THE EFFECT OF REGULATED DEFICIT IRRIGATION ON THE PRODUCTION AND FRUIT QUALITY OF PEACHES

by

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Thesis presented in partial fulfilment of the requirements for the degree

of

MASTER of SCIENCE

at the

UNIVERSITY OF STELLENBOSCH

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Maart 2002

DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted at any University for a degree.

SUMMARY

The effects of regulated deficit irrigation on the production and fruit quality of peaches were investigated. A field trial was carried out in a twelve-year-old Neethling peach orchard at Robertson Experiment Farm. Treatments consisted of five different soil water depletion levels applied during five different growth stages. Irrigation was applied at the five soil water depletion levels of which T1 was regarded as relatively wet (irrigation was applied when the average soil matric potential reached *ca.* –50 kPa). T2 was regarded as normal (irrigation applied at *ca.* –100 kPa) and three different deficit irrigation regimes T3, T4 and T5, irrigated at soil matric potentials of *ca.* –200, -400 and –800 kPa respectively. The five growth stages were Stage 1 (cell growth), Stage 2 (slow fruit growth), Stage 3 (rapid fruit growth), Stage 4 (ripening) and Stage 5 (post-harvest). The soil water content was monitored and irrigation was scheduled by means of a neutron probe. Vegetative and fruit growth, fruit mass and production were measured. Fruit were examined for bruises and firmness.

Fruit size, fruit mass, fruit quality, as well as production, were not sensitive to water deficits during the different growth stages with a normal crop load. However, a tendency to reduced shoot growth with decreasing soil matric potentials was observed during the slow fruit growth, rapid fruit growth as well as the ripening stages. The application of deficit irrigation during the slow fruit growth or post-harvest stages can save substantial amounts of water with a normal crop load, provided that normal irrigation is applied during the other growth stages.

A combination of water deficits during the ripening stage and high crop load resulted in smaller fruit and lower production. Fruit size, fruit mass, fruit quality, as well as production, were not sensitive to water deficits during either the cell growth, slow fruit growth or post harvest growth stages, provided that normal irrigation is applied in the other growth stages. Irrespective of crop load, soil matric potentials up to –200 kPa can be applied during anyone of the growth stages without seriously affecting the final fruit size, fruit mass, fruit quality or production. However, this soil water deficit may then only be applied in one of the growth stages and normal irrigation must be applied in the other four stages.

Although deficit irrigation reduced seasonal water consumption, it could not be justified as water saving with a heavy crop load.

OPSOMMING

Die effekte van gereguleerde tekort besproeiing op die produksie en vrugkwaliteit van perskes is ondersoek. 'n Veldproef is in 'n twaalf-jaar-oue Neethling perskeboord te Robertson Proefplaas uitgevoer. Die behandelings het bestaan uit vyf grondwater-ontrekkingspeile wat gedurende vyf verskillende groeistadiums toegepas is. Besproeing is toegedien by vyf verskillende grondwaterontrekkingsvlakke waar T1 beskou is as redelik nat (besproeiing is toegedien wanneer gemiddelde grondmatrikspotensiale *ca.* –50 kPa bereik het). Behandeling T2 is as normaal beskou (besproeiing toegedien by *ca.* –100 kPa en drie verskillende regimes van tekort besproeiing naamlik T3, T4 en T5 wat onderskeidelik by *ca.* –200, –400 en –800 kPa besproei is. Die vyf groeistadiums was onderskeidelik Stadium 1 (selgroei), Stadium 2 (stadige vruggroei), Stadium 3 (vinnige vruggroei), Stadium 4 (rypwording) en Stadium 5 (na-oes). Die grondwaterinhoud is gemonitor en die besproeiing is met behulp van 'n neutronpeiler geskeduleer. Vegetatiewe groei, vruggroei, vrugmassa en produksie is gemonitor. Vrugte is ook ondersoek vir kneusbaarheid en fermheid.

Geen negatiewe effek as gevolg van watertekorte is ten opsigte van vruggrootte, -massa, -kwaliteit sowel as produksie waargeneem gedurende die verskillende groeistadiums waar 'n normale vruglading gehandhaaf is nie. 'n Afnemende tendens in lootgroei met afnames in grondwatermatrikspotensiale is egter gedurende die stadige- en vinnige vruggroei-stadiums, asook in die vrugrypwordingstadium, waargeneem. 'n Aansienlike hoeveelheid water kan bespaar word deur gereguleerde tekort besproeiing gedurende die stadige vruggroei- of na-oes-stadiums toe te pas, mits 'n normale vruglading gehandhaaf word en normale besproeiing in die ander groeifases toegedien word .

'n Kombinasie van watertekorte en 'n hoë vruglading gedurende die rypwordingstadium het tot kleiner vrugte en laer produksies gelei. Vruggrootte, -massa, -kwaliteit en produksie is egter nie gevoelig vir watertekorte gedurende die selgroei-, stadige vruggroei- en na-oes-stadiums nie.

Tekort besproeiing by 'n grondwatermatrikspotensiaal van tot –200 kPa kan egter met 'n normale en hoë vruglading in enige van die fases toegepas word, sonder om die finale vruggrootte, -massa, -kwaliteit of produksie nadelig te beïnvloed. Hierdie tekort besproeiingsregime mag egter slegs in een

van die groeistadiums toegedien word en normale besproeiings moet in die ander groeistadiums toegedien word.

Alhoewel tekort besproeiing die seisoenale waterverbruik verminder het, kan dit nie geregverdig word as 'n waterbesparende praktyk indien 'n hoë vruglading gehandhaaf word nie.

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to the following:

Dr. J. E. Watts for his assistance, guidance, patience and support with this study and with the preparation of this thesis.

Mr. J. H. M. Karsten for his assistance and constructive criticism.

The Agricultural Research Council for making this study possible and for permission to use the results for thesis purposes.

The staff of the Soil Science Division of ARC Infruitec-Nietvoorbij for technical assistance and in particular Messrs. Frikkie Coetzee and André Ebrahim.

Mr. Frikkie Calitz for guidance on the statistical aspects of this study.

The Water Research Commission for financial assistance.

My family, particularly my mother and late father, for their loving encouragement.

CONTENTS

CHAPTER 1

INTRODUCTION AND SCOPE OF STUDY

Water stress experienced by fruit trees during periods of drought can be a limiting factor in fruit production. Such periods of drought occur from time to time in the Republic of South Africa. The effective utilisation of water is therefore of the utmost importance to the fruit producer and the country as a whole.

Economically viable fruit production in the Western Cape region of South Africa is only possible under irrigation. However, the increasing competition of industry and urbanisation for water currently allocated to agriculture necessitates a more efficient utilisation of water by the agricultural sector. Expected increases in water tariffs and predicted water shortages will also hamper the further development of irrigable land. Improved irrigation scheduling is therefore imperative to ensure optimal utilisation of water. For example, the amount of water allocated to producers in the Breede River Valley during the 1998/99 season was in the order of 7 450 cubic meters per hectare, whereas the estimated water requirement for peaches at Robertson Experiment Farm was 7 853 cubic meters per hectare. A water deficit of 400 cubic meters per hectare was expected for the season. However, application of regulated deficit irrigation from October to December could result in an estimated water saving of 1 680 cubic meters per hectare. This would mean that a saving of 17% on the water allocation could be achieved.

The current trend towards high-density plantings necessitates different managerial practices to ensure the control of vegetative growth. Optimum tree growth and optimum water utilisation can be obtained by regulated deficit irrigation (RDI), a practice whereby plant water deficits are manipulated by applying less water through irrigation than the trees would have used under normal conditions (Mitchell *et al.* 1984). The reason why RDI is effective relates to the growth pattern of shoots and fruit. For most deciduous fruit trees, the shoots grow rapidly during the early season and their growth slows down as rapid fruit growth begins. Water stress during this period will reduce the growth of shoots without markedly affecting fruit growth (Goodwin 2000).

Information on water use by trees under varying regulated deficit irrigation management systems, and the relationship to water use under conventional irrigation, would help to understand any adaptive process. It would also assist in the application of regulated deficit irrigation practices.

Research on the response of fruit trees to regulated deficit irrigation during different phenological growth stages was therefore undertaken in order to optimise the application of this technique .

The objectives of the study were:

- Firstly, to quantify the effect of regulated water deficiencies on the production and quality of peaches.
- Secondly, to determine the effect of regulated water deficiencies during different phenological growth stages on shoot-, fruit-and tree growth.
- Thirdly, to determine the water consumption of peach trees under regulated water deficiencies.

CHAPTER 2

LITERATURE REVIEW

The effect of water deficits on fruit growth

According to Zahner (1968), the stage of fruit enlargement in relation to soil moisture and irrigation practices has been studied for many decades, for example in *Citrus* by Bartholomew (1926), in *Pyrus* by Lewis, Work & Aldrich (1935), in *Malus* by Boynton (1937) and in *Prunus* by Hendrickson and Veihmeyer (1950). Zahner (1968) also concluded that the rate of fruit enlargement is strongly reduced following the rapid depletion of soil moisture and that the final fruit size and quality are strongly regulated by the amount of water available during fruit enlargement. Gospodinova (1997) found that water deficit under 50% evapotranspiration, applied during the second fruit development stage, can lead to a slightly negative effect on fruit quality. In a Golden Delicious apple orchard in Spain, low levels of irrigation resulted in a higher frequency of small fruits (Bonany *et al.* 1998). Fruit growth is the limiting factor in developing a usable water management system for apple size control (Ebel & Proebsting 1993). Regulated deficit irrigation sometimes suppresses fruit growth. However, there is some evidence of enhanced fruit growth rate when full irrigation is restored following the deficit period (Mitchell *et al.* 1982, 1984, 1986, Li *et al.* 1989). According to Chalmers *et al.* (1981), less severe water-withholding treatments during the dry weight stage of fruit growth increased fruit yield by as much as 36% when compared to the fully irrigated treatments, while reducing vegetative growth. Chalmers *et al.* (1983) states that reduced irrigation treatments suppressed fruit growth only slightly and then only when water was withheld from the trees during dry weight stage 2 (slow fruit growth) and stage 3 (rapid fruit growth and fruit ripening). They also found that, when all treatments received an equal and full allocation of water during dry weight stage 3 (rapid fruit growth and fruit ripening), fruit on trees that had previously received a restricted allocation of water, grew substantially faster, resulting in larger fruit at harvest.

Kotzé (1991) reported that the most rapid increase in fruit size, especially in the case of stone fruit, took place during the ripening stage i.e. the last two to three weeks before harvest. Apart from the fact that cell growth is decreased by water stress, water and nutrients can also be extracted from the fruit.

It is therefore clear that this stage of development is extremely critical and water stress will not only adversely affect fruit size and therefore yield, but also fruit quality.

According to Li *et al.* (1989, and references therein), the growth rate of peach fruit under conditions of severe water stress was not at all affected during the first stage of rapid fruit growth, although a very low leaf water potential and stomatal closure were observed. They also found that fruit expansion was significantly limited by water deficits during the final stage of rapid fruit growth. This suggests that cell enlargement appears more sensitive to water stress than cell division (Hsiao 1973). Li *et al.* (1989) also reported that a period of water stress imposed on peach trees during the stage 1 (first stage of rapid fruit growth) and stage 2 (fruit pith hardening) favoured fruit growth after alleviating water stress status in the trees. Mitchell & Chalmers (1982) also observed this effect on fruit growth during the post-stress period. Since the rate of cell enlargement is dependent on the cell's gross extensibility and turgidity status (Hsiao 1973), and the cell turgidity status in those water-stressed fruits is the same as in the non-stressed fruit during the post-stress period, it is possible that cell extensibility would be increased. This effect may be due to the violent changes of water status in the cells, from a good turgidity status to a significant water deficit, or inversely during the period of water stress or at the time of water stress removal (Li *et al.* 1989).

According to Goodwin (2000), fruit growth is rapid during the ripening stage and water stress must be avoided during this stage as the tree needs ample water to maintain fruit growth. This viewpoint is supported by Parker & Marini (1994), as they state that drought during the ripening stage will reduce fruit size and quality most seriously.

Fruit growth during the day was less and fruit shrinkage was greater with a heavy crop load than with a light crop load of peaches (McFadyen *et al.* 1996). This appeared to be correlated with lower fruit water potential and turgor potential in the heavy crop load. They conclude that increased crop loads increased fruit water deficits, which reduced fruit growth. The reduction in fruit size commonly associated with increased crop load may be due, at least in part, to the effect of crop load on fruit water relations.

The effect of water deficits on vegetative growth

Chalmers *et al.* (1981) found that a decrease in the rate of water application during spring had a strong effect on the vegetative growth of peaches. They also concluded that irrigation could be developed into a powerful tool to manipulate plant growth for greater fruit-fullness and less vegetative growth. However, increased yields with reduced irrigation can only be obtained when the tree has excess vegetative growth that can be suppressed in favour of fruit growth. They also suggested that appropriate irrigation strategies must be determined in accordance with the natural vigour of the crop, the age of the trees, the soil type, the fruit growth as well as the crop load.

Ten years of research at Tatura (Victoria, Australia) on peach and pear trees showed that the application of regulated deficit irrigation practices from the beginning of the growing season, can significantly limit vegetative growth, increase fruit yields and reduce the tendency to biennial bearing (Decroix 1992). Experiments performed on peaches (cv. Carnival) in Tunisia indicated that a restriction of water supply decreased shoot elongation and branch thickening by up to 35% and 12% respectively (Ghrab *et al.* 1998). Girona *et al.* (1993) indicated that regulated deficit irrigation caused only an 8% reduction in trunk growth relative to a well-watered control in peach trees (cv. Cal Red). However, they found no clear visible indications of decreased shoot growth with the regulated deficit irrigation trees compared to well-watered controls. This was probably a consequence of the relative long time needed to achieve moderate water stress in the RDI treatments on a deep soil. Research on peach trees (cv. Golden Queen) by Mitchell & Chalmers (1982) in Australia indicated that by withholding as much as 0,875 of the irrigation requirements of the tree (determined from pan evaporation) during periods of little growth or during the period of declining growth rate of the fruit, vegetative growth can be reduced by 75% without reducing fruit yield. In a lysimeter trial at the Tatura Centre (Victoria, Australia), Boland *et al.* (1993) reported a reduction in shoot extension, leaf area index, pruning weights and trunk cross-sectional area with RDI treatments in peaches.

Li *et al.* (1989) reported that restricted water supply instantaneously inhibited shoot elongation and shoot diameter increase in peach trees. They also found that neither after-effect nor favourable action of water stress were evident during the post-stress period. Their results also indicated that water deficit had no effect on leaf area. Based on the intensity of the growth inhibition by water deficiency, they classified the sensitivity of organs to water stress in the following order of severity: shoot diameter increase > shoot elongation growth > fruit growth > expansion of leaf area. They concluded that it is possible to control the vigour of peach trees without reducing fruit size and yield, and without affecting fruit quality, by applying deficit irrigation during the first rapid fruit growth and pith hardening phases.

In a study conducted near Prosser, Washington State (U.S.A.), Ebel *et al.* (1995) reported that RDI favoured reproductive growth over vegetative growth by suppressing vegetative growth in pear trees (cv. Redspur Delicious/MM.106). Regulated deficit irrigation combined with trickle irrigation reduced the number and length of vigorous shoots when compared to furrow-irrigated control trees. They also reported that crop load did not affect shoot length, but they obtained an inverse relationship between the number of vigorous shoots and crop load.

According to Chalmers *et al.* (1985) summer and winter pruning of peach trees can also be reduced and simplified. Summer shoot growth was decreased by 75% by applying RDI. Winter pruning would therefore become simpler, lighter and less expensive.

The effect of water deficits on production

Research on peaches (cultivar Carnival) in Tunis, Tunisia, indicated that a 30% irrigation restriction reduced crop yield and fruit load by respectively 10% to 25% and 5% to 23%, respectively, compared to the well-watered control (Ghrab *et al.* 1998). Boland *et al.* (1993) found that the yield of RDI trees (*Prunus persica* L. Batsch) irrigated weekly was reduced compared to that of the non-limiting irrigation treatments. In a trial on Bartlett (Williams' Bon Chretien) pears, the average yields over 5 years were increased by 20% and irrigation volume was reduced by 29% (Decroix 1992).

Fruitfulness increased as vegetative vigour in deciduous trees was reduced by RDI (Jerie *et al.* 1989). Flowering, fruit set, fruit number at harvest and in most cases total yield, were all increased by applying RDI to peach and pear trees (Mitchell *et al.* 1984; Mitchell *et al.* 1986; Mitchell *et al.* 1989).

The effect of water deficits on photosynthesis and stomatal conductance

Girona *et al.* (1993) stated that the leaf water potential of peach trees (cv. Cal Red) under RDI appeared to be less affected by plant water deficits than the stomatal conductance of the same trees during the second growth stage. Leaves of trees subjected to deficit irrigation were therefore photosynthetically more water-use efficient during the latter part of the stress period than those of the non-stressed trees. Boland *et al.* (1993) indicated that adaptation to water stress during RDI was associated with stomatal closure and reduced leaf area.

According to Kotzé (1991) stomata close quite rapidly when a tree is subjected to water stress. This already takes place at relatively low water tensions, especially during dry, hot days. The result is a decrease in the rate of photosynthesis with the concomitant decrease in shoot, leaf and fruit growth. The closure of stomata will also lead to decreased transpiration rates. Severe water stress will also retard cell division.

The effect of water deficits on fruit quality

Zahner (1968) and Ryall & Aldrich (1944) reported that well-watered pear trees produced fruits smoother in texture, higher in sugar content and lower in acids than the fruits on trees growing under normal summer soil water deficits. According to Smart & Coombe (1983), water stress can delay sugar accumulation in grapes through increased crop, reduction in photosynthetic rate or even premature leaf senescence. However, mild stress may enhance sugar accumulation by suppressing shoot growth or reducing canopy density, thereby permitting higher photosynthetic rates by interior leaves. According to Ebel & Proebsting (1993), smaller apples were obtained at harvest with the RDI-treatment compared to well-watered treatments. The fruit also had a higher concentration of soluble solids and lower titratable acidity. Starch degradation was also delayed in the RDI fruit and firmness of the fruit was not affected. Gospodinova (1997) found that water deficit at 50% evapotranspiration, applied during the second fruit growth stage, provided a slightly negative effect on the quality of the fruit. Water stress applied during the first two growth stages did not significantly affect peach fruit storage capacity (Li *et al.* 1989).

Researchers, from the Ecophysiological and Horticultural Research Unit, Paris, studied fruit growth and the accumulation of sugars and acids (Anon 2000). They found that peach fruit size is a vital characteristic in determining quality. Almost 50% of the dry mass of the fruit consists of sucrose, which accumulates in the fruit particularly during the fruit ripening stage. The fruit's carbon supply (mainly composed of sugars) depends on the flow of water, which is the transporting agent. If a peach has a poor water supply, it will also have a poor supply of sugar nutrients, which will be detrimental to fruit quality.

Li *et al.* (1989) reported that smaller fruit, higher levels of total soluble solids and longer storage capacity after harvest were characteristic of fruit from trees subjected to water stress in the fruit ripening stage.

Cell enlargement and subsequent fruit growth is dependent on water availability during the ripening stage (Parker & Marini 1994). Sugars resulting from photosynthesis accumulated in the fruit during the final few weeks before harvest. Drought stress during this stage resulted in small, poorly-coloured and poor-tasting fruit, which matured up to 10 days later than normal.

Water consumption

According to Girona *et al.* (1993 and references therein) RDI treatments on a peach (cv. Cal Red) orchard, resulted in a 40% saving in irrigation water. These savings were achieved with only minor effects on fruit size and production. Decroix (1992) concluded that the RDI system of irrigation scheduling can save considerable amounts of water without reducing yields with the additional benefit of reducing labour requirements for pruning. The results of Boland *et al.* (1993) showed that peach trees irrigated under frequent RDI with non-saline water were highly productive and efficient in the use of water throughout the season. According to Mitchell & Chalmers (1982), all reduced irrigation treatments saved considerable water. A replacement of 12,5% E_{ps} (evaporation over the planting square) to mid January followed by 100% replacement to harvest required 6 000 $m^3.ha^{-1}$ compared to 9 000 $m^3.ha^{-1}$ for 100% replacement during the season. They concluded that irrigation methods based on this approach prove to be highly suitable for growing fruit in areas with limited water supplies.

Summary

According to Chalmers *et al.* (1985) plants respond to RDI in a highly predictable and quantifiable manner. Shoot and secondary growth were suppressed in direct proportion to the water deficit. Fruit growth was also stimulated in a predictable way. They also reported that the most severe water deficit that they applied was with a water withdrawal of 87,5% of the normal water requirement, applied over 66% of the growing season. This reduced total water consumption by 33% and vegetative growth by 75% without reducing fruit size or production.

CHAPTER 3

THE EFFECT OF DEFICIT IRRIGATION ON THE PRODUCTION AND FRUIT QUALITY OF PEACHES WITH A NORMAL CROP LOAD

3.1 INTRODUCTION

There is little quantitative information available on the cropping response of fruit trees to water stress during different phenological stages. Chalmers *et al.* (1984) reported that final fruit size, number of fruit or production of peaches and apples were not affected by reduced water supply during the early stages of fruit growth until the end of shoot growth. The effects of water deficits during the rapid fruit growth stage on the final fruit size have been reported as being of little importance (Irving & Drost 1987). However, Lötter *et al.* (1985) reported that water deficits during the rapid fruit growth stage had a negative effect on the final fruit size.

In this study experiments were carried out in order to study the behaviour of peach trees under conditions of water deficits during the different phenological growth stages.

3.2 MATERIAL AND METHODS

3.2.1 Experimental design

The experiment was carried out during the 1998/99-season at Robertson in the Western Cape Province, Republic of South Africa, an area especially suited for the production of peaches (Figure 1). However, as the average annual rainfall at Robertson only amounts to 277,5 mm during the growth season, additional irrigation is required for the production of fruit. The field trial was established on the Experiment Farm of Infruitec-Nietvoorbij (an Institute of the Agricultural Research Council), located 33° 50' S, 19° 54' E and 156 m above sea level. An automatic weather station, situated approximately 500 m from the orchard, recorded daily precipitation (mm), hourly maximum and minimum temperature (°C), total daily solar radiation ($MJ.m^{-2}$), average daily wind speed ($m.s^{-1}$) at a height of 2 m and relative humidity (%). Daily evaporation from an American Class A pan was also recorded.

The orchard was established in June 1987 in a North-South oriented hedgerow planting pattern and the trees were trained as a closed vase. Tree spacing was 5 m x 3 m with four trees *(Prunus persica*

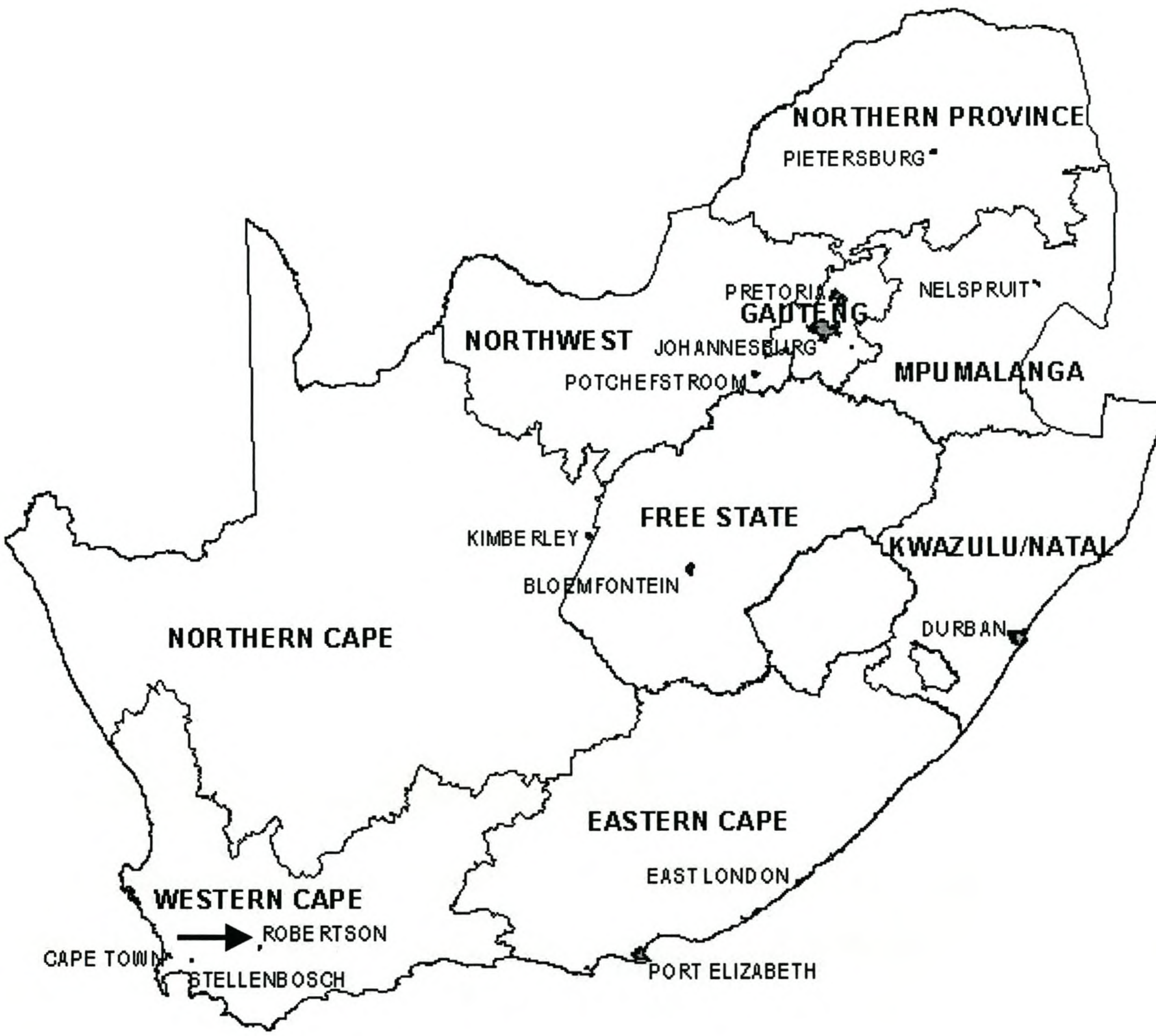

Figure 1. Map of the Republic of South Africa illustrating the locality where the trial was carried out.

(*L.*) Batsch) cultivar 'Neethling' on seedling rootstock, per treatment plot. Two guard trees bordered each plot.

Treatments consisted of five different soil water regimes applied during the following five growth stages:

Stage 1 - Cell enlargement and cell growth (*ca.* 40 days)

Stage 2 - Slow fruit growth (*ca.* 5 weeks)

Stage 3 - Rapid fruit growth (*ca.* 5 weeks)

Stage 4 - Ripening (*ca.* 7- 8 weeks)

Stage 5 – Post-harvest (*ca.* 12 weeks).

Irrigation was applied at the following five soil water depletion levels:

T1 - Relatively wet (irrigation was applied when the average soil matric potential for the soil profile of 600 mm reached *ca.* –50 kPa)

T2 - Normal (Irrigation was applied when the average soil matric potential for the soil profile of 600 mm reached *ca.* –100 kPa)

T3 - Deficit (Irrigation was applied when the average soil matric potential for the soil profile of 600 mm reached *ca.* –200 kPa)

T4 - Deficit (Irrigation was applied when the average soil matric potential for the soil profile of 600 mm reached *ca.* –400 kPa)

T5 – Deficit (Irrigation was applied when the average soil matric potential for the soil profile of 600 mm reached *ca.* –800 kPa).

