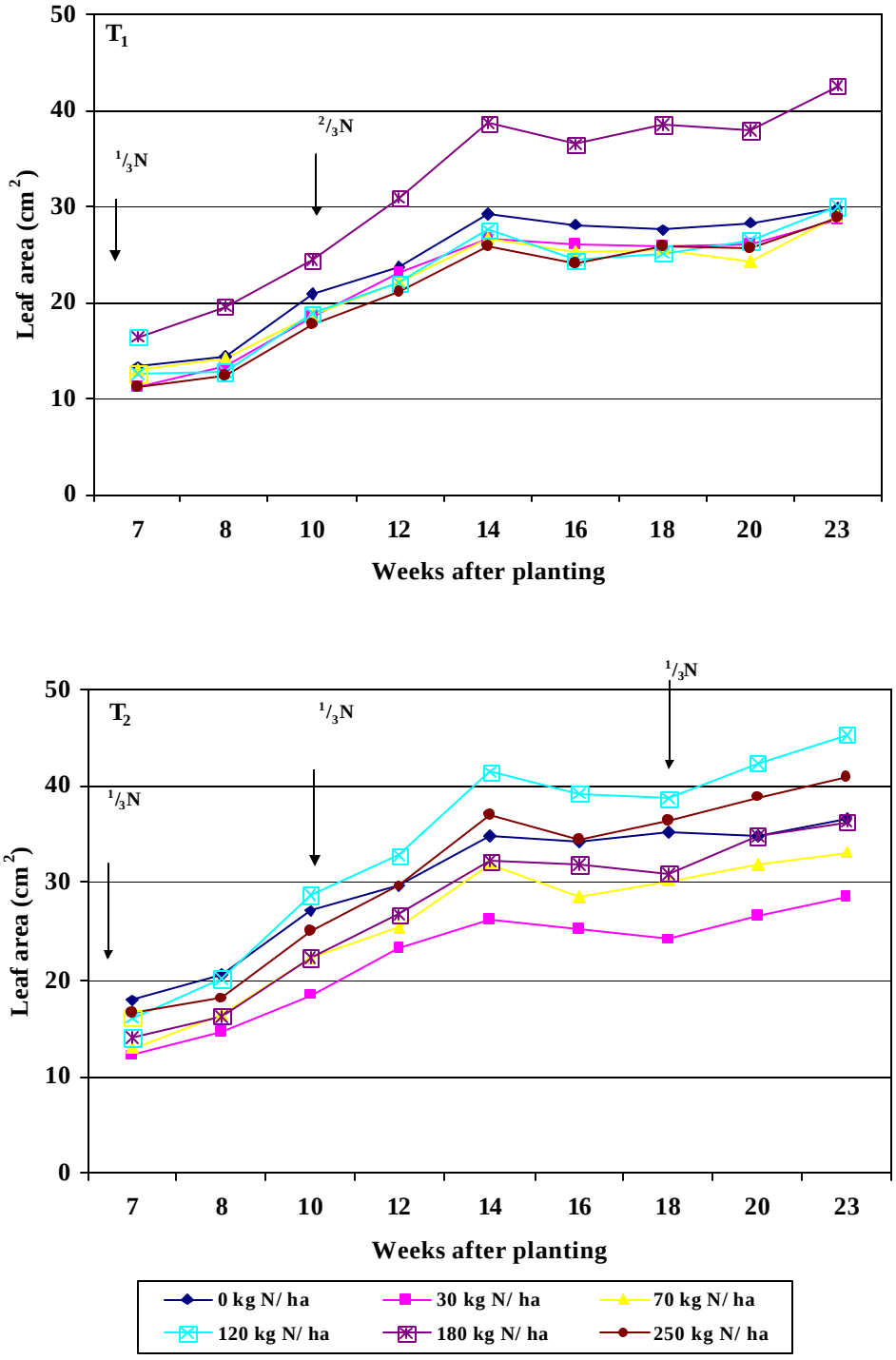

Figure 3.5: Effect of nitrogen levels and application times on the leaf area of Rupert plants grown from 3-4 cm bulblets in 2001

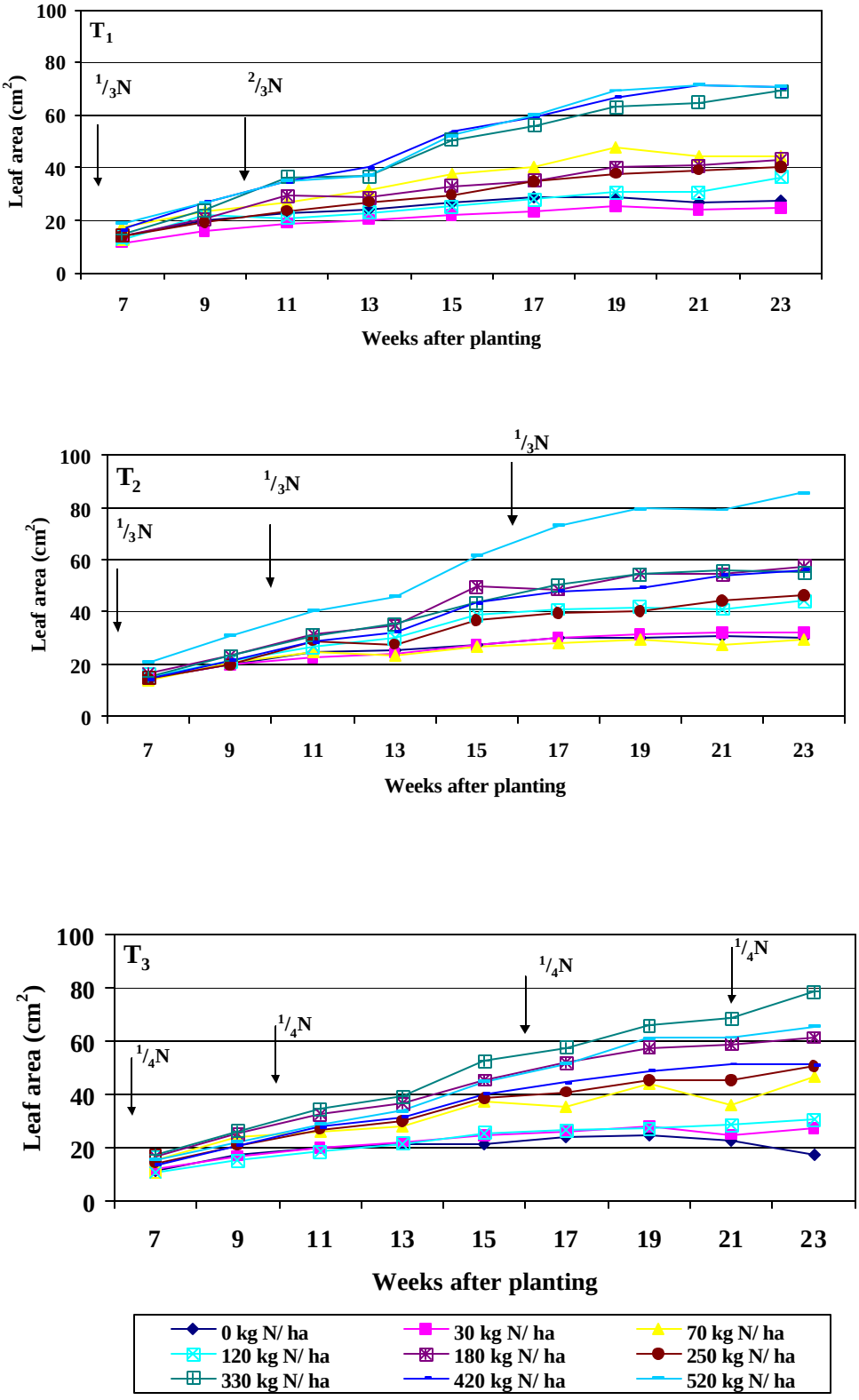

Figure 3.6: Effect of nitrogen levels and application times on the leaf area of Rupert plants grown from 3-4 cm bulblets in 2002

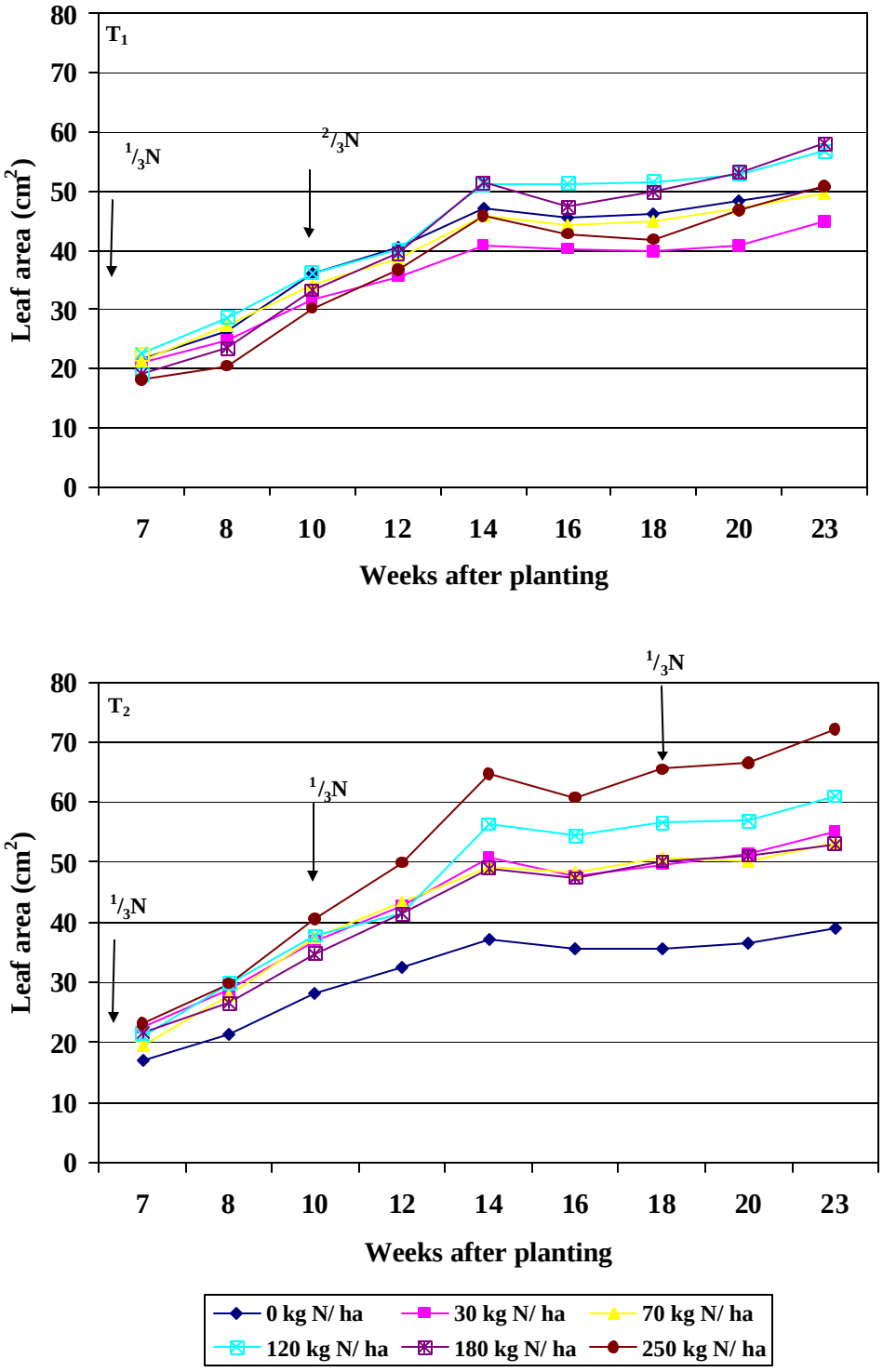

Figure 3.7: Effect of nitrogen levels and application times on the leaf area of Ronina plants grown from 3-4 cm bulblets in 2001

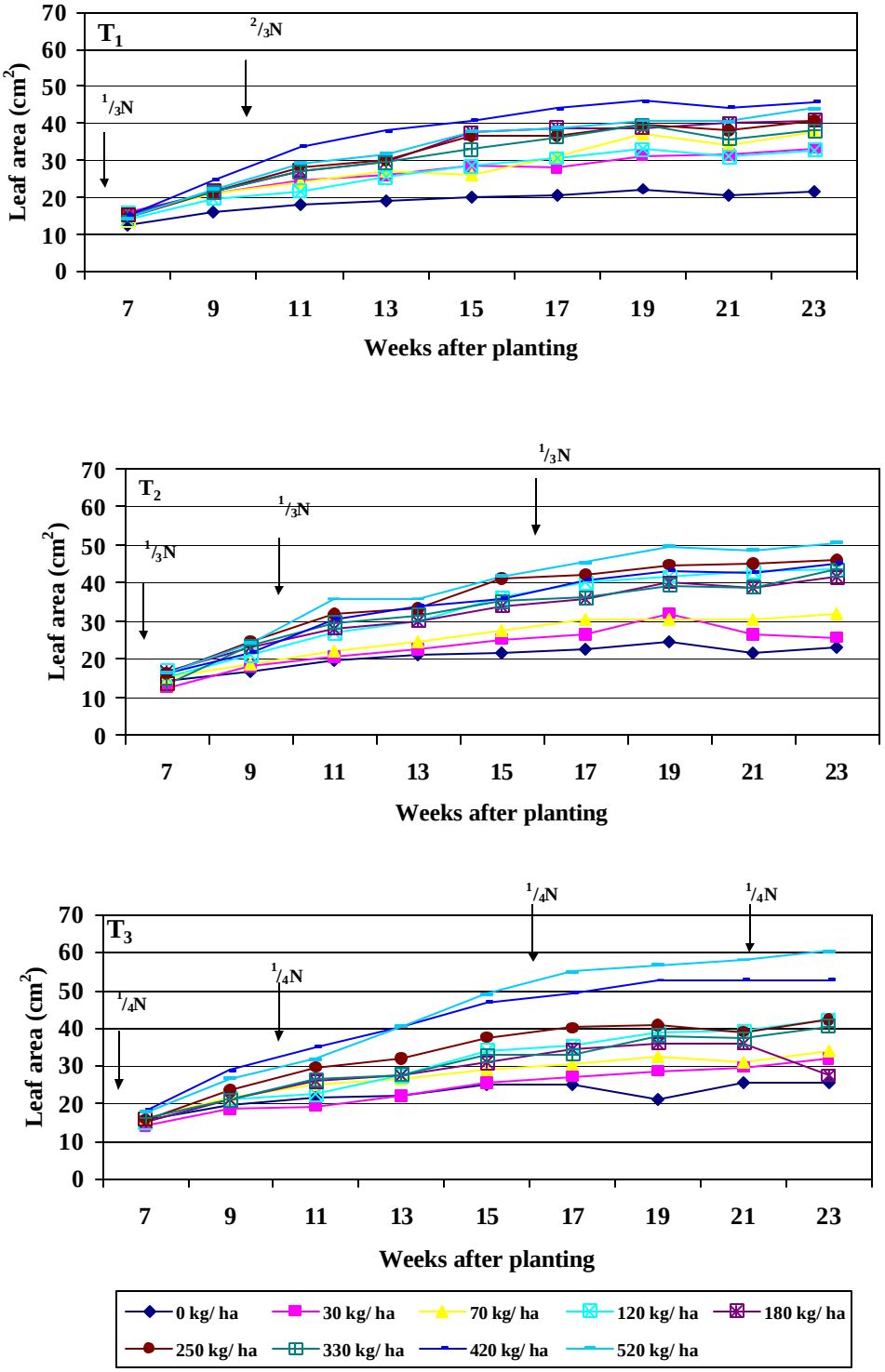

Figure 3.8: Effect of nitrogen levels and application times on the leaf area of Ronina plants grown from 3-4 cm bulblets in 2002

3.2.1.1 Plants grown from 2.5-3 cm bulblets

The effect of nitrogen levels and application times on the leaf area of *Lachenalia* plants grown from 2.5-3 cm bulblets is displayed in Figure 3.1 to 3.4. Discussion of these treatments will be limited to the treatments that caused significant differences in the leaf area of the plants.

As shown in Table 3.1 none of the interactions affected the leaf area of *Lachenalia* significantly in 2001. In this year at all eight times of measurement the leaf area of the two cultivars differed significantly. The leaf area of Ronina was without exception larger than that of Rupert (Table 3.2).

Table 3.2: Leaf area (cm^2) of Rupert and Ronina plants grown from 2.5-3 cm bulblets in 2001

Weeks after planting	Cultivar		LSD (T = 0.05)
	Rupert	Ronina	
8	9.52	11.20	**0.92**
10	12.23	14.61	**1.07**
12	13.90	16.65	**1.30**
14	15.76	18.75	**1.46**
16	17.54	20.56	**1.40**
18	17.64	21.49	**1.58**
20	17.96	22.76	**1.60**
23	16.86	23.28	**1.81**

Despite of that increasing nitrogen levels resulted in larger leaf areas of *Lachenalia* at every measurement time, it was only significant from 16 weeks after planting (Table 3.3). Surprisingly, the nitrogen application times had no significant effect on *Lachenalia's* leaf area in 2001 (Table 3.1).

Table 3.3: Effect of nitrogen levels on the leaf area (cm^2) of *Lachenalia* plants grown from 2.5-3 cm bulblets in 2001

Weeks after planting	Nitrogen levels kg ha^{-1}						LSD (T = 0.05)
	0	30	70	120	180	250	
8	9.48	10.24	10.80	10.18	10.78	10.69	**ns**
10	12.54	13.39	14.05	13.04	13.74	13.77	**ns**
12	13.66	15.03	15.90	14.75	16.06	16.27	**ns**
14	15.29	16.55	17.90	16.83	18.20	18.75	**ns**
16	16.68	18.12	19.64	19.15	20.18	20.53	**3.55**
18	16.95	18.57	20.31	19.92	20.63	21.03	**4.03**
20	17.26	19.42	21.03	20.38	21.98	22.10	**4.07**
23	16.97	19.05	20.49	20.46	21.93	21.53	**4.60**

In 2002 the leaf area of *Lachenalia* was affected at 13, 15, 17 and 19 weeks after planting significantly by the interaction between cultivars and nitrogen levels (Table 3.1). At those four measurement times Ronina had larger leaf areas than Rupert irrespective of nitrogen level (Table 3.4). The leaf area of both cultivars increased with higher nitrogen levels. Similar trends emerged from the data at 7, 9, 11, 21 and 23 weeks after planting, although not significant.

Table 3.4: Effect of nitrogen levels on the leaf area (cm^2) of Rupert and Ronina plants grown from 2.5-3 cm bulblets in 2002

Weeks after planting	Cultivar	Nitrogen levels kg ha^{-1} 0	30	70	120	180	250	330	420	520	LSD (T = 0.05)
7	**Rupert**	8.01	8.31	8.91	8.41	9.66	9.91	9.53	12.03	10.99	**ns**
	Ronina	11.64	12.16	12.15	13.01	14.38	12.52	14.60	14.74	14.95	
9	**Rupert**	10.38	10.43	11.43	11.17	13.23	13.72	13.31	16.38	15.68	**ns**
	Ronina	13.60	14.84	15.70	17.98	19.75	18.37	21.25	21.13	21.72	
11	**Rupert**	11.58	12.59	12.99	13.52	16.15	17.07	16.74	21.63	20.04	**ns**
	Ronina	15.93	17.75	18.42	22.18	25.31	23.05	27.11	27.34	28.99	
13	**Rupert**	12.47	13.52	14.63	15.09	17.74	19.10	18.46	23.89	22.50	**6.60**
	Ronina	15.42	18.45	19.35	24.65	26.55	26.77	31.11	30.10	33.50	
15	**Rupert**	12.46	14.19	15.95	16.25	19.03	22.02	20.75	28.55	26.31	**8.62**
	Ronina	16.85	19.37	20.68	26.99	29.71	29.77	35.21	33.69	37.84	
17	**Rupert**	12.65	14.56	16.26	16.97	19.96	22.70	21.78	30.10	26.41	**9.49**
	Ronina	17.23	21.67	22.31	28.93	32.19	31.63	38.10	36.14	41.24	
19	**Rupert**	13.01	15.11	16.50	17.46	20.25	23.35	22.07	33.19	30.09	**10.44**
	Ronina	18.00	22.43	22.79	29.19	32.62	33.54	40.15	37.17	41.60	
21	**Rupert**	12.37	14.16	15.53	17.45	20.03	23.15	21.56	32.77	31.94	**ns**
	Ronina	18.34	21.88	21.56	28.64	32.31	32.36	38.50	35.59	41.20	
23	**Rupert**	12.50	14.63	16.04	17.14	20.02	23.82	25.71	34.68	32.13	**ns**
	Ronina	17.56	21.92	21.53	28.63	32.49	32.17	39.89	36.62	40.85	

During 2002 the interaction between cultivars and nitrogen application times on the leaf area of *Lachenalia* was also significant, namely at all nine measurement times (Table 3.1). The leaf area of Ronina was, regardless of nitrogen application time, higher than that of Rupert as can be observed from Table 3.5. However, the time of nitrogen application had no significant influence on the leaf area of Rupert, this was not the case with Ronina. From 13 weeks after planting the T_3 treatment resulted in significant smaller leaf areas for Ronina when compared with the T_1 treatment. The leaf areas recorded with the T_2 treatment did not differed from those recorded with either the T_1 and T_3 treatments.

Table 3.5: Effect of nitrogen application times on the leaf area (cm^2) of Rupert and Ronina plants grown from 2.5-3 cm bulblets in 2002

Weeks after planting	Cultivar	Nitrogen application time			LSD (T = 0.05)
		T_1	T_2	T_3	
7	**Rupert**	9.21	9.56	9.82	**1.52**
	Ronina	13.31	12.56	13.31	
9	**Rupert**	12.48	12.86	13.23	**2.04**
	Ronina	19.81	17.27	17.69	
11	**Rupert**	15.29	15.95	16.19	**2.68**
	Ronina	25.07	22.18	21.44	
13	**Rupert**	16.63	17.83	18.01	**3.11**
	Ronina	27.12	24.52	23.65	
15	**Rupert**	18.30	20.12	20.08	**4.06**
	Ronina	30.75	27.16	25.46	
17	**Rupert**	18.51	21.10	20.89	**4.47**
	Ronina	33.01	29.64	27.17	
19	**Rupert**	19.65	22.15	21.87	**4.92**
	Ronina	34.53	29.91	28.05	
21	**Rupert**	19.34	21.63	22.00	**4.93**
	Ronina	33.71	29.29	27.12	
23	**Rupert**	19.76	22.10	23.69	**5.17**
	Ronina	34.17	28.95	27.43	

3.2.1.2 Plants grown from 3-4 cm bulblets

The effect of nitrogen levels and application times on the leaf area of *Lachenalia* plants grown from 3-4 cm bulblets is shown in Figures 3.5 to 3.8. Discussion of the results will be restricted to the treatments that caused significant differences in the leaf area of the plants.

The interaction between cultivars and nitrogen application times influenced the leaf area of *Lachenalia* at about every measurement in 2001 significantly (Table 3.1). As shown in Table 3.6 the leaf area of Ronina was for every application time treatment larger than that of Rupert. The leaf area of Rupert although not significant was larger with the T_2 than T_1 treatment. In the case of Ronina the T_2 treatment resulted in smaller leaf areas than the T_1 treatment which was also not significant.

In 2002 a significant interaction between cultivars and nitrogen levels on the leaf area of *Lachenalia* was recorded from 17 weeks and later after planting (Table 3.1). During this period the leaf area of both cultivars increased with higher nitrogen levels as shown in Table 3.7. This increase was more pronounced with Rupert than with Ronina. As a result

of this phenomenon Rupert had larger leaf areas than Ronina at nitrogen levels of 330 kg ha^{-1} and higher.

Table 3.6: Effect of nitrogen application times on the leaf area (cm^2) of Rupert and Ronina plants grown from 3-4 cm bulblets in 2001

Weeks after planting	Cultivar	Nitrogen application time		LSD (T = 0.05)
		T_1	T_2	
8	Rupert	14.53	17.69	4.50
	Ronina	27.36	25.10	
10	Rupert	19.84	24.05	5.58
	Ronina	35.88	33.60	
12	Rupert	23.88	27.97	6.63
	Ronina	41.94	38.49	
14	Rupert	26.70	31.03	7.50
	Ronina	46.74	42.28	
16	Rupert	27.45	32.29	ns
	Ronina	49.05	45.24	
18	Rupert	28.09	32.67	8.34
	Ronina	51.34	45.69	
20	Rupert	28.16	34.90	8.81
	Ronina	52.10	48.14	
23	Rupert	31.56	36.91	ns
	Ronina	55.60	51.74	

Table 3.7: Effect of nitrogen levels on the leaf area (cm^2) of Rupert and Ronina plants grown from 3-4 cm bulblets in 2002

Weeks after planting	Cultivar	Nitrogen levels kg ha^{-1}									LSD (T = 0.05)
		0	30	70	120	180	250	330	420	520	
7	Rupert	13.20	12.75	15.32	12.70	15.60	14.11	15.42	14.62	18.09	ns
	Ronina	14.19	14.37	15.48	14.82	15.94	15.65	14.94	16.61	16.16	
9	Rupert	18.90	17.48	22.60	19.37	23.12	19.93	24.57	22.98	26.60	ns
	Ronina	17.47	19.30	20.46	20.73	22.02	23.27	22.07	25.19	24.39	
11	Rupert	22.35	20.51	25.94	22.15	31.11	26.41	33.99	30.32	34.65	ns
	Ronina	19.91	21.53	23.82	23.76	27.12	29.96	27.73	33.22	32.27	
13	Rupert	23.45	22.24	27.48	24.85	33.33	28.22	37.20	34.50	38.86	ns
	Ronina	20.77	23.58	26.08	27.70	29.12	31.85	29.64	37.47	36.04	
15	Rupert	25.19	24.76	33.64	29.76	42.67	34.90	48.94	45.74	52.7	ns
	Ronina	22.25	26.42	27.58	32.96	34.20	38.48	33.70	41.13	42.90	
17	Rupert	27.57	26.60	34.40	31.86	45.16	38.37	54.69	50.42	61.48	18.66
	Ronina	22.79	27.23	30.72	35.42	36.50	39.71	35.26	44.72	46.39	
19	Rupert	27.83	28.13	40.05	33.23	50.58	41.14	60.98	54.85	69.91	20.70
	Ronina	22.75	30.75	33.30	37.83	38.40	41.70	39.05	47.27	48.97	
21	Rupert	26.60	26.93	35.97	33.43	51.38	42.96	62.92	58.89	70.47	21.74
	Ronina	22.65	29.29	31.85	37.75	38.39	40.77	37.41	46.59	49.07	
23	Rupert	24.95	27.97	40.25	37.13	54.00	45.61	67.51	59.11	74.08	23.77
	Ronina	23.59	30.35	34.52	39.49	36.72	42.90	40.68	47.93	51.72	

In this study the leaf area of plants grown from 3-4 cm bulblets was on average larger than the leaf area of plants grown 2.5-3 cm bulblets (Figure 3.1 to 3.8). This observation although not statistical verified coincide with that of Roodbol *et al.* (2002) in their study on *Lachenalia*. A possible reason for this phenomenon may be of more assimilates in the larger than smaller bulblets (Lian-Meilan, Chakrabarty, Paek & Lian, 2002).

