FRUIT SIZE IMPROVEMENT OF LEMONS

1 Introduction

Lemons are suited to Mediterranean-type and sub-tropical climatic conditions, although they can be grown in a wide range of climates. Lemons are grown in almost all the main citrus areas in South Africa, but more extensively in the 'intermediate', 'cool' and 'cold' areas like the Eastern and Western Cape. Small fruit size on lemons has become a concern for growers. Non-controllable factors and controllable factors before planting as well as controllable factors after planting all play a role in lemon fruit size. An individual factor or a combination of factors may be responsible for small fruit size and therefore all the factors influencing fruit size should be considered and managed optimally.

2 Non-controllable factors

These factors cannot be changed or manipulated once an orchard has been established. The climate of an area, in particular temperature and therefore effective heat units, plays a major role in lemon fruit growth. Lemon fruit growth follows a sigmoid growth curve similar to that of oranges, with three phases: cell division (phase I), cell enlargement (phase II) and maturation (phase III). Enough heat during phases I and II is essential for fruit growth. Although lemon trees can be planted in areas with a wide range of effective heat units per year (1100 to 1500), some orchards are planted in areas where yearly heat units are lower, or much higher, therefore in sub-optimal growing conditions. Fruit growth is slower in the cooler areas and fruit takes a longer time to reach maturity. The optimum temperature for fruit growth is 30°C, with 20-30°C hot enough for satisfactory fruit growth. However, the fruit growth rate decreases at temperatures above 30°C and below 20°C, with almost no fruit growth occurring at temperatures above 40°C and below 13°C. Therefore, it is advisable to calculate yearly effective heat units using temperatures ≥13°C and ≤ 35°C or even 32°C. However, lemons of adequate size can be produced in hot, humid areas, whereas hot, dry areas can result in smaller fruit. Therefore, the choice of the site of planting is very important and climatic norms for lemon production throughout the season as shown in the table below should be noted. Weather data should be obtained and effective heat units calculated when lemon orchards are established and, especially in seasons giving rise to smaller fruit, to determine if climate played a role.

Broad climatic norms for lemon production in inland and coastal production areas in Southern Africa (Barry et al., 1996):

Inland production areas		
Season	Ave. min. temp. (°C)	Ave. max. temp. (°C)
Spring (Aug - Nov)	10.5 - 15.5	25.5 - 30.0
Summer (Dec - Feb)	16.0 - 21.5	27.5 - 33.0
Autumn (Mar - May)	8.5 - 15.0	24.5 - 29.5
Winter (Jun - Jul)	2.5 - 10.0	19.5 - 26.0
Coastal production areas		
Season	Ave. min. temp. (°C)	Ave. max. temp. (°C)
Spring (Aug - Nov)	10.0 - 12.5	22.5 - 26.0
Summer (Dec - Feb)	14.5 - 17.0	27.0 - 32.0
Autumn (Mar - May)	10.5 - 13.5	21.0 - 25.5
Winter (Jun - Jul)	6.0 - 9.5	17.5 - 22.5

3 Controllable factors before planting

In addition, controllable factors before planting include the soil type (clay %), soil preparation determining the rooting depth, rootstock choice and cultivar choice. Heavier soils normally result in smaller fruit. Incompatibility between the rootstock and scion can also be a major cause of smaller fruit. Choose your tree spacing wisely when orchards are established, since narrow tree spacing (closer plantings) often results in very dense canopies. Since lemon trees (especially Eureka) tend to be tip-bearers (terminal bearers), pruning to open up trees and to control tree size in this case often removes a lot of bearing wood resulting in a less productive tree.

4 Controllable factors after planting

4.1 Irrigation: Cell division and fruit growth are very sensitive to any water stress. Water stress during phases I (cell division) and II (starting ± 60 days after full bloom) of fruit growth results in smaller fruit. Faster and more uniform fruit growth results from more frequent short-cycle irrigation compared to long-cycle irrigation. However, the best irrigation schedule is one that considers the tree's demand and the capacity of the soil.

The capacity of the irrigation system should never dictate when and how much water to apply. The design of the system should therefore satisfy the demand of the trees and the capacity of the soil. Maintaining the design specifications of the system is also important to maintain the efficiency. Measuring the delivery rate and operating pressure at least once per annum, should be standard practice. The larger (to some extent) the volume of soil irrigated (reservoir), the smaller the impact of an irrigation error on fruit size. Single line drippers and systems with two drippers per tree, leave no margin for error. A micro-jet system can compensate to some extent for management or system errors.

Another important factor that is often neglected is the wetting depth, especially with drip systems. Irrigation scheduling should be based on the effective rooting depth of a specific soil-orchard combination. The most effective instrument to check on irrigation schedules is a profile pit. This is the only direct method and can be done at any part in the orchard. Add to this measuring the delivery rate and operating pressure, and irrigation can effectively be optimized.