Irrigation treatments T3, T4 and T5 were regarded as deficit irrigation. These treatments were applied during only one of the growth stages each while the T2 treatment was applied for the remainder of the season. This resulted in twenty-five treatment combinations (Table 1). Each treatment was replicated three times.

Table 1. Irrigation treatments applied during the regulated deficit irrigation field trial with Neethling peaches at the Robertson Experiment Farm.

Treatment no.	Soil matric potential (-kPa)				
	Stage 1 (Cell growth)	Stage 2 (Slow fruit growth)	Stage 3 (Rapid fruit growth)	Stage 4 (Ripening)	Stage 5 (Post harvest)
A1	**50**	100	100	100	100
A2	**100**	100	100	100	100
A3	**200**	100	100	100	100
A4	**400**	100	100	100	100
A5	**800**	100	100	100	100
A6	100	**50**	100	100	100
A7	100	**100**	100	100	100
A8	100	**200**	100	100	100
A9	100	**400**	100	100	100
A10	100	**800**	100	100	100
A11	100	100	**50**	100	100
A12	100	100	**100**	100	100
A13	100	100	**200**	100	100
A14	100	100	**400**	100	100
A15	100	100	**800**	100	100
A16	100	100	100	**50**	100
A17	100	100	100	**100**	100
A18	100	100	100	**200**	100
A19	100	100	100	**400**	100
A20	100	100	100	**800**	100
A21	100	100	100	100	**50**
A22	100	100	100	100	**100**
A23	100	100	100	100	**200**
A24	100	100	100	100	**400**
A25	100	100	100	100	**800**

3.3.2 Crop load

Fruit were thinned out by hand at the end of the first growth stage to an average of 380 fruit per tree.

3.3.3 Soil preparation and soil analysis

Soil samples were taken on experimental plots at depths of 0-300 mm, 300-600 mm and 600-900 mm. The soil samples were analysed for water-holding capacities and soil water retention curves in accordance to the method of De Kock *et al.* (1977), as well as particle size distribution (De Kock undated). Although the soil properties varied throughout the orchard, it could be regarded as a sandy loam. Soil preparation was done before planting to a depth of 600 mm and plastic sheeting was installed between plant rows up to a depth of 1200 mm in order to avoid any lateral movement of water between plots.

3.3.4 Water application

The irrigation system consisted of MicroJet (blue-base) micro-emitters, spaced 5 m X 2,5 m, with a delivery rate of 32 $\ell.h^{-1}$, which wetted a strip of 3,0 m in the plant row. Water meters (Kent) recorded the total amount of water applied per treatment.

3.3.5 Monitoring of soil water content

Neutron probe access tubes were installed 1000 mm from the tree trunk in the plant row in each experimental plot. The neutron probe (Campbell Pacific Nuclear, California, USA) was calibrated in different soil types according to Karsten *et al. (1975).* Different calibration curves were obtained for depths shallower than 300 mm (Karsten & Van der Vyver 1979). The clay and silt contents for each measuring depth of each experimental plot were calculated from the particle size analyses. These values were entered into a computer program (program custom-developed by Mr. Karsten, an associate researcher at ARC Infruitec-Nietvoorbij) in order to calculate different calibration curves for each measuring depth of each experimental plot (Karsten *et al.* 1975). The volumetric soil water content was determined before and after each irrigation with the aid of the neutron probe at depths of 200, 300, 600 mm. These results were related to soil water tension by means of the different soil water retention curves. Irrigation was applied when the required soil water tensions were reached.

3.3.6 Growth measurements

There were twenty-five treatment combinations replicated three times with four experimental trees per replicate. In order to reach a manageable amount of fruit to be measured, it was decided to monitor the growth of four fruit per tree. This amounted to 1200 fruit measured per occasion. Forty-eight fruit per treatment were thus labelled and fruit growth was measured at fortnightly weekly intervals with the aid of electronic callipers (Mitutoyo Corporation, Japan). Twenty-four shoots per treatment (two shoots per tree) were labelled and shoot growth was measured with standard measuring tapes. The percentage shoot growth was determined as follows:

$$\text{\% Shoot growth} = \frac{\text{Shoot length at end of growth stage} - \text{Shoot length at start of growth stage}}{\text{Shoot length at start of growth stage}} \times \frac{100}{1}$$

Fruit and shoot growth measurements commenced after the fruit was thinned out at the start of Stage 2 at the beginning of October and continued until harvest. Tree stem circumferences were measured with standard measuring tapes at the start of the growing season and at the end of each growth stage. Tree volumes were estimated by measuring the height and the mean diameter of each tree's canopy with standard measuring tapes. Assuming that the shape of the trees were conical, the following formulae was used to calculate the volume of the trees:

$$\text{Volume} = 1{,}047r^2h$$

Possible effects of soil matric potentials on stem, shoot and fruit growth as well as tree volume were investigated for the different growth stages.

3.3.7 Harvest procedure

Fruit was selectively harvested at the standard degree of ripeness. This necessitated four harvests at weekly intervals. During each harvest, the mass of fruit from each experimental plot was determined separately. Simultaneously, fifty fruit from each experimental plot were randomly sampled. The mass of the samples were measured in order to obtain the average fruit mass of each experimental plots at each harvest. The weighted average fruit mass, according to the total mass of fruit per experimental plot at each harvest, was calculated to obtain the average fruit mass at harvest.

3.3.8 Fruit quality measurements

A sample of 45 fruit per treatment was collected at harvest and bruised according to the method of Robitaille & Janick (1973). Bruise volumes were determined after a period of 14 days of cold storage at 4°C after harvest using the equation of Pictian & Sun as referred to Topping & Luton (1986). The firmness of 45 fruit per treatment was determined one day after harvest according to the method of Bramlage (1986) and Truter (undated), with a dial-type penetrometer (Facchini, Alfonsine, Italy), mounted on a modified drill stand. The plunger had a diameter of 11 mm. Skin was removed on two opposite sides of a fruit and two readings were taken on each fruit. The juice of individual fruit was analysed for sugar content with a calibrated refractometer using the method of Bramlage (1986). Fruit and leaf samples of each treatment were analysed for chemical composition according to standard laboratory techniques (AOAC 1995).

3.3.9 Water consumption

Water consumption of the trees during each growth stage was determined by means of a water balance equation:

$$ET = SWC_b + R + I - SWC_e$$

Where ET = Water consumption during the growth stage (mm)

SWC_b = Water content of the soil profile at the start of the growth stage (mm)

SWC_e = Water content of the soil profile at the end of the growth stage (mm)

R = Rainfall during the growth stage (mm)

I = Irrigation applied during the growth stage (mm)

The total water consumption of a specific treatment was considered as the water consumption during the stage when the irrigation treatment was applied plus the water consumption for the specific treatment during the rest of the season when normal irrigation was applied.

Before each irrigation the soil water content of the specific treatment was measured with the neutron probe and the amount of water to be applied in order to reach field capacity, was calculated.

In order to ensure that drainage during irrigation can be considered as zero, only 80% of the calculated amount of water was consequently applied.

3.3.10 Data processing

An SAS (Version 6.12) software package for the analyses of variance and Student T-Test for significance of differences were used for the data. Statistical analysis of the water consumption could not be done as a mutual valve and water meter was connected to the irrigation pipes of the three replicates per treatment. An analysis of covariance was done to compare fruit growth measurements for the different treatment combinations.

3.3 RESULTS AND DISCUSSION

3.3.1 Shoot growth

The relationship between the percentage shoot growth as measured during the slow fruit growth, rapid fruit growth and ripening stages and the soil matric potential reached during the corresponding stages, are presented in Figures 2 to 4 respectively. In all three stages significant trends towards decreasing shoot growth with decreasing soil matric potential were obtained. The results correspond with results reported by Michell & Chalmers (1982) where similar trends were observed during the slow fruit growth stage.

The significance of the present results is that by manipulating irrigation applications during these periods excessive vegetative growth can be controlled. It is thus possible to eliminate adverse competition of vegetative growth to the advantage of fruit development. However, it is of importance to note that the different deficit irrigations were applied during only one of the different growth stages.

3.3.2 Stem growth and tree volume

No significant differences in increase of trunk circumferences or in tree volume were obtained between the different treatment combinations (data not shown).

3.3.3 Fruit growth

The effects of the different irrigation treatments during the five different growth stages are illustrated in Figures 5 to 9 respectively.

No fruit growth measurements were done during the cell growth stage (Stage 1) as the fruit was only thinned out at the end of this growth stage. However, the fruit growth for this treatment, as measured from the beginning of the slow fruit growth stage (Stage 2) until harvest, is presented in Figure 5. Due to the prevailing relative moderate climatic conditions during the early spring, no significant divergent soil matric potentials were reached during this growth stage. The irrigation targets of –50 kPa and –100 kPa were reached for treatments T1 and T2. However, the maximum soil matric potentials reached for T3, T4 and T5, were also in the order of –100 kPa instead of the targeted –200 kPa,

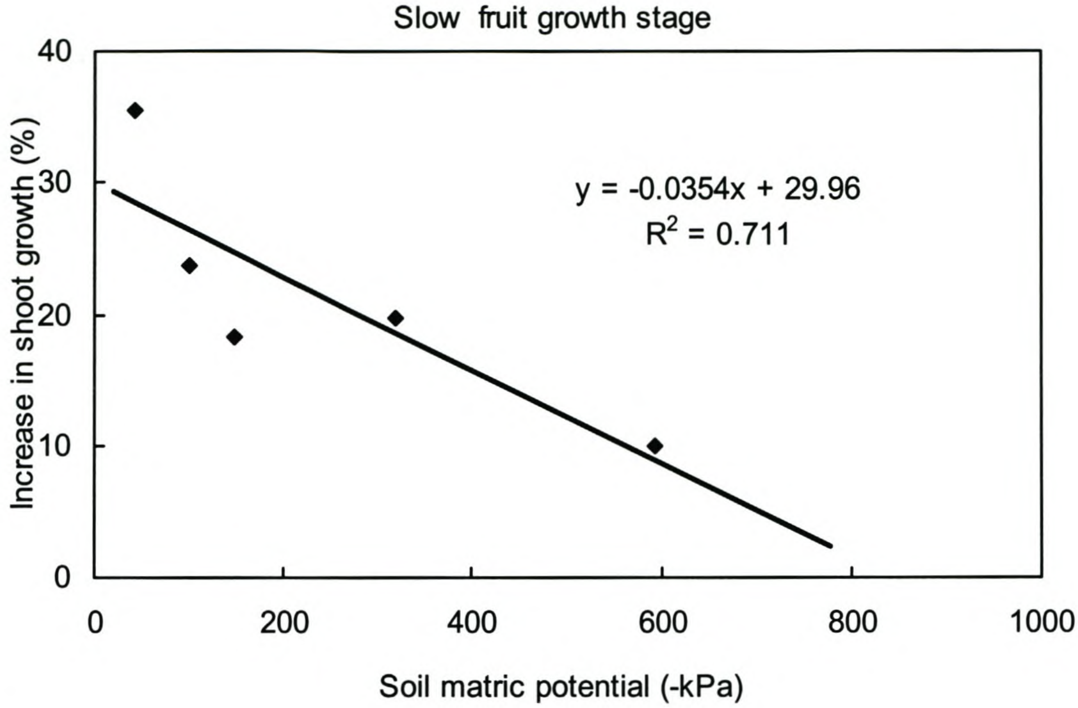

Figure 2. Relationship between percentage increase in shoot growth and soil matric potential as obtained during the slow fruit growth stage (Stage 2) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

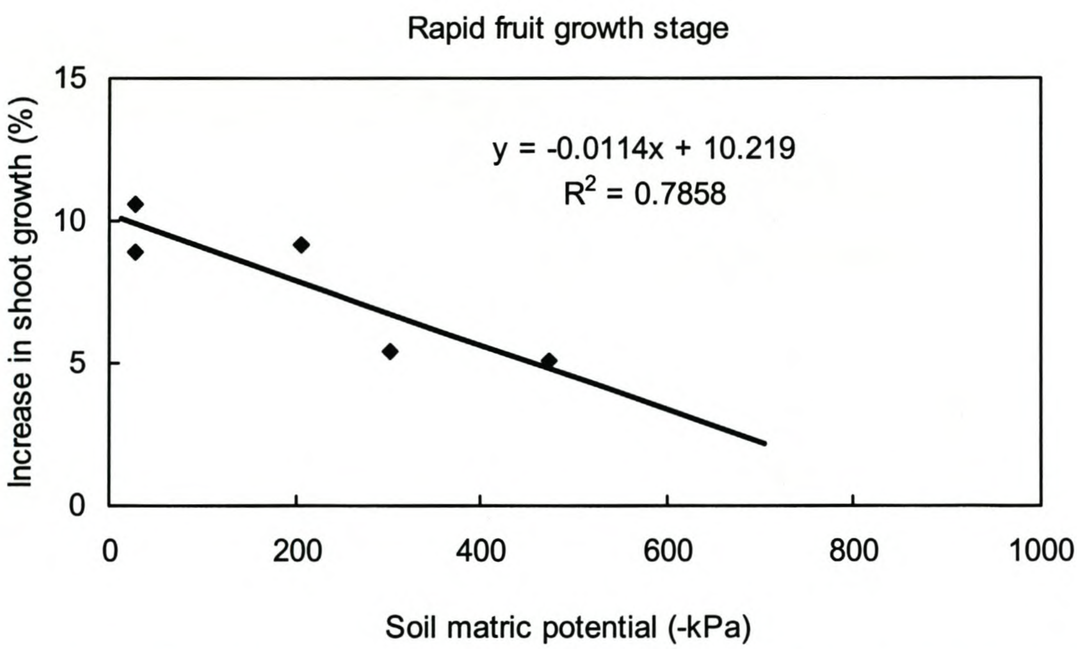

Figure 3. Relationship between percentage increase in shoot growth and soil matric potential as obtained during the rapid fruit growth stage (Stage 3) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

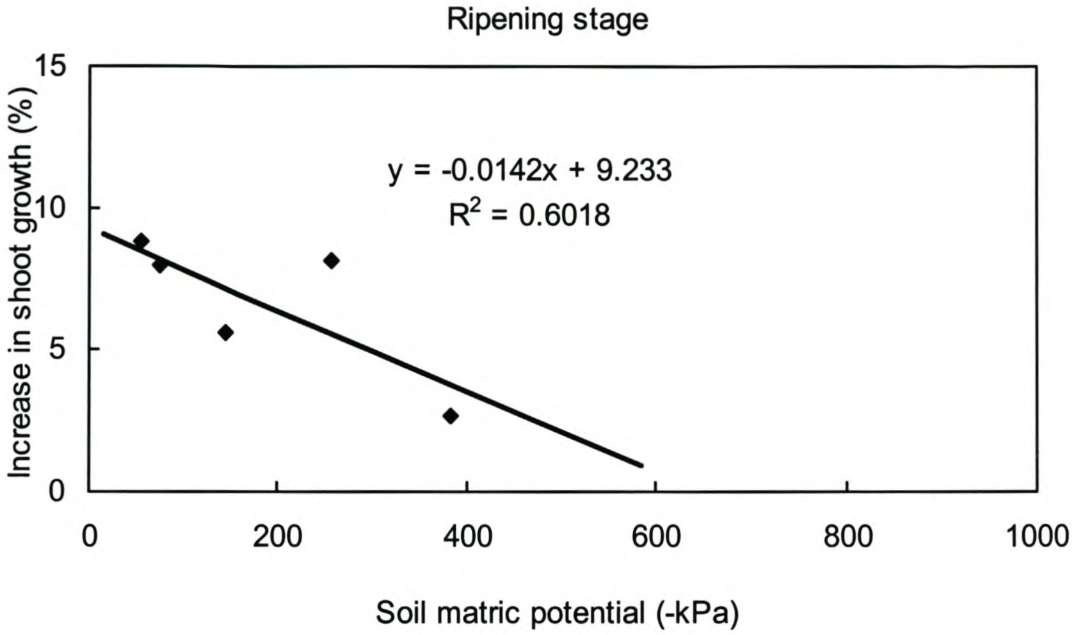

Figure 4. Relationship between percentage increase in shoot growth and soil matric potential as obtained during the fruit ripening stage (Stage 4) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

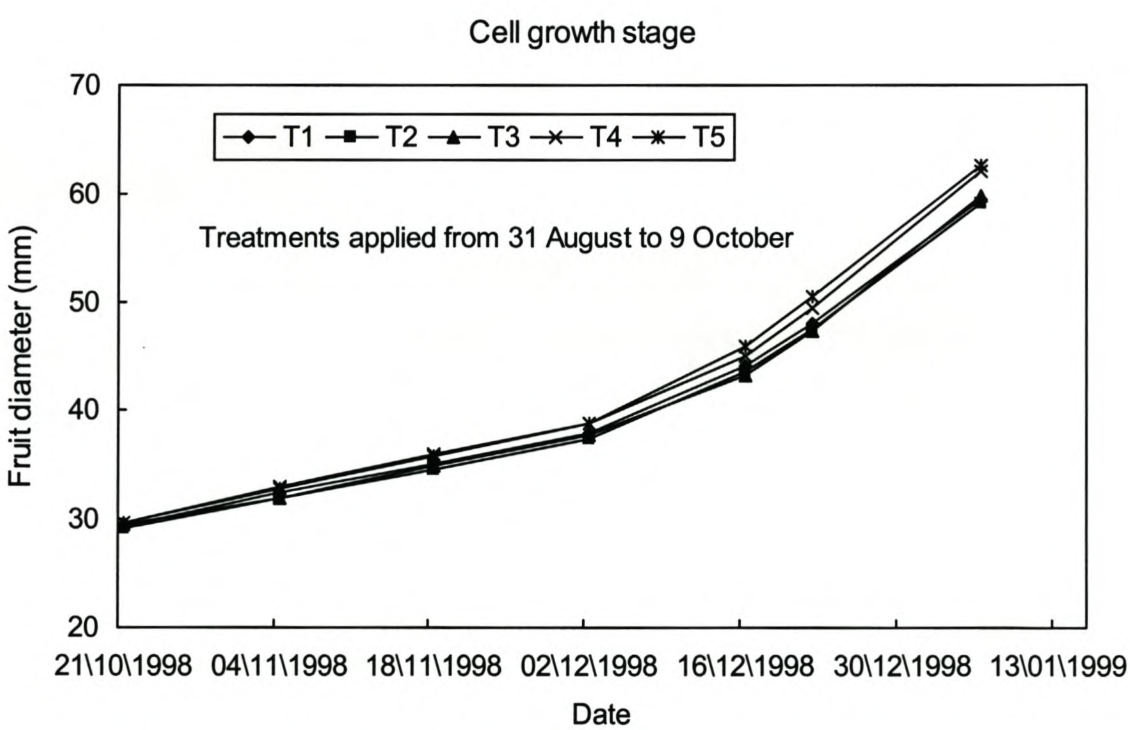

Figure 5. Effect of water deficits during cell growth (Stage 1) on fruit diameter of Neethling peaches as measured during the 1998/1999-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

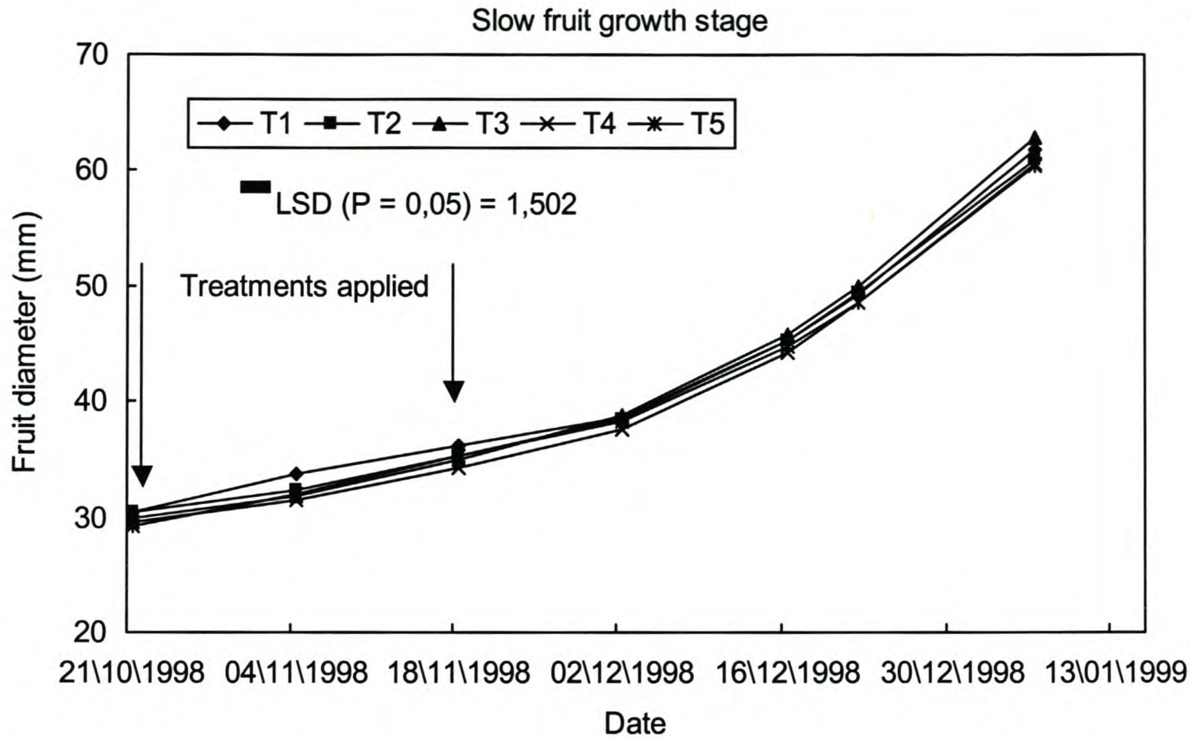

Figure 6. Effect of water deficits during slow fruit growth (Stage 2) on fruit diameter of Neethling peaches as measured during the 1998/1999-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

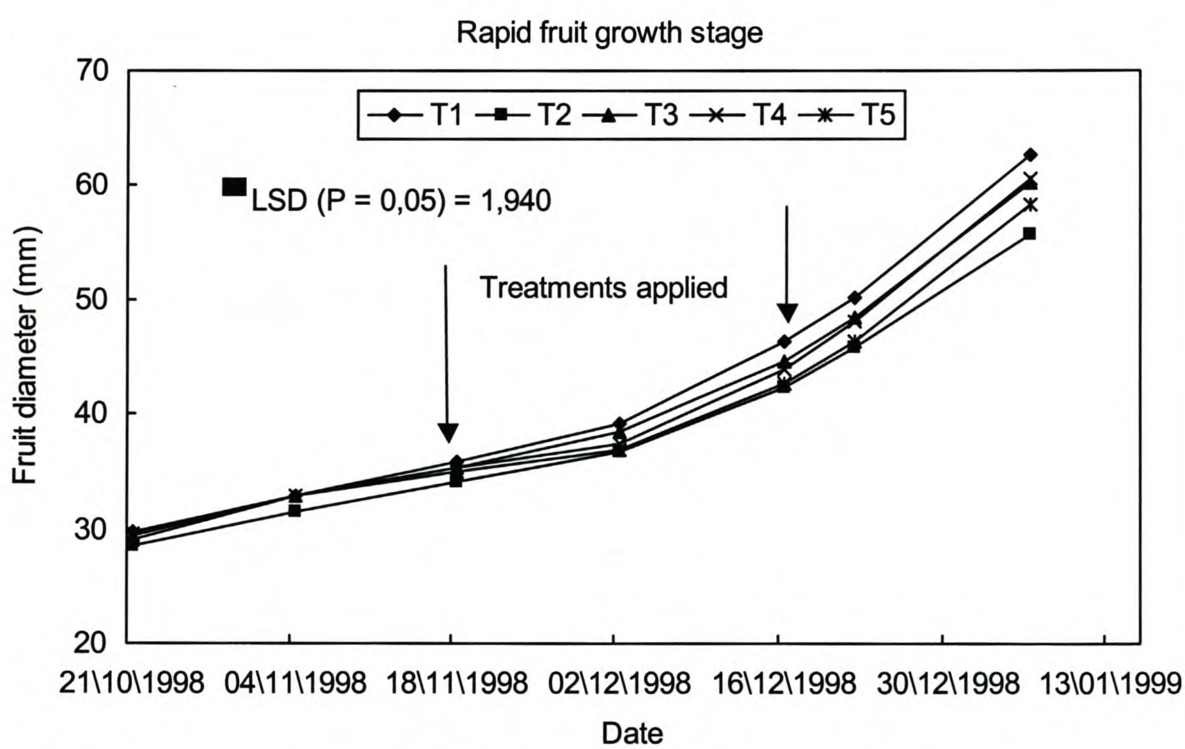

Figure 7. Effect of water deficits during rapid fruit growth (Stage 3) on fruit diameter of Neethling peaches as measured during the 1998/1999-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

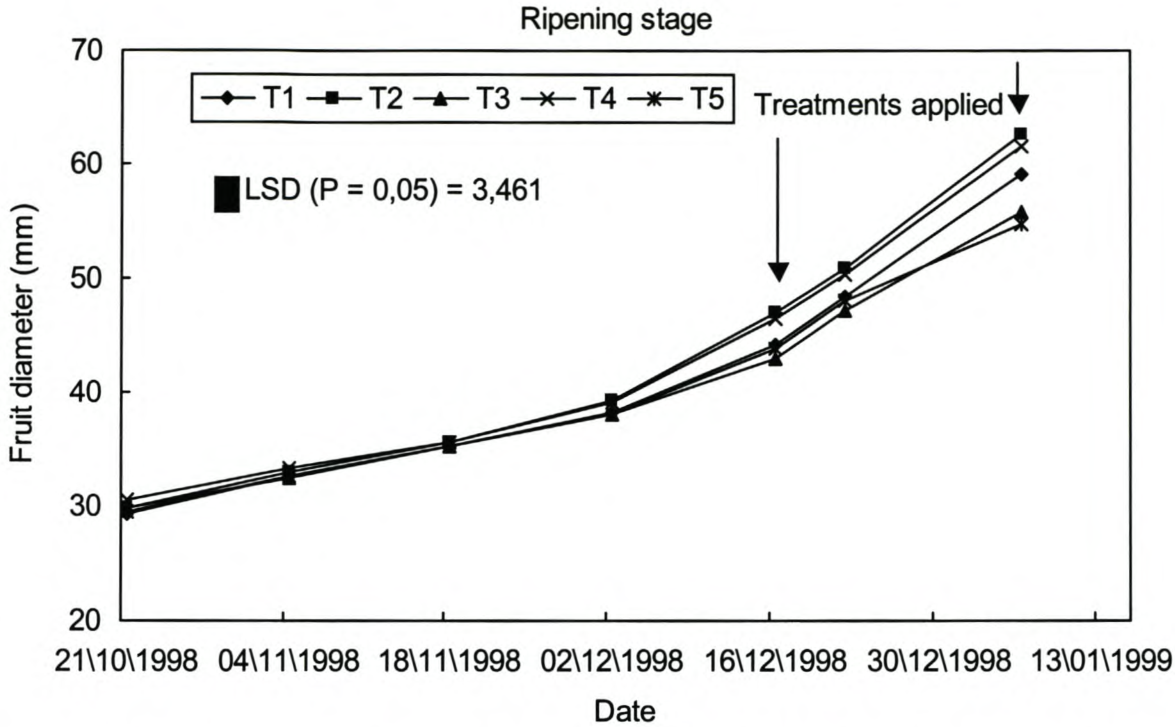

Figure 8. Effect of water deficits during fruit ripening stage (Stage 4) on fruit diameter of Neethling peaches as measured during the 1998/1999-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

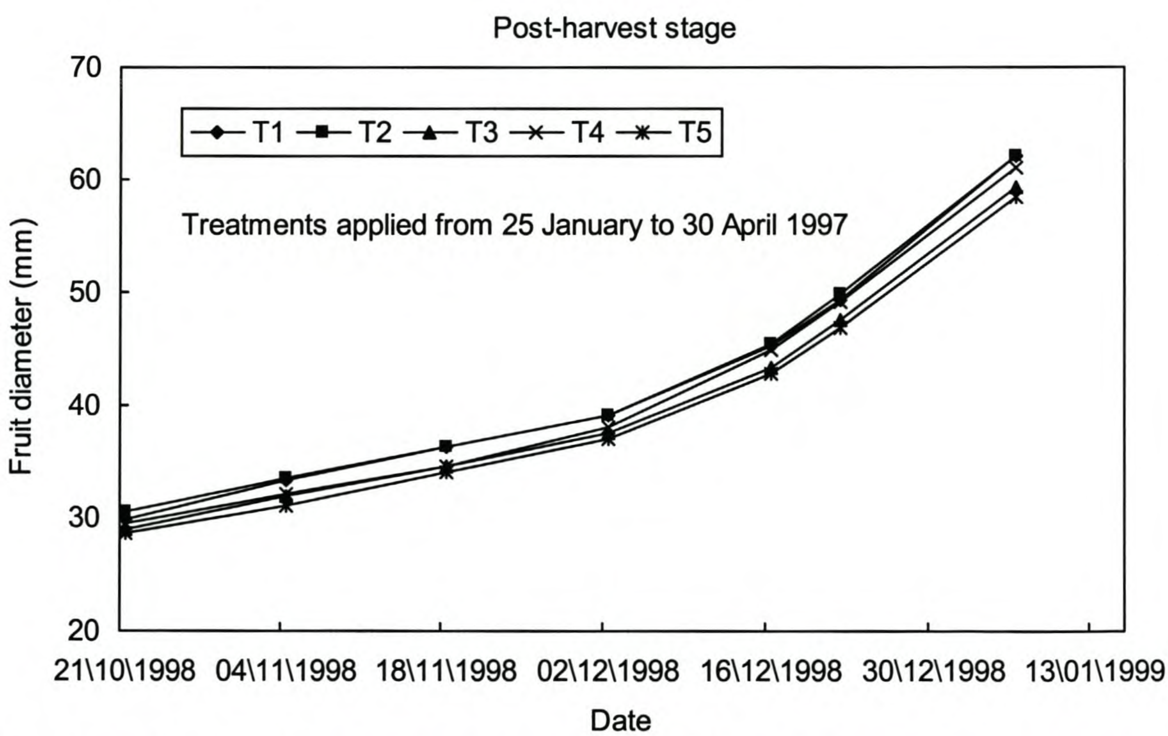

Figure 9. Effect of water deficits during post-harvest stage (Stage 5) of the previous season on fruit diameter of Neethling peaches as measured during the 1998/1999-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

–400 kPa and –800 kPa respectively. As can thus be expected, the irrigation treatments applied during this stage had no significant effect on the fruit size at harvest time.