The application of nitrogen promoted the growth of *Lachenalia* plants when leaf area serves as an index, irrespective of cultivar or nitrogen application time (Figure 3.1 to 3.8). However, it seems that Rupert and Ronina differed in their reaction to applied nitrogen in 2002 when more levels were introduced. The leaf area of Ronina was at every nitrogen level larger than that of Rupert when the two cultivars were grown from 2.5-3 cm bulblets (Table 3.4). This trend was reversed, especially at nitrogen levels of 330 kg ha^{-1} and more when Rupert and Ronina were grown from 3-4 cm bulblets (Table 3.7). Ronina is known as an active grower during autumn (Duncan, 1988) whereas Rupert tended to form more leaves per plant. The time of nitrogen application influenced the leaf area of the two cultivars also differently in some instances (Table 3.5 and 3.6). Ronina responded better to the T_1 treatment whereas it seems that Rupert responded better to the T_2 and T_3 treatments. This is probably due to the fact that Ronina flower about 3 weeks earlier than Rupert.

3.2.2 *BULB QUALITY*

3.2.2.1 Physical parameters

In order to establish the quality of *Lachenalia* bulbs after one season of enlargement the following physical parameters were measured: fresh mass, circumference and firmness. A summary of the analyses of variance that was done to determine the effect of different nitrogen levels and application times on the fresh mass, circumference and firmness of Rupert and Ronina bulbs grown from 2.5-3 cm and 3-4 cm bulblets in 2001 and 2002 is given in Table 3.8.

Table 3.8: Summary on the analyses of variance showing the significant effects of nitrogen levels and application times on the fresh mass, circumference and firmness of Rupert and Ronina bulbs grown from 2.5-3 cm and 3-4 cm bulblets in 2001 and 2002

Bulbs	Cultivar (C)	Nitrogen level (N)	Application time (T)	C X N	C X T	N X T
2001: 2.5-3 cm bulblets						
Fresh mass	*	*	*	*	ns	*
Circumference	*	*	*	*	ns	*
Firmness	*	ns	ns	ns	ns	ns
2002: 2.5-3 cm bulblets						
Fresh mass	*	*	ns	ns	ns	ns
Circumference	*	*	ns	ns	ns	ns
Firmness	*	*	ns	*	ns	ns
2001: 3-4 cm bulblets						
Fresh mass	*	ns	ns	ns	ns	ns
Circumference	*	ns	ns	ns	ns	ns
Firmness	*	ns	ns	ns	ns	ns
2002: 3-4 cm bulblets						
Fresh mass	*	*	ns	*	ns	ns
Circumference	*	*	ns	*	ns	ns
Firmness	*	*	ns	*	ns	*

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

As shown in Table 3.8 the fresh mass and the circumference of *Lachenalia* bulbs reacted similar on the different nitrogen levels and application times. The fresh mass increased linearly with circumference for bulbs grown from 2.5-3 cm bulblets. A correlation coefficient of 0.94 in 2001 and 0.93 in 2002 was obtained. Bulbs grown from 3-4 cm bulblets showed the same tendency. The correlation coefficient between the fresh mass and circumference for these bulbs was 0.91 in 2001 and 0.97 in 2002.

Lachenalia bulb producers grade bulbs for export mainly on circumference and not fresh mass. As a result of this grading process and because of the high correlation found between fresh mass and circumference only the data of bulb circumference will be presented and discussed in the following section.

3.2.2.1.1 Bulb circumference

3.2.2.1.1.1 Bulbs grown from 2.5-3 cm bulblets

As shown in Table 3.8 the interaction between cultivar and nitrogen levels influenced the circumference of *Lachenalia* bulbs grown from 2.5–3 cm bulblets significantly in 2001.

In this year the circumference of Ronina bulbs increased significantly from 6.70 cm at a 0 kg N ha^{-1} level to 7.75 cm at a 250 kg N ha^{-1} level (Table 3.9). However, Rupert bulbs did not show the same tendency since the maximum circumference of 7.26 cm was recorded at the 70 kg N ha^{-1} level.

Table 3.9: Effect of nitrogen levels on the circumference (cm) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2001

Nitrogen levels kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	6.27	6.70
30	7.05	6.76
70	7.26	6.80
120	6.26	7.05
180	6.98	7.25
250	6.59	7.75
LSD $_{(T = 0.05)}$	**0.43**	

The interaction between nitrogen levels and application times also influenced the circumference of the bulbs grown from 2.5-3 cm bulblets significantly in 2001. As shown in Table 3.10, the bulb circumferences responded better to the T_2 treatment than the T_1 treatment. In the case of the T_1 treatment the bulb circumference increased from 6.40 cm with 0 kg N ha^{-1} to 7.23 cm with 30 kg N ha^{-1} whereas with higher nitrogen levels the circumference tended to be lower. However in the case of the T_2 treatment the circumference of bulbs increased from 6.58 cm with 0 kg N ha^{-1} to 7.47 cm with 250 kg N ha^{-1}.

Table 3.10: Effect of nitrogen levels and application times on the circumference (cm) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2001

Nitrogen levels kg ha^{-1}	Nitrogen application times	
	T_1	T_2
0	6.40	6.58
30	7.23	6.58
70	7.00	7.03
120	6.38	6.93
180	6.98	7.25
250	6.87	7.47
LSD $_{(T = 0.05)}$	**0.48**	

In 2002 the circumference of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets differ significantly (Table 3.11). The circumference of Ronina bulbs was 0.45 cm more than the circumference of Rupert bulbs.

Table 3.11: Effect of nitrogen levels and application times on the circumference (cm) of Rupert and Ronina bulbs grown from 2.5-3 cm in 2002

Season	Cultivar		LSD $_{(T = 0.05)}$
	Rupert	Ronina	
2002	8.85	9.30	**0.10**

From Table 3.12 it is clear that nitrogen levels promoted the circumference of bulbs grown from 2.5-3 cm bulblets in 2002. The circumference of the bulbs increased from 7.83 cm when 0 kg N $ha^{-1}$was applied to 9.66 cm when 330 kg N ha^{-1} was applied. Higher nitrogen levels did not result in larger bulb circumferences.

Table 3.12: Effect of nitrogen levels on the circumference (cm) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen levels	Circumference
0	7.83
30	8.38
70	8.90
120	9.12
180	9.22
250	9.45
330	9.66
420	9.48
520	9.67
LSD $_{(T = 0.05)}$	**0.35**

3.2.2.1.1.2 Bulbs grown from 3-4 cm bulblets

Inspection of Table 3.8 showed that none of the interactions influenced the circumference of *Lachenalia* bulbs grown from 3-4 cm bulblets significantly in 2001. In this year it was only the circumference of Rupert and Ronina bulbs that differ significantly from each other with 1.21 cm as can be observed from Table 3.13.

Table 3.13: Effect of nitrogen levels and application times on the circumference (cm) of Rupert and Ronina bulbs grown from 3-4 cm bulblets in 2001

Season	Cultivar		LSD $_{(T = 0.05)}$
	Rupert	Ronina	
2001	8.97	10.18	**0.43**

As shown in Table 3.14 higher nitrogen levels promoted the circumference of Rupert and Ronina bulbs. The circumference of Rupert bulbs increased from 8.99 cm with a 0 kg N ha^{-1} application to 11.47 cm with a 520 kg N ha^{-1}application. For Ronina the circumference of the bulbs increased from 9.47 cm with a 0 kg N ha^{-1} application to 11.22 cm with a 250 kg N ha^{-1} application.

Table 3.14: Effect of nitrogen levels on the circumference (cm) of Rupert and Ronina bulbs grown from 3-4 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	8.99	9.47
30	9.53	10.22
70	10.22	10.40
120	10.24	10.72
180	9.57	10.89
250	10.71	11.22
330	11.02	10.72
420	11.14	11.06
520	11.47	11.08
LSD $_{(T = 0.05)}$	**1.29**	

3.2.2.1.2 Bulb firmness

3.2.2.1.2.1 Bulbs grown from 2.5-3 cm bulblets

None of the interactions affected the firmness of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2001 significantly (Table 3.8). This particular year only the firmness of Rupert and Ronina bulbs differed significantly from each other (Table 3.15). Ronina bulbs were softer than the bulbs of Rupert.

Table 3.15: Effect of nitrogen levels and application times on the firmness (mm) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2001

Season	Cultivar		LSD $_{(T = 0.05)}$
	Rupert	Ronina	
2001	6.82	8.58	**0.32**

In 2002, the interaction between cultivar and nitrogen levels influenced the firmness of bulbs grown from 2.5-3 cm bulblets significantly (Table 3.8). The firmness of Ronina bulbs increased significantly when the nitrogen levels increased (Table 3.16). Although not significant the same trend was observed for Rupert bulbs.

Table 3.16: Effect of nitrogen levels on the firmness (mm) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	12.7	23.6
30	12.6	23.2
70	12.4	22.4
120	11.4	20.2
180	11.1	19.3
250	10.8	17.5
330	11.2	18.0
420	11.3	16.6
520	10.7	17.8
LSD $_{(T = 0.05)}$	**2.88**	

3.2.2.1.2.2 Bulbs grown from 3-4 cm bulblets

None of the interactions influenced the firmness of *Lachenalia* bulbs grown from 3-4 cm bulblets significantly in 2001 (Table 3.8). Only the firmness of Rupert and Ronina bulbs differed significantly from each other in this year (Table 3.17). Ronina bulbs were softer than the bulbs of Rupert.

Table 3.17: Effect of nitrogen levels and application times the on firmness (mm) of Rupert and Ronina bulbs grown from 3-4 cm bulblets in 2001

Season	Cultivar		LSD $_{(T = 0.05)}$
	Rupert	Ronina	
2001	5.53	7.82	**0.39**

In 2002 the interaction between cultivar and nitrogen levels significantly influenced the firmness of bulbs grown from 3-4 cm bulblets (Table 3.8). Ronina bulbs were softer than Rupert bulbs irrespective of nitrogen level (Table 3.18). The firmness of Rupert bulbs was not significantly influenced by the nitrogen levels which were not the case with Ronina bulbs. As shown in Table 3.18 the firmness of Ronina bulbs increased to a nitrogen level of 120 kg ha^{-1} and remained almost constant at the higher levels.

Table 3.18: Effect of nitrogen levels on the firmness (mm) of Rupert and Ronina bulbs grown from 3-4 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	8.51	19.22
30	7.92	17.55
70	9.81	16.34
120	8.07	14.02
180	8.18	15.71
250	8.25	14.41
330	8.61	14.51
420	8.59	13.84
520	7.98	13.81
LSD $_{(T = 0.05)}$	**3.48**	

The firmness of bulbs grown from 3-4 cm bulblets in 2002 was also significantly influenced by the interaction between nitrogen levels and application times (Table 3.8). On inspection of Table 3.19 it is clear that the firmness of the bulbs increased as the nitrogen levels increased, regardless of the nitrogen application times. However, no trends in bulb firmness emerged between the T_1, T_2 and T_3 treatments that are worth mentioning.

Table 3.19: Effect of nitrogen levels and application times on the firmness (mm) of *Lachenalia* bulbs grown from 3-4 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	Nitrogen application time		
	1	2	3
0	14.22	14.84	12.53
30	13.65	11.06	13.49
70	11.96	13.40	13.86
120	11.96	11.01	10.17
180	11.35	12.28	12.21
250	11.34	9.88	12.76
330	13.04	11.02	10.62
420	10.14	11.64	11.87
520	11.61	10.16	10.91
LSD $_{(T = 0.05)}$	**4.51**		

The firmness of *Lachenalia* bulbs is usually associated with their shelf live which is important for the export market. In this study the firmness of the bulbs increased with higher nitrogen levels. This phenomenon is in contrast to results reported by Laughlin (1989) on other bulbous plants.

All the physical parameters that were measured as indices of *Lachenalia* bulb quality were influenced positive by higher applications of nitrogen. No conclusive remarks can be made on the effect of nitrogen application times on these physical parameters. Based on the physical parameters it seems that Ronina was more responsive to nitrogen fertilisation than Rupert.

As already mentioned earlier the aim of *Lachenalia* bulb producers is to produce bulbs with a circumference of at least 6 cm for the export market in the shortest possible time. In this study, irrespective of nitrogen level or application time all bulbs harvested after one season of enlargement from either Rupert or Ronina reached the minimum marketable size. However, higher levels of nitrogen promoted the bulb circumference which corresponded with results obtained by Roodbol *et al*, (2002). Surprising, even after increasing the maximum nitrogen level from 250 kg ha^{-1} in 2001 to 520 kg ha^{-1} in 2002 it is difficult to establish an optimum nitrogen level for ensuring marketable size bulbs. This type of behaviour was also observed by Maier *et al.* (1990) in fertilisation trials with onions.

3.2.2.2 Chemical parameters

3.2.2.2.1 Bulb nutrient content

In a pilot study done in 2001 the harvested bulbs of all four replications were pooled to ensure enough material for analysis of nutrients. There was some indication that nitrogen levels and application times influenced the N, P, K, Ca and Mg content of Rupert and Ronina bulbs grown from 2.5-3 cm and 3-4 cm bulblets. In 2002 the harvested bulbs from the four replications were analysed separately with the result that the analyses of variance on this data were possible. On the account of this and that the data of 2001 and 2002 showed more or less the same trends only the data of 2002 will be given and discussed in this section.

A summary on the analyses of variance that was done to determine the effects of different nitrogen levels and application times on the nutrient content of Rupert and Ronina bulbs grown from 2.5-3 cm and 3-4 cm bulblets in 2002 is given in Table 3.20. Inspection of Table 3.20 showed some inconsistency between bulb sizes and therefore data on the

effect of nitrogen levels and application times on the nutrient content of *Lachenalia* bulbs grown from 2.5-3 cm and 3-4 cm bulblets will be present and discuss separately.

Table 3.20: Summary on the analyses of variance showing the significant effects of nitrogen levels and application times on the nutrient content of Rupert and Ronina bulbs grown from 2.5-3 cm and 3-4 cm bulblets in 2002

Nutrients	Cultivar (C)	Nitrogen level (N)	Application time (T)	C X N	C X T	N X T
2002: 2.5-3 cm bulblets						
N	ns	*	*	ns	*	*
P	*	*	ns	*	*	ns
K	*	*	*	*	ns	ns
Ca	*	*	ns	ns	*	ns
Mg	ns	*	*	*	*	*
2002: 3-4 cm bulblets						
N	ns	*	*	ns	ns	*
P	*	*	*	ns	*	ns
K	*	*	*	ns	*	ns
Ca	*	*	*	*	*	*
Mg	ns	*	*	*	*	*

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

3.2.2.2.1.1 Bulbs grown from 2.5-3 cm bulblets

As reference the nutrient content of the 2.5-3 cm bulblets that were planted in 2002 for this experiment is given in Table 3.21. All the data on the effects of nitrogen levels and application times on the nutrient content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets are presented in Tables 3.22 to 3.27 for convenience. However, the discussion will be limited only to those treatments that caused significant differences in the content of a particular nutrient.

Table 3.21: Nutrient content (%) of 2.5-3 cm Rupert and Ronina bulblets at planting in 2002

Cultivar	N	P	K	Ca	Mg
Rupert	2.220	0.370	1.944	0.940	0.140
Ronina	2.982	0.320	1.864	1.120	0.129

Table 3.22: Nutrient content (%) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2002

Cultivar	N	P	K	Ca	Mg
Rupert	1.564	0.265	0.857	0.036	0.090
Ronina	1.510	0.217	0.886	0.029	0.090
LSD $_{(T = 0.05)}$	**ns**	**0.071**	**0.028**	**0.095**	**ns**

Table 3.23: Effect of nitrogen levels on the nutrient content (%) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	N	P	K	Ca	Mg
0	0.549	0.195	0.687	0.348	0.062
30	0.762	0.204	0.732	0.326	0.068
70	0.871	0.206	0.742	0.308	0.075
120	1.147	0.227	0.810	0.314	0.082
180	1.386	0.254	0.864	0.318	0.093
250	1.818	0.248	0.933	0.323	0.098
330	2.143	0.273	0.987	0.329	0.105
420	2.506	0.283	1.016	0.350	0.112
520	2.654	0.285	1.073	0.335	0.115
LSD $_{(T = 0.05)}$	**0.246**	**0.024**	**0.094**	**0.032**	**0.008**

Table 3.24: Effect of nitrogen application times on the nutrient content (%) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen application times	N	P	K	Ca	Mg
T_1	1.534	0.239	0.854	0.333	0.086
T_2	1.441	0.241	0.844	0.320	0.092
T_3	1.638	0.244	0.917	0.331	0.092
LSD $_{(T = 0.05)}$	**0.107**	**ns**	**0.041**	**ns**	**0.003**

Table 3.25: Effect of nitrogen levels on the nutrient content (%) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	N		P		K		Ca		Mg	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
0	0.521	0.577	0.222	0.168	0.685	0.688	0.385	0.311	0.062	0.062
30	0.817	0.707	0.226	0.181	0.698	0.767	0.350	0.302	0.066	0.069
70	0.892	0.850	0.213	0.198	0.670	0.814	0.331	0.286	0.071	0.079
120	1.197	1.098	0.243	0.211	0.828	0.972	0.344	0.283	0.082	0.083
180	1.349	1.423	0.267	0.241	0.802	0.926	0.356	0.279	0.092	0.094
250	1.859	1.776	0.271	0.224	0.939	0.927	0.351	0.295	0.099	0.097
330	2.248	2.040	0.312	0.233	1.020	0.954	0.374	0.284	0.111	0.100
420	2.605	2.407	0.320	0.245	1.025	1.007	0.387	0.313	0.116	0.109
520	2.591	2.717	0.314	0.255	1.043	1.103	0.382	0.288	0.114	0.117
LSD $_{(T = 0.05)}$	**ns**		**0.038**		**0.149**		**ns**		**0.012**	

Table 3.26: Effect of nitrogen application times on the nutrient content (%) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen application times	N		P		K		Ca		Mg	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
T_1	1.628	1.440	0.263	0.214	0.857	0.851	0.353	0.313	0.090	0.083
T_2	1.437	1.445	0.273	0.208	0.815	0.873	0.373	0.267	0.090	0.093
T_3	1.629	1.647	0.259	0.229	0.898	0.935	0.361	0.300	0.090	0.095
LSD $_{(T = 0.05)}$	**0.184**		**0.018**		**ns**		**0.024**		**0.006**	

Table 3.27: Effect of nitrogen levels and application times on the nutrient content (%) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	N			P			K			Ca			Mg		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
0	0.428	0.581	0.639	0.186	0.189	0.209	0.891	0.668	0.703	0.340	0.341	0.364	0.058	0.063	0.064
30	0.779	0.723	0.784	0.198	0.200	0.213	0.713	0.740	0.744	0.331	0.319	0.329	0.063	0.070	0.069
70	0.934	0.842	0.836	0.211	0.198	0.209	0.768	0.716	0.741	0.315	0.304	0.306	0.073	0.078	0.074
120	1.040	1.125	1.277	0.211	0.214	0.255	0.809	0.811	0.809	0.331	0.296	0.315	0.076	0.083	0.088
180	1.276	1.350	1.532	0.249	0.251	0.261	0.851	0.866	0.875	0.329	0.324	0.301	0.083	0.100	0.096
250	1.874	1.753	1.827	0.255	0.250	0.238	0.881	0.894	1.024	0.321	0.321	0.327	0.094	0.099	0.102
330	2.180	2.028	2.224	0.275	0.279	0.264	0.963	0.941	1.057	0.339	0.335	0.314	0.100	0.110	0.105
420	2.649	2.182	2.687	0.278	0.294	0.276	1.013	0.965	1.071	0.361	0.337	0.353	0.108	0.114	0.116
520	2.643	2.386	2.933	0.288	0.293	0.274	1.000	0.993	1.227	0.333	0.306	0.366	0.121	0.108	0.117
LSD $_{(T = 0.05)}$	**0.507**			**ns**			**ns**			**ns**			**0.016**		

Nitrogen

According to Table 3.20 the interaction between cultivar and nitrogen application times influenced the nitrogen content of *Lachenalia* bulbs grown from 2.5-3 cm bulblets significantly. As shown in Table 3.26 the nitrogen content of Rupert bulbs from the T_1 and T_3 treatments were significantly higher than that from the T_2 treatment. However, the nitrogen content of Ronina bulbs from the T_3 treatment was significant higher than that from the T_1 and T_2 treatments.

The interaction between nitrogen levels and application times also influenced the nitrogen content of these bulbs significantly (Table 3.20). Regardless of the nitrogen application time the nitrogen content of the bulbs increased with an increase in nitrogen level (Table 3.26). At the two highest nitrogen levels both the T_1 and the T_3 treatments produced bulbs with significant higher nitrogen content than the T_2 treatment.

Phosphorus

The interaction between cultivars and nitrogen levels influenced the phosphorus content of *Lachenalia* bulbs significantly as shown in Table 3.20. A higher phosphorus content was measured in Rupert bulbs than in Ronina bulbs irrespective of the nitrogen level (Table 3.25). Both cultivars responded positively on nitrogen levels. An increase in nitrogen level increased the phosphorus content of bulbs form both cultivars.

As indicated in Table 3.20 the phosphorus content of the bulbs was also influenced by the interaction between cultivar and nitrogen application times. The phosphorus content of Rupert bulbs was not significantly influenced by nitrogen application times, whereas the phosphorus content of Ronina bulbs from the T_3 treatment was significantly higher than that from the T_2 treatment (Table 3.26).

Potassium

The potassium content of *Lachenalia* bulbs were influenced by the interaction between cultivar and nitrogen levels (Table 3.20). As shown in Table 3.25 the potassium content of bulbs from both cultivars increased with increased levels of nitrogen. The potassium content of Ronina bulbs tended to be higher than that of Rupert bulbs at nitrogen levels of 180 kg ha^{-1} and lower whereas at nitrogen levels of 250 kg ha^{-1} and higher the potassium content of Rupert bulbs tended to be higher than that of Ronina bulbs. In Table 3.24 it is

displayed that a significantly higher potassium content was measured in bulbs from the T_3 treatment than in bulbs from the T_1 and T_2 treatments.

Calcium

As shown in Table 3.20 the interaction between cultivar and nitrogen application times influenced the calcium content of *Lachenalia* bulbs significantly. Although not significant the calcium content of Rupert bulbs was the highest with the T_2 treatment (Table 3.26). This treatment resulted in the lowest calcium content of Ronina bulbs which differed significantly.

The nitrogen levels influenced the calcium content of the bulbs significantly (Table 3.20). Calcium in comparison with the other nutrients did not showed a clear trend in response on nitrogen levels but it seems to increase with higher levels (Table 3.23).

Magnesium

The interaction between cultivar and nitrogen levels influenced the magnesium content of *Lachenalia* bulbs significantly (Table 3.20). Inspection of Table 3.25 showed that the magnesium content of Rupert bulbs tended to be higher than that of Ronina bulbs from a nitrogen level of 250 kg ha^{-1} and higher. The opposite is true from a nitrogen level of 180 kg ha^{-1} and lower.

According to Table 3.20 the magnesium content of the bulbs was influenced significantly by the interaction between cultivar and nitrogen application times. As indicated in Table 3.26 Rupert bulbs had a magnesium content of 0.09 % regardless of the nitrogen application time. However the magnesium content of Ronina bulbs from the T_2 and T_3 treatments was significantly higher than that from the T_1 treatment.

As shown in Table 3.20 the interaction between nitrogen levels and application times influenced the magnesium content of bulbs also significantly. The magnesium content of the bulbs increased with an increase in nitrogen levels for all three nitrogen application times (Table 3.27). Inspection of this table revealed that bulbs from the T_1 treatment had slightly lower magnesium content than the bulbs from the T_2 and T_3 treatments at all nitrogen levels except the highest one.

3.2.2.2.1.2 Bulbs grown from 3-4 cm bulblets

The nutrient content of the 3-4 cm bulblets that were planted in 2002 for this enlargement experiment is given in Table 3.28 for reference. As in the previous section for the sake of convenience the effects of nitrogen levels and application times on the nutrient content of Rupert and Ronina bulbs grown from 3-4 cm bulblets is presented in Tables 3.29 to 3.34. The discussion will be limited to those treatments that caused significant differences in the content of a particular nutrient.