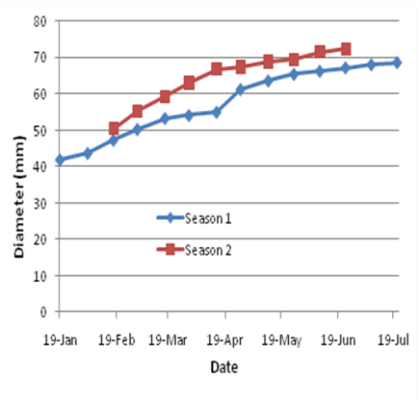
4.2 Fertilization: Although the N:K ratio in the leaves is an important factor indicating the potential for optimal fruit size, optimal concentrations of all 14 nutrient elements are equally important, especially during the critical stages of phases I and II. Concentrating on, for instance, potassium applications when magnesium is deficient, will not improve fruit size. If any deficiency is present it should be corrected as soon as possible, even during the less efficient period of July to September. The most efficient approach is a balanced one where the purpose of fertilization is to get all nutrients within the optimal range. Potassium is known to improve fruit size, but so are nitrogen, magnesium etc. A potassium stress will reduce fruit size but likewise for a nitrogen or water stress. Before resorting to quick fixes, evaluate the total nutritional status of the trees as well as the irrigation scheduling.

When potassium is lacking and the trees do not respond to soil applications, foliar applications of potassium nitrate or -sulphate at 3% can be used. Depending on several conditions (overall nutritional status, N:K-ratios, actual K and N levels) sprays can be applied in July (nitrate and sulphate), August-September (only sulphate) or November-December (both) to improve fruit size. The earlier the spray, the better will the effect on fruit size be. The optimal N-status is 2.30-2.60%, and 0.70-1.0% for K. When the K-status exceeds 1.25%, K is not the reason for the too-small fruit and additional K will serve no purpose.

4.3 Tree and root health: Any factor inhibiting water uptake and transport in a plant will have an adverse effect on fruit size. Control of nematodes and *Phytophthora* can improve fruit size. Lemon trees tend to turn yellow relatively soon after infection with *Phytophthora* and fruit size may be affected more than with other citrus types. Growers tend to act when signs of collar (foot) rot are noted by applying phosphonate stem paints or foliar sprays. However, when *Phytophthora* feeder root rot or nematodes are present they are normally neglected. Both these organisms cause a nibbling effect on the feeder roots. The results are that the trees need to replace these roots constantly which creates an energy sink. The first sign of such a sink is smaller fruit size. Certain trifoliate hybrid rootstocks such as X639 seldom show problems with collar rot but can develop *Phytophthora* feeder root rot problems. Nematodes can also build up over time on citrange rootstocks to levels as high as and even higher than on the more susceptible rough lemon rootstocks. Regular sampling of roots and soil for testing by the CRI Diagnostic Centre in Nelspruit is recommended. (For more information contact Wilma van der Westhuizen at 013 759 8031 or wb@cri.co.za)

4.4 Delaying harvest and selective harvesting: Although fruit growth is very slow during phase III (maturation) of fruit development just before harvest, delaying harvest and/or selective harvesting of larger fruit can result in a fruit size improvement. Make sure fruit are fully expanded before they are harvested. Yearly fruit size measurements throughout the season as done for other citrus types have often been neglected in most lemon orchards.

Therefore, monthly, bi-weekly or weekly fruit size measurements from the same tagged fruit from after physiological fruit drop until harvest are very important not only to accurately predict final fruit size at harvest but to make sure what the size of fruit on a tree should be at a specific time to meet export size requirements. If these requirements are not met, certain adjustments to the management program in terms of irrigation or nutrition should be made (see above). Fruit size measurements on Eureka lemon should be done for both the main crop from the spring flower/set and for the smaller crops since the time of set in the year may play a role in fruit size at harvest. A database of long term mean fruit growth rates can be used to compare growth rates between seasons and orchards and identify problem areas. Not only would fruit growth rates differ between different orchards and seasons, but the growth curve may flatten off earlier, especially in poor orchards and orchards with very heavy crop loads. Once a below average growth rate is identified, the abovementioned adjustments can be made. Note the differences in fruit growth rates in the graph below between two consecutive seasons for the same Eureka lemon orchard in Citrusdal in the Western Cape.



4.5 Pruning: Pruning in the winter after harvest and before bud break improves the light distribution inside the tree and improves the quality of the bearing wood by rejuvenating it. Pruning can also be used as a thinning technique. In very dense trees and especially older, larger trees light levels drop to below 30% in the inside of the tree and adversely affect fruit size. Reducing the tree volume of these larger trees by reducing tree height often improves light distribution in the tree and reduces the within-row and between-row tree shading which may result in larger fruit. Strong, vigorous and upright water shoots should be removed as early as possible.

4.6 Crop load: Although there are a lot of controllable and non-controllable factors that play a role in fruit size, fruit load (number of fruit) is normally the major contributing factor. The more fruit on a tree, the smaller the fruit are. Thinning changes the leaf:fruit ratio, resulting in more leaves contributing to the growth of a single fruit. Crop reduction, especially in heavy crop years with the aim of reducing fruit-to-fruit competition and therefore improving fruit size can be accomplished through blossom thinning by pruning during bloom and hand thinning. Unfortunately chemical thinning using synthetic auxins is not an option for lemons since there is no product registered for this use.

4.7 Hand thinning: Selective removal of fruit from heavily bearing trees (the small and blemished fruit as well as fruit in clusters are removed) as soon as possible after the November/December fruit drop (physiological fruit drop) period can improve fruit size and the earlier this can be done the greater the effect will be. This is, however, a time-consuming practice.

4.8 Summer girdling: Summer girdling in combination with some of the other control measures can have a positive effect on fruit size of most citrus types, but only if all the other factors that have an adverse effect on fruit size are managed optimally and neutralised. It is however, a time-consuming and unpopular option and not commonly used on lemons.

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5 Literature

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