Irrigation treatments applied during the slow fruit growth stage (Stage 2) resulted in significant differences in fruit size at the end of this stage. The application of normal irrigation during the two succeeding growth stages eliminated this effect at harvest (Figure 6).

Significant differences in fruit size for the different irrigation treatments applied during the rapid fruit growth stage (Stage 3) were obtained at the end of this stage (Figure 7). However, application of normal irrigation during the following ripening stage was not able to eliminate this effect and significant differences were still obtained at harvest.

As the different irrigation treatments applied during the ripening stage (Stage 4) prevailed until harvest time, the largest difference between fruit growth for the different irrigation treatments presented in Figure 8, were expected.

Obviously, no fruit growth measurements were possible during the post harvest stage of the present season. Results presented Figure 9 were obtained from the fruit growth measured for the period from the cell growth stage until harvest. The different irrigation treatments were applied during the post-harvest stage of the previous season. No effect of irrigation treatments was observed for this treatment combination.

It is important to note that the differences in fruit growth generated by the different irrigation treatments during the rapid fruit growth stage were not eliminated by normal irrigation applied in the following ripening stage. This implies that fruit size can adversely be affected by water deficits during both the rapid fruit growth and ripening stages.

3.3.4 Final fruit size

The final fruit size was significantly affected by the application of water deficit treatments during the rapid fruit growth and ripening stages (Figure 10). The unexpected small fruit size obtained with the

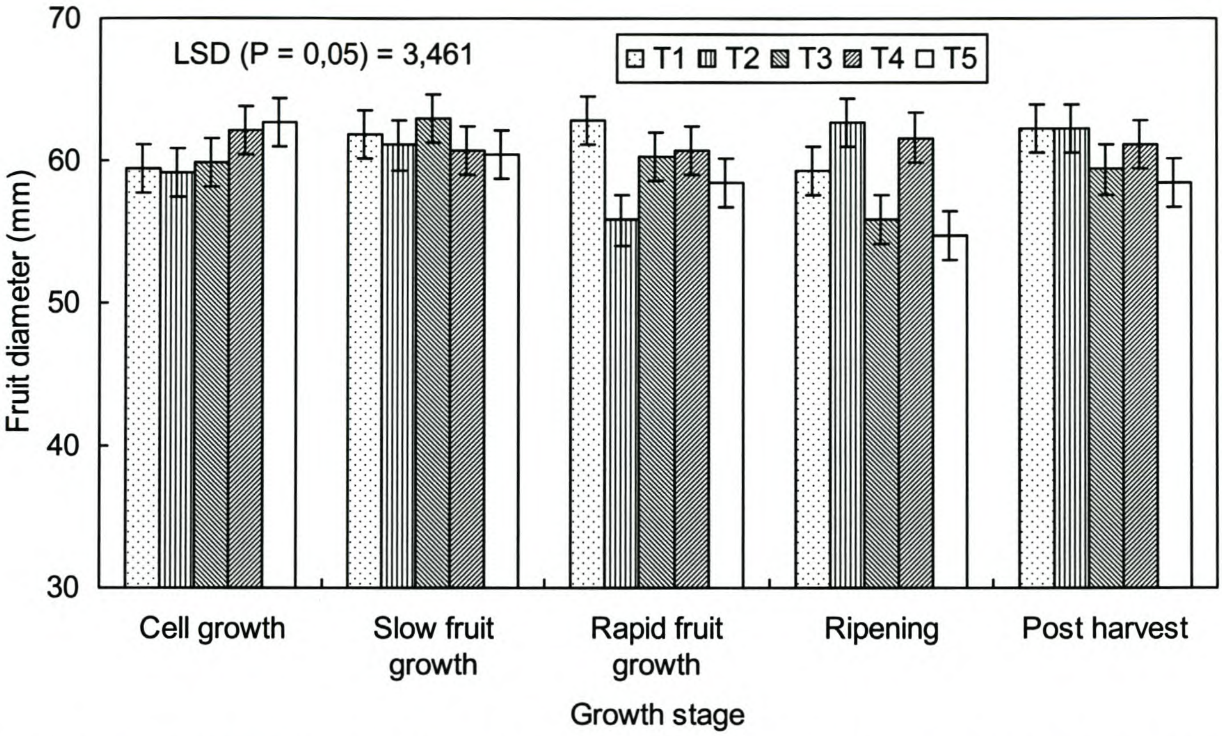

Figure 10. Effect of water deficits during the different growth stages on final fruit diameter of Neethling peaches as measured during the 1998/1999-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

T2 treatment in the rapid fruit growth stage was possibly due to smaller fruit randomly selected at the start of the season (Figure 7). The larger than expected fruit size obtained with the T4 treatment during the ripening stage can be ascribed to larger randomly selected fruit at the start of the growing season and rapid fruit growth from the beginning of December (Figure 8).

The relationship between fruit diameter and soil matric potential (Figure 11) is probably of no importance as no significant differences in soil water potentials were obtained during the cell growth stage. For the remaining stages certain trends were observed, but poor relationships were obtained between final fruit diameter and soil matric potential for all growth stages (Figures 11 to 15). These results indicate that fruit size was apparently not very sensitive to water deficits during the different growth stages. The soil water content can be depleted to up to –200 kPa can be applied during all the growth stages without seriously affecting the final fruit size.

3.3.5 Final fruit mass

Significant reduction in fruit mass was obtained with a soil matric potential exceeding –400 kPa during the ripening stage (Figure 16) resulting in the smallest fruit of all the treatment combinations. The effects of soil matric potential on fruit mass at harvest for the different growth stages are presented in Figures 17 to 21 respectively. No significant reductions in fruit mass were caused by water deficits during the different growth stages, except for a significant relationship (Figure 20) between fruit mass and soil matric potential during the ripening stage where a tendency of decreasing fruit diameter with decreasing soil matric potentials was observed. This corresponds with the findings of Li *et al.* (1989, and references therein). They reported that fruit expansion was significantly limited by water deficits during the ripening stage. A mean fruit mass (141,4 g) was obtained which is well within the norms of the Canning Industry. A soil matric potential of –200 kPa can be applied during all the different growth stages without any detrimental effect on the fruit mass.

3.3.6 Production

No significant differences in production were caused by water deficits during the different growth stages (Figure 22). The relationships between production and different soil matric potentials obtained for the different growth stages are illustrated in Figures 23 to 27. A good relationship between

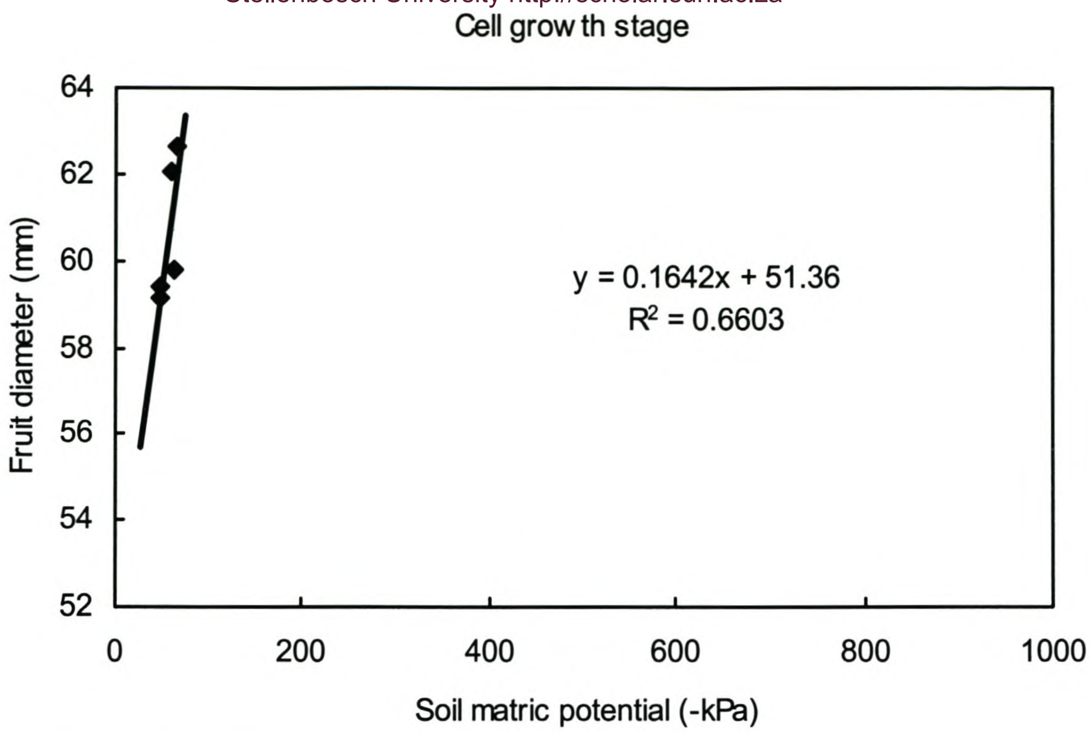

Figure 11. Relationship between final fruit diameter and soil matric potential as obtained for deficit irrigation during the cell growth stage (Stage 1) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

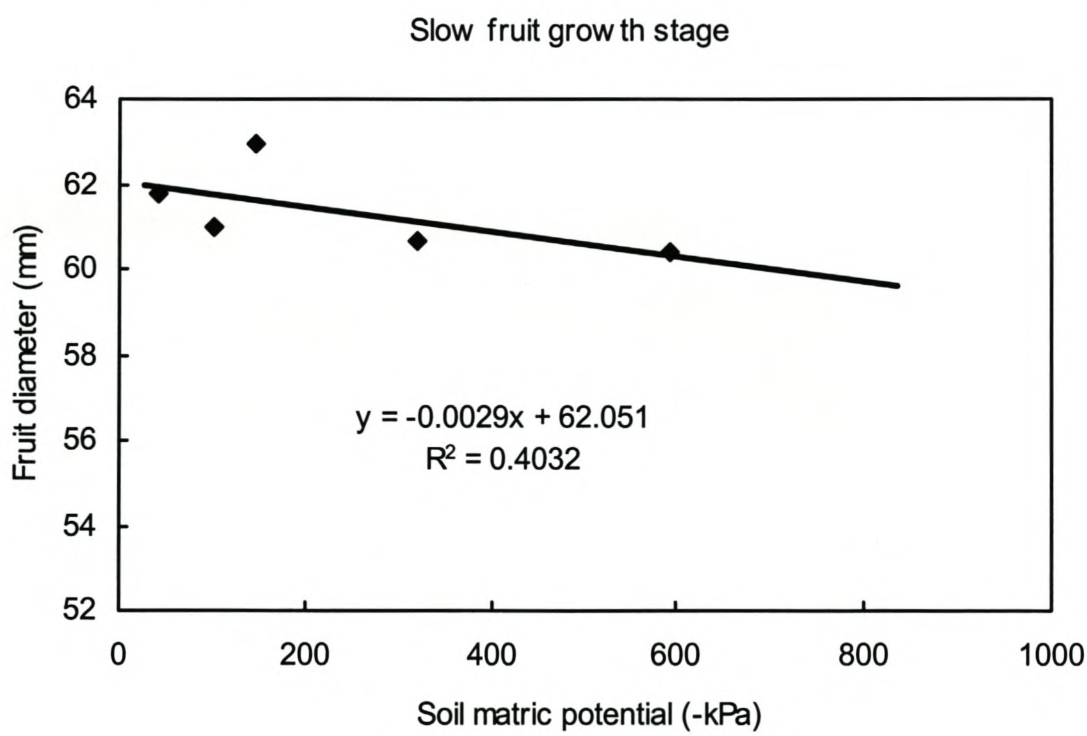

Figure 12. Relationship between final fruit diameter and soil matric potential as obtained for deficit irrigation during the slow fruit growth stage (Stage 2) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

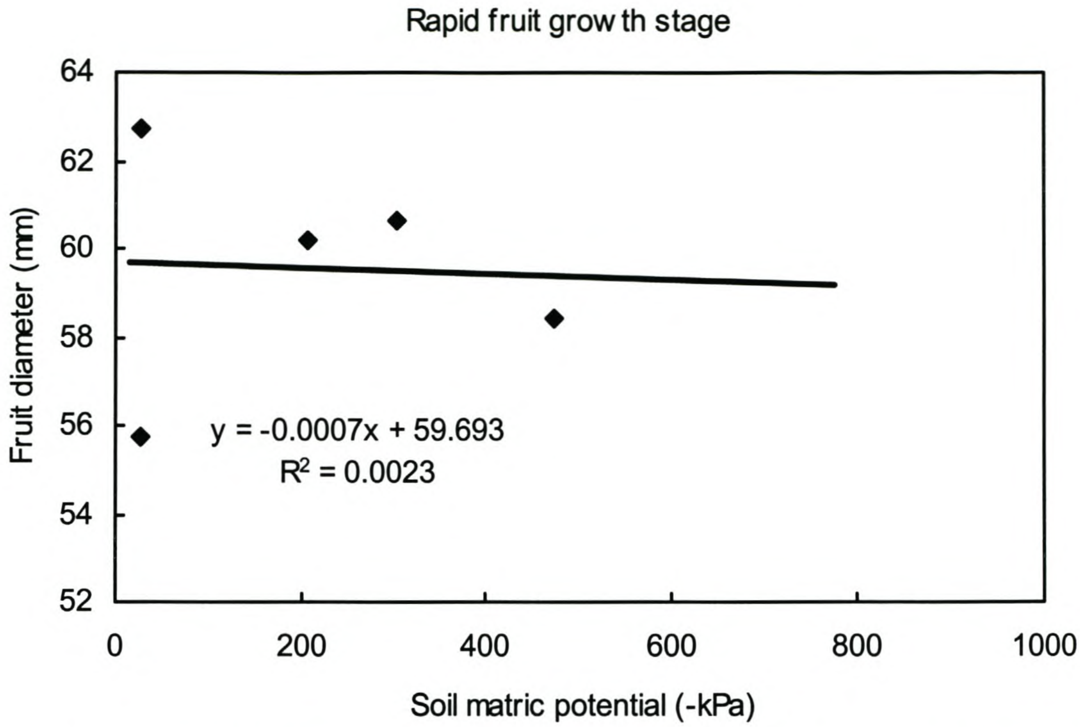

Figure 13. Relationship between final fruit diameter and soil matric potential as obtained for deficit irrigation during the rapid fruit growth stage (Stage 3) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

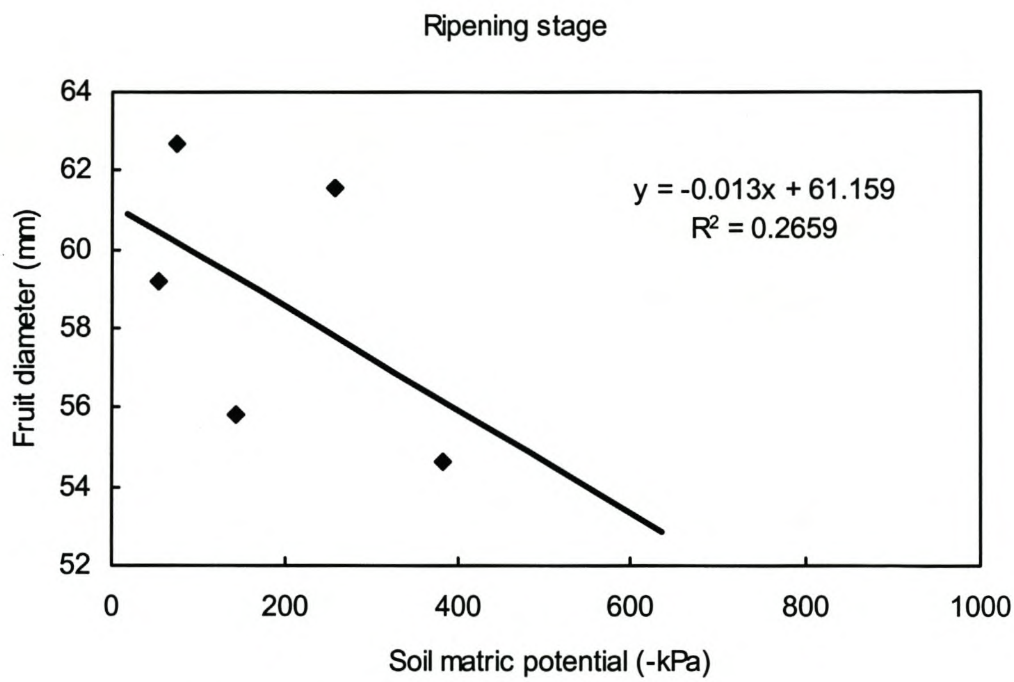

Figure 14. Relationship between final fruit diameter and soil matric potential as obtained for deficit irrigation during the ripening stage (stage 4) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

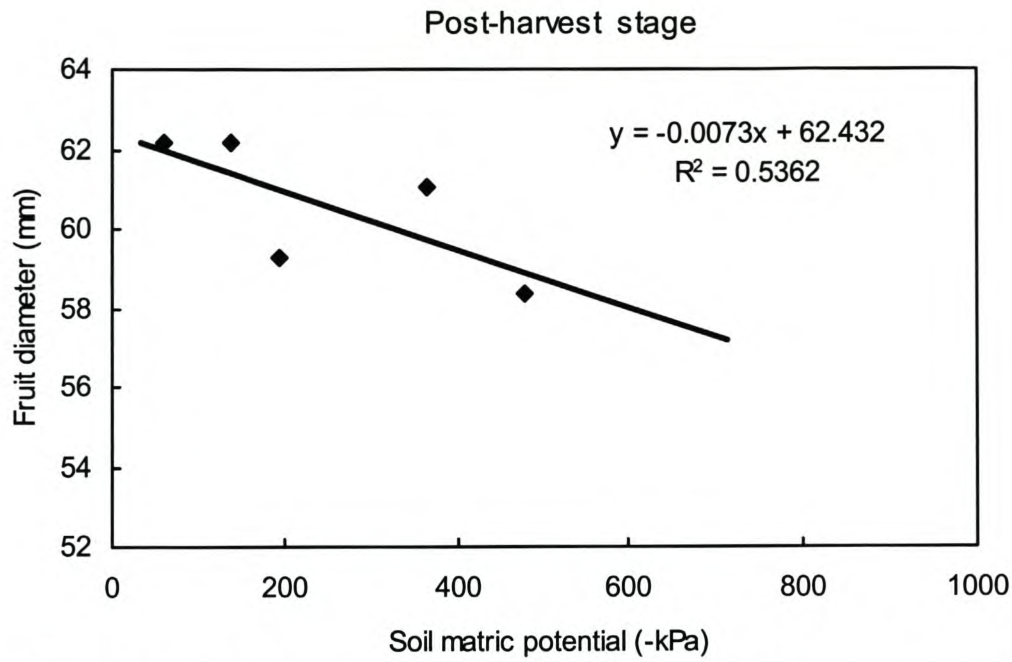

Figure 15. Relationship between final fruit diameter and soil matric potential as obtained for the post-harvest stage (Stage 5) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

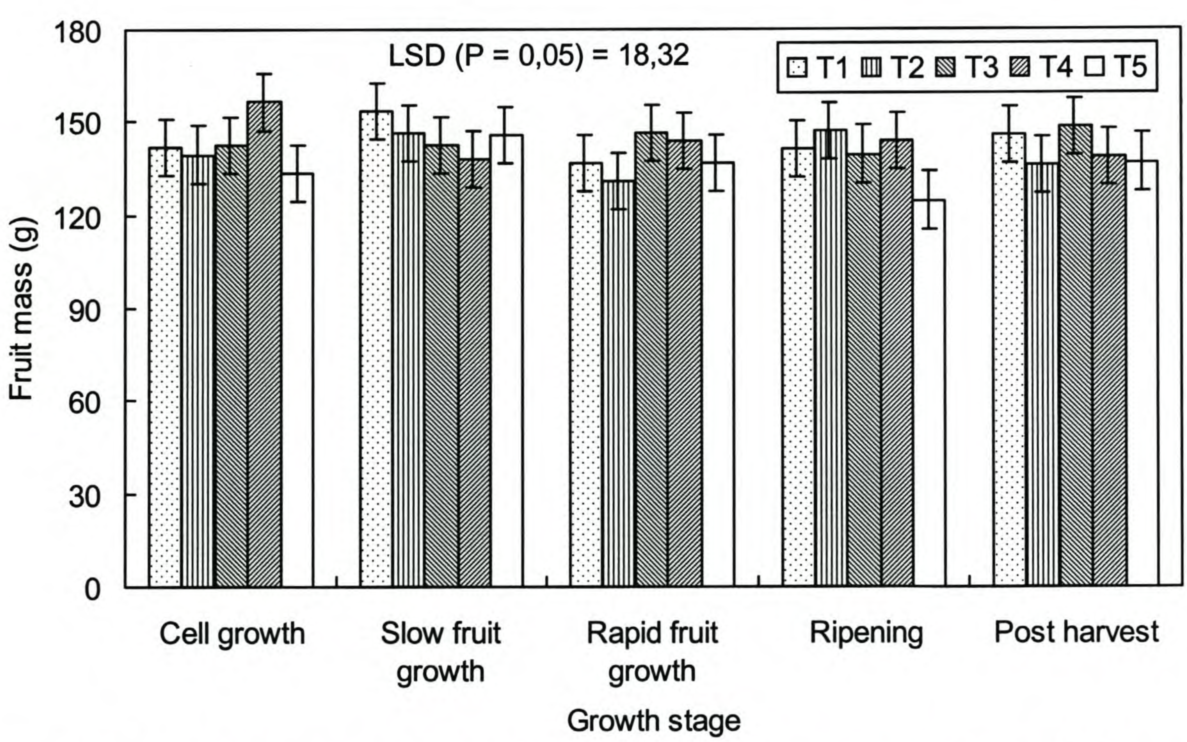

Figure 16. Effect of water deficits during the different growth stages on the final fruit mass of Neethling peaches as obtained during the 1998/1999-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

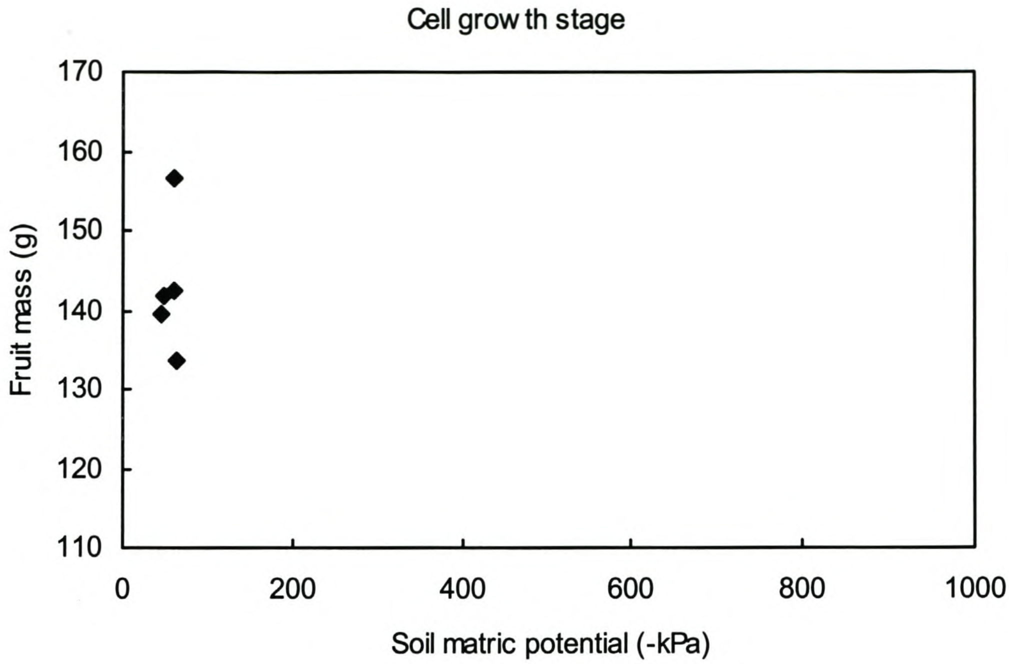

Figure 17. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the cell growth stage (Stage 1) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