Table 3.28: Nutrient content (%) of 3-4 cm Rupert and Ronina bulblets at planting in 2002

Cultivar	N	P	K	Ca	Mg
Rupert	2.251	0.370	2.076	1.620	0.160
Ronina	2.061	0.280	1.812	0.730	0.100

Table 3.29: Nutrient content (%) of Rupert and Ronina bulbs grown from 3-4 cm bulblets in 2002

Cultivar	N	P	K	Ca	Mg
Rupert	1.806	0.290	1.171	0.179	0.093
Ronina	1.866	0.269	1.057	0.258	0.093
LSD $_{(T = 0.05)}$	**ns**	**0.010**	**0.027**	**0.009**	**ns**

Table 3:30 Effect of nitrogen levels on the nutrient content (%) of *Lachenalia* bulbs grown from 3-4 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	N	P	K	Ca	Mg
0	0.688	0.211	0.920	0.217	0.064
30	0.824	0.235	0.957	0.201	0.070
70	1.174	0.265	1.034	0.203	0.081
120	1.572	0.272	1.080	0.232	0.093
180	1.851	0.279	1.092	0.240	0.096
250	2.165	0.296	1.160	0.225	0.103
330	2.422	0.311	1.247	0.220	0.105
420	2.817	0.321	1.254	0.220	0.111
520	3.017	0.318	1.283	0.211	0.111
LSD $_{(T = 0.05)}$	**0.249**	**0.034**	**0.027**	**0.029**	**0.007**

Table 3.31: Effect of nitrogen application times on the nutrient content (%) of *Lachenalia* bulbs grown from 3-4 cm bulblets in 2002

Nitrogen application times	N	P	K	Ca	Mg
T_1	1.816	0.279	1.171	0.226	0.098
T_2	1.698	0.261	1.076	0.225	0.089
T_3	1.996	0.295	1.095	0.205	0.092
LSD $_{(T = 0.05)}$	**0.109**	**0.015**	**0.040**	**0.013**	**0.003**

Table 3.32: Effect of nitrogen levels on the nutrient content (%) of Rupert and Ronina bulbs grown from 3-4 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	N		P		K		Ca		Mg	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
0	0.727	0.650	0.237	0.186	0.955	0.885	0.204	0.230	0.067	0.061
30	0.803	0.845	0.237	0.233	0.968	0.946	0.186	0.216	0.070	0.071
70	1.139	1.210	0.262	0.268	1.079	0.989	0.191	0.215	0.080	0.082
120	1.549	1.596	0.277	0.268	1.143	1.018	0.185	0.279	0.092	0.093
180	1.794	1.908	0.286	0.273	1.178	1.006	0.206	0.275	0.100	0.091
250	2.121	2.208	0.308	0.283	1.248	1.073	0.180	0.270	0.106	0.100
330	2.351	2.492	0.315	0.308	1.328	1.166	0.163	0.278	0.103	0.106
420	2.756	2.878	0.331	0.312	1.300	1.208	0.159	0.280	0.108	0.114
520	3.017	3.017	0.340	0.295	1.343	1,223	0.142	0.280	0.109	0.114
LSD $_{(T = 0.05)}$	**ns**		**ns**		**ns**		**0.046**		**0.012**	

Table 3.33: Effect of nitrogen applic ation times on the nutrient content (%) of Rupert and Ronina bulbs grown from 3-4 cm bulblets in 2002

Nitrogen application times	N		P		K		Ca		Mg	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
T1	1.793	1.839	0.278	0.281	1.149	1.193	0.247	0.205	0.104	0.091
T2	1.670	1.726	0.272	0.251	1.088	1.064	0.193	0.258	0.090	0.087
T3	1.955	2.036	0.314	0.276	1.277	0.914	0.099	0.312	0.083	0.100
$LSD_{(T = 0.05)}$	**ns**		**0.025**		**0.074**		**0.022**		**0.006**	

Table 3.34: Effect of nitrogen levels and application times on the nutrient content (%) of *Lachenalia* bulbs grown from 3-4 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	N			P			K			Ca			Mg		
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
0	0.541	0.834	0.691	0.221	0.184	0.229	1.030	0.870	0.860	0.178	0.246	0.226	0.066	0.063	0.062
30	0.665	0.928	0.879	0.224	0.229	0.251	1.021	0.928	0.922	0.157	0.239	0.208	0.068	0.071	0.073
70	1.087	1.097	1.340	0.260	0.230	0.304	1.084	0.958	1.061	0.145	0.255	0.208	0.078	0.082	0.082
120	1.532	1.559	1.626	0.286	0.249	0.281	1.179	1.071	0.990	0.251	0.248	0.197	0.096	0.095	0.086
180	1.698	1.607	2.247	0.284	0.260	0.294	1.124	1.043	1.111	0.294	0.228	0.199	0.104	0.091	0.092
250	2.234	1.973	2.287	0.320	0.267	0.301	1.244	1.089	1.149	0.246	0.237	0.192	0.113	0.098	0.098
330	2.603	2.071	2.591	0.303	0.300	0.331	1.261	1.241	1.239	0.264	0.180	0.217	0.114	0.092	0.108
420	2.876	2.568	3.007	0.309	0.324	0.331	1.260	1.258	1.245	0.257	0.206	0.196	0.120	0.103	0.111
520	3.111	2.644	3.296	0.308	0.310	0.335	1.338	1.231	1.281	0.241	0.188	0.205	0.121	0.100	0.112
$LSD_{(T = 0.05)}$	**0.514**			**ns**			**ns**			**0.060**			**0.015**		

Nitrogen

According to Table 3.20 the interaction between nitrogen levels and application times influenced the nitrogen content of *Lachenalia* bulbs grown from 3-4 cm bulblets significantly. Higher nitrogen levels increase the nitrogen content of bulbs irrespective of the application times (Table 3.34). The nitrogen content of bulbs from the T_3 and T_1 treatments was higher than that of bulbs from the T_2 treatment at the higher nitrogen levels. This trend started at 250 kg N ha^{-1} with the T_1 treatment and at 180 kg N ha^{-1} with the T_3 treatment.

Phosphorus

As shown in Table 3.20 the interaction between cultivar and nitrogen application times influenced the phosphorus content of *Lachenalia* bulbs significantly. The highest phosphorus was measured in Rupert bulbs from the T_3 treatment and in Ronina bulbs from the T_1 and T_3 treatments (Table 3.33). An increase in nitrogen level from 0 to 520 kg ha^{-1} resulted that the phosphorus content of the bulbs increased from 0.211 to 0.308 % (Table 3.30).

Potassium

The interaction between cultivar and nitrogen application times significantly influenced the potassium content of *Lachenalia* bulbs (Table 3.20). As can be observed from Table 3.33 the lowest and highest potassium content were measured respectively in Rupert bulbs with the T_2 and T_3 treatments and in Ronina bulbs with the T_3 and T_1 treatments. Ronina bulbs contained more potassium than Rupert bulbs with the T_1 treatment whereas with the T_3 treatment this trend was reversed.

The potassium content of the bulbs increased with higher nitrogen levels (Table 3.30). However, from 330 kg N ha^{-1} and higher the potassium content of the bulbs stabilised.

Calcium

As indicated in Table 3.20 the interaction between cultivar and nitrogen levels influenced the calcium content of *Lachenalia* bulbs significant. The calcium content of Rupert bulbs remained almost constant but from a nitrogen level of 180 kg ha^{-1} and higher it started to decrease (Table 3.32). In contrast the calcium content of Ronina bulbs increased with higher nitrogen levels.

The interaction between nitrogen levels and application times also influenced the calcium content of the bulbs (Table 3.20). As displayed in Table 3.34 the calcium content of bulbs from the T_1 treatment increased when the nitrogen level increased from 0 to 180 kg ha^{-1} and then remained almost constant. In the case of the T_2 treatment the calcium content of the bulbs remained almost constant to a nitrogen level of 250 kg ha^{-1} and then started to decrease. The calcium content of bulbs from the T_3 treatment showed no trend with regard to the nitrogen levels.

As shown in Table 3.20 the interaction between cultivar and nitrogen application times influenced the calcium content of *Lachenalia* bulb also significantly. The calcium content of Rupert bulbs decreased whereas the calcium content of Ronina bulbs increased from the T_1 to T_3 treatments as can be observed from Table 3.33.

Magnesium

The interaction between cultivar and nitrogen levels influenced the magnesium content of *Lachenalia* bulbs significantly (Table 3.20). Bulbs of Rupert and Ronina showed an increase in magnesium content with an increase in nitrogen levels (Table 3.32).

Inspection of Table 3.20 indicated that the interaction between nitrogen levels and application times also significantly influenced the magnesium content of *Lachenalia* bulbs. The magnesium content of the bulbs increased with higher nitrogen levels regardless of the application times (Table 3.34). Bulbs from the T_1 and T_3 treatments contained more magnesium than bulbs from the T_2 treatment at the higher nitrogen levels. This trend started with the T_1 treatment at 250 kg N ha^{-1} and with the T_3 treatment at 330 kg N ha^{-1}.

According to Table 3.20 the interaction between cultivar and nitrogen application times influenced the magnesium content of *Lachenalia* bulbs significantly. The lowest and highest magnesium content was recorded respectively in Rupert bulbs with the T_3 and T_1 treatments and in Ronina bulbs with the T_2 and T_3 treatments (Table 3.33).

The preceding results revealed that in most cases the nitrogen, phosphorus, potassium and magnesium content of *Lachenalia* bulbs grown from either 2.5-3 and 3-4 cm

bulblets increased with an increase in nitrogen levels (Table 3.23 and 3.30). Calcium is the only nutrient investigated that did not show such a clear trend and no obvious explanation can be given for this phenomenon. The content of all five nutrients in bulbs grown from 2.5-3 cm bulblets was the highest with the T_3 treatment (Table 3.24). However, in bulbs grown from 3-4 cm bulblets the T_3 treatment resulted in the highest content of nitrogen and phosphorus whereas the T_1 treatment resulted in the highest content of potassium, calcium and magnesium (Table 3.31). Based on the nutrient contents of the bulbs grown from either the 2.5-3 cm or 3-4 cm bulblets the response of Rupert and Ronina to nitrogen levels and application time were some what variable.

3.2.2.2.2 Bulb carbohydrate content

In a pilot study done in 2001 the harvested bulbs of all four replications were pooled to ensure enough material for analysis of carbohydrates. There was some indication that nitrogen levels and application times influenced the D-glucose, sucrose and starch content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets. In 2002 the harvested bulbs from the four replications were analysed separately with the result that analysis of variance on this data was possible. On account of this and that the data of 2001 and 2002 showed similar trends only the data of 2002 will be given and discussed in this section.

A summary of the analyses of variance that was done to determine the effect of different nitrogen levels and application times on the carbohydrate content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2002 is given in Table 3.35.

As reference the carbohydrate content of the 2.5-3 cm bulblets planted in 2002 is given in Table 3.36. However, for convenience all the absolute data are presented in Tables 3.37 to 3.42 but discussion will be limited to those treatments that caused significant differences in the content of a particular carbohydrate.

Table 3.35: Summary on the analyses of variance showing the significant effects of nitrogen levels and application times on the carbohydrate content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2002

Carbohydrates	Cultivar (C)	Nitrogen level (N)	Application time (T)	C X N	C X T	N X T
D-glucose	ns	ns	*	ns	ns	ns
Sucrose	*	*	ns	ns	*	*
Starch	*	*	*	*	*	*

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

Table 3.36: Carbohydrate content (g l^{-1}) of 2.5-3 cm Rupert and Ronina bulblets at planting in 2002

Cultivar	D-glucose	Sucrose	Starch
Rupert	0.019	0.335	9.09
Ronina	0.015	0.327	8.71

Table 3.37: Carbohydrate content (g l^{-1}) of Rupert and Ronina bulbs grown from 2.5 -3 cm bulblets in 2002

Cultivar	D-glucose	Sucrose	Starch
Rupert	0.020	0.267	10.60
Ronina	0.034	0.541	7.20
LSD $_{(T = 0.05)}$	**ns**	**0.037**	**3.57**

Table 3.38: Effect of nitrogen levels on the carbohydrate content (g l^{-1}) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	D-glucose	Sucrose	Starch
0	0.030	0.348	8.41
30	0.050	0.321	8.68
70	0.050	0.342	8.84
120	0.049	0.430	8.85
180	0.011	0.442	8.79
250	0.013	0.487	9.44
330	0.023	0.425	9.73
420	0.008	0.467	8.90
520	0.009	0.377	8.72
LSD $_{(T=0.05)}$	ns	0.124	1.20

Table 3.39: Effect of nitrogen application times on the carbohydrate content (g l^{-1}) of *Lachenalia* bulbs grown from 2.5 -3 cm bulble ts in 2002

Nitrogen application times	D-glucose	Sucrose	Starch
T_1	0.046	0.374	9.14
T_2	0.021	0.425	9.11
T_3	0.136	0.414	8.45
LSD $_{(T = 0.05)}$	**0.030**	**ns**	**0.52**

Table 3.40: Effect of nitrogen levels on the carbohydrate content (g l^{-1}) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	D-glucose		Sucrose		Starch	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
0	0.030	0.030	0.171	0.526	10.62	6.20
30	0.027	0.073	0.194	0.447	11.11	6.25
70	0.026	0.072	0.237	0.448	11.14	6.54
120	0.036	0.062	0.252	0.608	10.26	6.81
180	0.012	0.010	0.287	0.596	9.93	7.65
250	0.012	0.013	0.384	0.590	10.79	8.11
330	0.029	0.018	0.287	0.562	11.48	8.00
420	0.003	0.013	0.363	0.571	9.52	8.28
520	0.005	0.013	0.230	0.525	10.50	6.94
LSD $_{(T = 0.05)}$	**ns**		**ns**		**1.90**	

Table 3.41: Effect of nitrogen application times on the carbohydrate content (g l^{-1}) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen application times	D-glucose		Sucrose		Starch	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
T_1	0.026	0.065	0.290	0.458	9.41	8.86
T_2	0.020	0.023	0.241	0.609	11.51	6.71
T_3	0.014	0.013	0.271	0.557	10.87	6.02
LSD $_{(T = 0.05)}$	**ns**		**0.093**		**0.901**	

Table 3.42: Effect of nitrogen levels and application times on the carbohydrate content (g l^{1}) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2002

Nitrogen levels kg ha^{-1}	D-glucose			Sucrose			Starch		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
0	0.036	0.027	0.026	0.398	0.249	0.398	7.20	9.50	8.55
30	0.094	0.036	0.020	0.350	0.227	0.386	8.32	8.93	8.79
70	0.079	0.057	0.012	0.333	0.396	0.298	9.35	8.07	9.10
120	0.013	0.005	0.016	0.393	0.514	0.382	9.27	8.04	8.30
180	0.010	0.006	0.016	0.489	0.440	0.397	9.58	9.11	7.70
250	0.014	0.011	0.013	0.425	0.568	0.469	9.63	9.79	8.91
330	0.034	0.025	0.010	0.357	0.512	0.406	10.05	9.84	9.29
420	0.004	0.014	0.005	0.381	0.527	0.493	10.11	8.91	7.69
520	0.011	0.011	0.005	0.244	0.391	0.497	8.70	9.79	7.68
LSD $_{(T = 0.05)}$	**ns**			**0.257**			**2.48**		

D-glucose

According to Table 3.35 only nitrogen application times influenced the D-glucose content of the *Lachenalia* bulbs. The D-glucose content of bulbs from the T_3 treatment was respectively 3 and 6 times higher than that of bulbs from the T_1 and T_2 treatments (Table 3.39). Although not significant the D-glucose content of the bulbs tended to decrease with an increase in nitrogen levels (Table 3.38). The D-glucose content of Ronina bulbs was higher than that of Rupert bulbs although not significant (Table 3.37).

Sucrose

The interaction between cultivar and nitrogen application times influenced the sucrose content *of Lachenalia* bulbs significantly (Table 3.35). Nitrogen application time did not influenced the sucrose content of Rupert bulbs but Ronina bulbs from the T_2 and T_3 treatments contained more sucrose than bulbs from the T_1 treatment (Table 3.41). Regardless of nitrogen application time the sucrose content of Ronina bulbs was higher than that of Rupert bulbs

As shown in Table 3.35 the interaction between nitrogen levels and application times significantly influenced the sucrose content of *Lachenalia* bulbs. Inspection of Table 3.42 showed that the sucrose content of bulbs from the T_2 treatment increased

from 0.249 g l^{-1} at 0 kg N ha^{-1} to 0.568 g l^{-1} at 250 kg N ha^{-1} and then decreased to 0.391 g l^{-1} at 520 kg N ha^{-1}. This trend in glucose content in bulbs from the T_1 and T_3 treatments is not clear.

Starch

The starch content of *Lachenalia* bulbs was influenced by the interaction between cultivar and nitrogen levels (Table 3.35). As shown in Table 3.40 the starch content of Rupert bulbs was higher than that of Ronina bulbs. The starch content of Ronina bulbs increased with increasing nitrogen levels to reach a maximum of 8.28 g l^{-1} at 420 kg N ha^{-1}. This trend of starch content was absent in the Rupert bulbs.

The interaction between cultivar and time of nitrogen application influenced the starch content of *Lachenalia* bulbs significantly (Table 3.35). Rupert bulbs contained more starch than Ronina bulbs regardless of the nitrogen application time (Table 3.41). The starch content of Rupert bulbs from the T_2 and T_3 treatments was higher than those from the T_1 treatment. In contrast the starch content of Ronina bulbs from the T_1 treatment was higher than those from the T_2 and T_3 treatments.

As shown in Table 3.35 the interaction between nitrogen levels and application times also influenced the starch content of *Lachenalia* bulbs significantly. Inspection of Table 3.42 showed that the starch content of bulbs from the T_1 treatment increased from 7.20 g l^{-1} at 0 kg N ha^{-1} to 10.11 g l^{-1} at 420 kg N ha^{-1} and then decreased to 8.70 g l^{-1} at 520 kg N ha^{-1}. This clear trend in starch content was almost absent in the bulbs from the T_2 and T_3 treatments.

Assimilates produced by the aerial parts of geophytes like *Lachenalia* during active growth are transported to the storage organs until the aerial parts died off (Rees, 1992; Du Toit, 2001; Du Toit, Robbertse & Niederwieser, 2004). In most geophyte species sugars are mainly transported and stored as sucrose (Miller, 1992; De Hertogh & Le Nard, 1993; Theron & Jacobs, 1996; Smith, 1999). Sucrose was found to be the main storage sugar in the *Lachenalia* bulbs as was also the case in Dutch iris bulbs (Imanishi, Halevy, Kofranek, Han & Reid, 1994) and *Narcissus* bulbs (Ruamrungsri, Ruamrungsri, Ikarashi & Ohyama, 1999). The *Lachenalia* bulbs contained 0.4 mg

glucose g^{-1} DM and 6.1 mg sucrose g^{-1}DM whereas the Dutch iris bulbs contained 6.1 mg glucose g^{-1} DM and 52.1 mg sucrose g^{-1} DM. *Narcissus* bulbs contained 6-14 times more sucrose than glucose whereas the *Lachenalia* bulbs contained 15 times more sucrose than glucose.

According to Duffus & Duffus (1984) starch is the major storage carbohydrate and may accumulate to about 70-80 % of the dry weight of storage organs such as bulbs. Du Toit (2001) found that the maximum amount of starch stored in Ronina bulbs directly after full bloom was 160 mg g^{-1} DM whereafter it started to decrease slowly during senescence of the above growth and the decrease persisted during dormancy. In the present study the average starch content of *Lachenalia* bulbs at harvest was 890 mg g^{-1} DM.

In the case of *Lachenalia* bulbs the glucose content decreased whereas the sucrose and starch content increased as a result of higher nitrogen levels which agree with results reported by Maier *et al.*, (1990). However, cultivars and nitrogen application times had variable effects on the glucose, sucrose and starch content of *Lachenalia* bulbs which hampered a conclusive remark somewhat.

3.3 CONCLUSIONS

- No nutritional disorders were observed on the plants in this study, even those plants not fertilised with nitrogen.

- All bulbs harvested after one season of enlargement reached a circumference of 6 cm or more which is sufficient for export standards.

- Characteristics of cultivars must be taken in account by *Lachenalia* bulb producers when fertilisation decisions are made for the enlargement phase.

- By considering the response of the different parameters to nitrogen fertilisation it seems that the optimum level varied between 250 and 330 kg N ha^{-1}.

- The best response was obtained when the nitrogen was applied in four equal applications through the growing season.

CHAPTER 4

RESPONSE OF *Lachenalia* TO NITROGEN AND PHOSPHORUS OR POTASSIUM FERTILISATION IN THE NURSERY PHASE

4.1 INTRODUCTION

Lachenalia bulbs were influenced by nitrogen fertiliser in the nursery phase (Chapter 3). Nitrogen is not the only nutrient that is essential for plant growth, phosphorus and potassium is also important (FSSA, 2003). The uptake and role of nitrogen in plants is given in detail in Section 3.1 and will not be discussed again. Only the uptake and role of phosphorus and potassium in plants will be discussed in this chapter.

Phosphorus is absorbed by plants in one of two forms, either as the monovalent phosphate ion ($H_2PO_4^-$) or as the divalent phosphate ion ($HPO_4^=$). The ion absorbed is determined by the pH of the soil. There is a notable effect of nitrogen on phosphorus uptake by plants. When nitrogen and phosphorus are physically and /or chemically associated in the soil, phosphorus uptake is enhanced.

Phosphorus is a constituent of plant compounds such as enzymes and proteins and is a structural component of phosphoproteins, phospholipids and nucleic acids. Since it is part of nucleic acids and of genes and chromosomes, it plays a vital role in the life cycle of plants and is important in reproductive growth. It promotes early maturity and fruit quality. Phosphorus has been described as ubiquitous in the plant, being involved in nearly all metabolic processes (Bennett, 1993).

Phosphorus is contained in NADP, a part of the photosynthetic process. Its best known function is in energy storage and transfer through the compounds ADP and ATP. It is an integral part of the reproductive system as a component of the genetic memory system of RNA and DNA and is, therefore, involved in the transfer of genetic information. It is also involved in electron transport in oxidation-reduction reactions. Phosphorus plays a regulatory role in the formation and translocation of substances such as sugars and starches. It is important in the maturation processes and in seed formation. Phosphorus is involved in symbiotic nitrogen fixation (Bennett, 1993).

Potassium on the other hand is required for turgor buildup in plants and maintains the osmotic potential of cells, which in guard cells governs the opening of stomata. This osmotic regulation indicates the role potassium plays in water relations in the plant. It is involved in water uptake from soil, water retention in the plant tissue, and long distance transport of water and assimilates in the phloem and xylem. Potassium also functions in pH stabilization in the cell. It counteracts the negative charge of organic acids and inorganic anions such as Cl^- and $SO_4^{=}$. Potassium is required as an activator for more than sixty enzymes in meristematic tissue (Bennett, 1993; FSSA, 2003).

Potassium is important in cell growth primary through its effect on cell extension. With adequate potassium, cell walls are thicker and provide more tissue stability. This effect on cell growth normally improves resistance to lodging, pests and diseases. Potassium is required for production of high energy phosphate and is involved in starch as well as protein synthesis. It functions in nitrogen uptake and protein synthesis, lipid metabolism, photosynthetic processes, and carbohydrate metabolism (Bennett, 1993).

According to Teng & Timmer (1996) improving fertilisation efficiency is a key to achieving sustainable production with minimum environmental impact in intensively managed cropping systems. One factor that may contribute to low fertilisation efficiency is that nitrogen, phosphorus and potassium fertilisers are usually prescribed and applied separately, with little consideration of the interaction between these essential elements. The interaction between different nutrient elements may also play a role in different growth and yield components of plants (FSSA, 2003).

Excessive use of nitrogen fertiliser influences the balance of nutrients in the soil solution. Thus leads to nutritional disturbances that may manifest themselves in acute symptoms, but more often remain latent and materialise only as subnormal growth and quality. The increased use of fertiliser increased the importance of antagonism and synergism amongst ions, i.e. the interaction between nutrients. This may take on a variety of forms, such as inhibition or stimulation of uptake, displacement in metabolism, formation of scarcely soluble precipitates or dilution effects, and their role in inducing signs of deficiency or toxicity is considerable (Bergmann, 1992).

Attention should therefore be paid to the relative proportion of nitrogen, phosphorus and potassium and the possibility of overabundance of plant nutrients. An excess of one element means simultaneously a relative or absolute deficiency of the others. The opposite is also true if there is a deficiency of some nutrient. In both cases the result is an "unbalanced diet" for the plants (Bergmann, 1992). In other words for optimal plant growth the nutrients must be absorbed and distributed within the plant in certain proportions. On the other hand any disruption of this balance, within certain limits, will not always result in damage or loss in yield or quality.

It was observed by Kœugi, Sano & Goi (1964) and Raafat, El-Kadi & Harraway (1968) that the interaction between nutrients may influence growth of freesias. Nitrogen, phosphorus and potassium interact to form larger and more corms.

It is also known that nitrogen has an antagonistic relationship with potassium. The higher the nitrogen level the less potassium is available for the plant. Potassium on the other hand does not influence the availability of nitrogen for the plant (FSSA, 2003). Conover & Henny (1995) reported that anthurium pot plants produced the best growth quality when the nitrogen and potassium levels were low. Christmas bells (*Blandfordia*) showed improved growth with controlled released fertiliser with a ratio of 1 N: 1.5 K (Lamont, Cresswell & Griffith, 1990).

There are also many conflicting results in the literature. Nederpe & Van Eysinga (1978) reported that phosphorus and potassium had no significant effect on the foliage fresh mass and corm growth of freesias whereas Raafat *et al.* (1968) and Thomas, Matheson & Spurway (1998) reported that phosphorus and potassium increased foliar fresh mass and corm growth of freesias.

The role of nitrogen in the production of quality bulbs for the export pot plant industry was investigated in pot trials. Results indicating that nitrogen applied in the nursery phase influenced the growth and quality of bulbs significantly (Chapter 3). As also indicated by other researchers, the interaction between nutrients may influence the growth and quality of bulbs, it was therefore important to investigate the interaction between nitrogen and phosphorus or potassium.

The objective with this study was therefore to determine the response of two *Lachenalia* cultivars in the nursery phase to different combinations of nitrogen and phosphorus or potassium levels.

4.2 RESULTS AND DISCUSSION

4.2.1 NITROGEN AND PHOSPHORUS INTERACTION

4.2.1.1 Leaf area

A summary on the analyses of variance that was done to determine the effects of different nitrogen and phosphorus levels on the leaf area of Rupert and Ronina plants grown from 2.5-3 cm bulblets in 2003 is given in Table 4.1.

Table 4.1: Summary on the analyses of variance showing the significant effects of nitrogen and phosphorus levels on the leaf area of Rupert and Ronina plants grown from 2.5-3 cm bulblets in 2003

Weeks after planting	Cultivar (C)	Nitrogen level (N)	Phosphorus level (P)	C X N	C X P	N X P
4	*	*	ns	ns	ns	ns
7	*	*	ns	*	ns	ns
10	*	*	ns	*	ns	ns
14	*	*	ns	*	ns	ns
17	*	*	ns	*	ns	ns
20	*	*	ns	*	ns	ns
23	*	*	ns	*	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

As shown in Table 4.1 the interaction between nitrogen and phosphorus levels did not influenced the leaf area of *Lachenalia* plants significantly. The same was observed for the interaction between cultivar and phosphorus levels whereas phosphorus levels alone did also not had a significant influence on the leaf area.