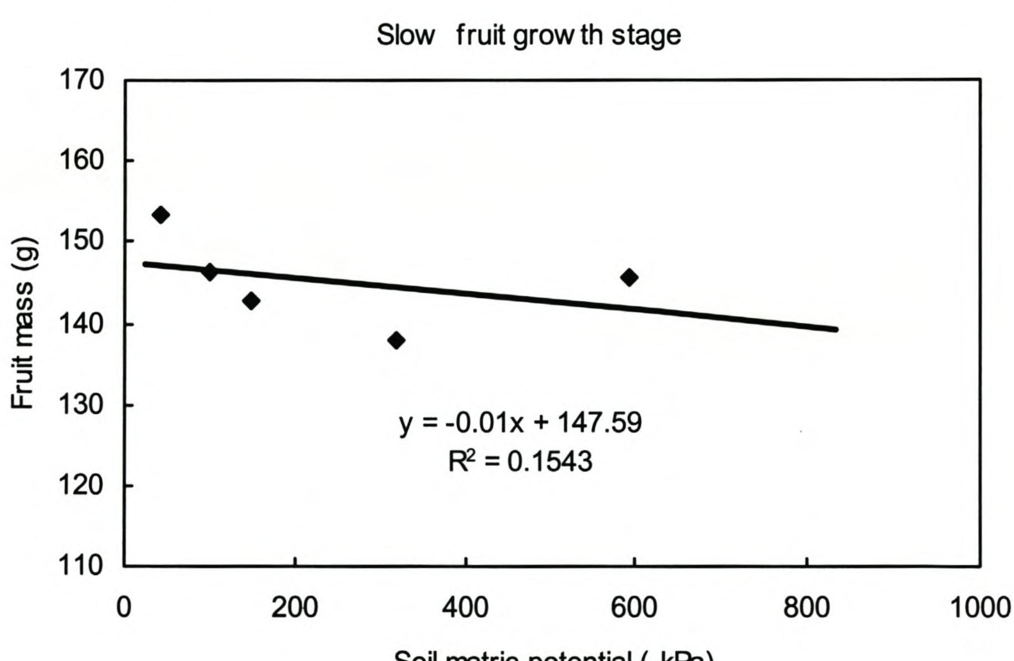

Figure 18. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the slow fruit growth stage (Stage 2) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

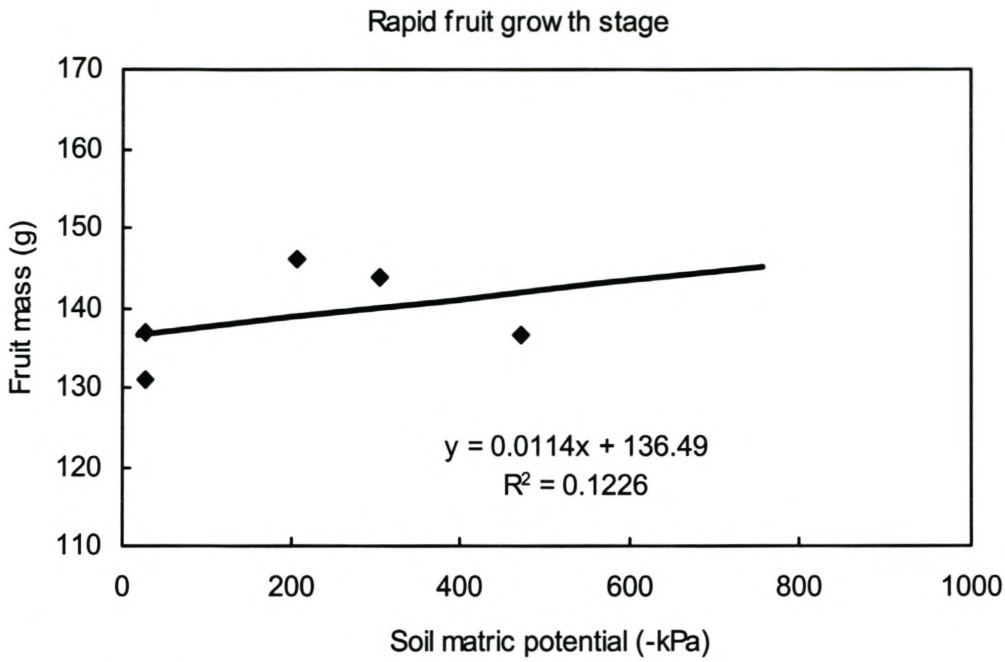

Figure 19. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the rapid fruit growth stage (Stage 3) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

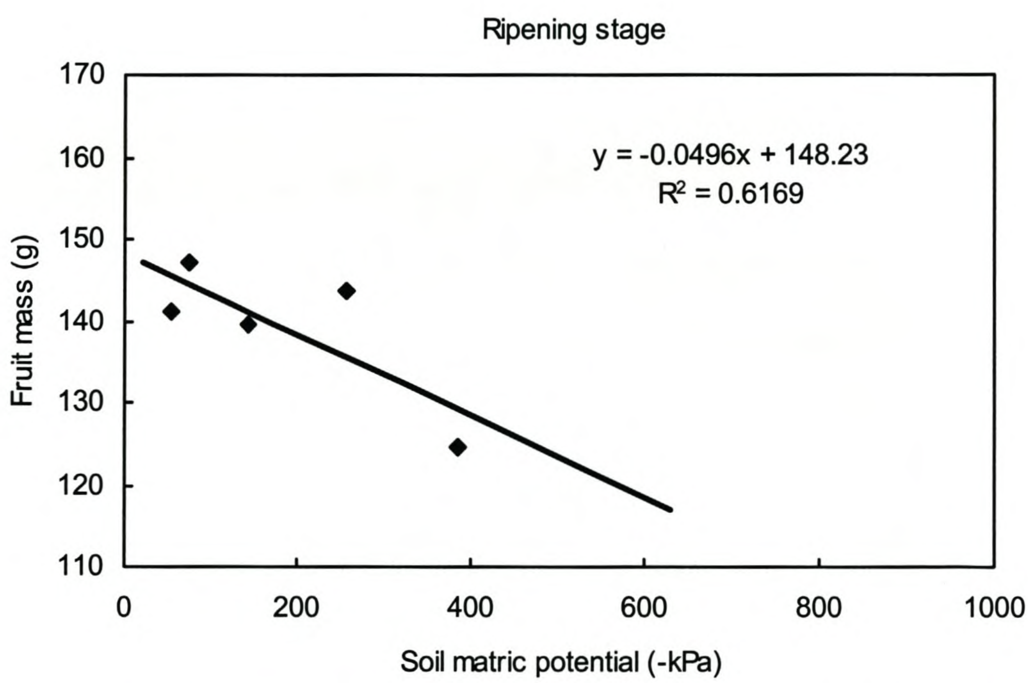

Figure 20. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the fruit ripening stage (Stage 4) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

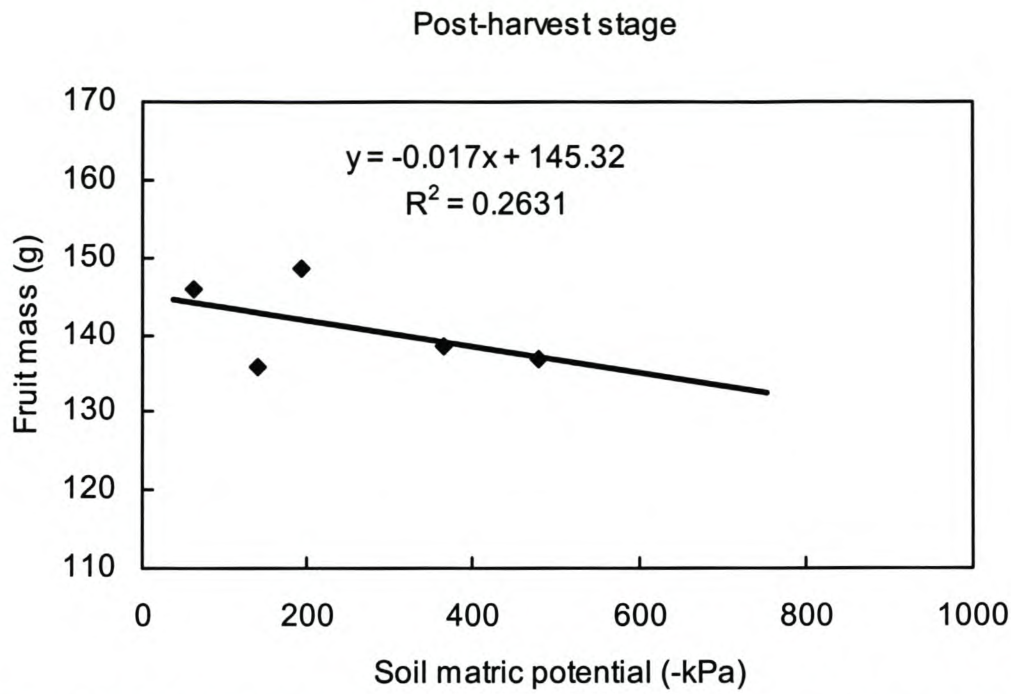

Figure 21. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the post-harvest stage (Stage 5) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

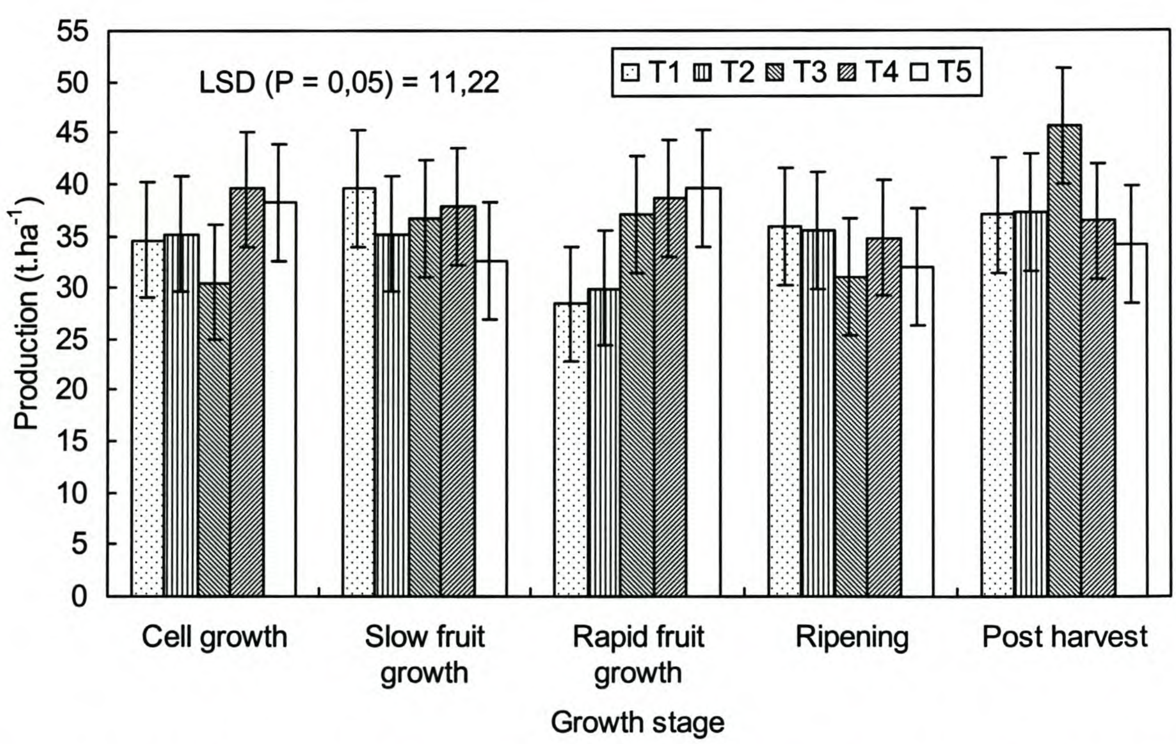

Figure 22. Effect of water deficits during the different growth stages on the production of Neethling peaches as obtained during the 1998/1999-season at Robertson Experiment Farm.

Refer to material and methods for explanation of treatments).

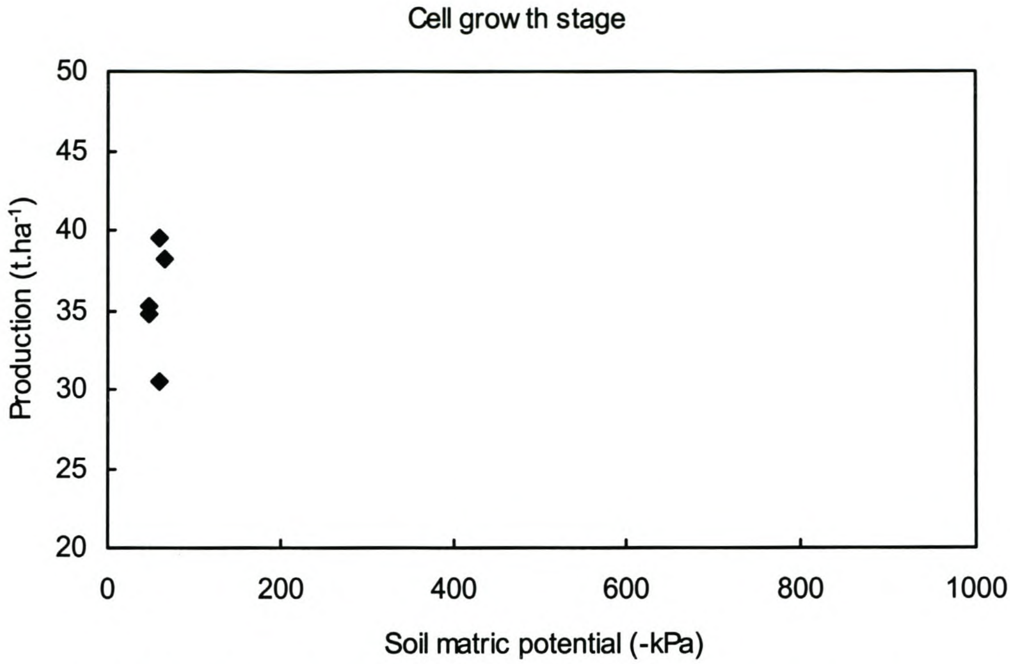

Figure 23. Relationship between production and soil matric potential as obtained for deficit irrigation during the cell growth stage (Stage 1) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

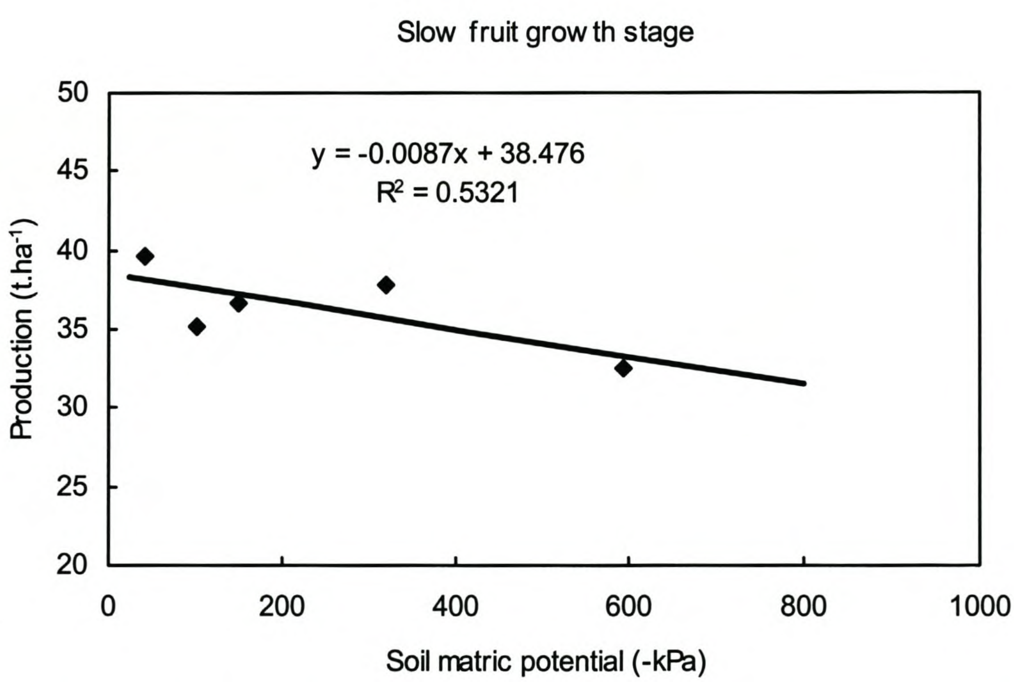

Figure 24. Relationship between production and soil matric potential as obtained deficit irrigation during for the slow fruit stage (Stage 2) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

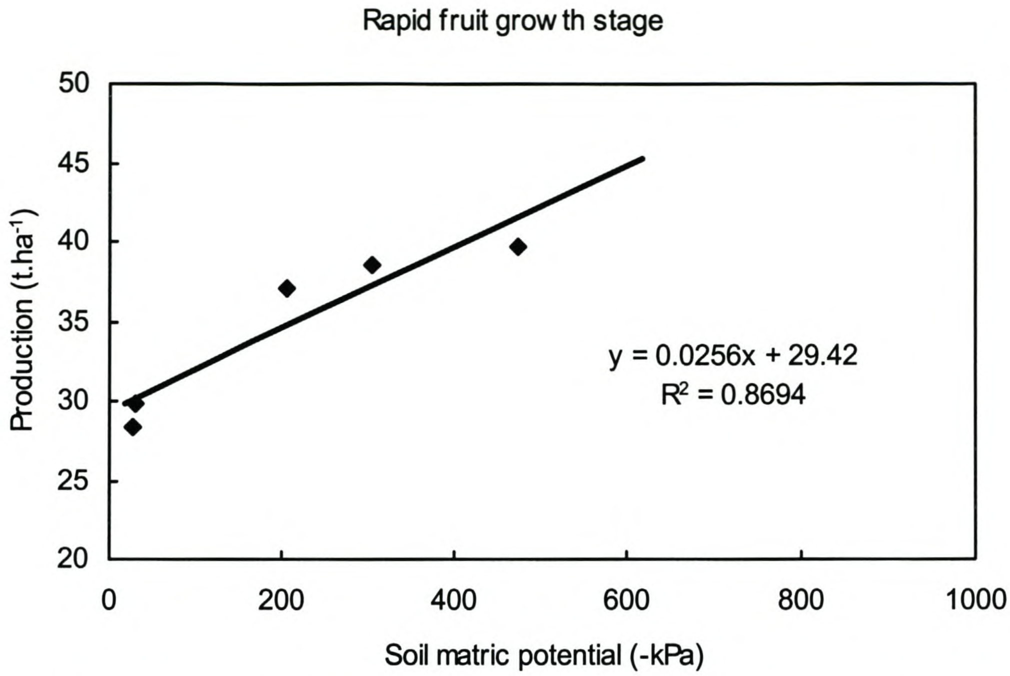

Figure 25. Relationship between production and soil matric potential as obtained for deficit irrigation during the rapid fruit stage (Stage 3) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

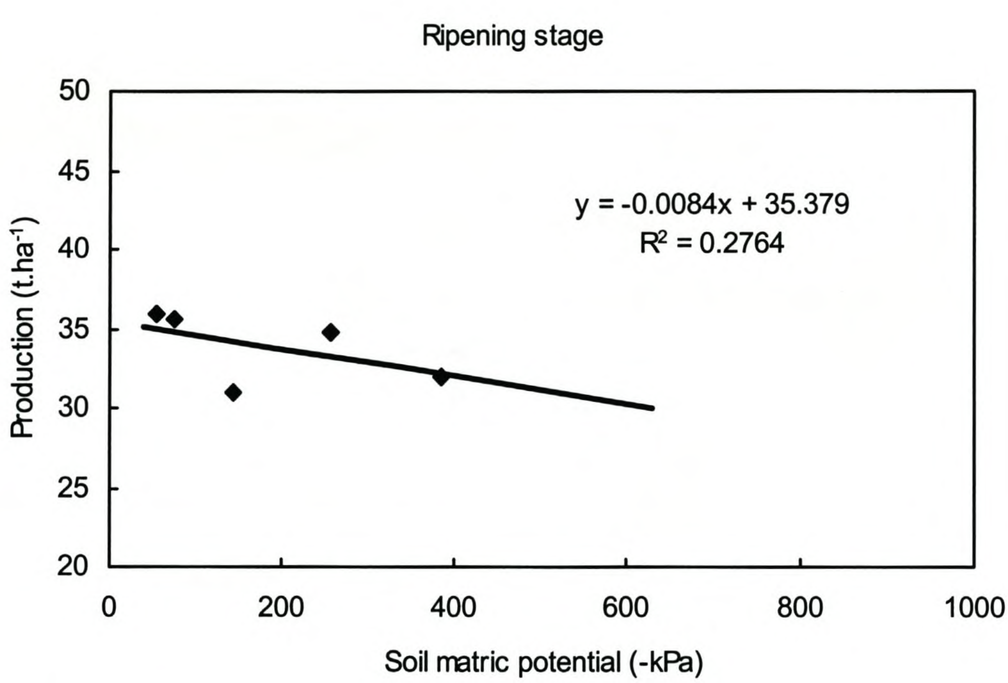

Figure 26. Relationship between production and soil matric potential as obtained for deficit irrigation during the fruit ripening stage (Stage 4) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

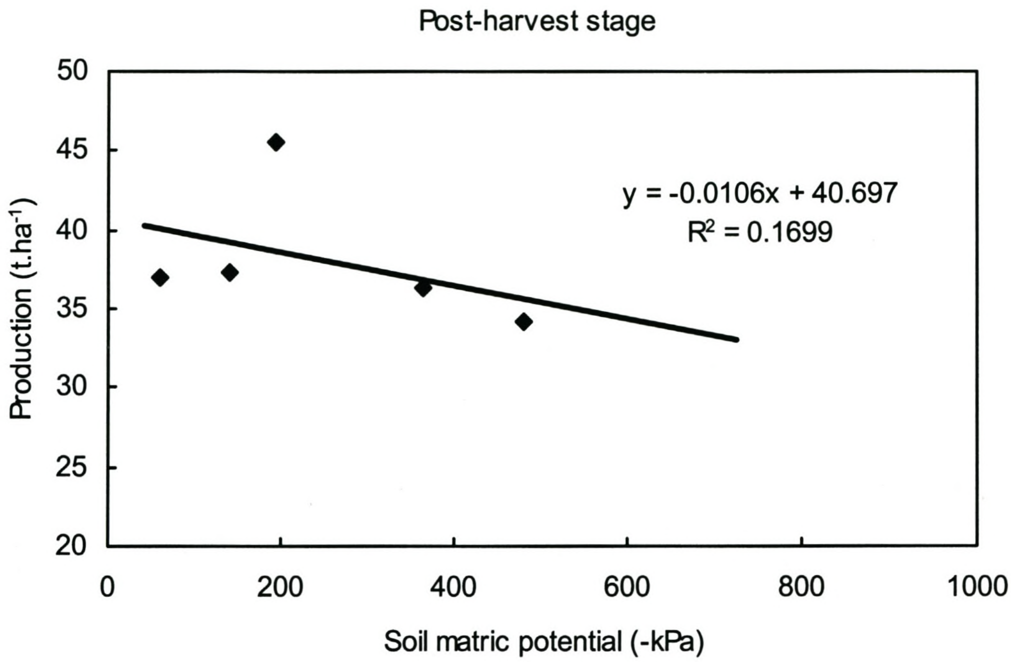

Figure 27. Relationship between production and soil matric potential as obtained for deficit irrigation during the post-harvest stage (Stage 5) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

production and soil matric potential was obtained during the rapid fruit growth stage where decreasing soil matric potentials resulted in higher productions (Figure 25). This corresponds with the results obtained by Mitchell *et al.* 1984, 1986 and 1989. No relationships between production and soil matric potential was obtained for the other growth stages. Production was not directly related to the measured fruit diameter or fruit mass (Figures 28 and 29).

3.3.7 Fruit quality

Results obtained from the investigation on the bruisability of the fruit indicated that water deficits, applied during the different growth stages, had no significant effect on the percentage of fruit that developed bruises (Figures 30 to 34). Although no relationships between bruisability of fruit and soil matric potential were obtained for all the different growth stages, a tendency was observed that bruisability decreased with decreasing soil matric potentials during the rapid fruit growth and ripening stages.

Water deficits did not affect the firmness of the fruit as no relationships between fruit firmness and soil matric potential were obtained for the different growth stages (Figures 35 to 39). This corresponds with results reported by Ebel *et al.* (1993)

In contrast to the results reported by Ebel *et al.*(1993), no significant differences were obtained with the different treatment combinations with regard to percentage moisture or total soluble acid in the fruit (data not shown).

3.3.8 Water consumption

Results presented in Figure 40 illustrate the total water consumption for the different treatment combinations. The amount of water consumed during the slow fruit growth, rapid fruit growth, ripening and post-harvest stages decreased with deceasing soil matric potential. Applying deficit irrigation during the slow fruit growth and post-harvest stages can save substantial amounts of water. These results correspond with those reported by Decroix (1992) and Girona *et al.* (1993).

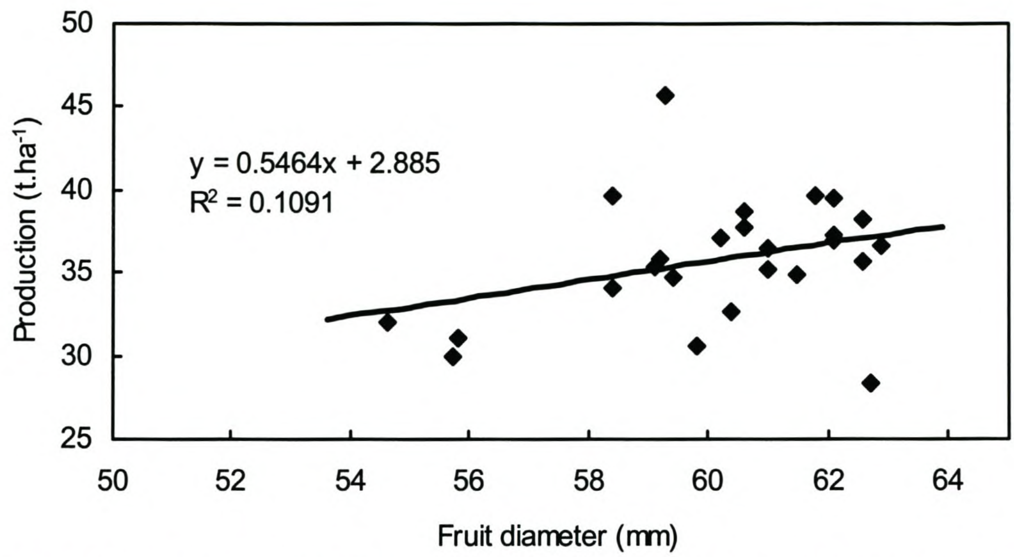

Figure 28. Relationship between production and final fruit diameter of Neethling peaches as obtained during the 1998/1999-season at Robertson Experiment Farm.