The interaction between cultivar and nitrogen levels on the leaf area of *Lachenalia* plants was significant from 7 weeks and later after planting (Table 4.1). However, at every measurement time the leaf area of Rupert increased from the 0 kg N ha^{-1} level to the 180 kg N ha^{-1} level whereafter it started to decrease (Table 4.2). The leaf area of Ronina plants increased also with higher nitrogen levels but reached a maximum at 4 and 7 weeks after planting with a 330 kg N ha^{-1} application, and at 10, 14, 17, 20 and 23 weeks after planting with a 520 kg N ha^{-1} application. As shown in Table 4.2 the leaf area of Ronina was without exception larger than that of Rupert.

Table 4.2: Effect of nitrogen levels on the leaf area (cm^2) of Rupert and Ronina plants grown from 2.5-3 cm bulblets in 2003

Weeks after planting	Rupert					Ronina					LSD (T = 0.05)
	0	70	180	330	520	0	70	180	330	520	
	kg N ha^{-1}					kg N ha^{-1}					
4	2.61	2.98	3.34	3.02	2.69	3.82	4.11	4.67	4.88	4.59	**ns**
7	6.22	6.90	7.81	7.34	7.09	8.57	10.34	11.64	12.62	12.23	**1.69**
10	8.73	9.92	11.20	10.86	10.63	11.32	14.31	17.17	18.95	19.63	**2.60**
14	10.48	12.34	14.15	13.57	13.16	13.95	18.29	22.69	24.77	24.60	**3.52**
17	11.26	14.14	16.07	16.70	14.41	16.38	22.83	26.86	29.26	29.70	**4.80**
20	11.42	14.73	16.99	16.60	15.24	17.00	23.64	29.32	31.93	32.45	**5.30**
23	10.90	13.78	17.50	16.51	14.48	17.87	25.24	32.01	33.63	35.78	**6.05**

From these results it is clear that phosphorus application did not influence the leaf area of *Lachenalia* plants like nitrogen application. Claassens (1990) reported that *Lachenalia* grow well under low phosphorus levels. Rupert and Ronina plants differ in their reaction to nitrogen application which coincides with the results reported in Section 3.2.1.1.

4.2.1.2 Bulb quality

4.2.1.2.1 Physical parameters

In order to establish the quality of *Lachenalia* bulbs, treated with different nitrogen and phosphorus levels, and harvested after one season of enlargement the following physical parameters were measured: fresh mass, circumference and firmness. A summary on the analyses of variance that was done to determine the effects of different nitrogen and phosphorus levels on the fresh mass, circumference and firmness of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003 is given in Table 4.3. As shown in Table 4.2 the leaf area of Ronina was without exception larger than that of Rupert.

Table 4.3: Summary on the analyses of variance showing the significant effects of nitrogen and phosphorus levels on the fresh mass, circumference and firmness of Rupert and Ronina bulbs grown from 2.5 -3 cm bulblets in 2003

Bulb	Cultivar (C)	Nitrogen level (N)	Phosphorus level (P)	C X N	C X P	N X P
Fresh mass	*	*	ns	*	ns	ns
Circumference	*	*	ns	*	ns	ns
Firmness	*	*	*	*	*	ns

LSD (T = 0.05)
ns = no significant differences
*** = significant differences**

As shown in Table 4.3 the fresh mass and the circumference of *Lachenalia* bulbs reacted similar on the different nitrogen and phosphorus levels. The fresh mass increased linearly with circumference and a correlation coefficient of 0.95 was found between bulb fresh mass and circumference. As mentioned earlier the grading of *Lachenalia* bulbs is mainly done on circumference and not fresh mass. On account of this grading process and because of the high correlation between bulb fresh mass and circumference only data of bulb circumference will be presented and discussed in this following section.

4.2.1.2.1.1 Bulb circumference

The circumference of *Lachenalia* bulbs was not significantly influenced by neither the interaction between cultivar and phosphorus levels nor the interaction between nitrogen and phosphorus levels as shown in Table 4.3. However, the interaction between cultivar and nitrogen levels significantly influenced the circumference of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets. Inspection of Table 4.4 showed that the circumference of Rupert bulbs increased from 7.15 cm at a 0 kg N ha^{-1} level to 8.40 cm at a 180 kg N ha^{-1} level and decreased to 8.15 cm at a 520 kg N ha^{-1} level. In contrast the circumference of Ronina bulbs increased from 7.85 cm at a 0 kg N ha^{-1} level to 9.5 cm at a 520 kg N ha^{-1} level. All *Lachenalia* bulbs harvested after one season of enlargement reached marketable size, even the bulbs that received no nitrogen. The circumference of Ronina bulbs was regardless of the nitrogen level larger than the circumference of Rupert bulbs.

Table 4.4: Effect of nitrogenlevels on the circumference (cm) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	7.15	7.85
70	8.00	8.45
180	8.40	8.75
330	8.20	8.95
520	8.15	9.25
LSD$_{(T = 0.05)}$	**0.53**	

4.2.1.2.1.2 Bulb firmness

As shown in Table 4.3 the interaction between cultivar and phosphorus levels significantly influenced the firmness of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003. The firmness of Rupert bulbs was not significantly influenced by the

phosphorus levels but tended to decrease from the 0 to 10 kg P ha^{-1} level and to increase from the 10 to 80 kg P ha^{-1} level (Table 4.5). Ronina bulbs did not show such a clear trend, however, its firmness decreased from the 0 to 30 kg P ha^{-1} level. The bulbs of Rupert were much firmer than the bulbs of Ronina irrespective of the phosphorus level.

Table 4.5: Effect of phosphorus levels on the firmness of Rupert and Ronina bulbs grown from 2.5 -3 cm bulblets in 2003

Phosphorus levels kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	6.48	10.46
10	6.82	10.70
30	6.58	11.53
50	6.34	10.20
80	6.22	11.54
LS $D_{(T = 0.05)}$	**1.41**	

The interaction between cultivar and nitrogen levels influenced also the firmness of *Lachenalia* bulbs significantly (Table 4.3). Ronina bulbs were softer than Rupert bulbs irrespective of the nitrogen level (Table 4.6). Although the nitrogen levels did not influenced the firmness of Rupert bulbs significantly it tended to be harder with higher nitrogen levels. The firmness of Ronina bulbs increased significantly when the nitrogen levels increased.

Table 4.6: Effect of nitrogen levels on the firmness of Rupert and Ronina bulbs grown from 2.5 -3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	6.70	13.15
70	6.51	11.33
180	6.65	10.47
330	6.32	9.42
520	6.26	9.75
$LSD_{(T = 0.05)}$	**1.41**	

The application of phosphorus only influenced the firmness of *Lachenalia* bulbs in that an increase in phosphorus levels tended to increase the firmness of Rupert bulbs and decrease the firmness of Ronina bulbs. Surprisingly, the interaction between nitrogen and phosphorus levels did not influence the fresh mass, circumference or firmness of the bulbs at all. The results on the influence of nitrogen application on the circumference and firmness of Rupert and Ronina bulbs coincide with the results reported Section 3.2.2.1.

4.2.1.2.2 Chemical parameters

4.2.1.2.2.1 Bulb nutrient content

In order to establish the nutrient content of *Lachenalia* bulbs after one season of enlargement the bulbs were analysed for the following nutrients: nitrogen, phosphorus, potassium, calcium and magnesium. A summary on the analyses of variance that was done to determine the effects of different nitrogen and phosphorus levels on the nutrient content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003 is given in Table 4.7.

Table 4.7: Summary on the analyses of variance showing the effects of nitrogen and phosphorus levels on the nutrient content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Nutrient content of bulbs	Cultivar (C)	Nitrogen level (N)	Phosphorus level (P)	C X N	C X P	N X P
N	*	*	ns	ns	ns	ns
P	*	ns	ns	ns	ns	ns
K	*	ns	ns	ns	ns	ns
Ca	*	*	ns	ns	ns	ns
Mg	*	ns	ns	ns	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

As reference the nutrient content of the 2.5-3 cm bulblets that were planted in 2003 is presented in Table 4.8. All the data on the effect of nitrogen and phosphorus levels on the nutrient content of *Lachenalia* bulbs grown from the 2.5-3 cm bulblets are presented in Tables 4.9 to 4.14 for convenience. However, the discussion will be limited to only those treatments that caused significant differences in the content of a particular nutrient.

Table 4.8: Nutrient content (%) of 2.5-3 cm Rupert and Ronina bulblets at planting in 2003

Cultivar	N	P	K	Ca	Mg
Rupert	2.220	0.370	1.944	0.940	0.140
Ronina	2.982	0.320	1.864	1.120	0.129

Table 4.9: Nutrient content (%) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Cultivar	N	P	K	Ca	Mg
Rupert	2.300	0.351	1.462	0.581	0.116
Ronina	1.944	0.270	1.042	0.435	0.089
LSD $_{(T = 0.05)}$	**0.343**	**0.018**	**0.085**	**0.018**	**0.007**

Table 4.10: Effect of nitrogen levels on the nutrient content (%) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	N	P	K	Ca	Mg
0	1.732	0.300	1.190	0.493	0.096
70	1.882	0.294	1.188	0.516	0.097
180	2.159	0.309	1.261	0.529	0.103
330	2.314	0.315	1.334	0.514	0.105
520	2.523	0.333	1.286	0.485	0.111
LSD $_{(T = 0.05)}$	**0.755**	**ns**	**ns**	**0.041**	**ns**

Table 4.11: Effect of phosphorus levels on the nutrient content (%) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Phosphorus levels kg ha^{-1}	N	P	K	Ca	Mg
0	2.117	0.305	1.310	0.510	0.101
70	2.064	0.312	1.205	0.504	0.101
180	2.100	0.308	1.234	0.488	0.099
330	2.236	0.315	1.243	0.526	0.105
520	2.091	0.311	1.238	0.510	0.104
LSD $_{(T = 0.05)}$	**ns**	**ns**	**ns**	**ns**	**ns**

Table 4.12: Effect of nitrogen levels on the nutrient content (%) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	N		P		K		Ca		Mg	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
0	1.963	1.501	0.333	0.267	1.326	1.054	0.555	0.431	0.112	0.081
70	1.944	1.769	0.332	0.257	1.400	0.981	0.572	0.460	0.107	0.087
180	2.333	1.984	0.351	0.268	1.479	1.043	0.615	0.444	0.115	0.090
330	2.440	2.189	0.355	0.275	1.595	1.073	0.606	0.423	0.118	0.092
520	2.769	2.276	0.383	0.283	1.514	1.059	0.556	0.414	0.127	0.094
LSD $_{(T = 0.05)}$	**ns**		**ns**		**ns**		**ns**		**ns**	

Table 4.13: Effect of phosphorus levels on the nutrient content (%) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Phosphorus levels kg ha^{-1}	N		P		K		Ca		Mg	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
0	2.312	1.922	0.345	0.266	1.517	1.103	0.587	0.433	0.118	0.085
10	2.186	1.941	0.354	0.271	1.398	1.012	0.578	0.429	0.114	0.088
30	2.321	1.879	0.343	0.273	1.410	1.059	0.551	0.425	0.111	0.088
50	2.392	2.081	0.357	0.273	1.465	1.021	0.600	0.453	0.117	0.094
80	2.287	1.896	0.356	0.267	1.520	1.016	0.588	0.432	0.119	0.089
LSD $_{(T = 0.05)}$	**ns**		**ns**		**ns**		**ns**		**ns**	

Table 4.14: Effect of nitrogen levels and phosphorus levels on the nutrient content (%) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	N					P					K					Ca					Mg				
	Phosphorus levels kg ha^{-1}																								
	0	10	30	50	80	0	10	30	50	80	0	10	30	50	80	0	10	30	50	80	0	10	30	50	80
0	1.74	1.87	2.15	2.23	2.60	0.29	0.29	0.31	0.30	0.33	1.22	1.27	1.31	1.30	1.45	0.48	0.52	0.53	0.50	0.52	0.09	0.10	0.11	0.10	0.11
70	1.76	2.03	1.96	2.25	2.32	0.31	0.30	0.29	0.32	0.34	1.09	1.14	1.28	1.31	1.20	0.51	0.53	0.51	0.50	0.47	0.09	0.10	0.10	0.11	0.11
180	1.74	1.69	2.22	2.24	2.62	0.29	0.29	0.31	0.31	0.34	1.18	1.20	1.21	1.41	1.18	0.46	0.50	0.52	0.49	0.46	0.09	0.09	0.10	0.10	0.11
330	1.80	1.87	2.35	2.51	2.65	0.31	0.30	0.31	0.32	0.33	1.28	1.18	1.20	1.21	1.35	0.53	0.51	0.52	0.56	0.50	0.11	0.10	0.10	0.11	0.11
520	1.63	1.95	2.11	2.35	2.43	0.31	0.29	0.32	0.32	0.32	1.18	1.16	1.30	1.44	1.25	0.49	0.51	0.55	0.52	0.48	0.10	0.10	0.11	0.11	0.11
LSD $_{(T = 0.05)}$	**ns**					**ns**					**ns**					**ns**					**ns**				

Nitrogen

The nitrogen content of Rupert and Ronina bulbs differed significantly from each other (Table 4.7). As indicated in Table 4.9 Rupert bulbs contained 0.37 % more nitrogen than Ronia bulbs. Regardless of this difference between Rupert and Ronina the nitrogen levels influenced the nitrogen content of *Lachenalia* bulbs significantly (Table 4.7). The nitrogen content of the bulbs increased from 1.73 % at a 0 kg N ha^{-1} level to 2.52 % at a 520 kg N ha^{-1} level (Table 4.10).

Phosphorus

As indicated in Table 4.7 the phosphorus content of Rupert and Ronina bulbs differed from each other significantly. Rupert bulbs contained 0.35 % phosphorus and Ronina bulbs 0.28 % phosphorus (Table 4.9). None of the other treatments influenced the phosphorus content of bulbs significantly (Table 4.7). Although not significant, increased nitrogen levels from 0 kg ha^{-1} to 520 kg ha^{-1} tended to increase the phosphorus content of bulbs from 0.30 % to 0.33 % (Table 4.10).

Potassium

Rupert bulbs contained significant more potassium than Ronina bulbs, *viz.* 1.46 % versus 1.04 % (Table 4.9). The other treatments did not have a significant influence on the potassium content of the bulbs (Table 4.7). Although not significant the potassium content of bulbs increased from 1.19 % at a 0 kg N ha^{-1} application to 1.33 % at a 330 kg N ha^{-1} application and decreased again to 1.29 % at a 520 kg N ha^{-1} application as shown in Table 4.10.

Calcium

As indicated in Table 4.7 Rupert and Ronina bulbs differed in their calcium content. The calcium content of Rupert bulbs was 0.58 % compared to the calcium content of Ronina bulbs that was 0.44 % (Table 4.9). Nitrogen levels also influenced the calcium content of the bulbs significantly. The calcium content of the bulbs increased from 0.49% at a 0 kg N ha^{-1} level to 0.53% at a 180 kg N ha^{-1} level whereafter it decreased to 0.49% at a 520 kg N ha^{-1} level (Table 4.10).

Magnesium

The magnesium content of Rupert and Ronina differed significantly (Table 4.7). As shown in Table 4.9 the magnesium content of Rupert bulbs was 0.12 % and that of Ronina bulbs was 0.09 %. Although not significant the magnesium content of the bulbs tended to increase with an increase in nitrogen levels, namely from 0.10 % at a 0 kg N ha^{-1} application to 0.11 % at a 520 kg N ha^{-1} application (Table 4.10).

The preceding results revealed that the application of phosphorus did not influence the nitrogen, phosphorus, potassium, calcium and magnesium content of *Lachenalia* bulbs at all (Table 4.7). Rupert bulbs contained significant more nitrogen, phosphorus, potassium, calcium and magnesium than Ronina bulbs (Table 4.9). Although not always significant the nitrogen, phosphorus, potassium, calcium and magnesium content of the bulbs increased with higher nitrogen application which corresponded with the results reported in Section 3.2.2.2.1.

4.2.1.2.2.2 Bulb carbohydrate content

In order to establish the carbohydrate content of *Lachenalia* bulbs after one season of enlargement the bulbs were analysed for the following: D-glucose, sucrose and starch. A summary on the analyses of variance that was done to determine the effects of different nitrogen and phosphorus levels on the carbohydrate content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003 is given in Table 4.15.

Table 4.15: Summary on the analyses of variance showing the significant effects of nitrogen and phosphorus levels on the carbohydrate content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Carbohydrate	Cultivar (C)	Nitrogen level (N)	Phosphorus level (P)	C X N	C X P	N X P
D-glucose	*	*	ns	*	ns	ns
Sucrose	*	*	*	ns	*	ns
Starch	*	*	*	*	ns	*

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

As reference the carbohydrate content of the 2.5-3 cm bulblets planted in 2003 is given in Table 4.16. Investigation of Table 4.15 showed that the D-glucose and sucrose content of

the bulbs were not significantly influenced by the interaction between nitrogen and phosphorus levels. This data will therefore not be shown or discussed. However all the other data are presented in Tables 4.17 to 4.22.

Table 4.16: Carbohydrate content (g l^{-1}) of 2.5-3 cm Rupert and Ronina bulblets at planting in 2003

Cultivar	D-glucose	Sucrose	Starch
Rupert	0.019	0.335	9.09
Ronina	0.015	0.327	8.71

Table 4.17: Carbohydrate content (g l^{-1}) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Cultivar	D-glucose	Sucrose	Starch
Rupert	0.035	0.340	8.55
Ronina	0.076	0.314	5.71
LSD $_{(T = 0.05)}$	**0.012**	**0.024**	**2.91**

Table 4.18: Effect of nitrogen levels on the carbohydrate content (g l^{-1}) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	D-glucose	Sucrose	Starch
0	0.116	0.209	7.46
70	0.090	0.297	6.60
180	0.052	0.335	7.13
330	0.014	0.370	7.01
520	0.007	0.425	7.47
LSD $_{(T = 0.05)}$	**0.026**	**0.053**	**0.64**

Table 4.19: Effect of phosphorus levels on the carbohydrate content (g l^{-1}) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Phosphorus levels kg ha^{-1}	D-glucose	Sucrose	Starch
0	0.058	0.302	7.15
10	0.054	0.324	7.44
30	0.067	0.302	7.29
50	0.047	0.355	7.04
80	0.053	0.352	6.75
LSD $_{(T = 0.05)}$	**ns**	**0.053**	**0.64**

Table 4.20: Effect of nitrogen levels on the carbohydrate content (g l^{-1}) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	D-glucose		Sucrose		Starch	
	Rupert	**Ronina**	**Rupert**	**Ronina**	**Rupert**	**Ronina**
0	0.101	0.130	0.241	0.176	8.94	5.98
70	0.056	0.125	0.289	0.306	7.59	5.61
180	0.010	0.094	0.355	0.316	8.96	5.29
330	0.003	0.024	0.363	0.377	8.54	5.48
520	0.005	0.008	0.454	0.396	8.74	6.21
LSD $_{(T = 0.05)}$	**0.043**		**ns**		**1.05**	

Table 4.21: Effect of phosphorus levels on the carbohydrate content (g l^{-1}) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Phosphorus levels kg ha^{-1}	D-glucose		Sucrose		Starch	
	Rupert	**Ronina**	**Rupert**	**Ronina**	**Rupert**	**Ronina**
0	0.044	0.072	0.341	0.262	8.50	5.80
10	0.047	0.060	0.341	0.307	8.86	6.03
30	0.033	0.100	0.329	0.276	8.73	5.85
50	0.024	0.071	0.339	0.371	8.42	5.67
80	0.028	0.078	0.351	0.354	8.27	5.22
LSD $_{(T = 0.05)}$	**ns**		**0.087**		**ns**	

Table 4.22: Effect of nitrogen and phosphorus levels on the starch content (g l^{-1}) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	Phosphorus levels kg ha^{-1}				
	0	10	30	50	80
0	8.58	6.98	8.05	6.54	7.16
70	7.20	7.45	6.46	6.81	5.05
180	5.58	7.85	6.75	8.05	7.40
330	7.01	7.80	6.69	6.49	7.06
520	7.38	7.14	8.48	7.31	7.05
LSD (T = 0.05)	1.92				

D-glucose

According to Table 4.15 the interaction between cultivar and nitrogen levels influenced the D-glucose content of *Lachenalia* bulbs significantly. As shown in Table 4.20 the D-glucose content of Ronina bulbs was significantly higher than that of Rupert bulbs except at the 180 kg ha^{-1} nitrogen level. The D-glucose content of Rupert bulbs decreased from 0.101 g l^{-1} at a 0 kg N ha^{-1} application to 0.005 g l^{-1} at a 520 kg N ha^{-1} application. A similar trend was observed for Ronina bulbs. The D-glucose content of Ronina bulbs decreased from 0.130 g l^{-1} at a 0 kg N ha^{-1} level to 0.008 g l^{-1} at a 520 kg ha^{-1} level.

Sucrose

The interaction between cultivar and phosphorus levels influenced the sucrose content of *Lachenalia* bulbs significantly (Table 4.15). As shown in Table 4.21 the sucrose content of Rupert bulbs was higher than that of Ronina bulbs at the 0, 10 and 30 kg P ha^{-1} levels whereas the sucrose content of Ronina bulbs was higher than that of Rupert bulbs at the 50 kg P ha^{-1} level. The sucrose content of Rupert bulbs was not influenced by the phosphorus levels. In contrast the sucrose content of Ronina bulbs increased from 0.262 g l^{-1} at a 0 kg P ha^{-1} application to 0.371 g l^{-1} at a 50 kg P ha^{-1} application. According to Table 4.18 the sucrose content of the bulbs increased from 0.209 g l^{-1} at a 0 kg N ha^{-1} application to 0.425 g l^{-1} at a 520 kg N ha^{-1} application.

Starch

As shown in Table 4.15 the interaction between cultivar and nitrogen levels influenced the starch content of *Lachenalia* bulbs significantly. Regardless of the nitrogen level Rupert bulbs contained significant more starch than Ronina bulbs but both cultivars did not show a clear trend in starch content in respect to the nitrogen levels (Table 4.20). According to Table 4.19 the starch content of the bulbs decreased from 7.15 % at a 0 kg P ha^{-1} application to 6.75 % at an 80 kg P ha^{-1} application. However, the highest starch content was measured at a 10 kg P ha^{-1} application. The interaction between nitrogen and phosphorus levels influenced the starch content of the bulbs significantly but no clear trend emerged upon inspection of Table 4.22.

From these results it is clear the application of phosphorus only influenced the sucrose and starch content of *Lachenalia* bulbs. Higher phosphorus applications tended to increase the sucrose content and decrease the starch content of the bulbs at harvest. Based on the carbohydrate indices the two cultivars reacted differently to the application of phosphorus. The influence of nitrogen application on the D-glucose, sucrose and starch content of the bulbs showed the same trends as was reported earlier in Section 3.2.2.2.2.

4.2.2 NITROGEN AND POTASSIUM INTERACTION

4.2.2.1 Leaf area

A summary on the analyses of variance that was done to determine the effects of nitrogen and potassium levels on the leaf area of Rupert and Ronina plants grown from 2.5-3 cm bulblets in 2003 is given in Table 4.23. Neither the potassium levels nor the interaction between nitrogen and potassium levels did influenced the leaf area of *Lachenalia* plants significantly.

Table 4.23: Summary on the analyses of variance showing the effects of nitrogen and potassium levels on the leaf area of Rupert and Ronina plants grown from 2.5-3 cm bulblets in 2003

Weeks after planting	Cultivar (C)	Nitrogen level (N)	Potassium level (K)	C X N	C X K	N X K
4	*	*	ns	ns	*	ns
7	*	*	ns	*	ns	ns
10	*	*	ns	*	*	ns
14	*	*	ns	*	ns	ns
17	*	*	ns	*	*	ns
20	*	*	ns	*	ns	ns
23	*	*	ns	*	*	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

The leaf area of *Lachenalia* plants was affected significantly by the interaction between cultivar and potassium levels at 4, 10, 17 and 23 weeks after planting (Table 4.23). However, for every measurement time the largest leaf area was recorded for Rupert plants at the 180 kg K ha^{-1} level and for Ronina plants at the 70 kg K ha^{-1} level (Table 4.24). At all seven times of measurement the leaf area of Ronina plants was significant larger than Rupert plants irrespective of the potassium levels.

Table 4.24: Effect of potassium levels on the leaf area (cm^2) of Rupert and Ronina plants grown from 2.5-3 cm bulblets in 2003

Weeks after planting	Rupert					Ronina					LSD (T = 0.05)
	0	70	180	330	520	0	70	180	330	520	
	kg K ha^{-1}					kg K ha^{-1}					
4	3.19	2.71	3.22	2.80	2.48	4.74	5.36	4.79	4.60	5.17	**ns**
7	7.46	6.51	7.67	7.15	7.21	10.64	11.72	11.16	11.39	11.97	**2.51**
10	11.08	9.58	11.57	10.71	10.79	15.78	18.27	16.44	16.97	17.26	**3.10**
14	14.06	12.33	14.30	13.98	14.17	20.29	24.21	22.41	22.06	23.31	**ns**
17	15.68	13.51	16.13	15.20	15.75	22.93	28.46	25.92	26.56	26.29	**4.96**
20	16.48	14.32	17.67	15.90	17.09	25.82	30.52	28.90	29.17	28.57	**ns**
23	15.60	13.51	18.72	15.50	17.69	25.54	32.49	29.05	31.12	30.52	**6.97**

From week 7 and later after planting the interaction between cultivar and nitrogen levels influenced the leaf area of *Lachenalia* plants significantly (Table 4.23). As shown in Table 4.25 at every measurement time Ronina plants had regardless of the nitrogen level a larger leaf area than Rupert plants. However, the leaf area of both the Rupert and Ronina plants increased with higher nitrogen levels to reach a maximum at the 330 kg N ha^{-1} level.