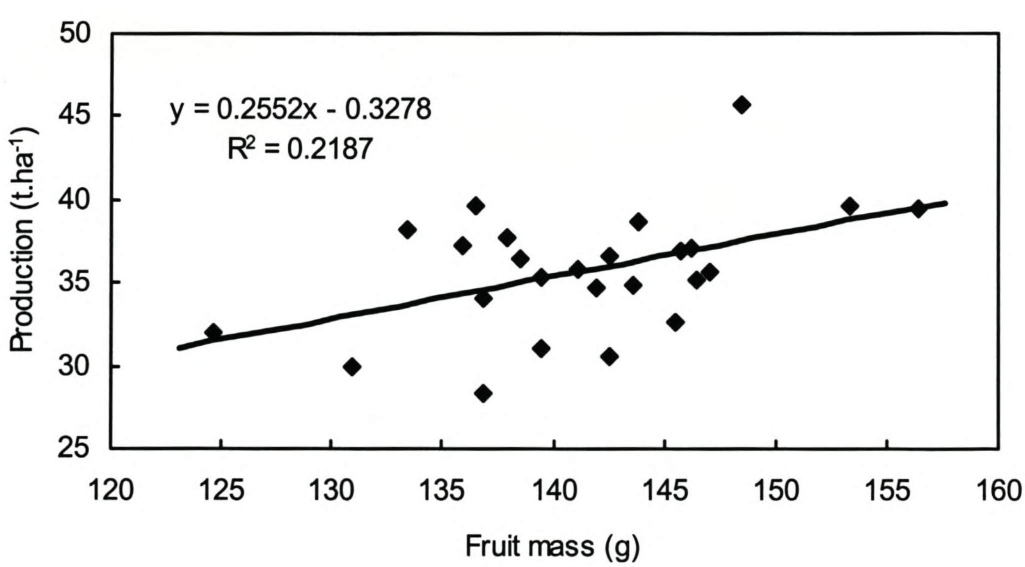

Figure 29. Relationship between production and fruit mass of Neethling peaches as obtained during the 1998/1999-season at Robertson Experiment Farm.

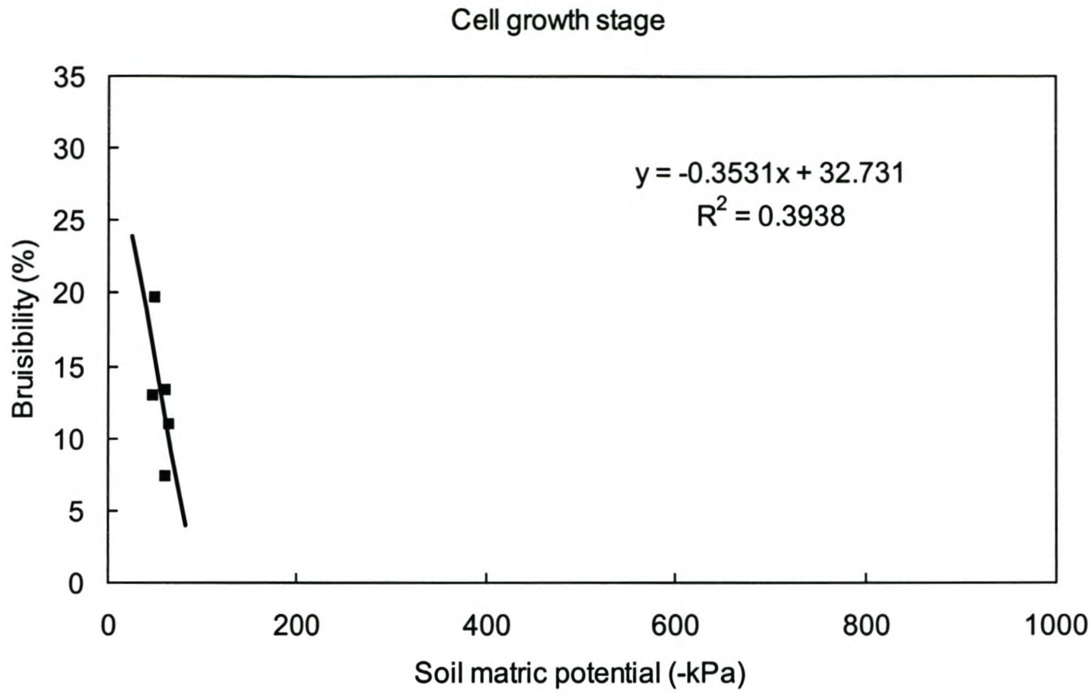

Figure 30. Relationship between the bruisibility of the fruit and soil matric potential as obtained for deficit irrigation during the cell growth stage (Stage 1) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

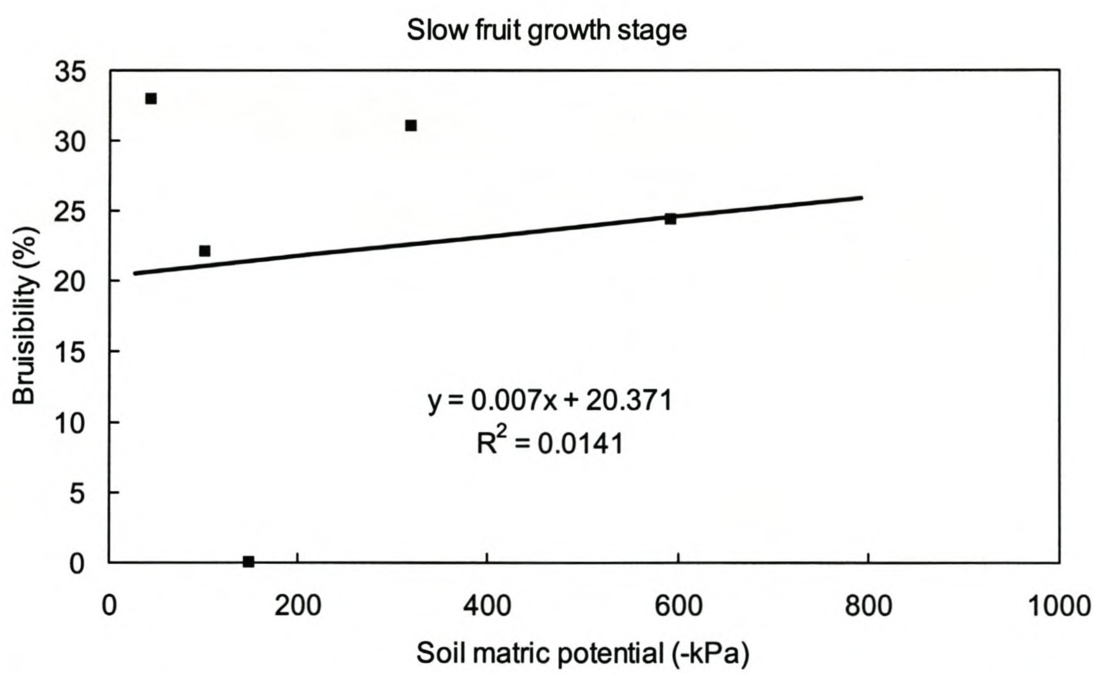

Figure 31. Relationship between the bruisibility of the fruit and soil matric potential as obtained for deficit irrigation during the slow fruit growth stage (Stage 2) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

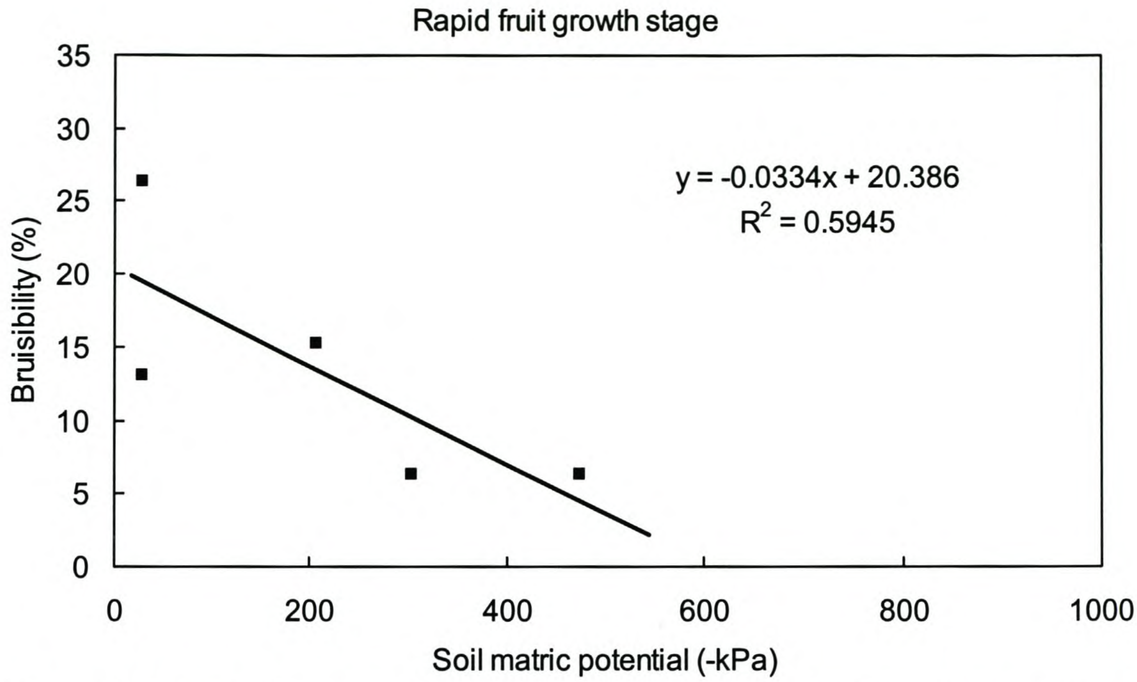

Figure 32. Relationship between the bruisibility of the fruit and soil matric potential as obtained for deficit irrigation during the rapid fruit growth stage (Stage 3) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

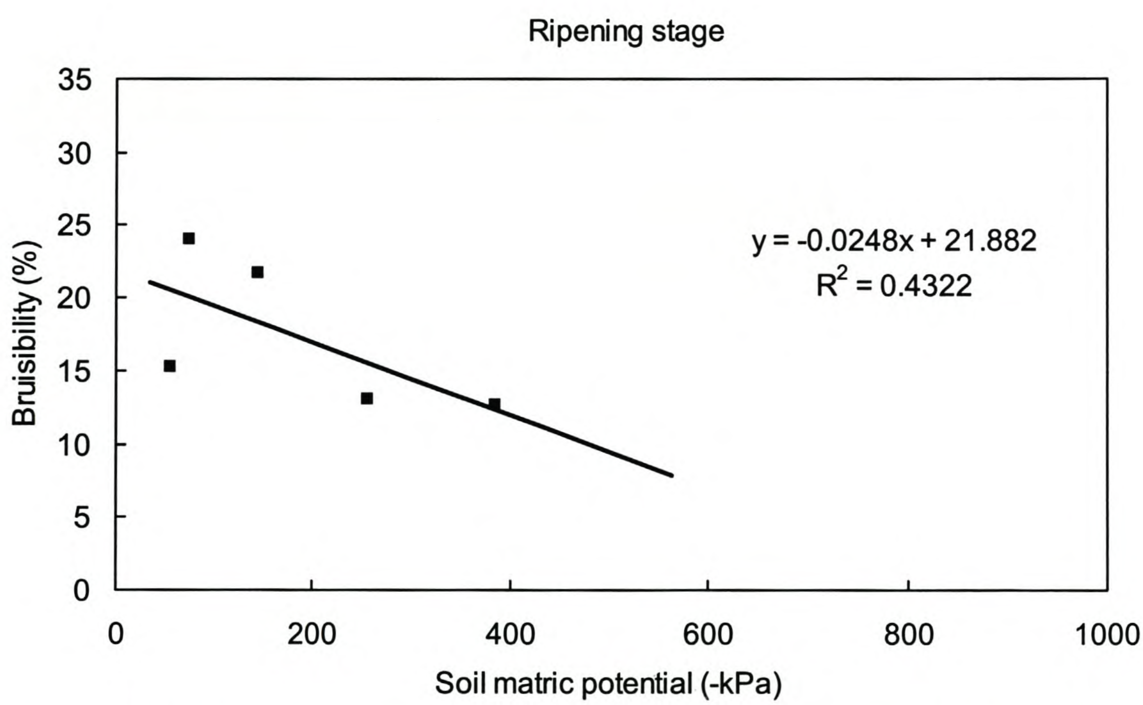

Figure 33. Relationship between the bruisibility of the fruit and soil matric potential as obtained for deficit irrigation during the fruit ripening stage (Stage 4) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

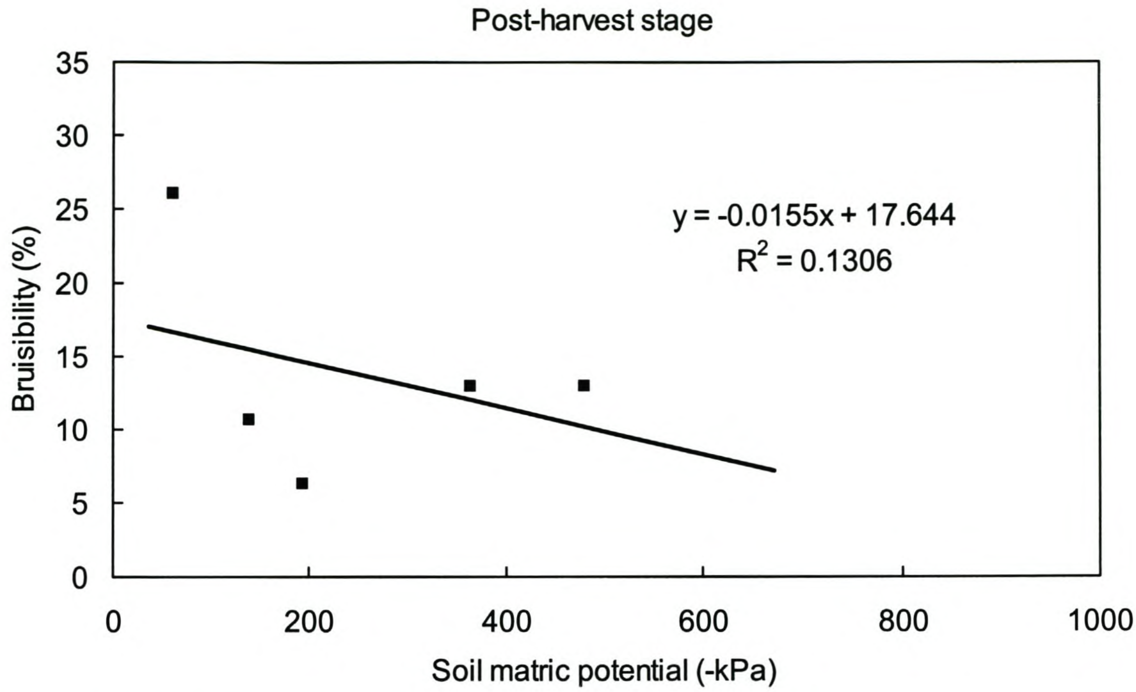

Figure 34. Relationship between the bruisibility of the fruit and soil matric potential as obtained for deficit irrigation during the post-harvest stage (Stage 5) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

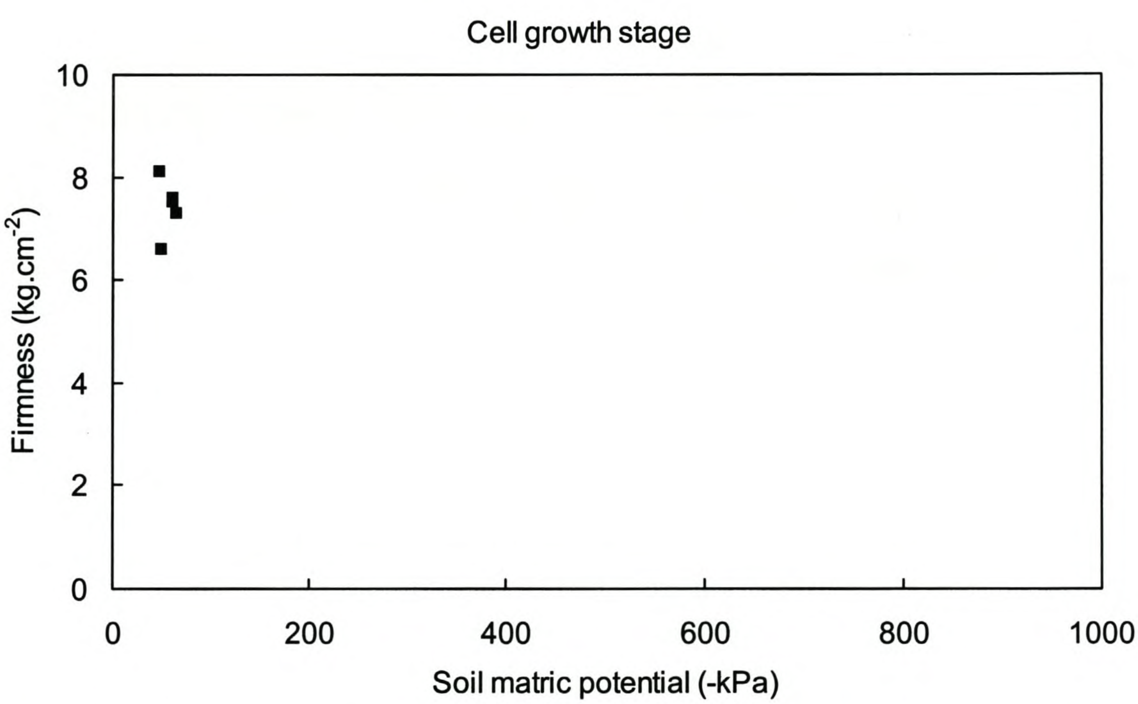

Figure 35. Relationship between the firmness of the fruit and soil matric potential as obtained for deficit irrigation during the cell growth stage (Stage 1) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

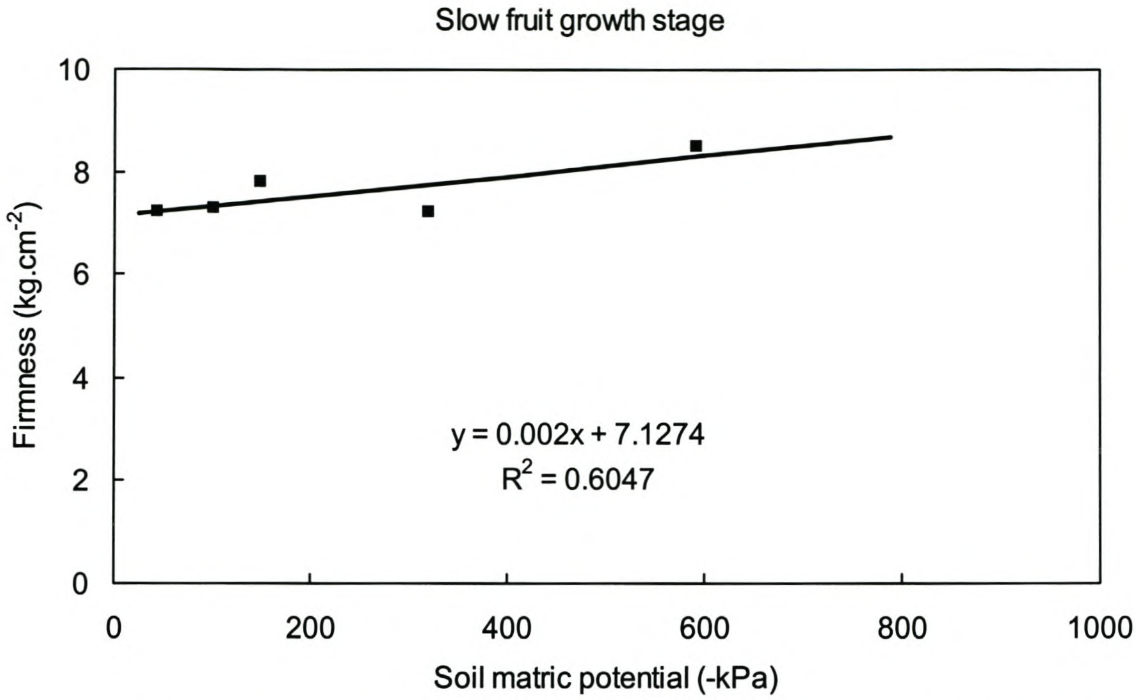

Figure 36. Relationship between the firmness of the fruit and soil matric potential as obtained for deficit irrigation during the slow fruit growth stage (Stage 2) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

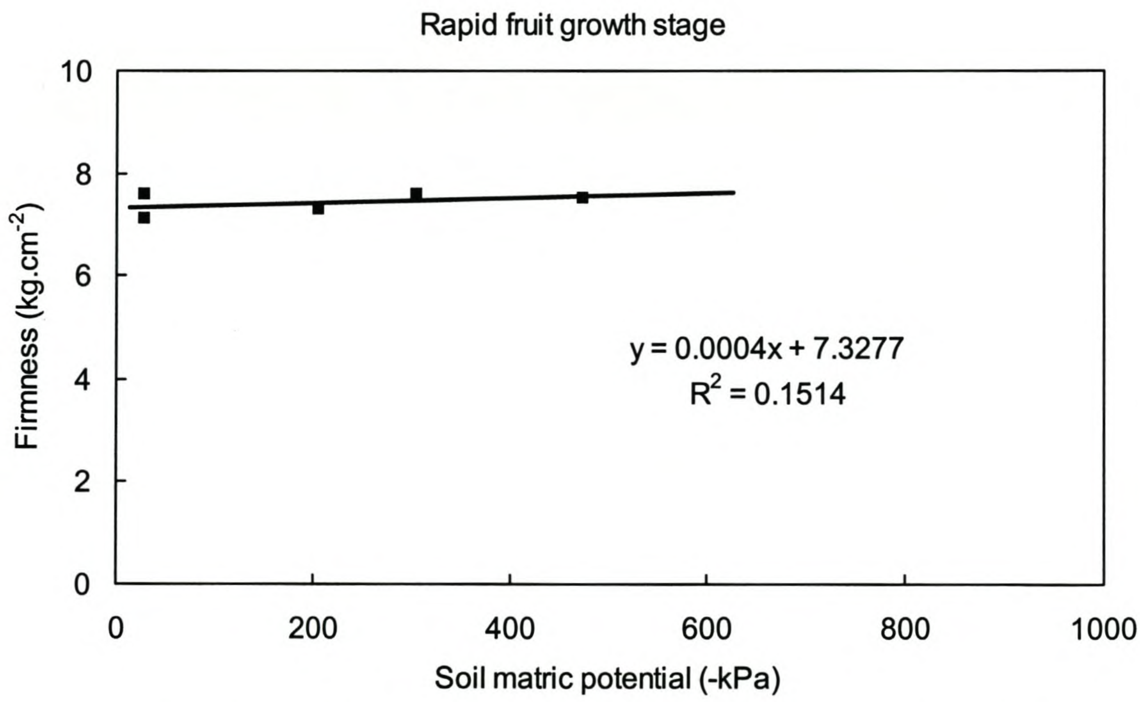

Figure 37. Relationship between the firmness of the fruit and soil matric potential as obtained for deficit irrigation during the rapid fruit growth stage (Stage 3) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

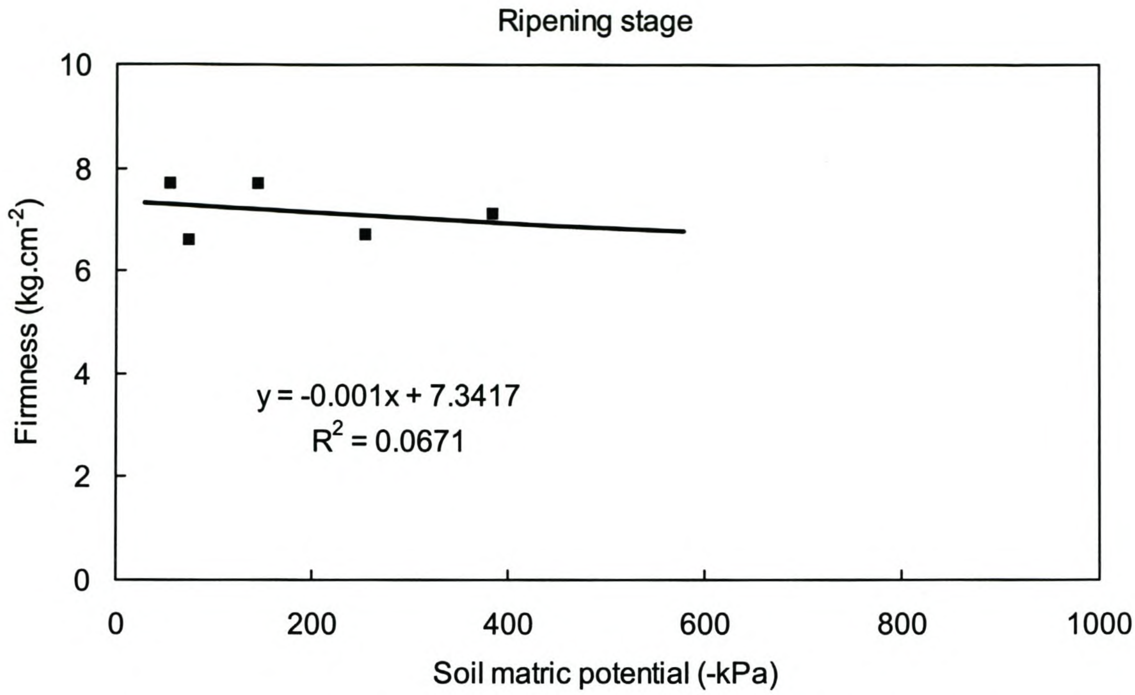

Figure 38. Relationship between the firmness of the fruit and soil matric potential as obtained for deficit irrigation during the fruit ripening stage (Stage 4) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

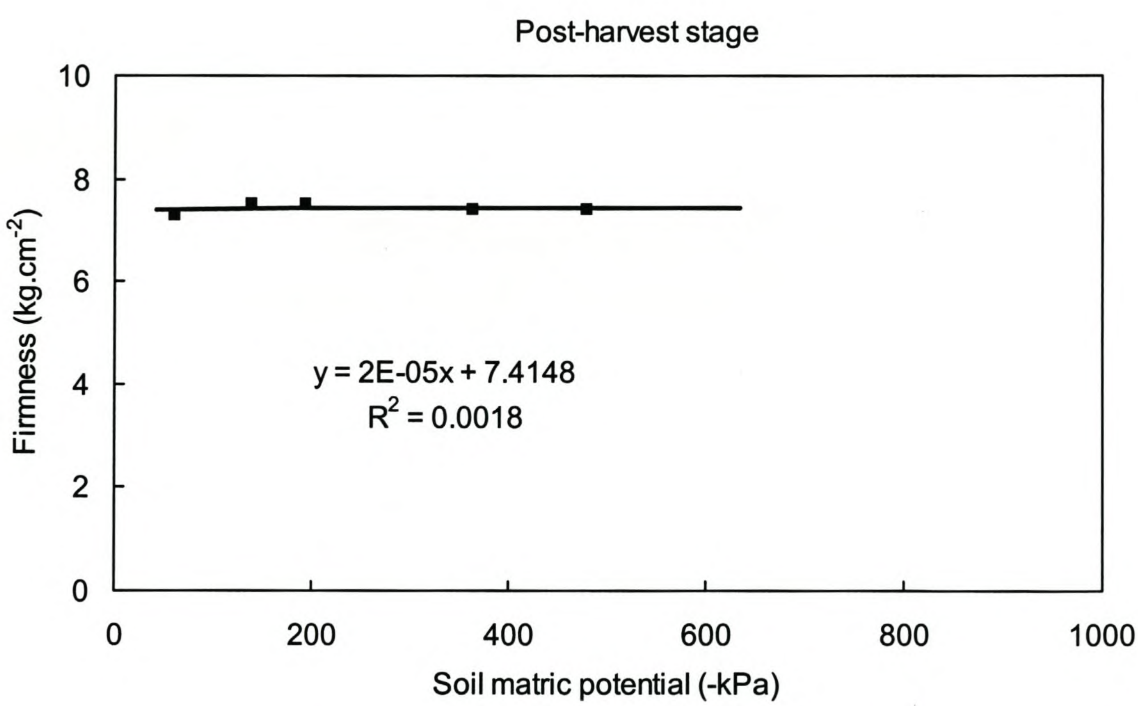

Figure 39. Relationship between the firmness of the fruit and soil matric potential as obtained during deficit irrigation for the post-harvest stage (Stage 5) of Neethling peaches during the 1998/1999-season at Robertson Experiment Farm.