Table 4.25: Effect of nitrogen levels on the leaf area (cm^2) of Rupert and Ronina plants grown from 2.5 -3 cm bulblets in 2003

Weeks after planting	Rupert					Ronina					LSD (T = 0.05)
	0	70	180	330	520	0	70	180	330	520	
	kg N ha^{-1}					kg N ha^{-1}					
4	2.70	2.76	3.08	3.16	2.71	4.19	5.31	4.74	5.24	5.17	**ns**
7	6.77	6.67	7.29	8.07	7.21	8.70	11.09	10.93	13.13	13.03	**2.51**
10	9.72	10.13	10.85	12.21	10.82	12.11	15.94	15.83	20.33	20.51	**3.10**
14	11.76	13.21	14.25	15.59	14.03	14.62	20.99	22.43	26.32	27.88	**4.39**
17	12.63	14.40	16.17	17.50	15.57	16.36	23.87	25.38	31.54	33.01	**4.96**
20	12.83	15.41	17.05	18.73	17.43	17.47	26.90	27.61	34.69	36.31	**5.71**
23	11.45	13.96	18.19	20.06	17.34	18.21	27.23	29.39	37.07	36.82	**6.97**

The fact that the interaction between nitrogen and potassium levels did not influenced the leaf area of *Lachenalia* plants significantly is contrasting to what was found with similar research on freesias. Several researchers reported a strong interaction between nitrogen and potassium on the foliage growth freesia (Kosugi *et al.*, 1964; Thomas *et al.*, 1998). It seems however that the positive effect of either the nitrogen or potassium application on the leaf area of *Lachenalia* plants depend very much on the cultivar which coincides with research on other bulbous species (Nederpe & Van Eysinga, 1978; Clemens & Morton,1999).

4.2.2.2 Bulb quality

4.2.2.2.1 Physical parameters

In order to establish the quality of *Lachenalia* bulbs after one season of enlargement the following parameters were measured: fresh mass, circumference and firmness. A summary on the analyses of variance that was done to determine the effects of different nitrogen and potassium levels on the fresh mass, circumference and firmness of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003 is given in Table 4.26.

Table 4.26: Summary on the analyses of variance showing the effects of nitrogen and potassium levels on the fresh mass, circumference and firmness of Rupert and Ronina bulbs grown from 2.5 -3 cm bulblets in 2003

Bulb	Cultivar (C)	Nitrogen level (N)	Potassium level (K)	C X N	C X K	N X K
Fresh mass	*	*	ns	*	ns	ns
Circumference	*	*	ns	*	ns	ns
Firmness	*	*	ns	*	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

As shown in Table 4.26 the fresh mass and the circumference of *Lachenalia* bulbs reacted similar on different nitrogen and potassium levels. The fresh mass increased linearly with circumference and a correlation coefficient of 0.96 was calculated between the two parameters. Because of this high correlation and also the grading procedure used by producers mentioned earlier only the data of the circumference will be presented and discussed in the following section.

4.2.2.2.1.1 Bulb circumference

Upon investigation of Table 4.26 it is clear that potassium levels did not influenced the circumference of *Lachenalia* bulbs at all. However, it was not the case with nitrogen levels. The interaction between cultivar and nitrogen levels influenced the circumference of Rupert and Ronina bulbs significantly. The circumference of Ronina bulbs was significantly larger than that of Rupert bulbs irrespective of the nitrogen level but higher nitrogen levels increased the circumference of both Rupert and Ronina bulbs (Table 4.27). The circumference of Ronina bulbs increased from 7.6 cm at a 0 kg N ha^{-1} application to 9.1 cm at a 330 kg N ha^{-1} application and decreased again to 9.05 cm at 520 kg N ha^{-1}. As shown in Table 4.27 the largest Rupert bulbs were harvested with a 180 kg N ha^{-1} application.

Table 4.27 : Effect of nitrogen levels on the circumference (cm) of Rupert and Ronina bulbs grown from 2.5 -3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	7.00	7.60
70	7.80	8.65
180	8.35	8.70
330	8.10	9.10
520	7.80	9.05
LS $D_{(T = 0.05)}$	**0.52**	

4.2.2.2.1.2 Bulb firmness

As shown in Table 4.26 like with bulb circumference the potassium levels did not influenced the firmness of *Lachenalia* bulbs either. The interaction between cultivar and nitrogen levels did have a significant influence on the firmness of the bulbs. Rupert bulbs were regardless of the nitrogen level firmer than Ronina bulbs (Table 4.28). Although not significant Rupert bulbs fertilised with nitrogen was firmer than bulbs those not fertilised.

The firmness of Ronina bulbs increased with approximately 30 % as a result of a nitrogen level increase from 0 to 520 kg ha^{-1}.

Table 4.28 : Effect of nitrogen levels on the firmness (mm) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	8.41	15.92
70	7.18	13.58
180	6.91	11.41
330	7.32	11.05
520	7.22	10.83
LS $D_{(T = 0.05)}$	**1.46**	

From these results it is clear that potassium application did not influenced the physical parameters of bulb quality which was not the case with nitrogen application. The results obtained on the influence of nitrogen levels on the physical parameters of Rupert and Ronina bulbs confirm results reported earlier in Section 3.2.2.1.

4.2.2.2.2 Chemical parameters

4.2.2.2.2.1 Bulb nutrient content

In order to establish the nutrient content of *Lachenalia* bulbs after one season of enlargement the bulbs were analysed for the following nutrients: nitrogen, phosphorus, potassium, calcium and magnesium. A summary on the analyses of variance that was done to determine the effects of different nitrogen and potassium levels on the nutrient content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets and harvested after one season in 2003 is given in Table 4.29.

Table 4.29: Summary on the analysis of variance showing the effects of nitrogen and phosphorus levels on the nutrient content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Nutrients	Cultivar (C)	Nitrogen level (N)	Potassium level (K)	C X N	C X K	N X K
N	ns	ns	ns	ns	ns	ns
P	*	ns	ns	ns	ns	ns
K	*	ns	ns	ns	ns	ns
Ca	*	ns	ns	ns	ns	ns
Mg	*	ns	ns	ns	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

The nutrient content of the 2.5-3 cm bulblets that were planted in 2003 for this enlargement experiment is given in Table 2.30 for reference. All the data on the effect of nitrogen and potassium levels on the nutrient content of *Lachenalia* bulbs is given in Tables 4.31 to 4.37. As shown in Table 4.29 neither the nitrogen levels nor the potassium levels influenced the nutrient content of the bulbs significantly. The only significant difference in bulb nutrient content resulted between cultivars. Rupert bulbs contained more nitrogen, phosphorus, potassium, calcium and magnesium than Ronina bulbs (Table 4.31). Although not significant nitrogen levels tended to increase the nitrogen, phosphorus, potassium and magnesium content of the bulbs (Table 3.32). Upon inspection of the other tables no trends emerged that are worth mentioning.

Table 4.30: Nutrient content (%) of 2.5-3 cm Rupert and Ronina bulblets at planting in 2003

Cultivar	N	P	K	Ca	Mg
Rupert	2.220	0.370	1.944	0.940	0.140
Ronina	2.982	0.320	1.864	1.120	0.129

Table 4.31: Effect of nitrogen and potassium levels on the nutrient content (%) of Rupert and Ronina bulbs grown from 2.5 -3 cm bulblets in 2003

Cultivar	N	P	K	Ca	Mg
Rupert	2.46	0.329	1.840	0.584	0.113
Ronina	2.19	0.300	1.372	0.515	0.095
LSD $_{(T = 0.05)}$	**ns**	**0.025**	**0.880**	**0.027**	**0.008**

Table 4.32: Effect of nitrogen on the nutrient content (%) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	N	P	K	Ca	Mg
0	2.02	0.295	1.554	0.523	0.097
70	1.99	0.317	1.589	0.547	0.106
180	2.31	0.311	1.595	0.551	0.103
330	2.57	0.317	1.600	0.555	0.105
520	2.72	0.322	1.692	0.548	0.108
LSD $_{(T = 0.05)}$	**ns**	**ns**	**ns**	**ns**	**ns**

Table 4.34: Effect of potassium levels on the nutrient content (%) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Potassium levels kg ha^{-1}	N	P	K	Ca	Mg
0	2.29	0.309	1.552	0.543	0.104
70	2.25	0.308	1.542	0.537	0.102
180	2.34	0.318	1.640	0.556	0.105
330	2.34	0.300	1.598	0.525	0.101
520	2.38	0.327	1.698	0.562	0.108
LSD $_{(T = 0.05)}$	**ns**	**ns**	**ns**	**ns**	**ns**

Table 4.35: Effect of nitrogen levels on the nutrient content (%) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	N		P		K		Ca		Mg	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
0	2.20	1.85	0.306	0.284	1.689	1.420	0.540	0.506	0.104	0.090
70	2.14	1.83	0.339	0.295	1.848	1.331	0.590	0.505	0.119	0.093
180	2.39	2.23	0.326	0.297	1.830	1.360	0.580	0.521	0.111	0.095
330	2.67	2.47	0.338	0.295	1.860	1.340	0.590	0.519	0.115	0.096
520	2.88	2.56	0.337	0.308	1.976	1.408	0.572	0.524	0.118	0.099
LSD $_{(T = 0.05)}$	**ns**		**ns**		**ns**		**ns**		**ns**	

Table 4.36: Effect of potassium levels on the nutrient content (%) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Potassium levels kg ha^{-1}	N		P		K		Ca		Mg	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
0	2.48	2.10	0.331	0.287	1.771	1.333	0.578	0.507	0.116	0.093
70	2.28	2.23	0.315	0.301	1.714	1.371	0.547	0.528	0.106	0.097
180	2.51	2.17	0.335	0.301	1.912	1.369	0.600	0.513	0.115	0.095
330	2.39	2.29	0.312	0.289	1.811	1.385	0.546	0.504	0.108	0.094
520	2.62	2.15	0.353	0.301	1.994	1.402	0.601	0.523	0.121	0.095
LSD $_{(T = 0.05)}$	**ns**		**ns**		**ns**		**ns**		**ns**	

Table 4.37: Effect of nitrogen and potassium levels on the nutrient content (%) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	N					P					K					Ca					Mg				
	Potassium levels kg ha^{-1}																								
	0	70	180	330	520	0	70	180	330	520	0	70	180	330	520	0	70	180	330	520	0	70	180	330	520
0	1.82	1.85	2.28	2.70	2.81	0.28	0.32	0.30	0.32	0.32	1.48	1.56	1.53	1.55	1.64	0.51	0.56	0.52	0.57	0.56	0.96	0.11	0.10	0.11	0.11
70	2.04	1.69	2.22	2.50	2.82	0.29	0.32	0.31	0.30	0.32	1.52	1.53	1.53	1.53	1.59	0.53	0.52	0.57	0.52	0.55	0.94	0.10	0.10	0.10	0.11
180	2.21	2.16	2.22	2.50	2.61	0.31	0.31	0.32	0.31	0.34	1.69	1.56	1.63	1.58	1.74	0.55	0.58	0.57	0.56	0.53	0.10	0.11	0.10	0.10	0.11
330	2.05	2.03	2.35	2.59	2.69	0.29	0.29	0.30	0.32	0.30	1.51	1.49	1.60	1.69	1.69	0.50	0.50	0.54	0.54	0.55	0.09	0.10	0.10	0.11	0.11
520	2.00	2.20	2.50	2.58	2.65	0.31	0.35	0.31	0.33	0.34	1.59	1.79	1.68	1.64	1.79	0.54	0.57	0.60	0.57	0.56	0.10	0.12	0.11	0.10	0.11
LSD $_{(T = 0.05)}$	**ns**					**ns**					**ns**					**ns**					**ns**				

4.2.2.2.2.2 Bulb carbohydrate content

The D-glucose, sucrose and starch content were determined as parameters of the carbohydrate content of *Lachenalia* bulbs. A summary on the analyses of variance that was done to determine the effects of different nitrogen and potassium levels on the carbohydrate content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets and harvested after one season in 2003 is given in Table 4.38. As reference the carbohydrate content of the 2.5-3 cm bulblets planted in 2003 is given in Table 4.39. However for convenience all the absolute data are presented in Tables 4.40 to 4.44 but the discussion will be limited to those treatments that caused significant differences in the content of a particular carbohydrate.

As shown in Table 4.38 the interaction between nitrogen and potassium levels influenced the D-glucose, sucrose and starch content of bulbs significantly. Upon thorough inspection of these data no clear trends emerged that are worth mentioning. Therefore this data will not be shown or discussed in this section.

Table 4.38: Summary on the analyses of variance showing the effects of nitrogen and potassium levels on the carbohydrate content of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Carbohydrate	Cultivar (C)	Nitrogen level (N)	Potassium level (K)	C X N	C X K	N X K
D-glucose	*	*	ns	*	ns	*
Sucrose	*	*	*	*	ns	*
Starch	*	*	*	*	*	*

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**

Table 4.39: D-glucose, sucrose and starch content (g l^{1}) of Rupert and Ronina 2.5-3 cm bulblets at planting in 2003

Cultivar	D-glucose	Sucrose	Starch
Rupert	0.019	0.335	9.09
Ronina	0.015	0.327	8.71

Table 4.40: Effect of nitrogen and potassium levels on the carbohydrate content (g l^{-1}) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Cultivar	D-glucose	Sucrose	Starch
Rupert	0.013	0.382	9.05
Ronina	0.010	0.255	6.53
LSD $_{(T = 0.05)}$	**0.002**	**0.021**	**0.30**

Table 4.41: Effect of nitrogen levels on the carbohydrate content (g l^{-1}) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	D-glucose	Sucrose	Starch
0	0.025	0.336	8.18
70	0.016	0.310	8.44
180	0.006	0.292	7.60
330	0.003	0.302	7.45
520	0.003	0.352	7.29
LSD $_{(T = 0.05)}$	**0.004**	**0.046**	**0.67**

Table 4.42: Effect of potassium levels on the carbohydrate content (g l^{-1}) of *Lachenalia* bulbs grown from 2.5-3 cm bulblets in 2003

Potassium levels kg ha^{-1}	D-glucose	Sucrose	Starch
0	0.014	0.355	7.8l
70	0.010	0.325	7.95
180	0.011	0.308	7.23
330	0.012	0.301	7.89
520	0.010	0.304	8.06
LSD $_{(T = 0.05)}$	**ns**	**0.046**	**0.67**

Table 4.43: Effect of nitrogen levels on the carbohydrate content (g l^{1}) of Rupert and Ronina bulbs grown from 2.5-3 cm bulblets in 2003

Nitrogen levels kg ha^{-1}	D-glucose		Sucrose		Starch	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
0	0.029	0.021	0.378	0.295	9.21	7.16
70	0.016	0.015	0.388	0.232	10.02	6.85
180	0.006	0.007	0.339	0.246	8.77	6.43
330	0.004	0.004	0.369	0.236	8.23	6.68
520	0.008	0.004	0.437	0.267	9.05	5.53
LSD $_{(T = 0.05)}$	**0.006**		**0.028**		**1.10**	

Table 4.44: Effect of potassium levels on the carbohydrate content (g l^{-1}) of Rupert and Ronina bulbs grown from 2.5 -3 cm bulblets in 2002

Potassium levels kg ha^{-1}	D-glucose		Sucrose		Starch	
	Rupert	Ronina	Rupert	Ronina	Rupert	Ronina
0	0.014	0.014	0.433	0.277	8.49	7.17
70	0.012	0.009	0.379	0.272	8.97	6.93
180	0.013	0.011	0.350	0.265	8.38	6.08
330	0.013	0.011	0.369	0.234	9.41	6.37
520	0.012	0.007	0.381	0.228	10.03	6.10
LSD $_{(T = 0.05)}$	**ns**		**ns**		**1.08**	

D-glucose

The interaction between cultivar and nitrogen levels influenced the D-glucose content of *Lachenalia* bulbs significantly according to Table 4.38. As indicated in Table 4.43 Rupert bulbs contained more D-glucose than Ronina bulbs at only the 0 kg N ha^{-1} level. The D-glucose content of Rupert bulbs decreased from 0.029 g l^{-1} at a 0 kg N ha^{-1} application to 0.004 g l^{-1}at a 330 kg N ha^{-1}application and increased again to 0.008 g l^{-1}at 520 kg N ha^{-1} application. For Ronina bulbs the D-glucose content decreased from 0.021 g l^{-1} at a 0 kg N ha^{-1} application to 0.004 g l^{-1} at either the 330 or 520 kg N ha^{-1} applications.

Sucrose

According to Table 4.38 the sucrose content of *Lachenalia* was influenced significantly by the potassium levels. The sucrose content decreased from 0.355 g l^{-1} at a 0 kg N ha^{-1} application to 0.301 g l^{-1} at a 330 kg N ha^{-1} application whereafter it stayed stable (Table 4.42).

The sucrose content of *Lachenalia* bulbs was influenced by the interaction between cultivar and nitrogen levels (Table 4.38). As shown in Table 4.43 the sucrose content of Rupert bulbs was irrespective of the nitrogen level significant higher than that of Ronina bulbs. No clear trends were observed with regard to the influence of nitrogen levels on the sucrose content of either Rupert or Ronina bulbs. However, the lowest and highest sucrose contents were recorded respectively for Rupert bulbs at the 180 and 520 kg N ha^{-1} levels and for Ronina bulbs at the 0 and 70 kg N ha^{-1} levels.

Starch

As can be observed from Table 4.38 the interaction between cultivar and potassium significantly influenced the starch content of *Lachenalia* bulbs. Regardless of the potassium level the starch content of Rupert bulbs was higher than that of Ronina bulbs (Table 4.44). The starch content of Rupert bulbs increased from 8.49 g l^{-1} at a 0 kg K ha^{-1} level to 10.03 g l^{-1} at 520 kg K ha^{-1} level whereas the starch content of Ronina bulbs decreased from 7.17 g l^{-1} at a 0 kg K ha^{-1} level to 6.10 g l^{-1} at a 520 kg K ha^{-1} level.

As shown in Table 4.38 the interaction between cultivar and nitrogen also influenced the starch content significantly. The starch content of Rupert bulbs was irrespective of the nitrogen level higher than that of Ronina bulbs (Table 4.43). However, the starch content of both Ronina and Rupert bulbs showed no clear trends with respect to the nitrogen levels worth mentioning.

These results indicated that Rupert bulbs contained more D-glucose, sucrose and starch than Ronina bulbs. However, application of nitrogen increased the D-glucose content and decreased the starch content of the bulbs. Both the sucrose and starch content of the bulbs were decreased by the application of potassium. The interaction between nitrogen and potassium applications influenced the D-glucose, sucrose and starch content of the bulbs but no clear trends emerged.

4.3 CONCLUSIONS

- Differences between cultivars should be taken into account by *Lachenalia* bulb producers in their fertilisation program.

- According to the response of the different parameters to nitrogen it seems that the optimum level ranged between 330 and 520 kg N ha^{-1}.

- Neither the interaction between nitrogen and phosphorus levels nor the interaction between nitrogen and potassium levels had a large influence on the growth and development of *Lachenalia*.

- The fact that phosphorus and potassium had little influence on the growth and development of *Lachenalia* can be ascribed to the soil containing sufficient concentration of those two nutrients, *viz.* 15 mg P kg^{-1} and 166 mg K kg^{-1}.

CHAPTER 5

RESPONSE OF *Lachenalia* TO NITROGEN FERTILISATION IN THE POT PLANT PHASE

5.1 INTRODUCTION

The largest percentage of *Lachenalia* bulbs produced in South African nurseries are exported to Europe. In Europe these bulbs are then planted to grow pot plants. As mentioned earlier 3 million bulbs were exported to Europe in the 2002 season for this reason (Personal communication, 2003: J.G. Niederwieser, Pretoria).

Because of many different varieties, excellent flower variation and also regular flowering the genus *Lachenalia* is regarded as a very suitable pot plant (Hancke, 1991; Coertze *et al.*, 1992). Both the *Lachenalia* cv's. Rupert and Ronina used in this study are known for their excellent flowering characteristics (Coertze *et al.*, 1992; Niederwieser, Anandajayasekeram, Coetzee, Martella, Pieterse & Marasas, 1997).

The European market demands quality pot plants, and a pot plant which inflorescence will flower at the same time. Uneven flowering is one of the main problems experience by *Lachenalia* flower growers (du Toit, 2001).

Only *Lachenalia* bulbs with a circumference of 6 cm or more are exported to Europe. These bulbs are the best for quality *Lachenalia* pot plants (Louw, 1993). Various researches emphasize the fact that a minimum bulb, rhizome or tuber size is necessary to produced quality flowers (Theron & De Hertogh, 2001), for example: Dutch iris (Rees, 1985); *Heliconia* (Clemens & Morton, 1999); amaryllis (*Hippeastrum* spp.) (Clemens *et al.*, 1998); *Leucocoryne coquimbensis* (Kim *et al.*, 1998) and tulips (Le Nard & De Hertogh, 1993; Franssen & Voskens, 1997).

Louw (1993) stated that the nutritional status of *Lachenalia* bulbs before flower initiation can influence the quality of the inflorescence and the offsets. The initiation and differentiation of the inflorescence of *Lachenalia* occur during the dormant period according to Louw (1993) when plants are grown in a greenhouse and Du Toit (2001) reported that flower initiation of *Lachenalia* cv. Ronina is spontaneous and takes place before dormancy and flower differentiation occur during dormancy when plants are grown in a climate controlled cabinet.

The uptake and role of nitrogen in plants is given in detail in Section 3.1 and will not be discussed again. Nitrogen needed for early root and leaf growth of *Lachenalia* pot plants after planting are mainly coming from nitrogen present in the bulbs and nitrogen absorbed by the roots. Ruamrungsri *et al.*, (1997) reported that narcissus absorbed a large amount of nitrogen from culture solution during the shoot growth phase and that about 70% of the absorbed nitrogen is transported and eventually accumulated in the new scales of narcissus bulbs for usage in the next season. Berghoef & Zevenbergen (1990) also reported that the mother corm of freesias was the main source for assimilates during the first growing phase.

De Hertogh & Le Nard (1993) classified the nutrient requirements of bulb crops into four groups: bulbs containing sufficient nutrients to flower without nutrient being applied (*Hippeastrum* and *Narcissus*); bulbs that require little additional fertiliser or just $Ca(NO_3)_2$ to reduce physiological disorders (*Tulipa*); bulbs with low fertiliser requirements (*Freesia* and *Liatris*); and bulbs requiring moderate fertiliser rates (*Gladiolus* and *Lilium*). Schiappacasse, Hirzel & Ruz (1997) also found that the flower quality of *Liatris callilepis* was not influenced by increasing fertiliser levels during the growing season which supported the classification system of De Hertogh & Le Nard (1993) concerning *Liatris*. But the opposite is also true for *Alstroemeria* where the length of the flower stems, total number of florets and flower buds per stem and the total dry mass of the top growth increase with nitrogen fertilisation during the growth season (Smith, Elliott & Bridgen, 1998).

From the foregoing discussions it is clear that the nutritional status of bulbs before dormancy, which are influenced by nitrogen fertilisation during the nursery phase may influence the flowering of *Lachenalia* pot plants. Nitrogen applied to *Lachenalia* in the nursery phase can be absorbed by the plant and a part of it can accumulate in the bulbs. This nitrogen is an important source of assimilates during the early growth of *Lachenalia* in the pot plant phase. The question arises whether additional nitrogen fertilisation is necessary in the pot plant phase to improve flower quality.

The objective with this study was to determine the response of two *Lachenalia* cultivars in the pot plant phase to different nitrogen levels when grown from bulbs whereof the nitrogen fertilisation history differed.

5.2 RESULTS AND DISCUSSION

In 2002 *Lachenalia* plants grown from 7-8 cm bulbs formed more than one plant per bulb despite that at planting the bulbs did not show any signs of splitting. However, in 2003 *Lachenalia* plants grown from 7-8 cm bulbs formed only one plant per bulb. As a result of this phenomenon it was decided to distinguish between primary and secondary plants in the discussion of the results when necessary. Primary plants are regarded as the first plant that developed from a bulb and secondary plants as the other plants that developed from the same bulb.

5.2.1 *LEAF AREA*

The leaf area of the primary plants was determined on a regular basis through the growing season. In the case of the secondary plants the leaf area was determined only in week 23 after planting.

5.2.1.1 Primary plants

A summary on the analyses of variance that was done to determine the effects of different nitrogen levels on the leaf area of Rupert and Ronina primary plants grown from 7-8 cm bulbs is given in Table 5.1.

Table 5.1: Summary on the analyses of variance showing the effects of nitrogen levels on the leaf area of Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2002 and 2003

Weeks after planting	Cultivar (C)	Nitrogen (N_p)	Nitrogen (N_n)	Time (T_n)	C X N_p	C X N_n	C X T_n	N_p X N_n	N_p X T_n	N_n X T_n
2002										
7	*	*	ns	*	*	*	ns	*	ns	ns
9	*	*	ns	*	*	*	ns	*	ns	ns
11	*	*	ns	*	*	*	ns	*	ns	ns
13	*	*	ns	*	*	*	ns	*	ns	ns
15	*	*	ns	*	*	*	ns	*	ns	ns
19	*	*	ns	*	*	ns	ns	*	ns	ns
21	*	*	ns	*	*	ns	ns	*	ns	ns
23	*	*	ns	*	*	ns	ns	*	ns	ns
2003										
Weeks after planting	**Cultivar (C)**	**Nitrogen (N_p)**	**Nitrogen (N_n)**	**Time (T_n)**	**C X N_p**	**C X N_n**	**C X T_n**	**N_p X N_n**	**N_p X T_n**	**N_n X T_n**
4	ns	*	*	ns	ns	*	ns	*	ns	ns
7	*	*	*	ns	ns	*	ns	*	ns	ns
10	*	*	*	ns	ns	*	ns	*	ns	ns
14	*	*	*	ns	ns	*	ns	*	ns	ns
17	*	*	*	ns	ns	*	ns	*	ns	ns
20	*	*	*	ns	ns	*	ns	*	ns	ns
23	*	*	*	ns	ns	*	ns	ns	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**
N_p = nitrogen levels in the pot plant phase
N_n = nitrogen levels in the nursery phase
T_n = nitrogen application times in the nursery phase

For the sake of convenience all the data are presented in a graphical format (Figures 5.1 to 5.8). As expected in 2002 (Figures 5.1 to 5.4) and 2003 (Figures 5.4 to 5.8) the leaf area of the primary plants increased with increasing nitrogen levels, irrespective of cultivars that were planted as well as the nitrogen levels and application times in the nursery phase.

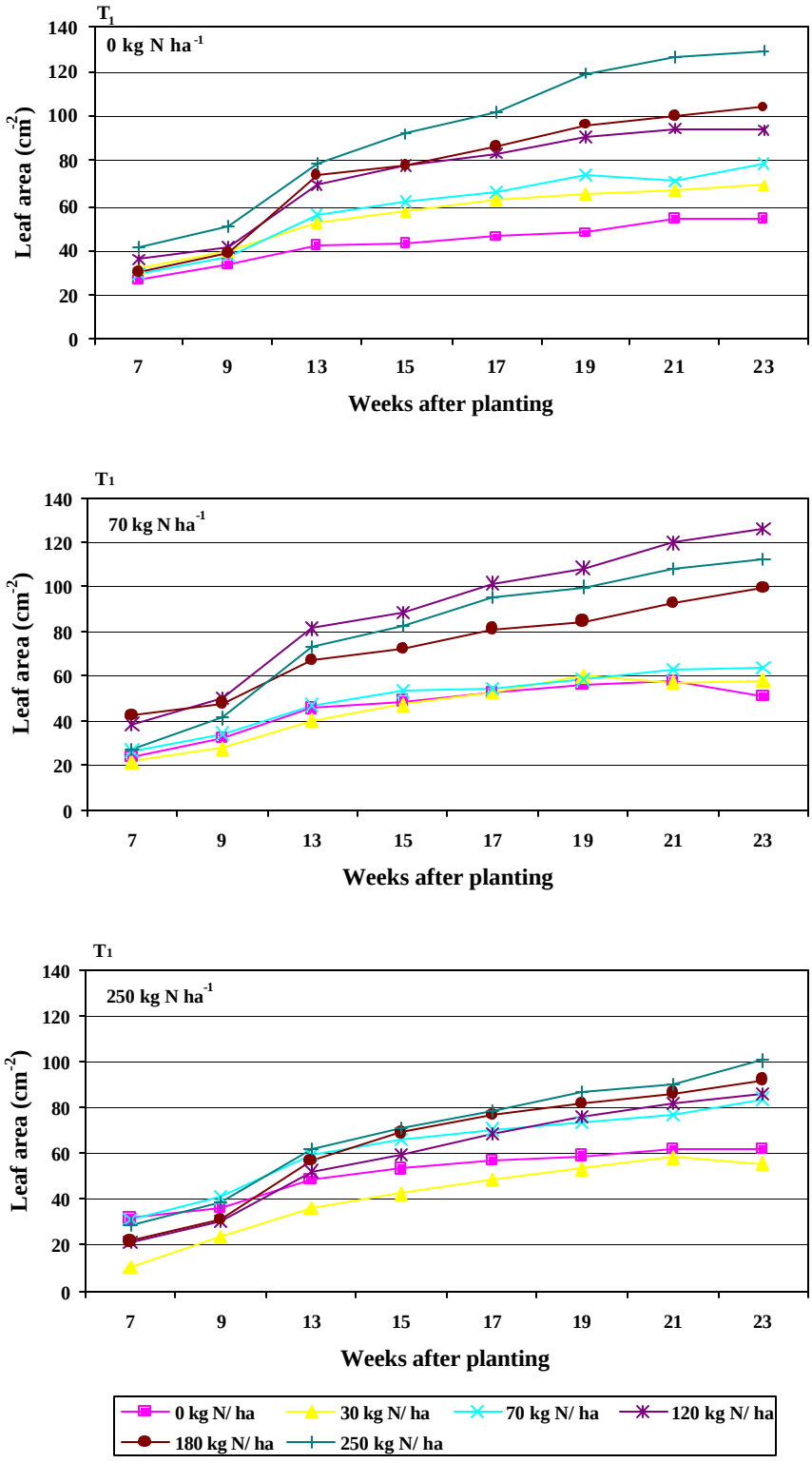

Figure 5.1: Effect of nitrogen levels on the leaf area of Rupert primary plants grown from 7-8 cm bulbs in 2002 that received the T_1 treatment before

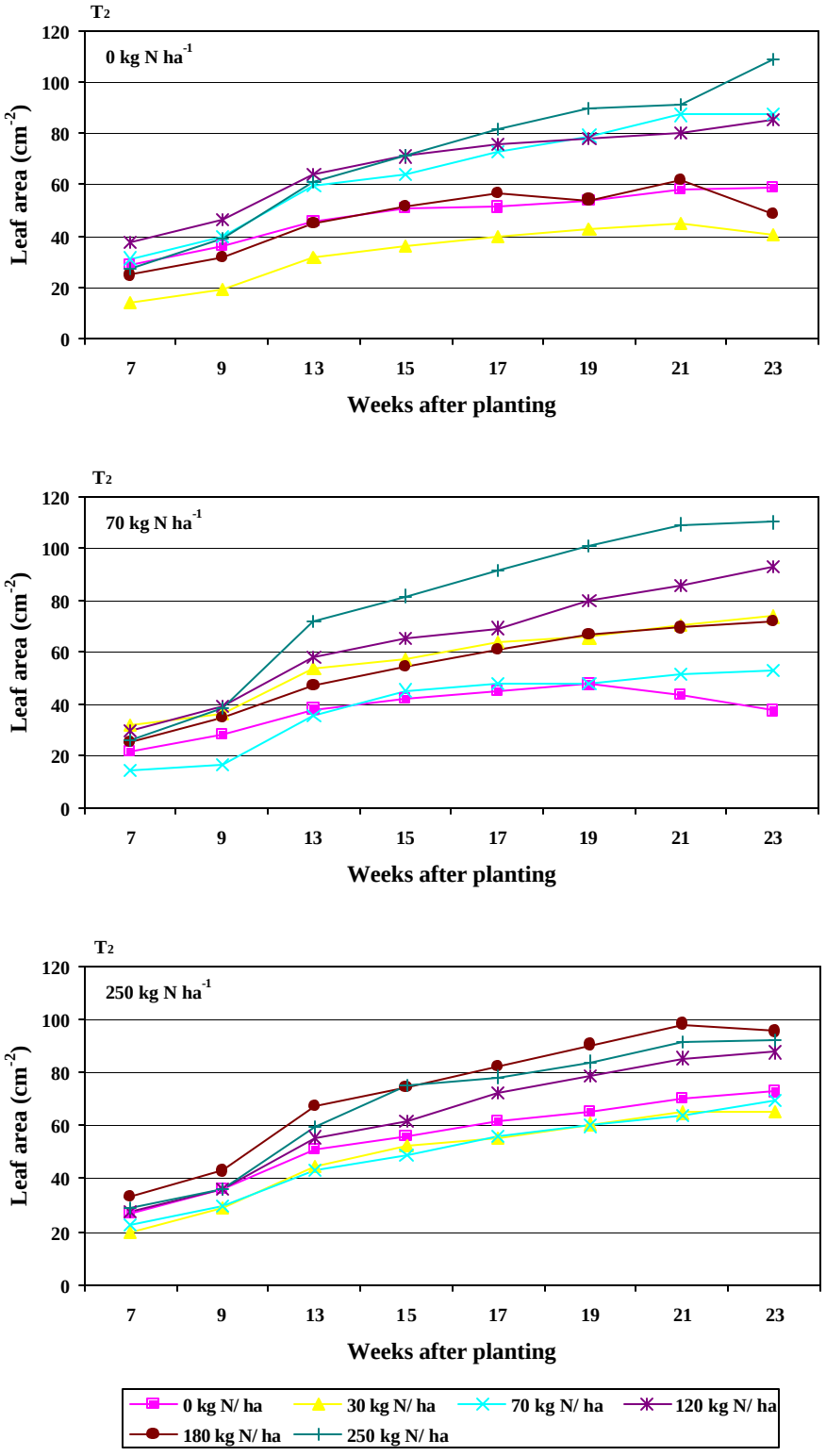

Figure 5.2: Effect of nitrogen levels on the leaf area of Rupert primary plants grown from 7-8 cm bulbs in 2002 that received the T_2 treatment before

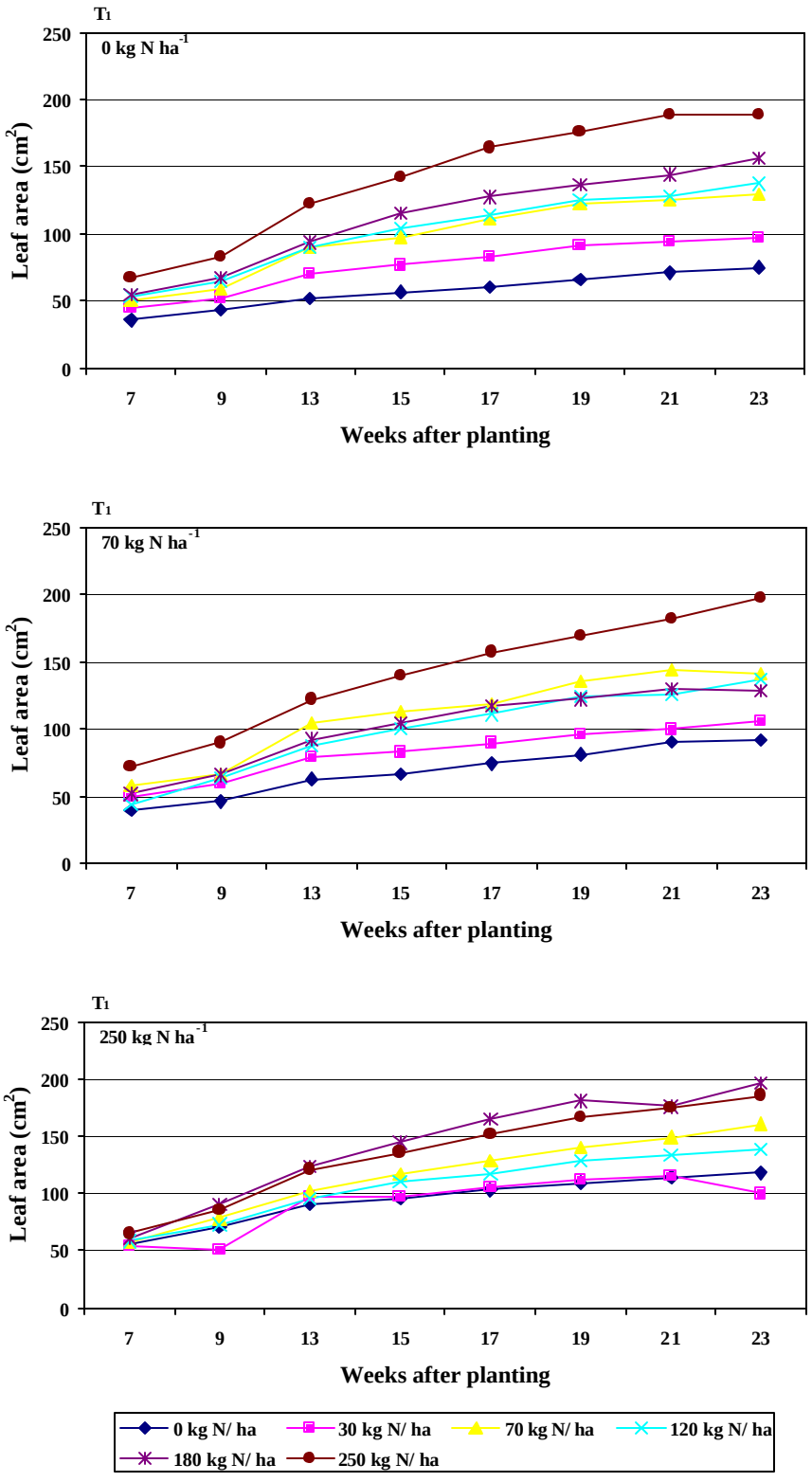

Figure 5.3: Effect of nitrogen levels on the leaf area of Ronina primary plants grown from 7-8 cm bulbs in 2002 that received the T_1 treatment before

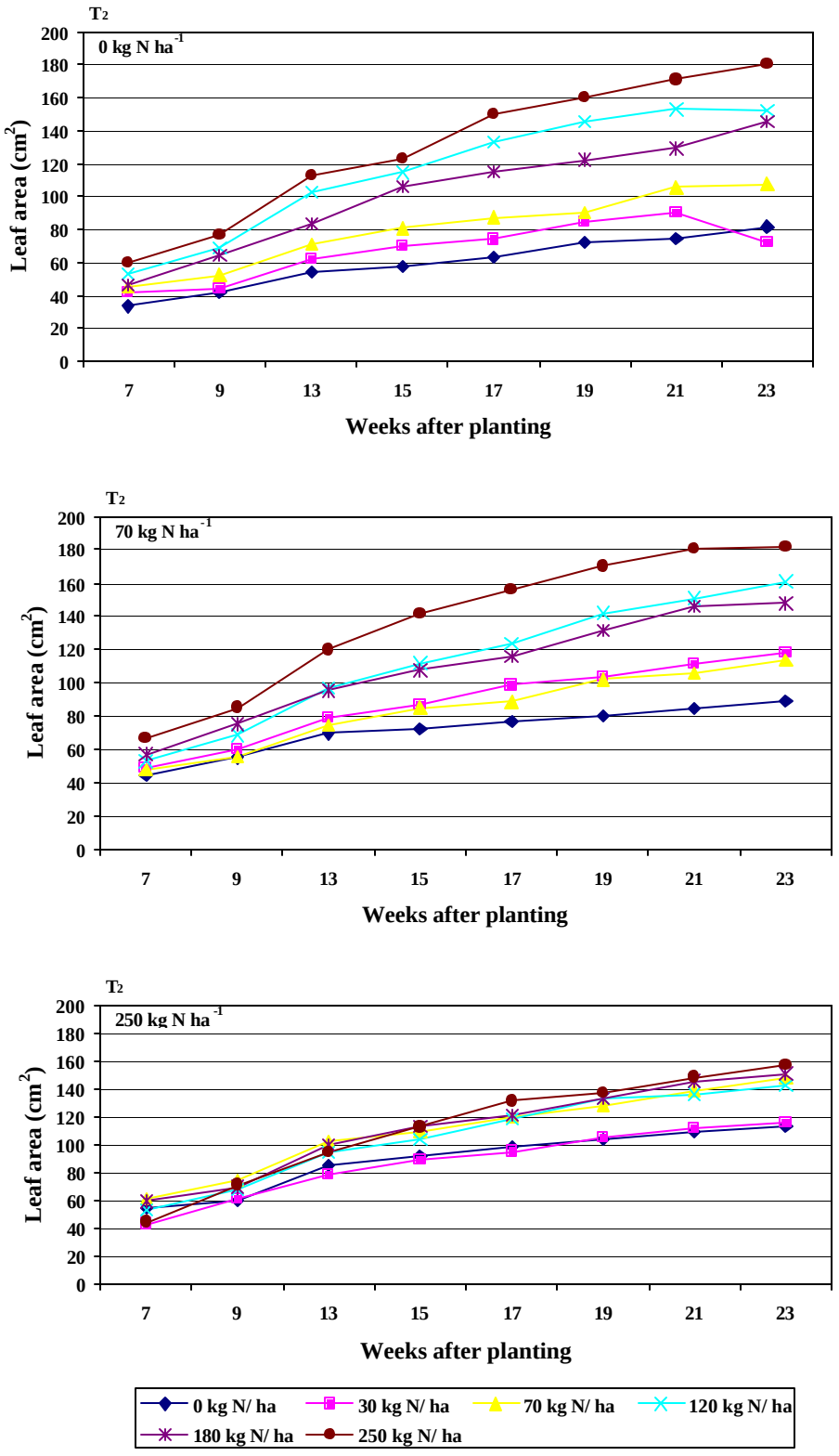

Figure 5.4: Effect of nitrogen levels on the leaf area of Ronina primary plants grown from 7-8 cm bulb in 2002 that received the T_2 treatment before

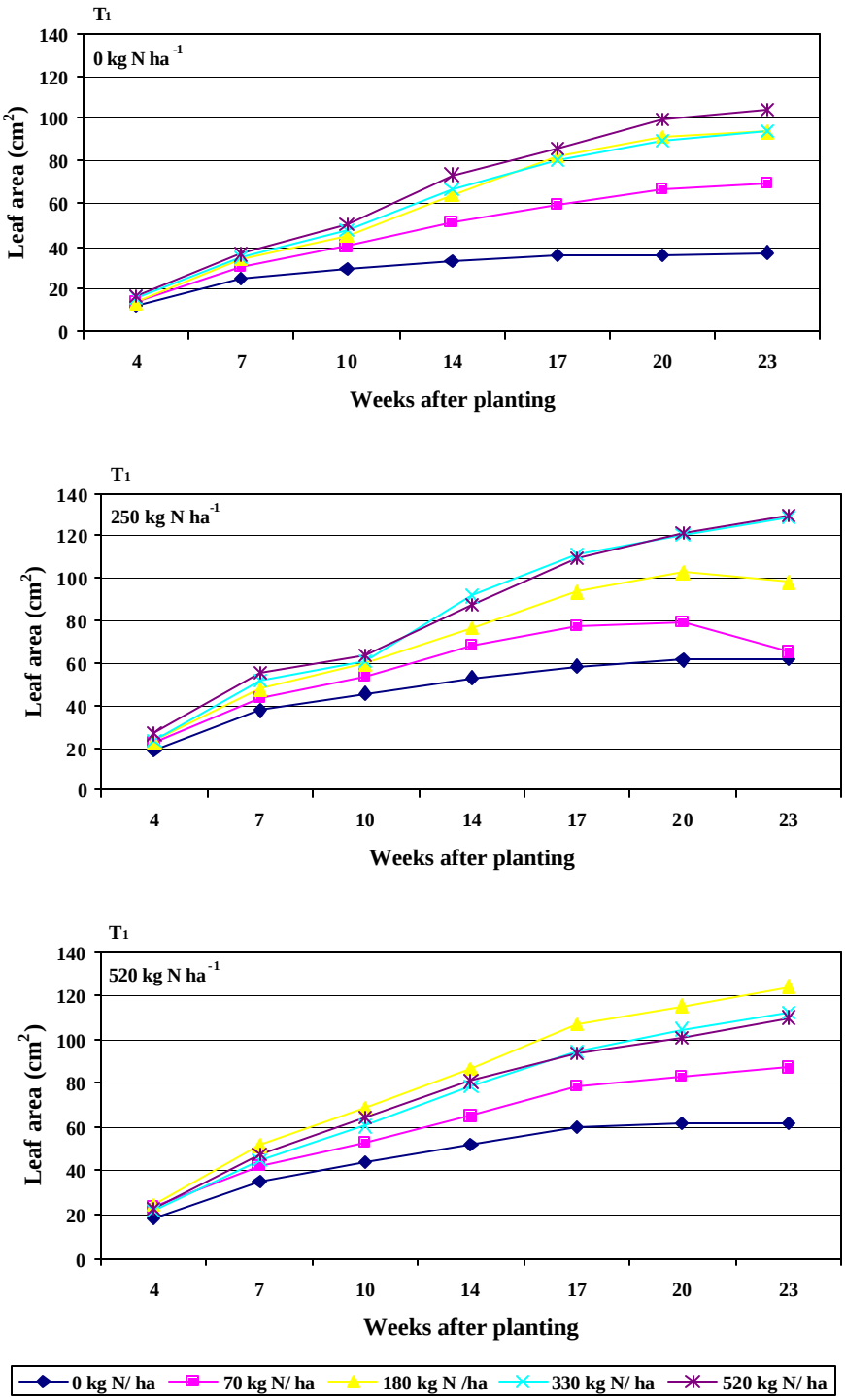

Figure 5.5: Effect of nitrogen levels on the leaf area of Rupert primary plants grown from 7-8 cm bulbs in 2003 that received the T_1 treatment before

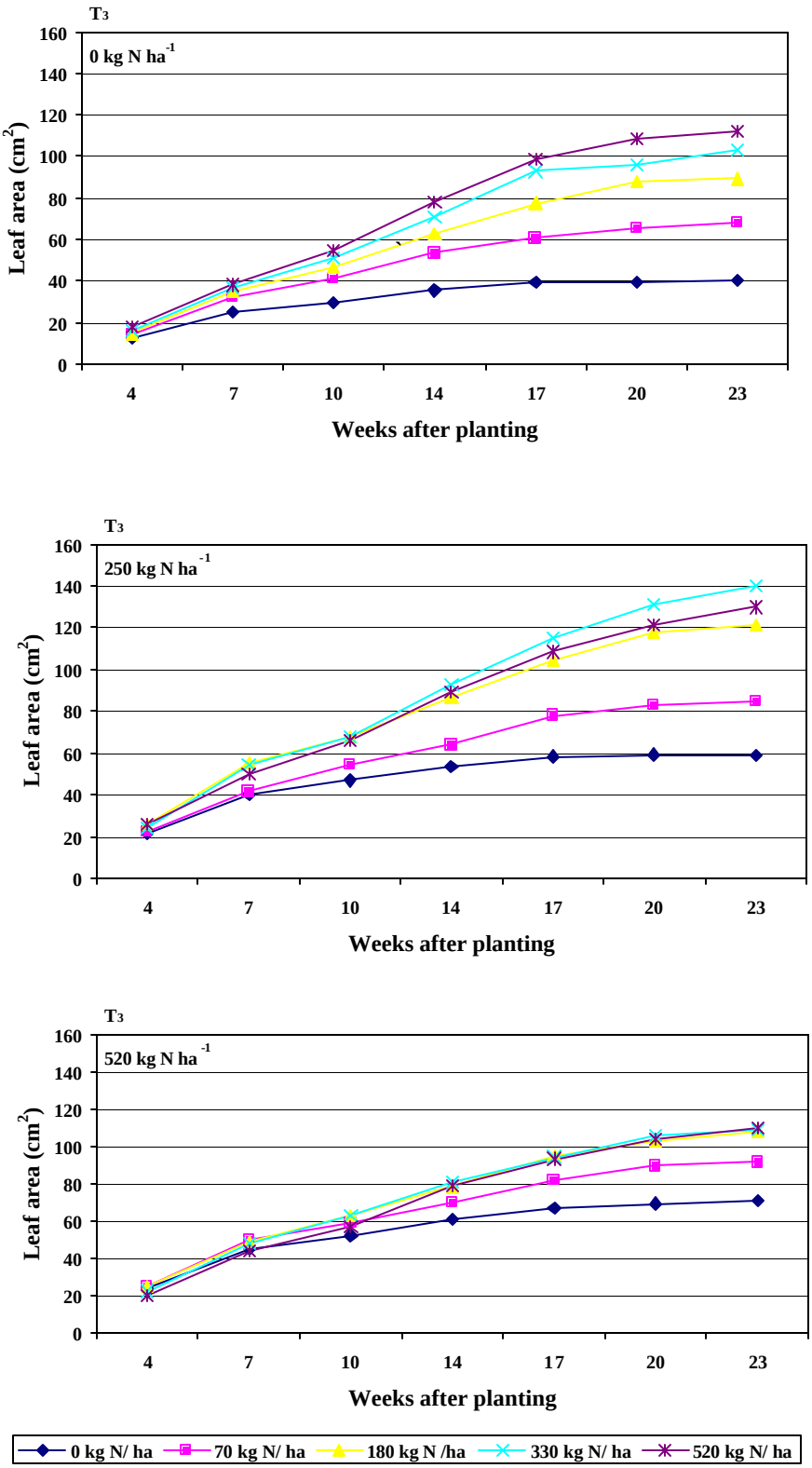

Figure 5.6: Effect of nitrogen levels on the leaf area of Rupert primary plants grown from 7-8 cm bulbs in 2003 that received the T_2 treatment before

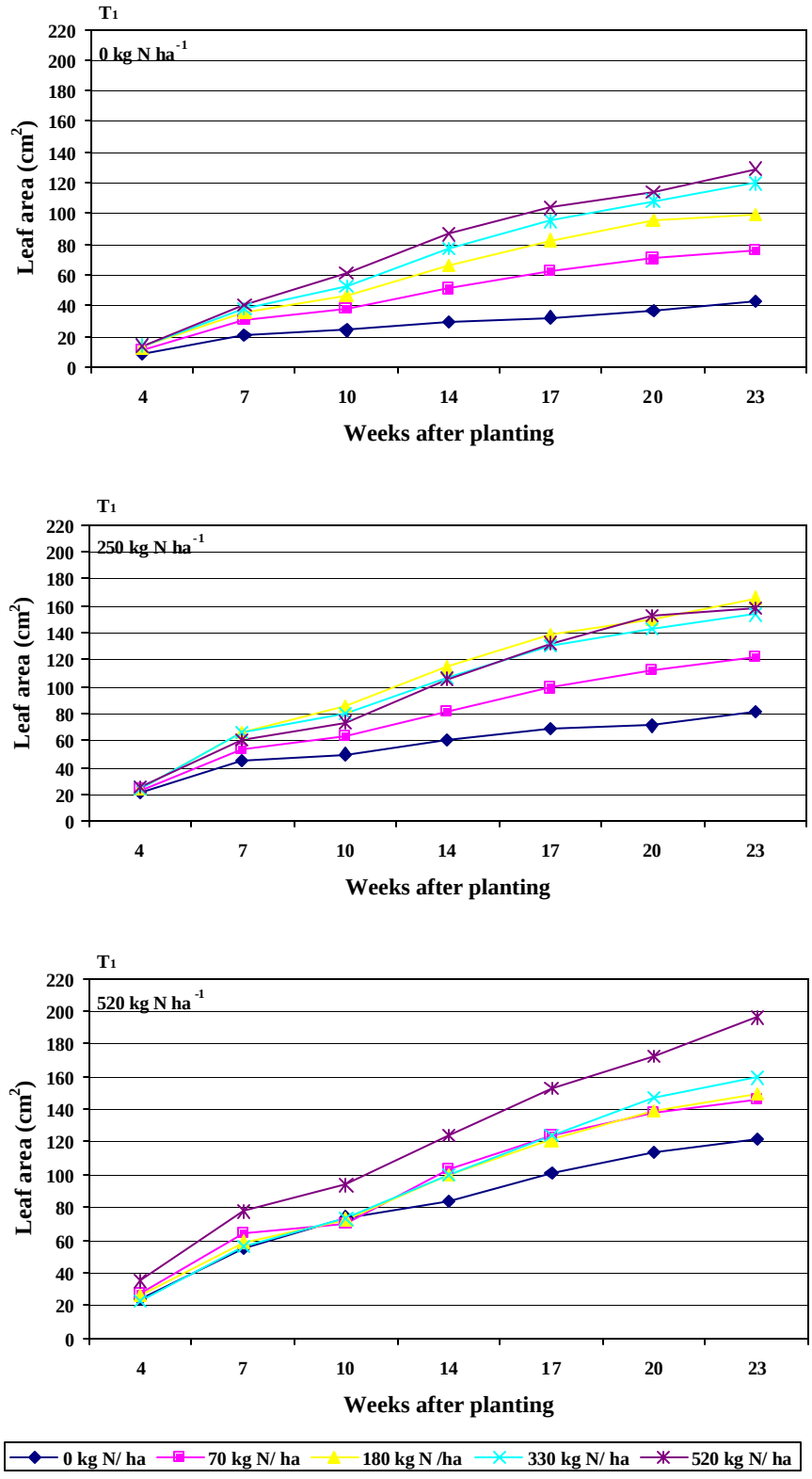

Figure 5.7: Effect of nitrogen levels on the leaf area of Ronina primary plants grown from 7-8 cm bulbs in 2003 that received the T_1 treatment before