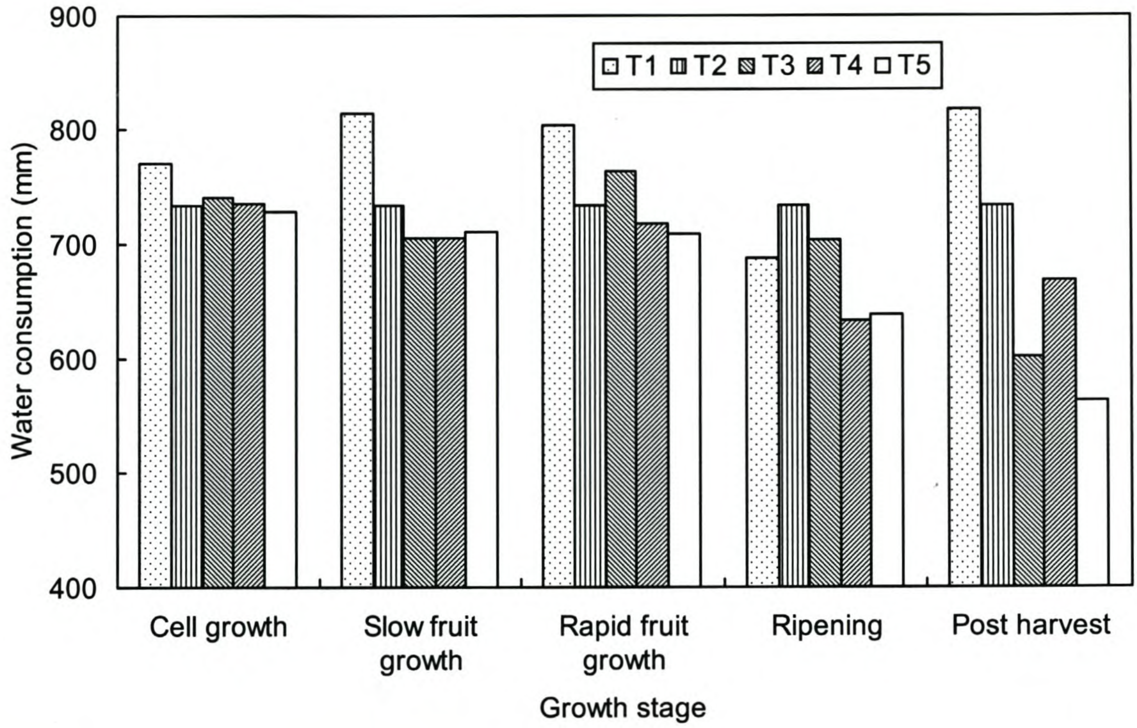

Figure 40. Total water consumption of Neethling peaches during the 1998/1999-season as affected by water deficits during the different growth stages as measured in the wetted strip at Robertson Experiment Farm.

3.4 CONCLUSIONS

Excessive vegetative growth is generally a problem in peach orchards as it is to the disadvantage of fruit growth. Results of this trial proved that excessive shoot growth could be controlled by applying deficit irrigation practices during the slow and rapid fruit growth as well as during the ripening stage.

In addition, fruit size, fruit mass and fruit quality, as well as production, were not sensitive to water deficits during the different growth stages and soil matric potentials up to –200 kPa could be applied during all the growth stages without seriously affecting the final fruit size, fruit mass, fruit quality or the production. The application of deficit irrigation during the slow fruit growth stage of the present season or the post harvest stage of the previous season, can save substantial amounts of water without seriously affecting production.

CHAPTER 4

THE EFFECT OF DEFICIT IRRIGATION ON THE PRODUCTION AND FRUIT QUALITY OF PEACHES WITH A HIGH CROP LOAD

4.1 MATERIAL AND METHODS

The trial was continued in the following season (1999/2000) in the same orchard. The procedures followed were identical to the 1998/1999 trial with the only exception that a 50% higher crop load was allowed in the second trial. The average crop load in the second trial was 572 fruit per tree compared to 380 fruit per tree for the first trail. Fruit growth measurements were done once a week but vegetative growth was not measured.

4.2 RESULTS AND DISCUSSION

4.2.1 Meteorological conditions

A comparison between relevant meteorological conditions that were experienced during the respective growing seasons of the two trials are presented in Table 2. Similar meteorological conditions prevailed during the 1998/1999 and the 1999/2000-seasons. No major differences in average daily maximum temperature, average daily wind speed or relative humidity were experienced during the two different seasons. However, the total rainfall during the 1998/1999-season was much higher than the total rainfall for the 1999/2000-season. The average Penman-Monteith evaporation was somewhat higher for the 1998/1999-season compared to the present season.

4.2.2 Stem growth and tree volume

No significant differences in increase of trunk circumferences or in tree volume occurred obtained between the different treatment combinations (data not shown).

4.2.3 Fruit growth

The effects of the five different irrigation treatments on fruit growth during the different phenological growth stages are illustrated in Figures 41 to 45 respectively.

Table 2. Relevant meteorological conditions that prevailed during the two trials at Robertson Experiment Farm.

Month	Average daily maximum temperature (°C)		Average daily wind speed ($m.s^{-1}$)		Total rainfall (mm)		Average daily Penman-Monteith evaporation (mm)		Relative daily humidity (%)	
	1998/1999	1999/2000	1998/1999	1999/2000	1998/1999	1999/2000	1998/1999	1999/2000	1998/1999	1999/2000
Feb.	31,8	30,7	2,33	2,40	2,6	17,4	5,85	5,55	70,2	77,8
Mar.	28,5	30,8	2,21	2,14	18,4	0,8	4,71	3,86	71,6	89,6
Apr.	27,1	26,5	2,02	2,03	35,4	0,4	3,54	1,71	73,4	93,9
Sep.	22,7	22,2	2,46	2,60	13,6	0,2	3,97	3,51	66,5	71,4
Oct.	26,3	26,9	2,55	2,49	0,2	2,4	5,87	4,29	63,7	73,1
Nov.	26,9	28,6	2,50	2,92	44,8	0	5,86	7,24	67,6	60,5
Dec.	29,5	33,2	2,57	2,29	54,8	23,6	6,68	6,83	67,8	63,2
Jan.	32,0	31,4	2,44	2,39	5,2	10,0	6,81	6,06	71,3	65,1
Average	28,1	28,8	2,38	2,41	--------	--------	5,41	4,88	69,0	74,3
Total	--------	--------	--------	--------	175,0	54,8	--------	--------	--------	--------

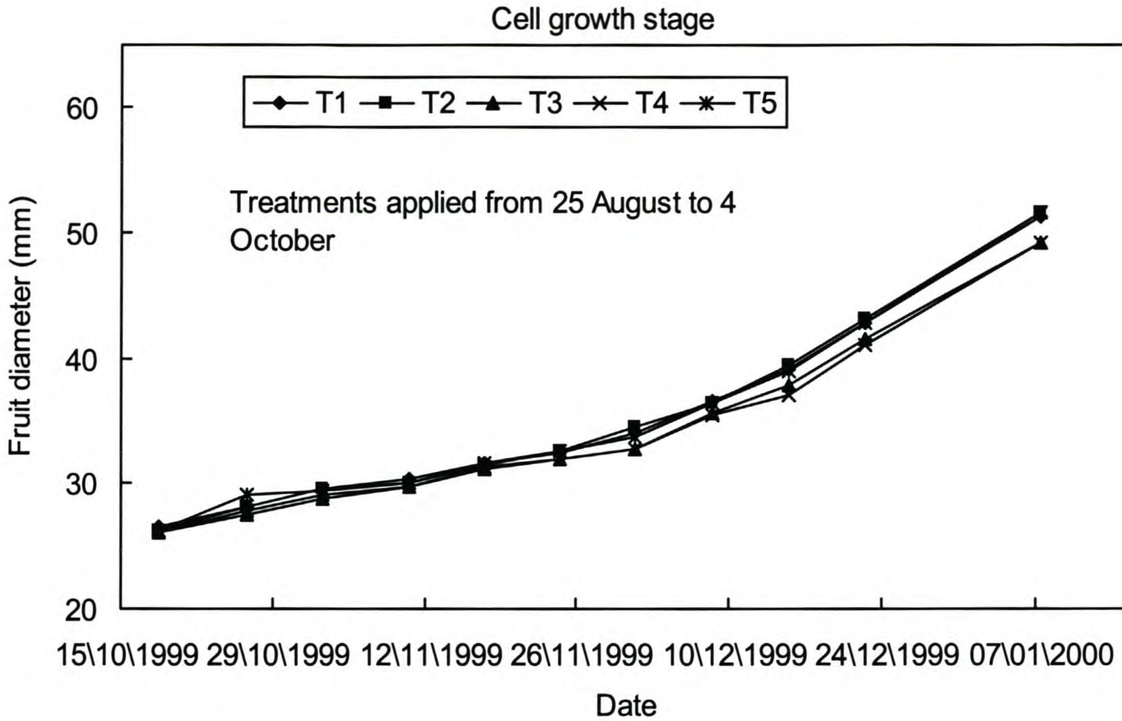

Figure 41. Effect of water deficits during cell growth (Stage 1) on fruit diameter of Neethling peaches as measured during the 1999/2000-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

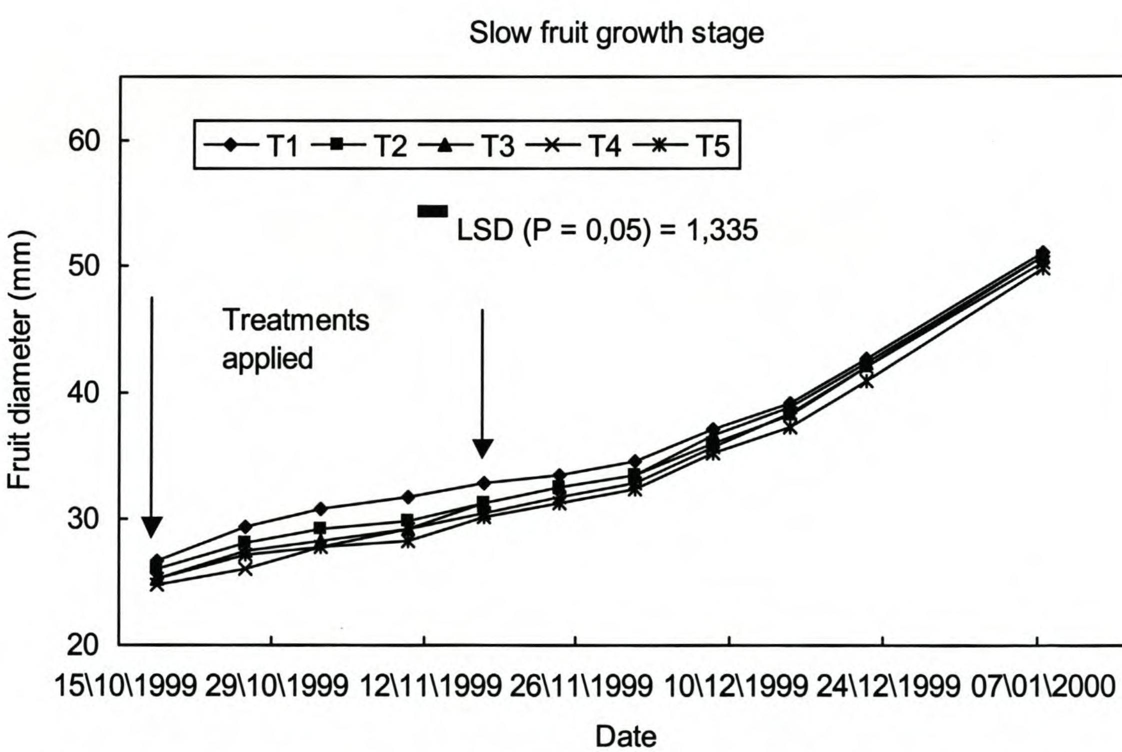

Figure 42. Effect of water deficits during slow fruit growth (Stage 2) on fruit diameter of Neethling peaches as measured during the 1999/2000-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

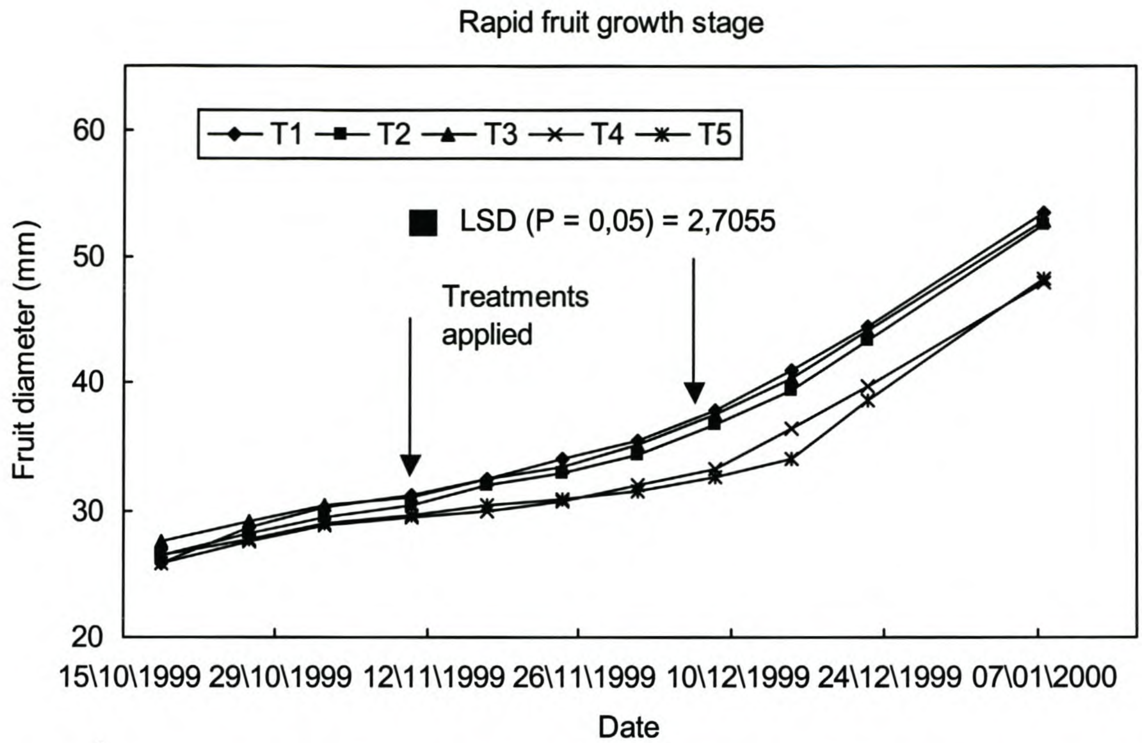

Figure 43. Effect of water deficits during rapid fruit growth (Stage 3) on fruit diameter of Neethling peaches as measured during the 1999/2000-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

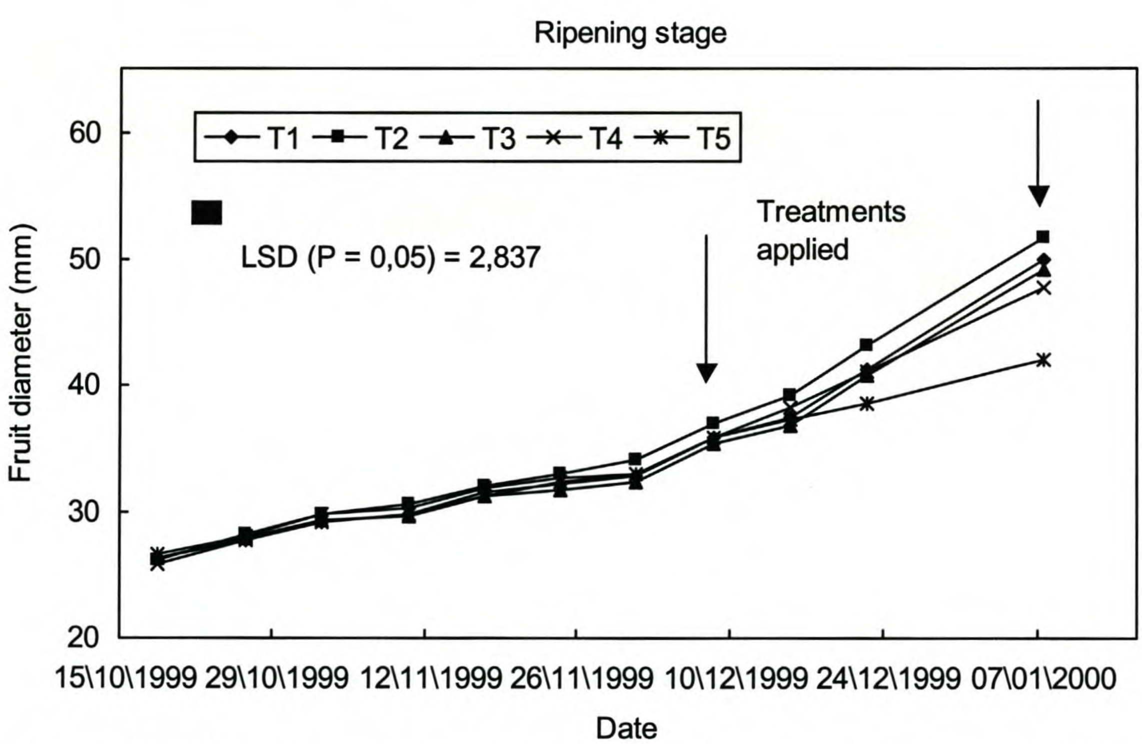

Figure 44. Effect of water deficits during ripening (Stage 4) on fruit diameter of Neethling peaches as measured during the 1999/2000-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

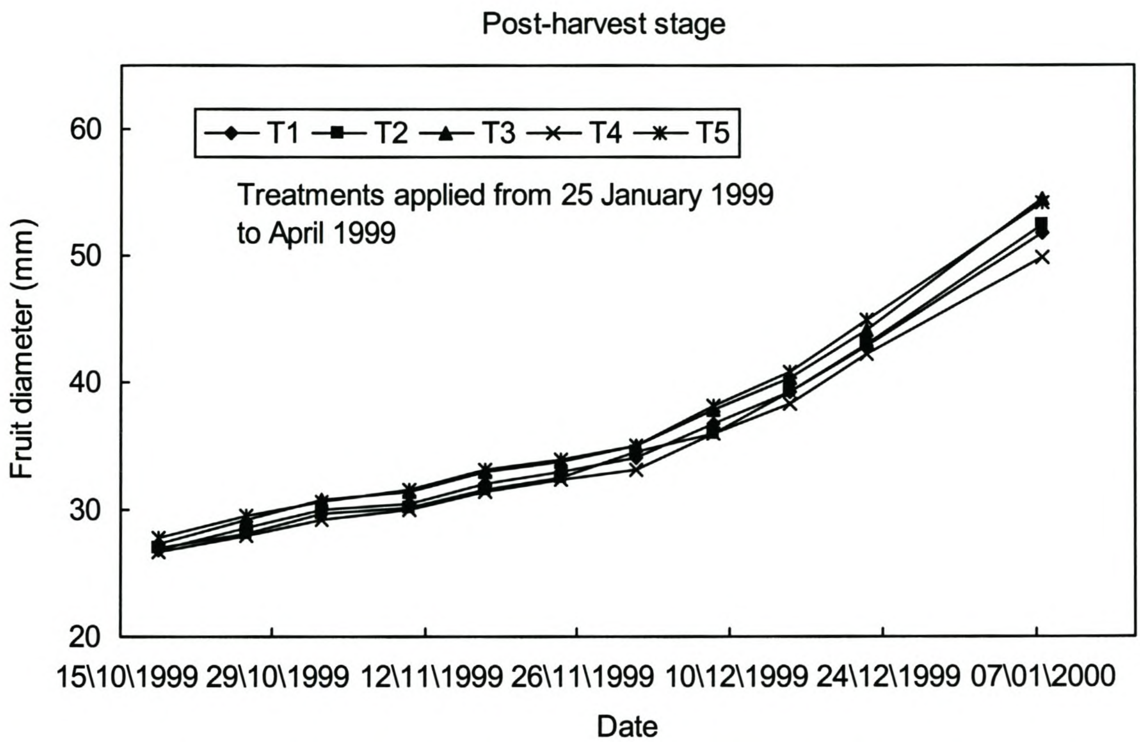

Figure 45. Effect of water deficits during post-harvest (Stage 5) of the previous season on fruit diameter of Neethling peaches as measured during the 1999/2000-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

Similar to the first experiment, no fruit growth measurements were done during the cell growth stage, as this stage preceded thinning. No effect of irrigation treatments on fruit growth was obtained throughout the season (Figure 41).

Significant differences in fruit diameter were obtained by the different irrigation treatments applied during the slow fruit growth stage (Figure 42). At the end of this stage, the fruit of the T1 treatment was the largest and differed statistically from the fruit of the T5 treatment. However, similar to the first experiment, these differences were eliminated at harvest by applying normal irrigation during the consecutive rapid fruit growth and ripening stages. This suggests that fruit growth can recover from the negative effects of deficit irrigation applied earlier in the growing season. These results correspond with those reported by Li *et al.* (1989) and Mitchell *et al.* (1982,1984,1986).

Irrigation treatments applied during the rapid fruit growth stage again induced differences in fruit growth during this period (Figure 43). The largest fruit size was obtained with the T1 treatment, followed by the T2, T3, T4 and T5 treatments. However, in correspondence to results obtained in the previous season, the differences were not eliminated by the application of normal irrigation during the following ripening stage and the treatment sequence remained the same. The treatment sequence during this stage was T1, T3, T2, T4 and T5.

Water deficits applied during the ripening stage significantly affected fruit growth (Figure 44). It is thus important not to apply any severe water deficits during this stage since this is the final and most important fruit growth stage. Water deficits during this stage might have inhibited the conversion of acids and starch to sugars. These results correspond with those reported by Anon. (2000).

The irrigation treatments applied during the post-harvest stage of the 1989/1999-season had a significant effect on fruit growth during the 1999/2000-season (Figure 45).

4.2.4 Final fruit size

The final fruit size was significantly affected by irrigation treatments applied during the rapid fruit growth, ripening and post-harvest stages (Figure 46). Smaller fruit was obtained with the deficit irrigation treatments during the rapid fruit growth, as well as the ripening stages, while no definite trend was observed during the post-harvest stage.

The final fruit size correlated to soil matric potentials reached in the five different phenological stages, are presented in Figures 47 to 51 respectively. It was not possible to reach lower (more negative) soil matric potentials during the cell growth stage due to the relatively mild climatic conditions that were experienced during this stage (Figure 47). However, compared to the previous experiment, the soil matric potentials actually reached during this stage were significantly lower and a good relationship between final fruit size and soil matric potential was obtained. Similar results were obtained for the slow fruit growth, rapid fruit growth and ripening stages, where good relationships were obtained between final fruit size and soil matric potentials (Figures 48 to 50).

Although significant differences in fruit size during the post-harvest stage were obtained (Figure 46), no significant relationship between fruit size and soil matric potential was observed (Figure 51).

Results obtained during the 1999/2000-season were most of the time contradictory to results obtained during the 1998/1999-season, where no significant relationships between fruit size and soil matric potentials were reached. This can be ascribed to the higher crop load during the 1999/2000-season. It can be assumed that fruit trees with an higher than normal crop load will be more sensitive to water deficits than trees with a normal crop load. In addition, due to lower rainfall during the 1999/2000-season, it was possible to reach much lower (more negative) soil matric potentials compared to the 1998/1999-season. This also contributed to the better relationships obtained between fruit size and soil matric potentials.