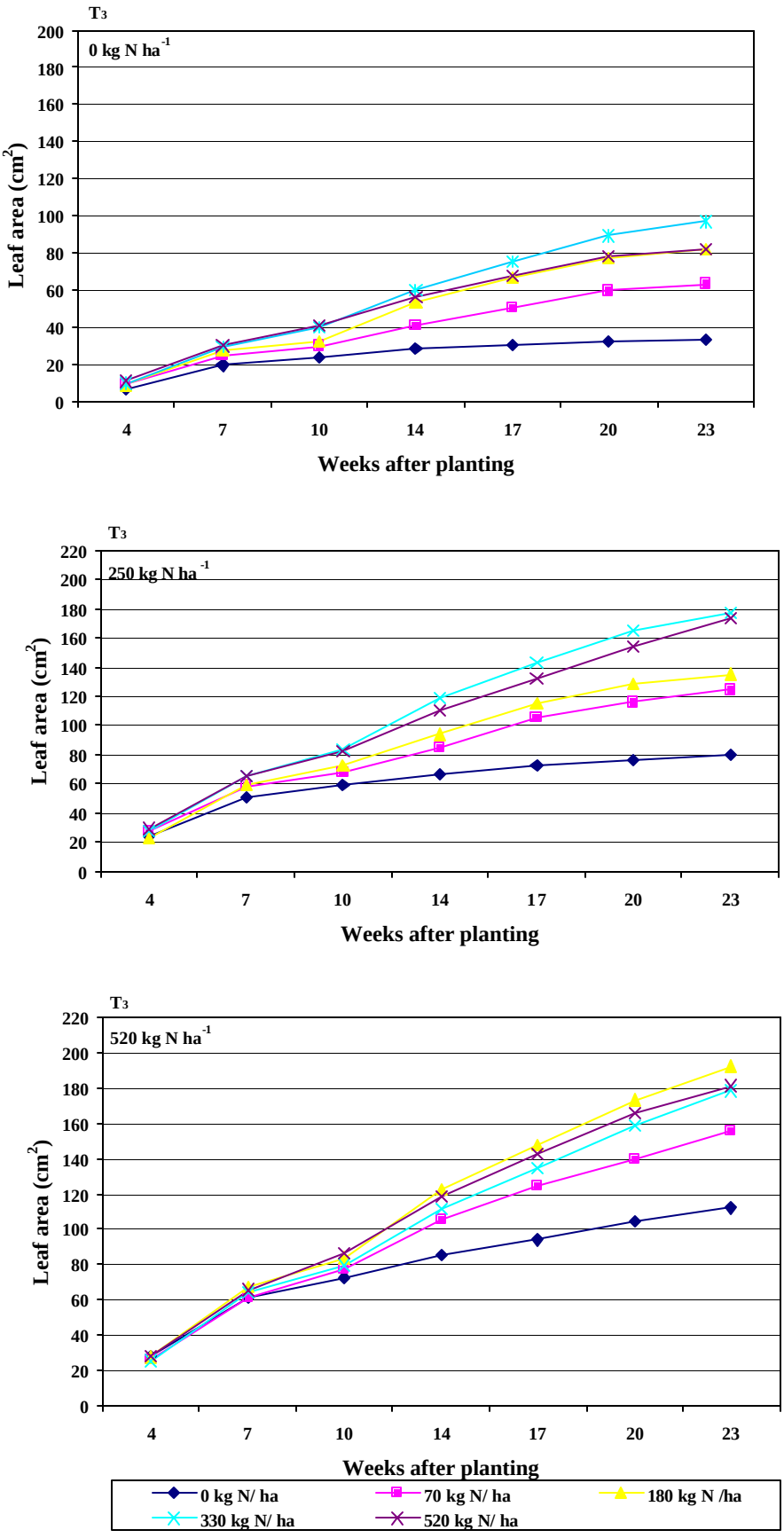

Figure 5.8: Effect of nitrogen levels on the leaf area of Ronina primary plants grown from 7-8 cm bulbs in 2003 that received the T_2 treatment before

Inspection of Table 5.1 showed that the influence of the different treatments on the leaf area of the primary plants were not consistent in 2002 and 2003. The discussion will focus therefore firstly, on the 2002 data and secondly on the 2003 data.

5.2.1.1.1 Plants grown in 2002

The effect of nitrogen levels on the leaf area of *Lachenalia* primary plants grown in 2002 is displayed in Figures 5.1 to 5.4. Only the treatments that effected the leaf area of the plants significantly as shown in Table 5.1 will be addressed.

The interaction between cultivar and nitrogen levels in the nursery phase influenced the leaf area of the primary plants significantly from 7 weeks after planting up to 15 weeks after planting (Table 5.1). As shown in Table 5.2 the leaf area of Ronina primary plants was larger than the leaf area of Rupert primary plants at all eight times of measurement irrespective of the nitrogen levels in the nursery phase. The leaf area of Ronina primary plants increased as the nitrogen levels in the nursery phase increased. Although not significant the leaf area of Rupert primary plants tended to decrease at 7, 9, 11 and 13 weeks after planting as the nitrogen levels in the nursery phase increased.

Table 5.2: Effect of nitrogen levels in the nursery phase on the leaf area (cm^2) of Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2002

Weeks after	Cultivar	Nitrogen levels 0	70	250	LSD (T = 0.05)
7	**Rupert**	29.91	27.40	25.27	**5.87**
	Ronina	48.89	52.60	55.69	
9	**Rupert**	37.86	35.56	34.06	**7.32**
	Ronina	60.01	65.74	70.97	
11	**Rupert**	47.22	44.52	43.72	**8.47**
	Ronina	72.68	78.46	87.11	
13	**Rupert**	56.57	57.41	52.93	**9.91**
	Ronina	83.74	90.23	98.66	
15	**Rupert**	74.52	79.23	82.30	**11.29**
	Ronina	83.55	83.21	88.37	
19	**Rupert**	74.07	72.98	72.33	**ns**
	Ronina	115.89	121.29	131.48	
21	**Rupert**	79.86	79.12	80.05	**ns**
	Ronina	127.00	134.45	143.75	
23	**Rupert**	77.97	75.81	77.28	**ns**
	Ronina	122.94	129.10	137.66	

Inspection of Table 5.1 showed that the interaction between cultivar and nitrogen levels in the pot plant phase also influenced the leaf area of the primary plants significantly. Higher nitrogen levels in the pot plant phase increased the leaf area of both Rupert and Ronina primary plants (Table 5.3). The largest leaf area was recorded with Ronina primary plants at the 250 kg N ha^{-1} level and with Rupert primary plants at the 120 kg N ha^{-1} level. Regardless of the nitrogen levels the leaf area of Ronina primary plants was larger than the leaf area of Rupert plants.

Table 5.3: Effect of nitrogen levels in the pot plant phase on the leaf area (cm^2) of Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2002

Weeks after	Cultivar	Nitrogen levels 0	30	70	120	180	250	LSD (T = 0.05)
7	Rupert	26.54	21.60	25.87	31.63	29.64	29.91	9.52
	Ronina	44.08	47.01	53.30	52.47	54.94	62.55	
9	Rupert	33.59	29.25	33.10	40.54	37.85	40.62	11.87
	Ronina	52.84	54.49	64.42	67.77	72.04	81.89	
11	Rupert	39.84	36.37	41.22	51.96	47.89	53.66	13.74
	Ronina	63.47	69.04	79.07	80.05	87.08	97.78	
13	Rupert	45.05	43.13	49.99	63.34	64.63	67.70	16.07
	Ronina	68.95	77.65	90.94	94.41	98.04	115.26	
15	Rupert	48.88	48.81	56.39	70.71	66.50	78.88	18.30
	Ronina	73.27	83.65	100.48	107.29	115.02	132.50	
19	Rupert	54.91	57.83	65.28	85.16	78.96	96.62	23.52
	Ronina	85.30	98.68	119.78	132.97	137.59	163.00	
21	Rupert	55.94	60.38	72.57	95.18	85.20	108.78	27.38
	Ronina	94.78	101.44	133.38	144.77	154.21	181.82	
23	Rupert	57.40	60.34	68.70	91.10	84.73	99.87	24.01
	Ronina	90.63	103.59	127.97	137.90	145.03	174.27	

As shown in Table 5.1 the interaction between nitrogen levels in the nursery phase and nitrogen levels in the pot plant phase influenced the leaf area of the primary plants. At all eight measurements the leaf area of plants not fertilised with nitrogen in the pot plant phase increased with higher nitrogen levels in the nursery phase (Table 5.4). Regardless of the nitrogen levels in the nursery phase the leaf area of the plants increased on account of higher nitrogen levels in the pot plant phase. The largest leaf areas were recorded on primary plants grown from bulbs that received either 0 or 70 kg N ha^{-1} in the nursery phase and 250 kg N ha^{-1} in the pot plant phase.

Table 5.4: Effect of nitrogen levels in the nursery phase and nitrogen levels in the pot plant phase on the leaf area (cm^2) of Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2002

Weeks after planting	Nitrogen levels kg ha^{-1}	Nitrogen levels 0	30	70	120	180	250	LSD $_{(T = 0.05)}$
7	**0**	31.19	33.22	39.05	45.07	38.91	48.98	**12.45**
	70	32.50	37.74	36.56	41.15	44.12	47.92	
	250	42.24	31.95	43.14	39.92	43.84	41.79	
9	**0**	38.85	38.90	47.26	55.47	50.64	62.48	**15.52**
	70	40.34	45.69	43.26	55.26	55.81	63.54	
	250	50.46	41.00	55.76	51.74	58.39	57.75	
11	**0**	45.59	47.41	57.14	68.74	63.77	77.04	**17.97**
	70	47.12	54.92	55.79	65.38	65.75	79.98	
	250	62.24	55.78	67.50	63.89	72.93	70.15	
13	**0**	48.53	54.20	69.16	81.38	74.07	93.60	**21.01**
	70	53.86	62.88	65.43	81.06	83.03	96.67	
	250	68.61	64.09	76.81	74.19	86.91	84.18	
15	**0**	51.93	60.05	75.93	91.79	87.50	107.03	**23.93**
	70	57.33	68.46	73.91	91.48	84.69	111.44	
	250	73.97	70.17	85.45	83.74	100.09	98.60	
19	**0**	59.78	70.86	91.39	109.77	102.15	135.93	**30.75**
	70	66.21	81.25	85.68	113.46	101.36	134.86	
	250	84.33	82.66	100.51	104.00	121.32	118.64	
21	**0**	67.45	69.76	100.69	117.22	113.66	151.79	**35.80**
	70	67.38	88.94	92.89	129.17	111.89	150.46	
	250	91.26	84.03	115.34	113.53	133.58	133.65	
23	**0**	64.35	74.00	97.19	113.89	108.90	144.41	**31.39**
	70	69.00	84.56	90.85	120.27	109.38	140.69	
	250	88.70	87.34	106.97	109.35	126.36	126.10	

Except for these interactions the different nitrogen application times in the nursery phase influenced the leaf area of primary plants significantly (Table 5.1). The leaf area of primary plants grown from the T_1 treatment bulbs was larger than those from the T_2 treatment bulbs at all eight measuring times as shown in Table 5.5.

Table 5.5: Effect of nitrogen application time in the nursery phase on the leaf area (cm^2) of *Lachenalia* primary plants grown from 7-8 cm bulbs in 2002

Weeks after planting	Nitrogen application times		LSD $_{(T = 0.05)}$
	T_1	T_2	
7	41.49	38.49	**2.33**
9	52.36	49.04	**2.91**
11	64.55	60.02	**3.36**
13	76.03	70.49	**3.93**
15	85.04	78.69	**4.48**
19	101.94	94.07	**5.76**
21	111.20	103.54	**6.70**
23	106.95	99.97	**5.88**

5.2.1.1.2 Plants grown in 2003

The effect of nitrogen levels on the leaf area of *Lachenalia* plants grown in 2003 is displayed in Figures 5.5 to 5.8. As in the previous section only the treatments that affected the leaf area of the plants significantly as given in Table 5.1 will be discussed. According to Table 5.1 the interaction between cultivars and nitrogen levels in the nursery phase influenced the leave area of the primary plants significantly. For Rupert primary plants the largest leaf area was recorded at the 250 kg N ha^{-1} level and for Ronina primary plants at the 520 kg N ha^{-1} (Table 5.6). The leaf area of Rupert primary plants was larger than the leaf area of Ronina primary plants when grown from bulbs not fertilised with nitrogen in the nursery phase. This trend was reversed when primary plants were grown from bulbs fertilised at a rate of 70 or 520 kg N ha^{-1} in the nursery phase.

Table 5.6: Effect of nitrogen levels in the nursery phase on the leaf area (cm^2) of Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2003

Weeks after planting	Cultivar	Nitrogen levels kg ha^{-1}			LSD $_{(T = 0.05)}$
		0	70	250	
7	**Rupert**	14.86	23.37	22.57	**2.40**
	Ronina	10.58	25.01	27.03	
9	**Rupert**	32.83	47.71	45.59	**4.44**
	Ronina	29.58	58.98	63.25	
13	**Rupert**	43.63	56.61	58.25	**6.04**
	Ronina	38.94	71.71	78.29	
15	**Rupert**	59.00	76.22	73.05	**7.96**
	Ronina	54.92	94.29	105.38	
19	**Rupert**	71.27	91.36	86.34	**9.85**
	Ronina	66.68	113.66	126.61	
21	**Rupert**	77.99	99.64	93.56	**11.29**
	Ronina	76.18	126.84	145.23	
23	**Rupert**	81.16	101.7	98.37	**13.19**
	Ronina	82.44	136.95	159.23	

The interaction between nitrogen levels in the nursery phase and nitrogen levels in the pot plant phase influenced the leaf area of the primary plants significantly (Table 5.1). At all seven measurements the leaf area of the primary plants grown from bulbs not fertilised with nitrogen in the pot plant phase increased with higher nitrogen levels in the nursery phase (Table 5.7). Irrespective of the nitrogen levels in the nursery phase the leaf area of the plants increased with higher levels in the pot plant phase. The largest leaf areas were measured on primary plants that received 250 kg N ha^{-1} in the nursery phase and 330 kg N ha^{-1} in the pot plant phase.

Table 5.7: Effect of nitrogen levels in the nursery phase and nitrogen levels in the pot plant phase on the leaf area (cm^2) of Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2003

Weeks after planting	Nitrogen levels kg ha^{-1}	Nitrogen levels kg ha^{-1} 0	70	180	330	520	LSD (T = 0.05)
7	0	10.03	12.09	12.61	14.06	14.82	4.50
	250	21.37	23.98	23.79	24.95	26.86	
	520	23.48	25.47	25.65	23.18	26.22	
9	0	22.55	29.38	32.99	34.91	36.19	8.36
	250	43.27	49.40	56.82	59.41	57.81	
	520	49.14	54.40	56.74	53.24	58.58	
13	0	26.80	37.43	42.63	47.80	51.76	11.36
	250	50.30	59.76	71.43	73.09	66.22	
	520	60.61	64.59	71.93	68.34	75.29	
15	0	31.62	49.03	61.80	68.65	73.66	15.02
	250	58.40	74.56	92.81	102.50	97.97	
	520	70.33	85.70	96.92	92.58	100.54	
19	0	34.39	58.28	77.24	85.96	89.00	18.54
	250	64.54	89.88	112.78	124.82	120.54	
	520	80.30	102.07	117.71	111.86	120.44	
21	0	36.02	65.57	88.05	95.66	100.14	21.24
	250	66.97	97.48	124.64	139.91	137.21	
	520	87.28	112.59	132.50	129.02	135.59	
23	0	38.45	69.28	91.08	103.45	106.75	ns
	250	70.46	98.88	129.91	149.77	147.62	
	520	91.52	120.02	143.49	139.71	149.27	

From the preceding results it is clear that the leaf area of Ronina primary plants is larger than that of Rupert primary plants, especially when fertilised with nitrogen. Nitrogen fertilisation in the nursery phase resulted in higher nutrient and carbohydrate contents in the bulbs (Chapter 3 and 4) which promoted without any doubt the leaf area of plants

from both cultivars in the pot plant phase positively. This trend was also observed by other researches such as Ruamrungsri *et al*., (1997) and Berghoef & Zevenbergen (1990) with other bulbous crops. Regardless of nitrogen fertilisation in the nursery phase all the plants responded to nitrogen fertilisation in the pot plant phase. These results agree with results obtained for *Alstroemeria* (Smith *et al.*, 1998; Chiari, Elliott & Bridgen, 1999).

5.2.1.2 Secondary plants

A summary on the analyses of variance that was done to determine the effects of the different nitrogen levels on leaf area of Rupert and Ronina secondary plants grown from 7-8 cm bulbs in 2002 is given in Table 5.8.

Table 5.8: Summary on the analysis of variance showing the effects of nitrogen levels on the leaf area of Rupert and Ronina secondary plants grown from 7-8 cm bulbs in 2002

Cultivar (C)	Nitrogen (N_p)	Nitrogen (N_n)	Time (T_n)	C X N_p	C X N_n	C X T_n	N_p X N_n	N_p X T_n	N_n X T_n
*	ns	*	ns	ns	ns	ns	ns	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**
N_p = nitrogen levels in the pot plant phase
N_n = nitrogen levels in the nursery phase
T_n = nitrogen application times in the nursery phase

None of the interactions influenced the leaf area of the secondary plants significantly as shown in Table 5.8. However, the leaf area of the secondary plants of Rupert was 5.17 cm^2 and that of Ronina 2.47 cm^2 (Table 5.9).

Table 5.9: Leaf area (cm^2) of Rupert and Ronina secondary plants in 2002

Cultivar	Leaf area cm^{-2}
Rupert	5.17
Ronina	2.47
LSD $_{(T = 0.05)}$	**2.44**

The application of nitrogen in the nursery phase influenced the average leaf area of the secondary plants significantly (Table 5.8). As indicated in Table 5.10 the leaf area of the secondary plants grown from bulbs not fertilised with nitrogen increased from 0.46 cm^2 to 6.65 cm^2 at a 250 kg N ha^{-1} application.

Table 5.10: Effect of nitrogen levels in the nursery phase on the leaf area of *Lachenalia* secondary plants in 2002

Nitrogen level kg ha^{-1}	Leaf area secondary plant cm^{-2}
0	0.46
70	4.35
250	6.65
LSD $_{(T = 0.05)}$	**3.58**

The results clearly indicated although the two cultivars differed with respect to their leaf area, application of nitrogen increased the leaf area of both cultivars. These differences in leaf area related to the number of secondary plants that formed from a bulb. Application of nitrogen at rates of 0, 70 and 250 kg N ha^{-1} in the nursery phase resulted in that Rupert formed respectively 1.75, 2.77 and 3.04 secondary plants and Ronina formed respectively 1.06, 1.29 and 1.46 secondary plants.

The fact that *Lachenalia* did not form any secondary plants in 2003 indicated that nitrogen fertilisation in the nursery phase cannot be the only reason for this phenomenon observed in 2002. According to Rees (1992) the environmental factor that regulates bulb growth of the family Hyacinthaceae to which *Lachenalia* belongs most, is temperature. Therefore it is not surprising that Louw (1992) is of opinion that the temperature to which *Lachenalia* bulbs are subjected in the nursery phase can influence their physiological state at harvest. This may influence the capacity of *Lachenalia* bulbs to form secondary plants or not. In this study it could also be that the temperature of the glasshouse was increased too early and suddenly during the nursery phase in 2001 than in 2002 with the ultimate result that the respective bulbs formed secondary plants in 2002 and not in 2003. In 2002 the temperature of the glasshouse was increased a few weeks later and for a longer period than in 2001.

5.2.2 *INFLORESCENCE QUALITY*

In order to establish the quality of *Lachenalia* inflorescences the following parameters were measured: inflorescences per plant, florets per inflorescence, peduncle length and peduncle diameter. As mentioned earlier in Section 5.2.1 the bulbs formed in 2002 not only primary plants but also secondary plants which produced their own inflorescences

during the pot plant phase. For the sake of convenience the data on primary plants and secondary plants with respect to the quality parameters will be discussed separately.

Studying of the summaries on the analyses of variance for the inflorescences per plant (Tables 5.11), florets per inflorescence (Table 5.18), peduncle length (Table 5.23) and peduncle diameter (Table 5.27) showed that nitrogen application time in the nursery phase did not influence any of the parameters significantly. Surprisingly none of the parameters were influenced by the interaction between nitrogen levels in the nursery phase and nitrogen levels in the pot plant phase and also the interaction between nitrogen levels in the pot plant phase and nitrogen application times in the nursery phase either. These data will not be shown or discussed in the following sections.

5.2.2.1 Inflorescences per plant

A summary on the analyses of variance that was done to determine the effects of the different nitrogen levels on the number of inflorescences per plant for Rupert and Ronina plants grown from 7-8 cm bulbs in 2002 and 2003 is given in Table 5.11. Only the data of treatments that caused significant difference in the number of inflorescences will be presented and discussed.

Table 5.11: Summary on the analyses of variance showing the effects of nitrogen levels on the number of inflorescences per plant for Rupert and Ronina plants grown from 7-8 cm bulbs in 2002 and 2003

Plant	Cultivar (C)	Nitrogen (N_p)	Nitrogen (N_n)	Time (T_n)	C X N_p	C X N_n	C X T_n	N_p X N_n	N_p X T_n	N_n X T_n
2002										
Primary	ns	*	*	ns	ns	ns	*	ns	ns	ns
Secondary	*	ns	*	ns	ns	ns	ns	ns	ns	ns
2003										
Primary	ns	ns	ns	ns	*	ns	ns	ns	ns	ns

LSD $(T = 0.05)$
ns = no significant differences
*** = significant differences**
N_p = nitrogen levels in the pot plant phase
N_n = nitrogen levels in the nursery phase
T_n = nitrogen application times in the nursery phase

5.2.2.1.1 Primary plants

5.2.2.1.1.1 Plants grown in 2002

Investigation of Table 5.11 showed that the interaction between cultivar and nitrogen application times in the nursery phase influenced the number of inflorescences per

primary plant in 2002 significantly. The inflorescences for Rupert were more at the T_2 treatment than at the T_1 treatment whereas the trend was reversed for Ronina (Table 5.12).

Table 5.12: Effect of nitrogen application times in the nursery phase on the number of inflorescences per plant for Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2002

Nitrogen application times (T_n)	Cultivar		LSD $_{(T = 0.05)}$
	Rupert	Ronina	
T_1	1.33	1.62	**0.34**
T_2	1.54	1.44	

Nitrogen applied in the nursery phase influenced the number of inflorescences per primary plant significantly in 2002 (Table 5.11). The inflorescences increased from 1.28 at a nitrogen level of 0 kg ha^{-1} to 1.68 at a level of 250 kg ha^{-1} as shown in Table 5.13.

Table 5.13: Effect of nitrogen levels in the nursery phase on the number of inflorescences per plant fo r *Lachenalia* primary plants grown from 7-8 cm bulbs in 2002

Nitrogen levels (N_n) kg ha^{-1}	Number of inflorescence
0	1.28
70	1.50
250	1.68
LSD $_{(T = 0.05)}$	**0.27**

As indicated in Table 5.11 the nitrogen applied in the pot plant phase influenced the number of inflorescences per primary plant in 2002 significantly. The inflorescences increased from 1.21 at a 0 kg N ha^{-1} level to 1.71 at a 70 kg N ha^{-1} level whereafter it decreased to 1.38 at a 250 kg N ha^{-1} level (Table 5.14).

Table 5.14: Effect of nitrogen levels in the pot plant phase on the number of inflorescences per plant for *Lachenalia* primary plants grown from 7-8 cm bulbs in 2002

Nitrogen levels (N_p) kg ha^{-1}	Number of inflorescence
0	1.21
30	1.56
70	1.71
120	1.56
180	1.50
250	1.38
LSD $_{(T = 0.05)}$	**0.46**

5.2.2.1.1.2 Plants grown in 2003

Inspection of Table 5.11 indicated that the interaction between cultivar and nitrogen levels in the pot plant phase influenced the number of inflorescences per primary plant in 2003 significantly. Only at the 70 kg N ha^{-1} level the inflorescences differed with 0.99 for Rupert and 1.08 for Ronina (Table 5.15).

Table 5.15: Effect of nitrogen levels in the pot plant phase on the number of inflorescences per plant for Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2003

Nitrogen levels (N_p) kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	1	1
70	0.99	1.08
180	1	1
330	1	1
520	1	1
LSD $_{(T = 0.05)}$	**0.10**	

5.2.2.1.2 Secondary plants

The cultivars differed significantly with regard to the number of inflorescences per secondary plant in 2002 (Table 5.11). As shown in Table 5.16 the inflorescences for Rupert was plants 2.15 and for Ronina only 1.80.

Table 5.16: Number of inflorescences per plant for Rupert and Ronina secondary plants grown from 7-8 cm bulbs in 2002

Season	Cultivar		LSD $_{(T = 0.05)}$
	Rupert	Ronina	
2002	2.15	1.80	**0.27**

As indicated in Table 5.11 nitrogen levels in the nursery phase influenced the number of inflorescences per secondary plant significantly in 2002. The inflorescences increased from 1.45 at a level of 0 kg N ha^{-1} to 2.32 at a level of 250 kg N ha^{-1} (Table 5.17).