The present results revealed that fruit size were sensitive to water deficits during all the pre-harvest stages. These results are similar to those reported by Li *et al.* (1989, and references therein). In general, soil matric potentials of up to –200 kPa could be applied during any one of the growth stages

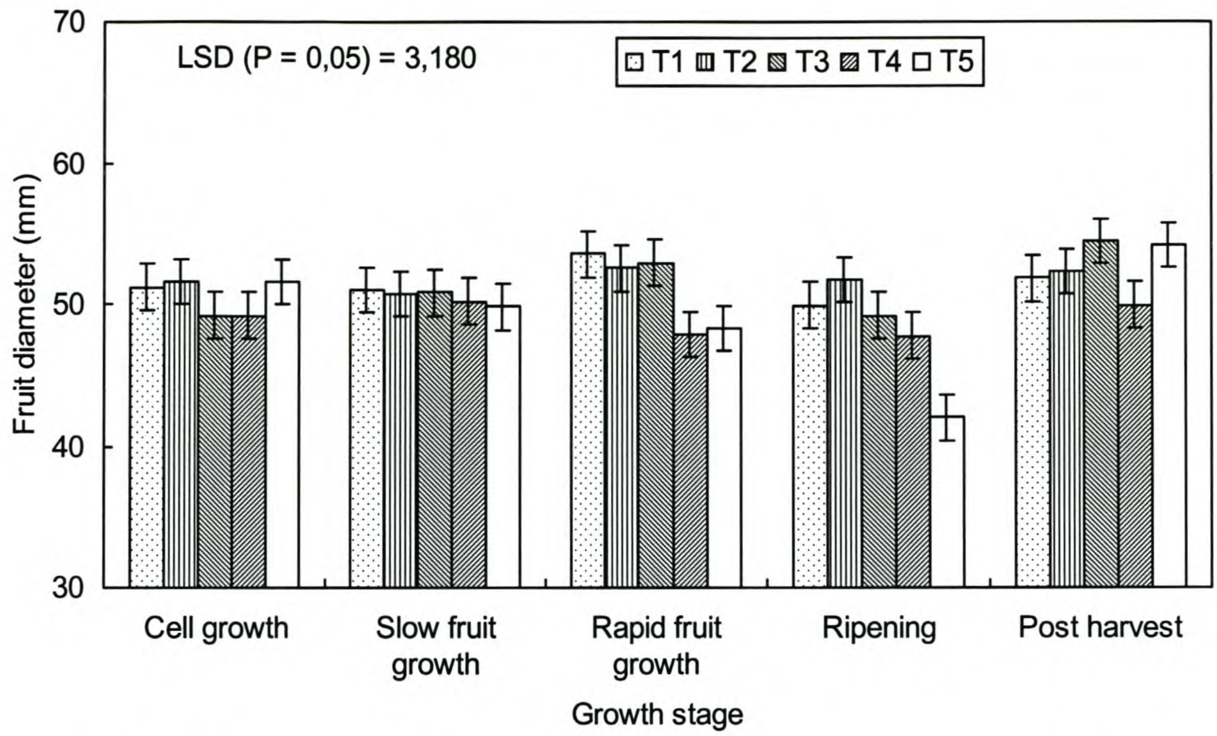

Figure 46. Effect of water deficits during the different growth stages on final fruit diameter of Neethling peaches as measured during the 1999/2000-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

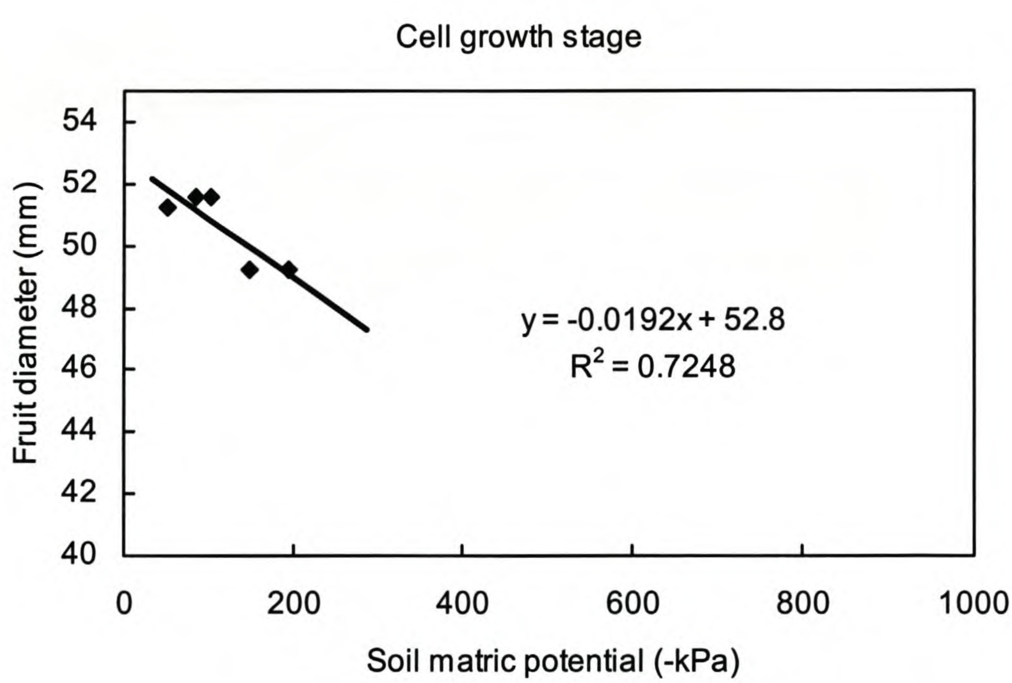

Figure 47. Relationship between final fruit diameter and soil matric potential as obtained for deficit irrigation during the cell growth stage (Stage 1) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

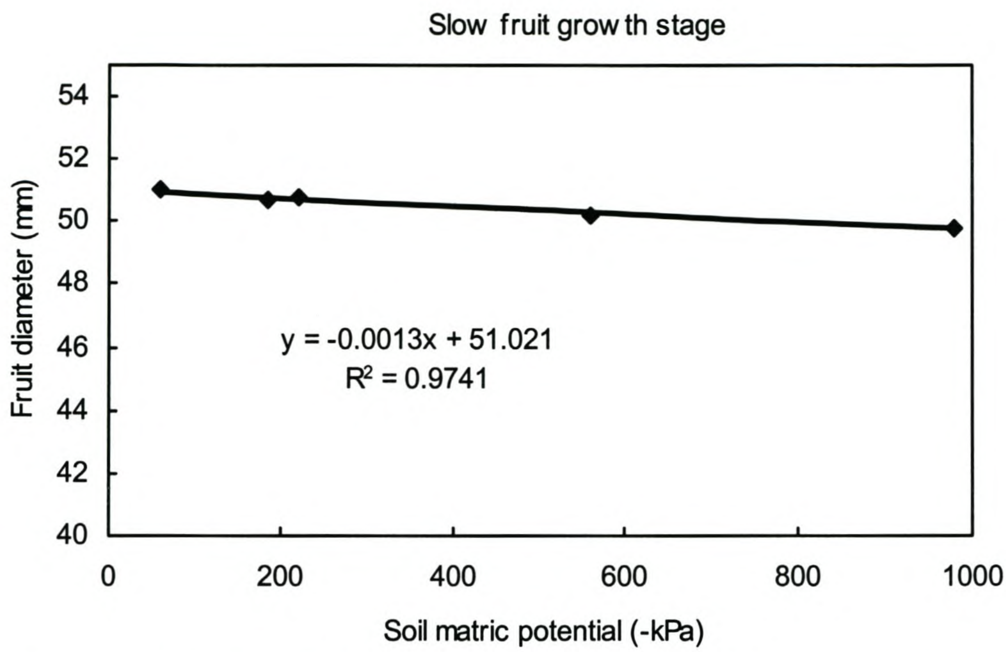

Figure 48. Relationship between final fruit diameter and soil matric potential as obtained for deficit irrigation during the slow fruit growth stage (Stage 2) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

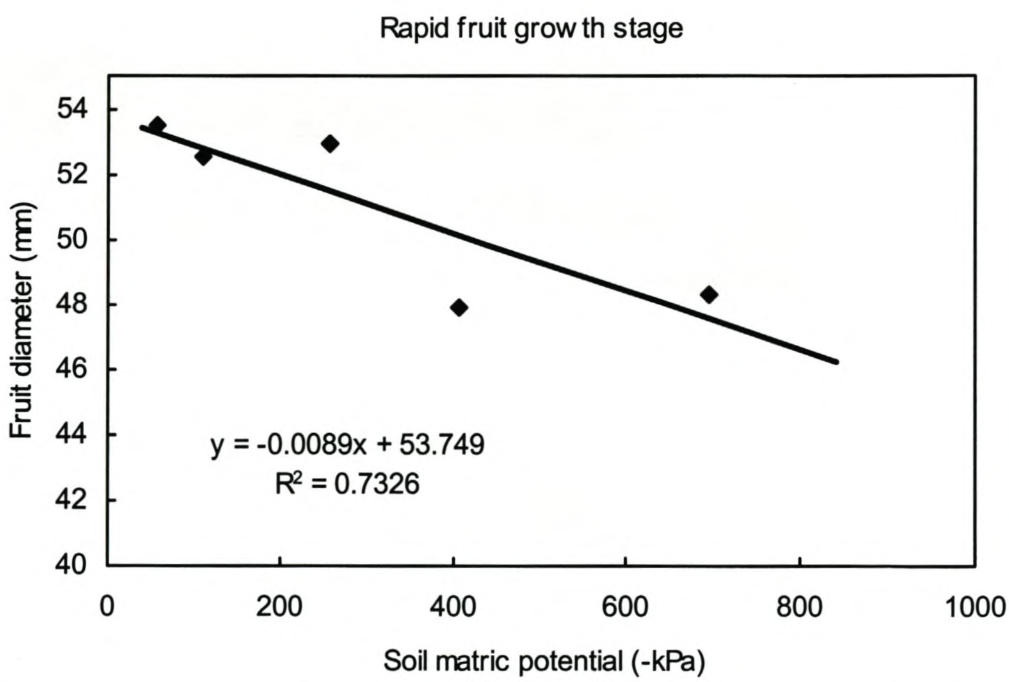

Figure 49. Relationship between final fruit diameter and soil matric potential as obtained for deficit irrigation during the rapid fruit growth stage (Stage 3) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

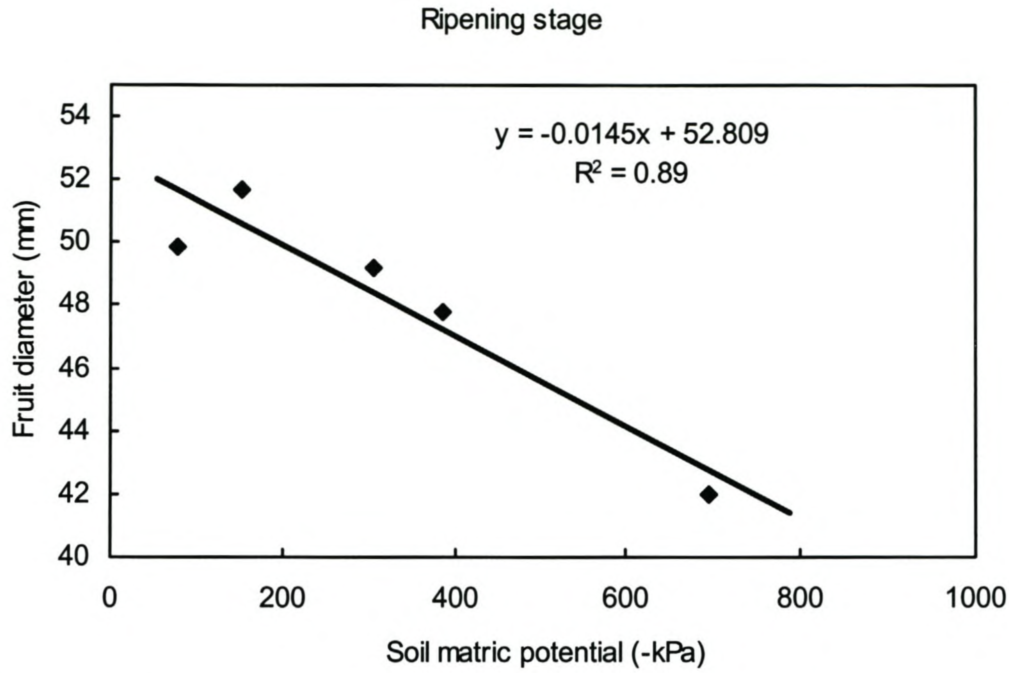

Figure 50. Relationship between final fruit diameter and soil matric potential as obtained for deficit irrigation during the fruit ripening stage (Stage 4) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

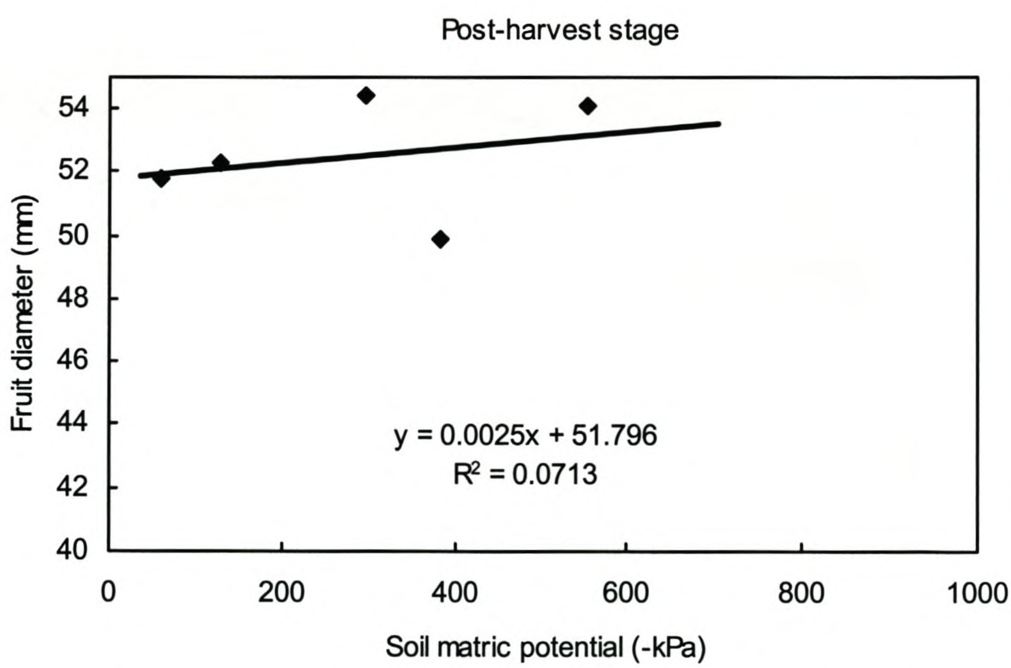

Figure 51. Relationship between final fruit diameter and soil matric potential as obtained for deficit irrigation during the post-harvest stage (Stage 5) of the previous season of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

without seriously affecting the final fruit size. However, normal irrigation should be applied in the other growth stages.

4.2.5 Fruit mass

The most significant reduction in fruit mass was caused by water deficits during the ripening stage (Figure 52). The relationships between fruit mass and soil matric potential for the different phenological growth stages are presented in Figures 53 to 57. No significant relationships between fruit mass and soil matric potentials were reached during the different growth stages, except during the ripening stage where a significant relationship between fruit mass and soil matric potential was obtained (Figure 56). This is in correspondence with results obtained during the 1998/1999-season (Figure 20) and is reflected in Figure 52.

Water deficits should therefore definitely be avoided during the ripening stage. This suggests that water deficits limited accumulation of solids in fruit. This viewpoint is supported by Parker & Marini (1994).

Present results indicated that, except for the ripening stage, soil matric potentials of up to –200 kPa can be applied during any one of the growth stages without serious negative effects on fruit mass.

Smaller fruit was obtained with all the treatment combinations during the 1999/2000-season (Figure 52) in comparison to the 1998/1999-season (Figure 16). This can be ascribed to the higher crop load during the 1999/2000-season.

4.2.6 Production

The production obtained for the different treatment combinations are presented in Figure 58, while the relationships between production and soil matric potentials for the respective growth stages are shown in Figures 59 to 63.

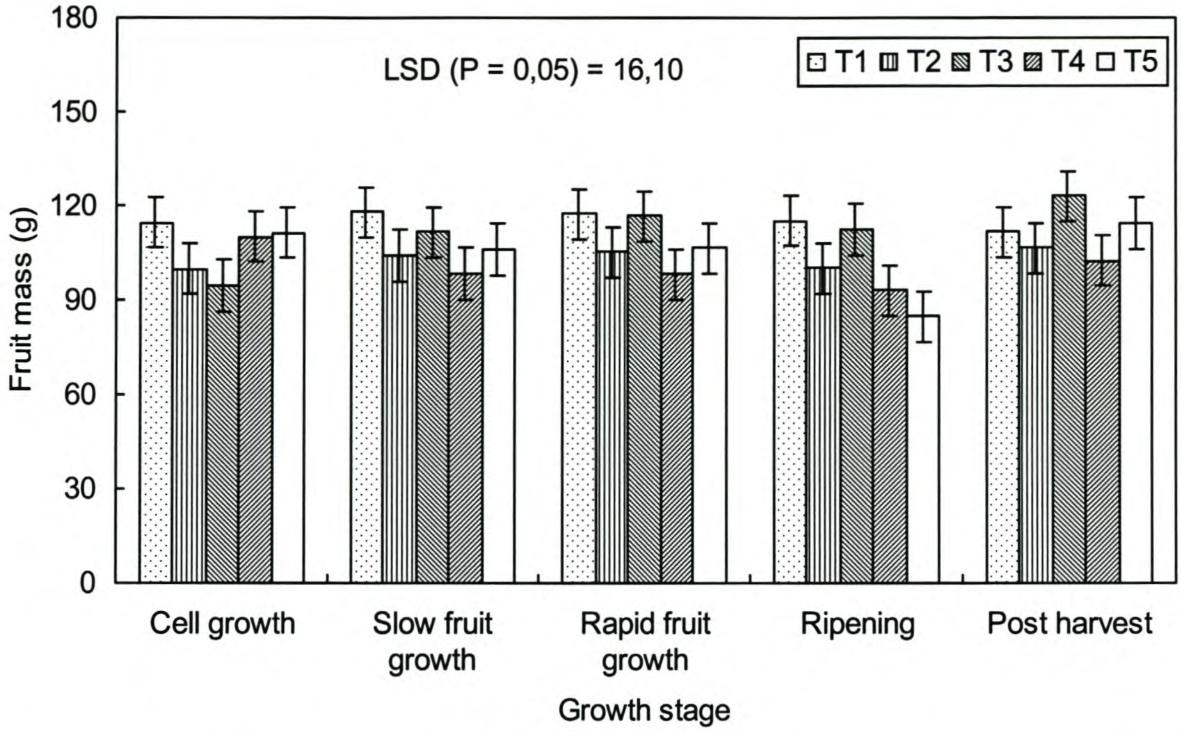

Figure 52. Effect of water deficits during the different growth stages on the final fruit mass of Neethling peaches as obtained during the 1999/2000-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

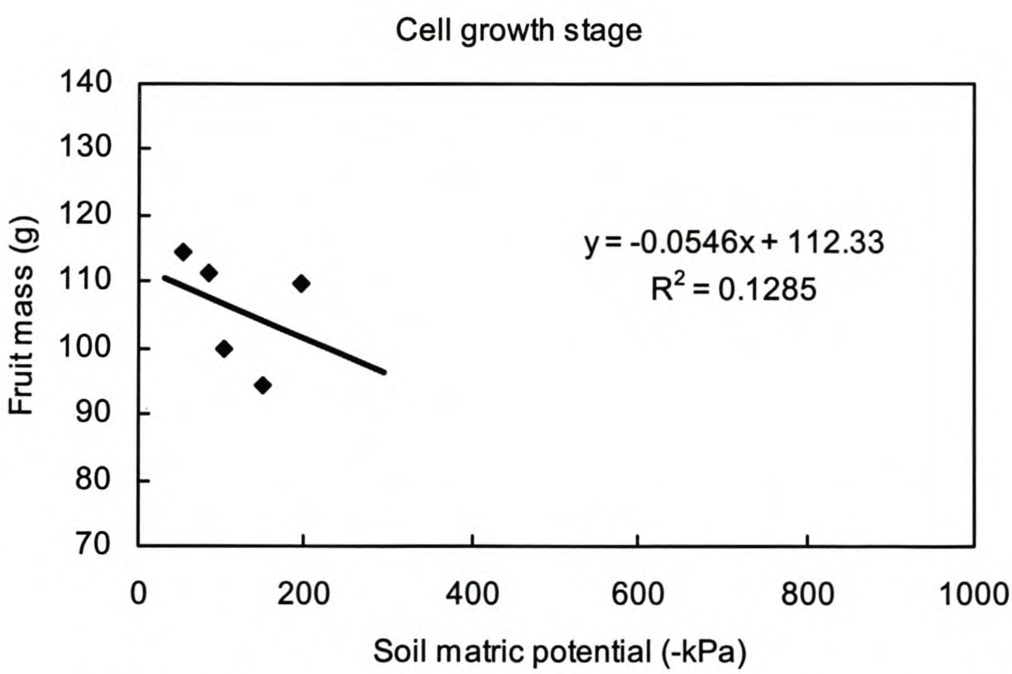

Figure 53. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the cell growth stage (Stage 1) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

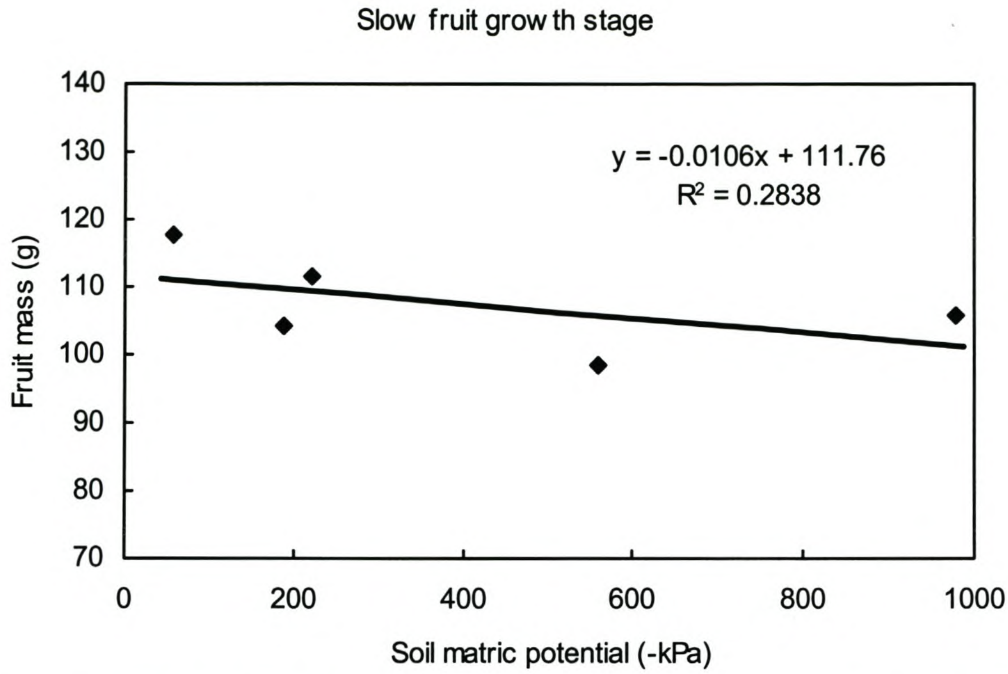

Figure 54. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the slow fruit growth stage (Stage 2) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

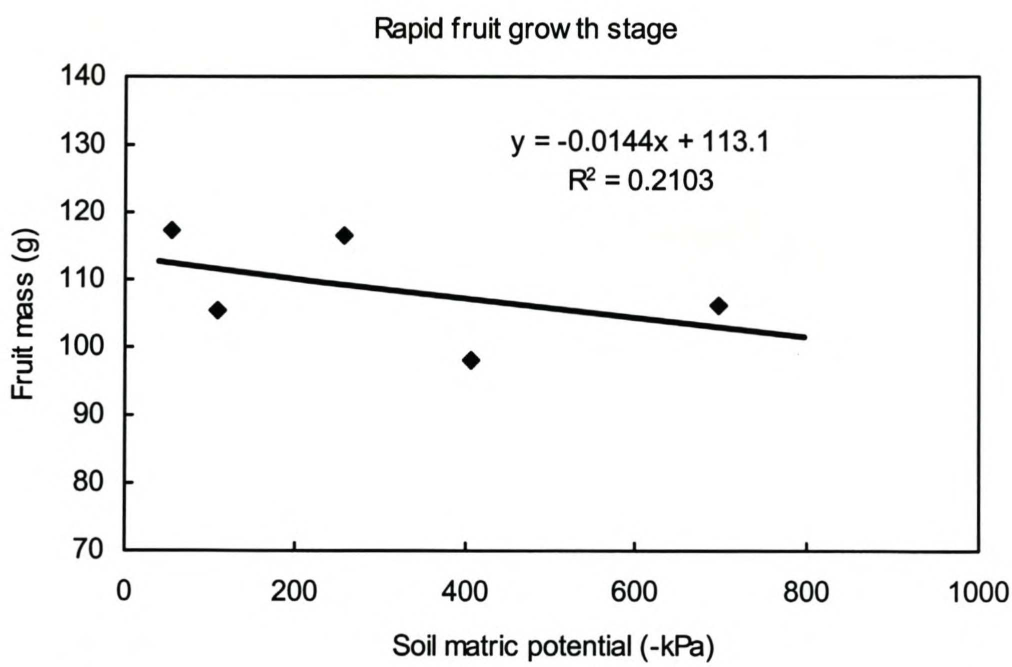

Figure 55. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the rapid fruit growth stage (Stage 3) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

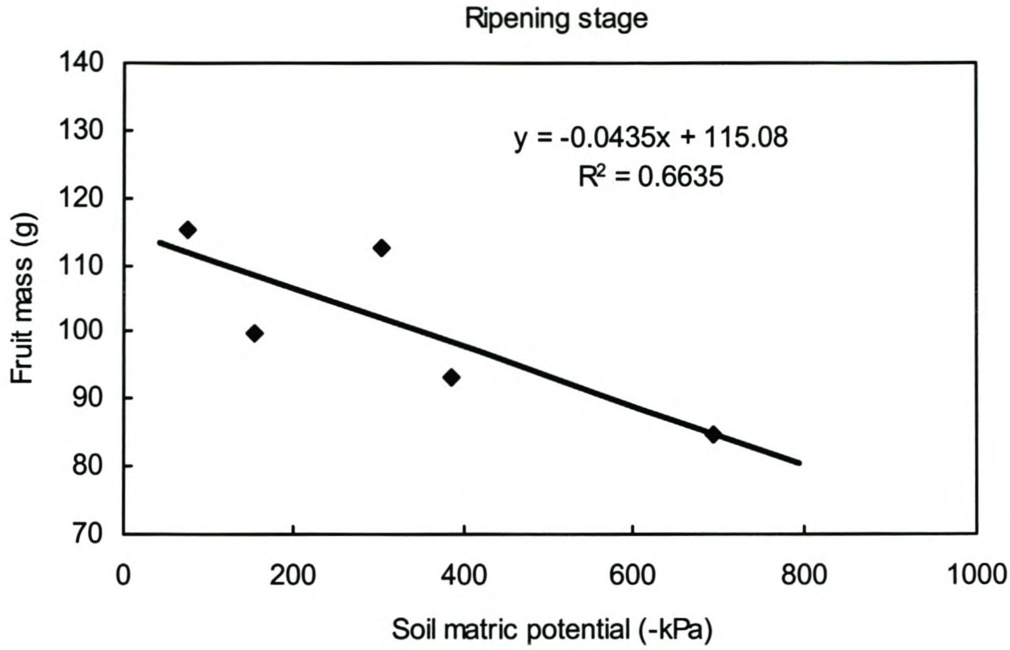

Figure 56. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the fruit ripening stage (Stage 4) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

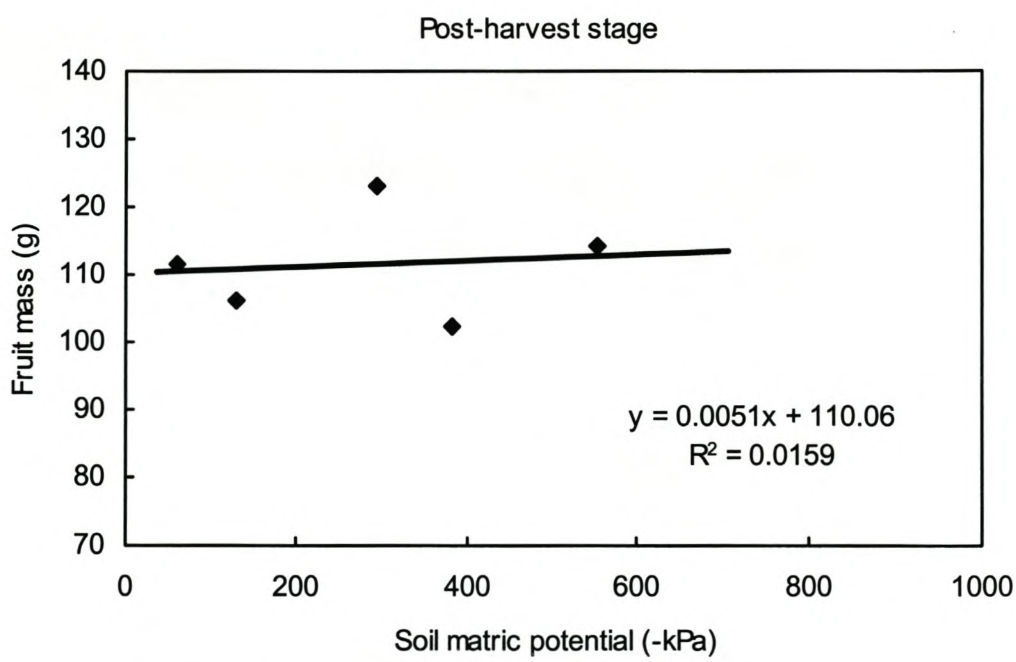

Figure 57. Relationship between fruit mass and soil matric potential as obtained for deficit irrigation during the post-harvest stage (Stage 5) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

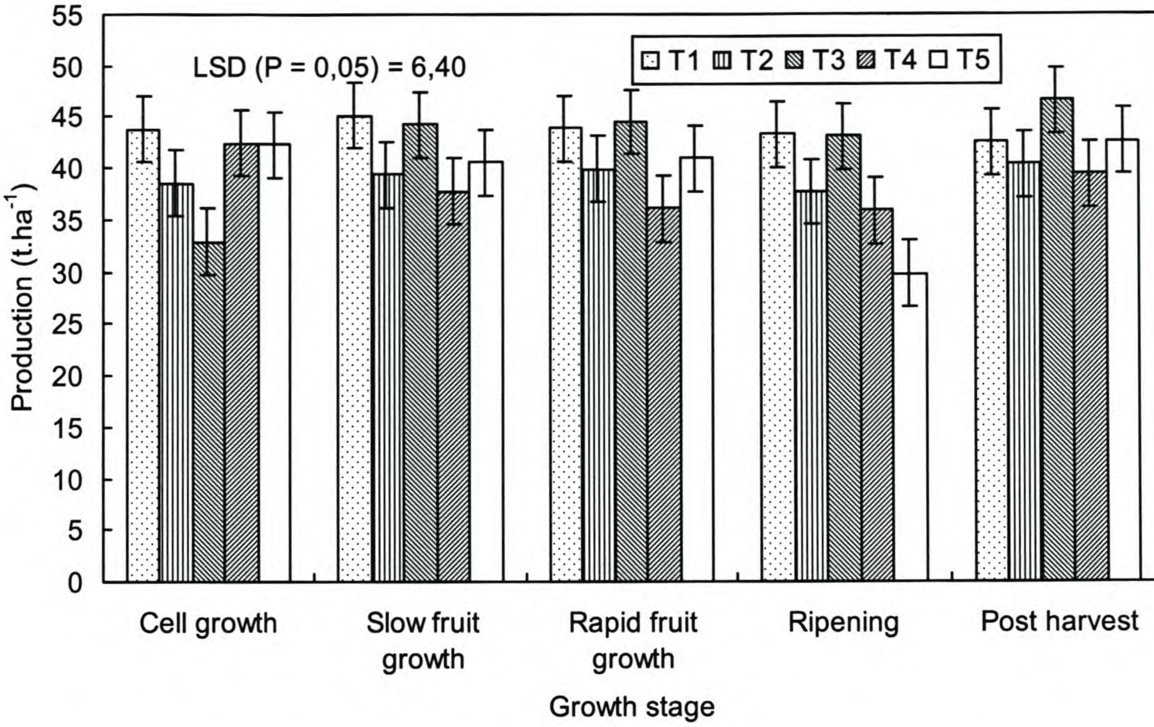

Figure 58. Effect of water deficits during the different growth stages on the production of Neethling peaches as obtained during the 1999/2000-season at Robertson Experiment Farm. (Refer to material and methods for explanation of treatments).