Table 5.17: Effect of nitrogen levels in the nursery phase on the number of inflorescences per plant for *Lachenalia* secondary plants grown from 7-8 cm bulbs in 2002

Nitrogen levels (N_n) kg ha^{-1}	Number of inflorescence
0	1.45
70	2.15
250	2.32
$LSD_{(T = 0.05)}$	**0.40**

These data showed that nitrogen fertilisation in the nursery phase and in the pot plant phase increased the number of inflorescences formed on either the primary or secondary *Lachenalia* plants. However, it seems that the primary plants produced the most inflorescences when the equivalent of 70 kg N ha^{-1} was applied in the pot plant phase irrespective of the amount of nitrogen applied in the nursery phase.

Several other researchers reported that nitrogen applied in the previous season influenced the flower performance of bulbous crops. For some flower crops high nitrogen levels decreased flowering and for other flower crops high nitrogen levels increased flowering. Clemens, Dennis, Ingle, Thomas & Welsh (1994) reported that for Calla tubers their flowering performance was reduced by higher and increased by lower nitrogen application rates in the previous season. This nitrogen carry-over effect was reported also for *Lilium* (Boon & Niers, 1986). Clemens *et al.* (1998) reported that fertilisation during the previous growth season had a major effect on flowering of replanted tubers of *Zantedeschia*. Almost 100 % more flowers developed from tubers grown under low nitrogen and high phosphorus conditions than tubers grown under high nitrogen and high phosphorus conditions. In contrast the number of flowers formed by Sandersonia plants increased with increasing rates of nitrogen (Clark, 1997; Clark & Burge, 1999).

5.2.2.2 Florets per inflorescence

A summary on the analyses of variance that was done to determine the effects of the different nitrogen levels on the number of florets per inflorescences for Rupert and Ronina plants grown from 7-8 cm bulbs in 2002 and 2003 is given in Table 5.18. Only the data of treatments that influenced the number of florets significantly will be presented and discussed.

Table 5.18: Summary on the analyses of variance showing the effects of nitrogen levels on the number of florets per inflorescence for Rupert and Ronina plants grown from 7-8 cm bulbs in 2002 and 2003

Plant	Cultivar (C)	Nitrogen (N_p)	Nitrogen (N_n)	Time (T_n)	C X N_p	C X N_n	C X T_n	N_p X N_n	N_p X T_n	N_n X T_n
2002										
Primary	*	ns	ns	ns	ns	*	ns	ns	ns	ns
Secondary	*	*	ns	ns	ns	*	*	ns	ns	*
2003										
Primary	*	*	*	ns	*	ns	ns	ns	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**
N_p = nitrogen levels in the pot plant phase
N_n = nitrogen levels in the nursery phase
T_n = nitrogen application times in the nursery phase

5.2.2.2.1 Primary plants

5.2.2.2.1.1 Plants grown in 2002

As indicated in Table 5.18 the number of florets per inflorescence was influenced significantly by the interaction between cultivar and nitrogen levels in the nursery phase. Rupert inflorescences contained significant more florets than Ronina inflorescences irrespective of the nitrogen levels in the nursery phase. The number of florets per inflorescence for Rupert decreased with an increase in nitrogen level, namely from 46.77 at a 0 kg N ha^{-1} level to 39.27 at a 250 kg N ha^{-1} level (Table 5.19). However, the number of florets per inflorescence for Ronina increased with an increase in nitrogen level, namely from 22.73 at a 0 kg N ha^{-1} to 25.04 at a 70 kg N ha^{-1} level.

Table 5.19: Effect of nitrogen levels in the nursery phase on the number of florets per inflorescence for Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2002

Nitrogen levels (N_p) kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	46.77	22.73
70	40.00	25.04
250	39.27	25.94
LSD $_{(T = 0.05)}$	**6.40**	

5.2.2.2.1.2 Plants grown in 2003

In 2003 the interaction between cultivar and nitrogen levels in the pot plant phase influenced the number of florets per inflorescence significantly (Table 5.18). Rupert inflorescences produced significant more florets than Ronina regardless of the nitrogen

levels in the pot plant phase. In the case of Rupert the number of florets per inflorescence increase from 48.13 at a 0 kg N ha^{-1} application to 64.38 at a 330 kg N ha^{-1} application whereafter it decrease to 62.42 at a 520 kg N ha^{-1} application (Table 5.20). For Ronina the number of florets per inflorescences increased only slightly with higher nitrogen levels.

Table 5.20: Effect of nitrogen levels in the pot plant phase on the number of florets per inflorescence for Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2003

Nitrogen levels (N_p) kg ha^{-1}	Cultivar	
	Rupert	Ronina
0	48.13	26.96
70	54.88	27.71
180	62.38	28.79
330	64.38	28.50
520	62.42	28.71
LSD $_{(T = 0.05)}$	**6.38**	

5.2.2.2.2 Secondary plants

As shown in Table 5.18 the interaction between cultivar and nitrogen application times in the nursery phase significantly influenced the number of florets per inflorescences. The number of florets per inflorescence for Rupert was significantly more than for Ronina (Table 5.21). For Rupert the T_1 treatment resulted the most florets per inflorescence whereas for Ronina the T_2 treatment resulted in the most florets per inflorescence.

Table 5.21: Effect of nitrogen application times in the nursery phase on the number of florets per inflorescence for Rupert and Ronina secondary plants grown from 7-8 cm bulbs in 2002

Nitrogen application times (T_n)	Cultivar		LSD $_{(T = 0.05)}$
	Rupert	Ronina	
T_1	29.71	19.25	**5.40**
T_2	24.87	21.49	

The interaction between nitrogen levels and application times in the nursery phase significantly influenced the number of florets per inflorescence (Table 5.18). Inspection of Table 5.22 showed that the number of florets per inflorescence was more with the T_2 treatment than with the T_1 treatment. The number of florets decreased from 29.94 at a 0 kg N ha^{-1} level to 23.79 at a 250 kg N ha^{-1} level for the T_2 treatment. For the T_1

treatment the number of florets per inflorescence did not differed between nitrogen levels.

Table 5.22: Effect of nitrogen levels in the nursery phase on the number of florets per inflorescence for Rupert and Ronina secondary plants grown from 7-8 cm bulbs in 2002

Nitrogen levels (N_p) kg ha^{-1}	Nitrogen application time (T_n)	
	T_1	T_2
0	20.94	29.94
70	19.60	28.15
250	20.56	23.79
LSD $_{(T = 0.05)}$	**7.33**	

From these results it is evident in addition to the nitrogen applied in the nursery phase that nitrogen applied in the pot plant phase may also influence the number of florets formed per inflorescence. The influence of nitrogen application on the number of florets per inflorescence is more evident for Rupert than for Ronina. These results correspond with results obtained by Roodbol *et al.* (2002). According to Smith *et al.* (1998) the total number of florets per inflorescence for *Alstroemeria* increased with a higher nitrogen concentration in the fertiliser solution.

5.2.2.3 Peduncle length

A summary on the analyses of variance that was done to determine the effects of the different nitrogen levels on the peduncle length of Rupert and Ronina plants grown from 7-8 cm bulbs for 2002 and 2003 is given in Table 5.23. Only the data of those treatments that had a significant influence on the peduncle length will be presented and discussed.

Table 5.23: Summary on the analyses of variance showing the effects of nitrogen levels on the peduncle length of Rupert and Ronina plants grown from 7-8 cm bulbs in 2002 and 2003

Plant	Cultivar (C)	Nitrogen (N_p)	Nitrogen (N_n)	Time (T_n)	C X N_p	C X N_n	C X T_n	N_p X N_n	N_p X T_n	N_n X T_n
2002										
Primary	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Secondary	ns	*	ns	ns	ns	ns	ns	ns	ns	ns
2003										
Primary	*	ns	*	ns	ns	ns	*	ns	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**
N_p = nitrogen levels in the pot plant phase
N_n = nitrogen levels in the nursery phase
T_n = nitrogen application times in the nursery phase

5.2.2.3.1 Primary plants

5.2.2.3.1.1 Plants grown in 2002

In this year neither the nitrogen levels in any of the two phases nor the nitrogen application times in the nursery phase influenced the peduncle length significantly (Table 5.23). Even the peduncle length of Rupert and Ronina did not differ.

5.2.2.3.1.2 Plants grown in 2003

As shown in Table 5.23 the interaction between cultivar and nitrogen application time in the nursery phase influenced the peduncle length significantly. The peduncles of Rupert were longer than the peduncle of Ronina (Table 5.24). The peduncle length of neither Rupert nor Ronina was affected by the nitrogen application times in the nursery phase.

Table 5.24: Effect of nitrogen application times in the nursery phase on the peduncle length (cm) of Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2003

Nitrogen application times (T_n)	Cultivar		LSD $_{(T = 0.05)}$
	Rupert	Ronina	
T_1	22.87	20.39	**1.23**
T_3	23.89	20.08	

The application of nitrogen in the nursery phase influenced the peduncle length significantly (Table 5.23). As shown in Table 5.25 the peduncle length increased from 18.71 cm at a 0 kg N ha^{-1} level to 23.38 cm at a 250 kg N ha^{-1}level.

Table 5.25: Effect of nitrogen levels in the nursery phase on the peduncle length (cm) of *Lachenalia* primary plants grown from 7-8 cm bulbs in 2003

Nitrogen levels (N_n) kg ha^{-1}	Peduncle length
0	18.71
250	23.38
520	23.33
LSD $_{(T = 0.05)}$	**0.97**

5.2.2.3.2 Secondary plants

The peduncle length of the secondary plants was influenced by the nitrogen levels in the pot plant phase (Table 5.23). As shown in Table 5.26 the peduncle lengths recorded at the 0, 30, 70, 120 and 180 kg N ha^{-1} levels were almost similar but shorter than the peduncle length recorded at the 250 kg N ha^{-1} level.

Table 5.26: Effect of nitrogen levels in the pot plant phase on the peduncle length (cm) of *Lachenalia* secondary plants grown from 7-8 cm bulbs in 2002

Nitrogen levels (N_p) kg ha^{-1}	Peduncle length
0	19.82
30	20.70
70	21.20
120	20.44
180	21.92
250	24.20
LSD $_{(T = 0.05)}$	**3.78**

Roodbol *et al.* (2002) reported that the longest *Lachenalia* peduncles were obtained in the second season during full flowering with the basic nutrient solution recommended by the Commissie Bemesting Glastuinbouw (1992). However, when the strength of this solution was either doubled of halved it had no significant influence on the peduncle length of *Lachenalia* at all (Roodbol *et al.*, 2002).

Several researchers reported an increased in peduncle length of other bulbous flower plants with an increase in nitrogen levels: *Alstroemeria* (Smith *et al.*, 1998); *Gloriosa* (Carow, 1980); tulips, gladiolus, tuberose (Bankar, 1988; Sidhu & Arora, 1989) and Indonesian wax ginger flowers (*Tapeinochilus ananassae*) (Broschat, 1995).

5.2.2.4 Peduncle diameter

A summary on the analyses of variance that was done to determine the effects of the different nitrogen levels on the peduncle diameter of Rupert and Ronina plants grown from 7-8 cm bulbs for 2002 and 2003 is given in Table 5.27. In 2002 the peduncle diameter of only Rupert was measured whereas in 2003 the peduncle diameter of both Rupert and Ronina was measured. Only the data of those treatments that influenced the peduncle diameter significantly will be presented and discussed.

Table 5.27: Summary on the analyses of variance showing the effects of nitrogen levels on the peduncle diameter of Rupert and Ronina plants grown from 7-8 cm bulbs in 2002 and 2003

Plant	Cultivar (C)	Nitrogen (N_p)	Nitrogen (N_n)	Time (T_n)	C X N_p	C X N_n	C X T_n	N_p X N_n	N_p X T_n	N_n X T_n
2002										
Primary	na	*	ns	ns	na	na	na	ns	ns	ns
Secondary	na	*	ns	ns	na	na	na	ns	ns	ns
2003										
Primary	*	*	*	ns	ns	ns	ns	ns	ns	ns

LSD $_{(T = 0.05)}$
ns = no significant differences
*** = significant differences**
na = not available
N_p = nitrogen levels in the pot plant phase
N_n = nitrogen levels in the nursery phase
T_n = nitrogen application times in the nursery phase

5.2.2.4.1 Primary plants

5.2.2.4.1.1 Plants grown in 2002

In 2002 only the nitrogen levels in the pot plant phase influenced the peduncle diameter of Rupert significantly (Table 5.27). As mentioned earlier the peduncle diameter of only Rupert was measured. The peduncle diameter of Rupert increased from 0.77 cm at a 0 kg N ha^{-1} level to 0.88 cm at a 120 kg N ha^{-1} level whereafter it tended to decrease with higher nitrogen levels (Table 5.28).

Table 5.28: Effect of nitrogen levels in the pot plant phase on the peduncle diameter (cm) of Rupert primary plants grown from 7-8 cm bulbs in 2002

Nitrogen levels (N_p) kg ha^{-1}	Peduncle diameter
0	0.77
30	0.74
70	0.77
120	0.88
180	0.81
250	0.86
LSD $_{(T = 0.05)}$	**0.01**

5.2.2.4.1.1 Plants grown in 2003

Cultivars differ significantly in their peduncle diameter as shown in Table 5.27. The peduncle diameter of Rupert was 0.86 cm and that of Ronina 0.76 cm (Table 5.29).

Table 5.29: Effect of nitrogen levels on the peduncle diameter (cm) of Rupert and Ronina primary plants grown from 7-8 cm bulbs in 2003

Season	Cultivar		LSD $_{(T = 0.05)}$
	Rupert	Ronina	
2003	0.86	0.76	**0.02**

As can be observed from Table 5.27 nitrogen applied in the pot plant phase influenced the peduncle diameter of *Lachenalia* significantly. Inspection of Table 5.30 showed that the peduncle diameter increased from 0.73 cm at a 0 kg N ha^{-1} application to 0.85 cm at a 180 kg N ha^{-1} application whereafter it decreased to 0.83 cm at a 520 kg N ha^{-1} application.

Table 5.30: Effect of nitrogen levels in the pot plant phase on the peduncle diameter (cm) of *Lachenalia* primary plants grown from 7-8 cm bulbs in 2003

Nitrogen levels (N_p) kg ha^{-1}	Peduncle diameter
0	0.73
70	0.80
180	0.85
330	0.84
520	0.83
LSD $_{(T = 0.05)}$	**0.05**

The nitrogen applied in the nursery phase influenced the peduncle diameter of *Lachenalia* also significantly (Table 5.27). As shown in Table 5.31 the peduncle diameter increased from 0.72 cm at the 0 kg N ha^{-1} level to 0.86 cm at the 520 kg N ha^{-1} level.

Table 5.31: Effect of nitrogen levels in the nursery phase on the peduncle diameter (cm) of *Lachenalia* primary plants grown from 7-8 cm bulbs in 2003

Nitrogen levels (N_n) kg ha^{-1}	Peduncle diameter
0	0.72
250	0.85
520	0.86
LSD $_{(T = 0.05)}$	**0.03**

5.2.2.4.2 Secondary plants

The peduncle diameter of Rupert secondary plants was significantly influenced by the nitrogen levels applied in the pot plant phase as shown in Table 5.27. As indicated in

Table 5.32 the peduncle diameter increased from 0.55 cm at the 0 kg N ha^{-1} level to 0.73 cm at the 250 kg ha^{-1} level.

Table 5.32: Effect of nitrogen levels in the pot plant phase on the peduncle diameter (cm) of Rupert secondary plants grown from 7-8 cm bulbs in 2002

Nitrogen levels (N_p) kg ha^{-1}	Peduncle diameter
0	0.55
30	0.58
70	0.59
120	0.59
180	0.71
250	0.73
$LSD_{(T = 0.05)}$	**0.02**

These data showed that the peduncle of Rupert is thicker than the peduncle of Ronina. The application of nitrogen in the nursery phase as well as in the pot plant phase increased the peduncle diameter of *Lachenalia*. However, the peduncle quality of *Sandersonia* was not significantly influenced by nitrogen levels (Clark, 1997; Clark & Burge, 1999).

The results on most of the parameters that were measured emphasised the importance of proper nitrogen fertilisation in both the nursery and pot plant phases for ensuring optimum growth and development of *Lachenalia* pot plants. The fact that *Lachenalia* bulbs harvested after one season of enlargement in the nursery phase, stored in the dormant season and then planted in the pot plant phase did not showed any signs of deterioration despite of nitrogen fertilisation is therefore very promising. According to Wright (1993) the bulbs of various other flower crops are susceptible to deterioration in the dormant season when fertilised with nitrogen in the nursery phase.

The differences recorded between the cultivars Rupert and Ronina can be attributed to their growth period. Ronina was in full bloom 13-14 weeks after planting whereas Rupert was in full bloom 18-19 weeks after planting. The time of nitrogen application should therefore also be of importance in both the pot plant phase and nursery phases. This aspect warrants further investigation.

Despite of this difference in grow period both cultivars responded to nitrogen fertilisation in the pot plant phase. Neither Rupert not Ronina showed acceleration or delay in flowering on account of low or high nitrogen fertilisation as some other bulbous flower

crops (Bakly, 1974; Brewster, 1983; Clarck, 1997; Clemens *et al.*, 1998; Thomas *et al.*, 1998; Clark & Burge, 1979; Diaz-Perez, Purvis & Paulk, 2003). It seems that *Lachenalia* has a low nitrogen requirement in the pot plant phase when grown from bulbs that were properly fertilised in the nursery phase like *Alstroemeria* (Chiari *et al.*, 1999) and *Tulipa* (Gilford & Rees, 1973; Shoub & De Hertogh, 1975). Good quality bulbs of these species usually have enough reserves to supply in the needs of the pot plants. Based on Le Nard & De Hertogh (1993) classification of bulbous crops with respect to their nutrient requirements *Lachenalia* can probably be classified as a crop that required little additional nitrogen fertilisation in the pot plant phase to produce quality plants.

5.3 CONCLUSIONS

- Based on the response of the parameters that were measured it is clear that nitrogen fertilisation in the pot plant phase enhanced the ability to flower and quality of *Lachenalia*.

- The response of *Lachenalia* to nitrogen fertilisation in the pot plant phase depends very much on the nitrogen fertilisation history of the bulbs in the nursery phase.

- Differences in the characteristics of *Lachenalia* cultivars should also be taken into account when decisions are made on nitrogen fertilisation for the pot plant phase.

- The best flowering capacity and quality was obtained with a nitrogen rate of 330 to 520 kg N ha^{-1} in the pot plant phase when *Lachenalia* was grown from bulbs that were enlarged in the nursery phase with a similar nitrogen fertilisation rate.

- From the results it seems that *Lachenalia* is a bulbous crop that required little additional nitrogen fertilisation in the pot plant phase when nitrogen fertilisation in the nursery phase was proper to produce bulbs with sufficient reserves.

CHAPTER 6
SUMMARY AND RECOMMENDATIONS

6.1 SUMMARY

The flower industry is constantly looking for new and unique products. *Lachenalia*, an indigenous bulbous crop, with its many varieties is one such a crop with great potential not only as a pot plant but also as cut flowers and garden bulbs. As in the case of many other new crops very little is known on the production aspects of *Lachenalia*.

Lachenalia bulblets first go through an enlargement (nursery) phase before bulbs are ready for the export market. The main aim of this phase is to produce bulbs of export quality in the shortest possible time. Most research up to now was done in sand culture and little is known on the response of *Lachenalia* bulblets planted in soil when fertilised with nitrogen, phosphorus and potassium. The influence of nitrogen fertiliser applied during the enlargement phase on the growth and flowering of replanted *Lachenalia* bulbs, in the pot plant phase, is also not yet well studied. It is well established that an interaction between nitrogen and phosphorus and also between nitrogen and potassium exist. Little or if any research is done up to now on the role played by these interactions on *Lachenalia* bulb quality.

The main objective therefore of this study was to quantify the effect of nitrogen, phosphorus and potassium fertilisation on the growth, yield and quality of *Lachenalia* cultivars when cultivated in soil in both the nursery and pot plant phases. In order to achieve this three different pot trials was conducted in the greenhouse.

Trial one

This trial was done to determine the response of two *Lachenalia* cultivars namely; Rupert and Ronina bulblets to nine different nitrogen levels (0, 30, 70, 120, 180, 250, 330, 420 and 520 kg N ha^{-1}) applied on three different application times (T_1, T_2 and T_3) in the nursery phase.

No nutritional disorders were observed on the *Lachenalia* plants in this study, even those plants not fertilised with nitrogen. All the bulbs harvested after one season of

enlargement from these plants reached a circumference of 6 cm or more which is sufficient for export standards.

Results showed clear differences between the Rupert and Ronina cultivars irrespective of nitrogen fertilisation. Ronina plants had in most cases a larger leaf area than Rupert plants. The bulbs of Ronina were also larger than the bulbs of Rupert. Except for potassium, the content of nitrogen, phosphorus, calcium and magnesium were higher in Rupert than Ronina bulbs. The carbohydrate indices, *viz.* D-glucose, sucrose and starch were also higher in Rupert than Ronina bulbs.

Furthermore nitrogen application did influence the growth and development of *Lachenalia* plants in the enlargement phase. Higher nitrogen levels positively influenced the leaf area of the plants. Bulb fresh mass and circumferences also increased with an increase in nitrogen levels but the firmness of bulbs decreased. Increasing nitrogen levels caused an increase in bulb nutrient content but at high levels it started to decrease. The bulbs' D-glucose content decreased whereas the sucrose and starch content increased with increasing nitrogen levels.

The two cultivars differed in their response to nitrogen application times. Based on leaf area together with bulb nutrient and carbohydrate content it appeared that the best results were obtained with the T_3 treatment, *viz.* when the nitrogen is applied in four equal applications through the growing season of *Lachenalia*.

Trial two

This trial was done to establish the response of the two *Lachenalia* cultivars (Rupert and Ronina) to nitrogen (0, 70, 180, 330 and 520 kg N ha^{-1}) and phosphorus (0, 10, 30, 50 and 80 kg P ha^{-1}) or potassium (0, 70, 180, 330 and 520 kg K ha^{-1}) fertilisation in the nursery phase.

Data from this pot trial showed that the two cultivars differed in that Ronina plants had a larger leaf area than Rupert plants. Ronina bulbs were also larger and softer than Rupert bulbs. Rupert bulbs contained more nitrogen, phosphorus, potassium, calcium and magnesium than Ronina bulbs. The glucose content of Ronina bulbs was higher than that of Rupert bulbs.

Higher nitrogen levels influenced the leaf area of *Lachenalia* plants in the enlargement phase positively. Both the circumference and firmness of the bulbs increased with an increase in nitrogen levels. Although not always significant the bulbs' nitrogen, phosphorus, potassium and magnesium content increased whereas the calcium content decreased with an increase in nitrogen level. Higher levels of nitrogen increased the sucrose and starch content and decrease the D-glucose content of the bulbs.

The interaction between nitrogen and phosphorus levels did not influenced any of the parameters measured. However, the firmness of Rupert bulbs increased whereas the firmness of Ronina bulbs decreased with higher phosphorus levels. The sucrose and starch content of bulbs from both cultivars increased with increasing phosphorus levels.

The interaction between nitrogen and potassium levels influenced the D-glucose, sucrose and starch content of *Lachenalia* bulbs but no clear trends emerged. However increasing potassium levels increased the leaf area of the plants but at high levels it started to decrease.

The fact that neither phosphorus nor potassium influenced the growth and development of *Lachenalia* can probably be ascribed to that the soil contained sufficient of those two nutrients, *viz.* 15 mg P kg^{-1} and 166 mg K kg^{-1}.

Trial three

This trial was to ascertain the response of the two *Lachenalia* cultivars, Rupert and Ronina, to nitrogen applied in the pot plant phase (0, 30, 70, 120, 180, 250, 330, 420 and 520 kg N ha^{-1}). Bulbs with fertilisation history in the nursery phase were planted *viz.* three nitrogen levels (0, 70, 250 and 520 kg ha^{-1}) and two application times (T_1 and T_2).

The leaf area of Ronina primary plants was larger than Rupert primary plants especially when fertilised with nitrogen. The leaf area of primary plants was also promoted by nitrogen fertilisation in the nursery phase. Nitrogen applied in the nursery phase and nitrogen applied in the pot plant phase influenced the number of florets formed per inflorescence positively. Increased nitrogen levels in the nursery phase increased the peduncle length of *Lachenalia* plants. The peduncle diameter was increased with an increase in nitrogen levels in the nursery phase as well as nitrogen levels in the pot plant phase. Results of this pot trial showed that *Lachenalia* has a low nitrogen requirement in

the pot plant phase when grown from bulbs that where properly fertilised in the nursery phase.

6.2 RECOMMENDATIONS

Based on the results from these three pot trials the following recommendations can be made with respect to the fertilisation of *Lachenalia* when cultivated in soil:

- Characteristics of cultivars must be taken in account by *Lachenalia* bulb producers when fertilisation decisions are made for the enlargement phase.

- By considering the response of the different parameters to nitrogen fertilisation it seems that the optimum level varied between 250 and 520 kg N ha^{-1}. It seems that 330 kg N ha^{-1} can be considered as an optimum nitrogen level for bulb production in the enlargement phase.

- The best response will be obtained in the enlargement phase when the nitrogen is applied in four equal applications through the growing season of *Lachenalia*.

- Nitrogen fertilisation in the nursery phase will result in higher nutrient and carbohydrate content in *Lachenalia* bulbs which will promote the leaf area and flower quality of pot plants.

- The best flowering capacity and quality will be obtained with a nitrogen rate of 330 to 520 kg N ha^{-1} in the pot plant phase when *Lachenalia* was grown from bulbs that were enlarged in the nursery phase with a similar nitrogen fertilisation rate.

- Characteristics of cultivars must also be taken in account when decisions are made on nitrogen fertilisation in the pot plant phase

In retrospect only a few aspects on the fertilisation of *Lachenalia* were addressed in this study and in future the following warrants further investigation:

- The response of *Lachenalia* to even higher application of nitrogen in the nursery phase to obtain a proper crop response curve to establish an optimum nitrogen level.
- The occurrence of post harvest disorders and weight loss of *Lachenalia* bulbs treated with high levels of nitrogen.
- The response of *Lachenalia* to different ratios of ammonium to nitrate applications
- The response of *Lachenalia* in the nursery and pot plant phases to phosphorus and potassium fertilisation when grown in soil with low levels of these two nutrients.
- The response of *Lachenalia* to different nitrogen application times in the pot plant phase, especially in coordination with the growth stages.

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