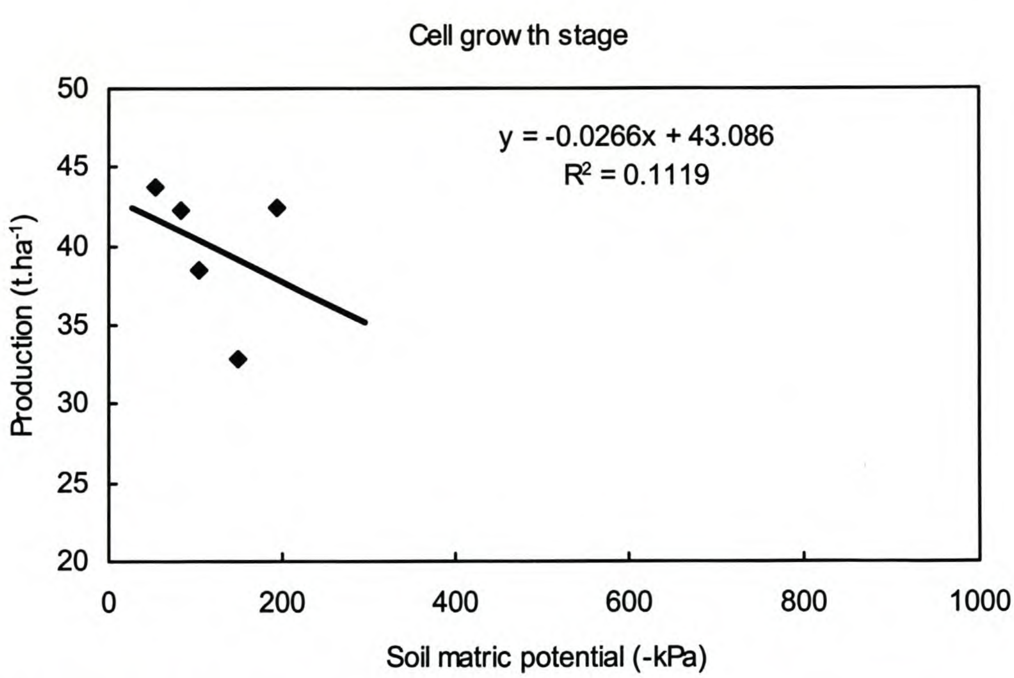

Figure 59. Relationship between production and soil matric potential as obtained for deficit irrigation during the cell growth stage (Stage 1) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

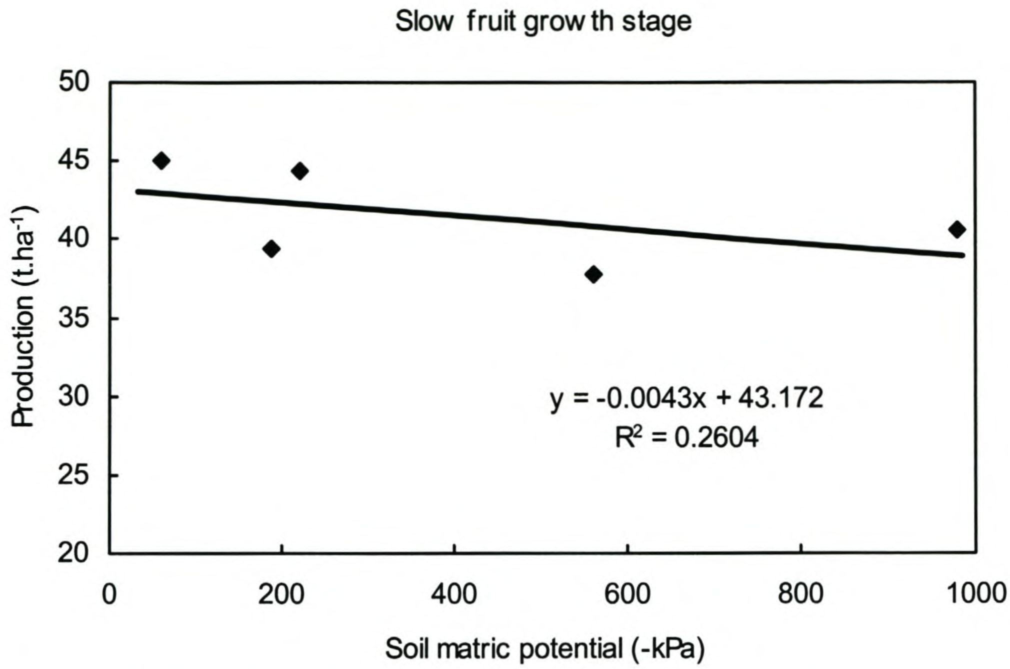

Figure 60. Relationship between production and soil matric potential as obtained for deficit irrigation during the slow fruit growth stage (Stage 2) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

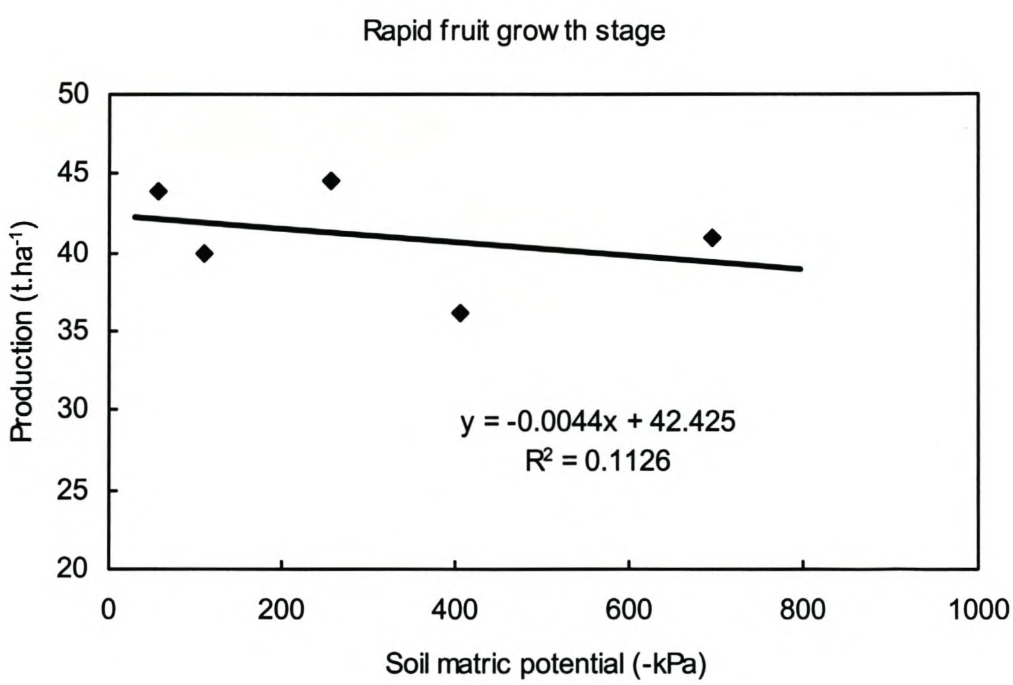

Figure 61. Relationship between production and soil matric potential as obtained for deficit irrigation during the rapid fruit growth stage (Stage 3) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

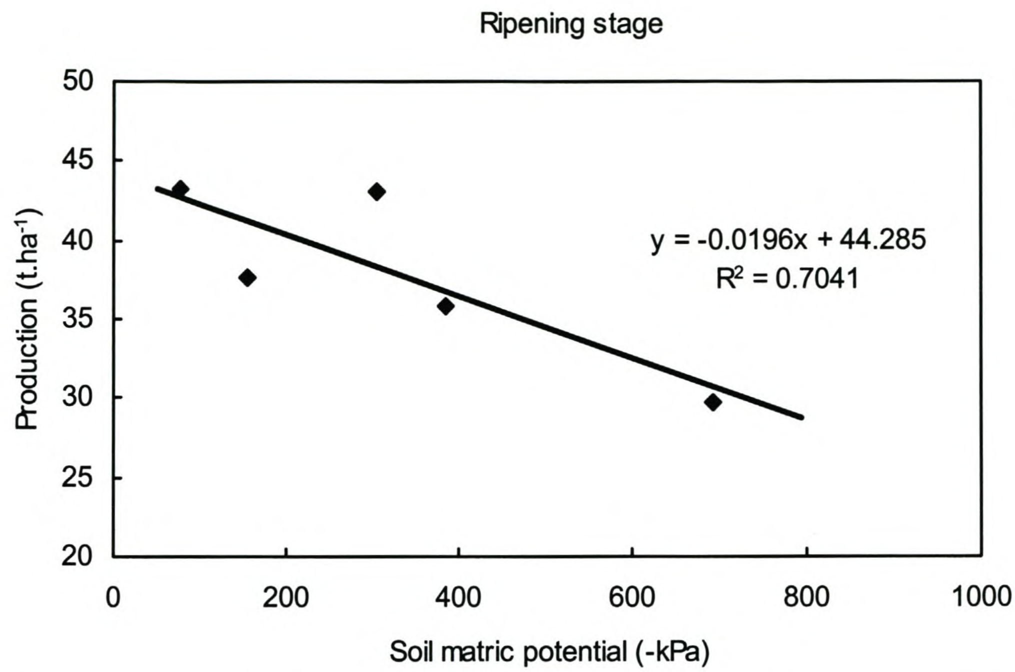

Figure 62. Relationship between production and soil matric potential as obtained for deficit irrigation during the fruit ripening stage (Stage 4) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

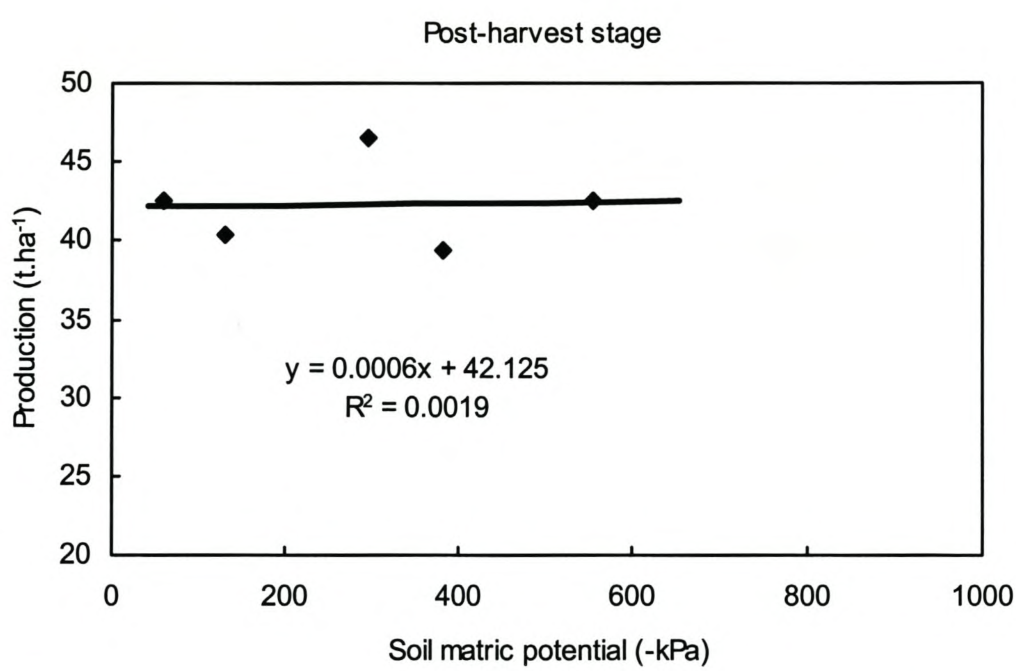

Figure 63. Relationship between production and soil matric potential as obtained for deficit irrigation during the post-harvest stage (Stage 5) of Neethling peaches during the 1999/2000-season at Robertson Experiment Farm.

A significant negative effect on production was induced by water deficits during the ripening stage (Figure 58). This effect was confirmed in Figure 62, where a good relationship between production and soil matric potential was obtained.

Relationships between production and fruit diameter as well as between production and fruit mass are illustrated in Figures 64 and 65 respectively. The same tendencies as in the 1998/1999-season (Figures 28 and 29), were observed. In contrast to the latter, a very good relationship between production and fruit mass was observed during the 1999/2000 season. This can be expected as similar tendencies are observed when the individual growth stages in Figures 53 to 57 are compared with tendencies in Figures 59 to 63.

The decrease in production induced by water deficits during the ripening stage corresponds with results reported by Ghrab (1998), while a similar tendency was observed during the 1998/1999-season. The present results suggested that soil matric potentials of up to –200 kPa could be allowed during any one of the stages without the risk of seriously reducing the production.

4.2.7 Fruit quality

The different deficit irrigation treatments had no significant effect on the amount of fruit bruised, total soluble solids or the firmness of the fruit (data not shown). These results correspond with those obtained during the 1998/99-season.

4.2.8 Water consumption

The water consumption recorded for the different treatment combinations during the 1999/2000-season is presented in Figure 66.

Water consumption is largely dependent on the meteorological conditions experienced during the trial, such as evaporation and amount and timing of rainfall. For instance, a relative small amount of rain on a dry top layer of soil will have little or no effect on the replenishment of water. Tree volume and crop load can also have a significant effect on water consumption.

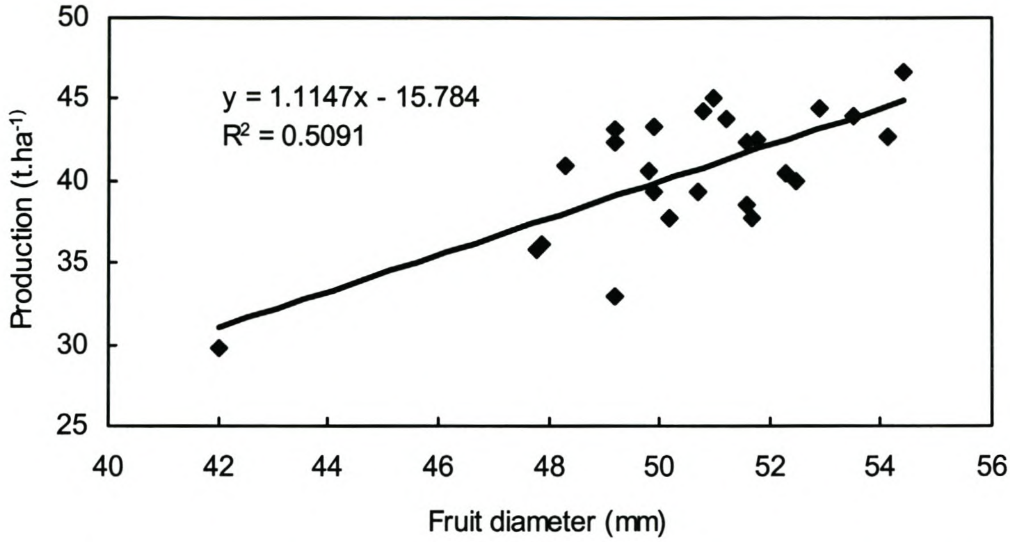

Figure 64. Relationship between production and final fruit diameter of Neethling peaches as obtained during the 1999/2000-season at Robertson Experiment Farm.

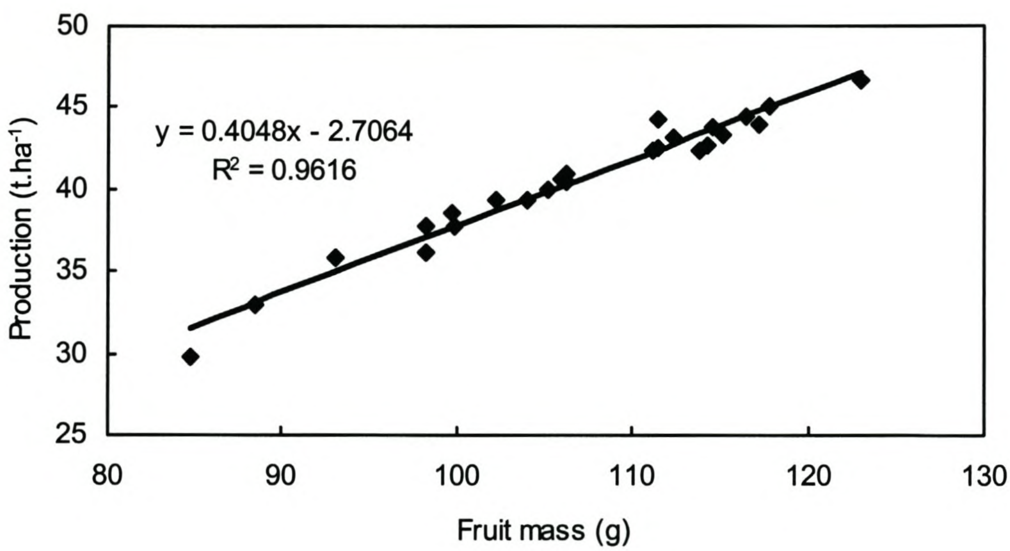

Figure 65. Relationship between production and fruit mass of Neethling peaches as obtained during the 1999/2000-season at Robertson Experiment Farm.

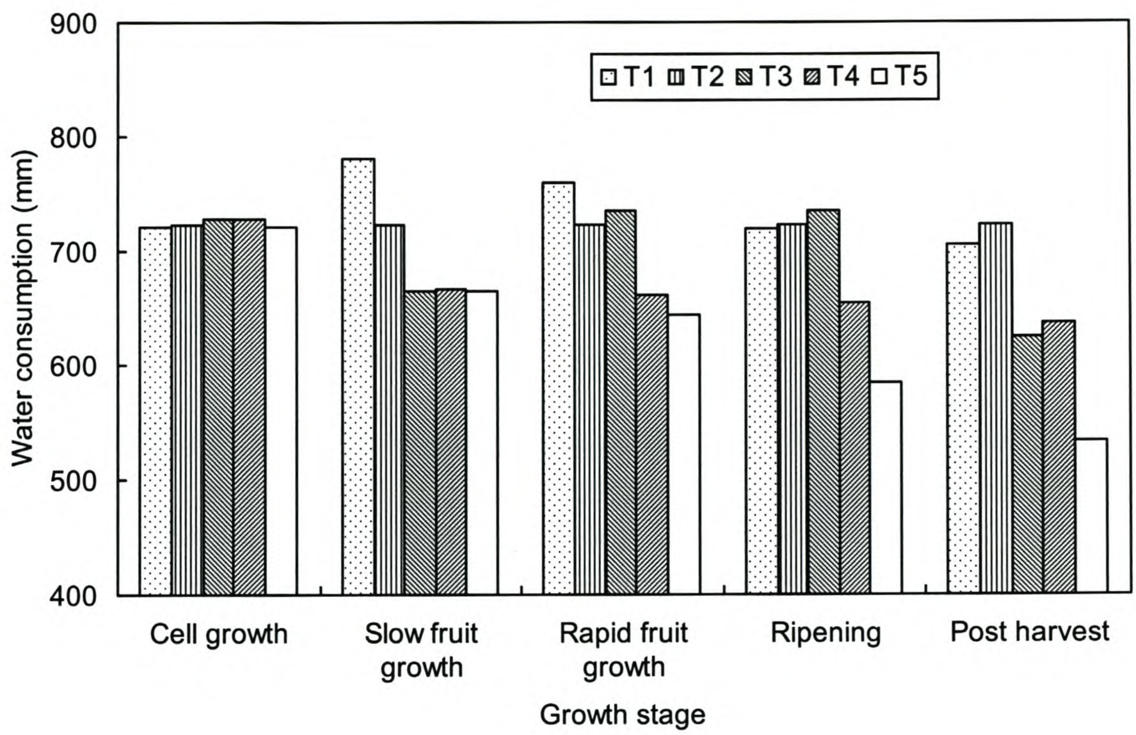

Figure 66. Total water consumption of Neethling peaches during the 1999/2000-season as affected by water deficits during the different growth stages as measured in the wetted strip at Robertson Experiment Farm.

The water consumption during the 1999/2000-season was on average lower than the water consumption during the 1998/1999-season (Figure 40). This is in correspondence to the slightly lower Penman-Monteith evaporation of the 1999/2000-season as indicated in Table 2.

During both seasons, no considerable differences in water consumption were obtained during the cell growth stage. This can be related to sparse foliage and mild meteorological conditions experienced during the beginning of the season. For instance, during the rapid fruit growth stage of both seasons, an unexpected but considerable higher water consumption was obtained with treatment T3 (*ca.* –200 kPa), compared to the normal T2 treatment (*ca.* –100 kPa). This can be ascribed to tree size. The average tree volumes as stem circumferences as measured after harvest in the 1998/1999-season were respectively 15,4 m^3 and 439 mm for the T3 treatment compared to 10,2 m^3 and 393 mm for treatment T2. In the second season the respective average stem circumferences were 463 mm and 414 mm.

In general, apart from the cell growth stage, deficit irrigation treatments tended to reduce seasonal water consumption. By applying the water deficit T3 treatment (*ca.* –200 kPa) instead of the normal T2 (ca.-100 kPa) treatment during the post harvest stage, an average saving of 1150 m^3 of water can be saved per hectare per season without any adverse effects on the production of the trees.

4.3 CONCLUSIONS

Production related more directly to fruit mass than fruit diameter. The effects of water deficits on fruit mass therefore reflected in the production. This was confirmed by the serious negative effect of water deficits during ripening on production. The application of deficit irrigation during the ripening stage had a negative effect on fruit mass, fruit size and production. No negative effects of the application of deficit irrigation were obtained on fruit mass, fruit size and production during the slow fruit growth stage of the present season and the post harvest stage of the previous season. However, similar to results from the previous season, substantial amounts of irrigation water were saved during these stages. It is suggested that soil matric potential up to –200 kPa can be applied during all stages, without the risk of seriously reducing fruit mass or the production.

CHAPTER 5

GENERAL DISCUSSION

Metreorological conditions

No major differences in the meteorological conditions, recorded during the 1998/1999-season or 1999/2000 growing season, were experienced. However, the total rainfall recorded during the first season was much higher than during the second season, while the average Penman-Monteith evaporation for the first season exceeded that of the second season.

The latter parameter is a determining factor in the water requirements of any crop. The result being that, despite the higher crop load during the second season, the water consumption was generally higher during the first season. The higher (and in some respects untimely) rainfall regarding the application of deficit irrigation, as well as the lower crop load during the first season, had the effect that higher soil matric potentials were reached during the second season. The effect of water deficits were thus more readily observable during the second season.

Cell growth stage

The mild climatic conditions experienced during this stage had the effect that no significant water deficits were reached during this stage. No significant effects of irrigation treatments on fruit size or production were obtained and shoot growth is still in a initial stage.

The water requirement during this stage is about 35 mm, of which at least 50% is provided by rainfall during a normal year. This stage is of little importance in terms of water saving aspects.

Slow fruit growth stage

By the application of water deficits during the slow fruit growth stage, it was possible to limit excessive vegetative growth. The deficit irrigation treatments had a significant negative effect on fruit growth at the end of this stage. However, this effect was eliminated at harvest time by application of normal irrigation treatments during the successive rapid fruit growth and ripening stages. No negative effect of irrigation treatments was observed on the production.

This stage can thus be considered as a suitable period for applying deficit irrigation with the aim of saving water and to limit excessive vegetative growth.

Rapid fruit growth stage

As with the slow fruit growth stage, it was possible to limit vegetative growth by applying deficit irrigation. The application of deficit irrigation during this stage had a negative effect on fruit growth at the end of this stage. However, this negative effect was not eliminated by the application of normal irrigation during the succeeding ripening stage and the effect was nevertheless observed at harvest time.

Although production was not significantly affected by irrigation treatments, severe water deficits are not recommendable during this stage.

Ripening stage

The application of water deficits during this stage had a negative effect on fruit size as the smallest fruit was obtained, although vegetative growth was limited. The production was also decreased by water deficits during this stage. The application of water deficits during this stage is not recommendable and normal irrigations should therefore be applied.

Post-harvest stage

No effects of deficit irrigation applied during the post-harvest stage of the previous season were transferred to the succeeding season. Substantial savings of irrigation water can be obtained by applying deficit irrigation during this stage without affecting fruit size or production in the following season.

The different deficit irrigation treatments, applied in any one of the growth stages, had no significant effect on the amount of fruit bruised, total soluble solids, or the firmness of the fruit.

It is important to note that the different deficit irrigation treatments were applied during only one of the five different growth stages with normal irrigation treatments in the remaining four growth stages.

Deficit irrigation treatments with soil matric potentials of up to –200 kPa can be applied without any adverse effect on the fruit size or the production of peaches.

CHAPTER 6

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