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FACTORS IMPORTANT FOR OPTIMAL IRRIGATION SCHEDULING OF AVOCADO ORCHARDS

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ABSTRACT

The purpose of this paper is to review available literature on avocado irrigation and to identify the most critical factors for optimal irrigation scheduling.

It was shown that over irrigation and prolonged over saturated conditions should be avoided at all cost and that avocado trees should be planted on well drained soils, especially under high rainfall conditions. Although a root and irrigation depth of 600 mm is acceptable, it is advisable to determine the root depth for every situation. Knowledge of the water holding capacity of the soil will help to determine the irrigation cycle length. It is recommended that tensiometers be used for irrigation scheduling and that a soil matric potential of -30 kPa at 300 mm depth on a light soil and -50 kPa on a heavy soil is not exceeded. Although the avocado appears to be fairly insensitive to a mild water stress, the critical period where optimal irrigation scheduling is essential, is at fruit-set and the early fruit growth stages.

The water requirement of the avocado varies during the season, from relatively low in winter to high in midsummer, decreasing again towards the end of the season.

INTRODUCTION

Irrigation is probably the most important aspect of successful subtropical fruit production. Optimal irrigation scheduling is more important for avocados than for most other subtropical crops, due to its susceptibility to Phytophthora root rot which is enhanced by over irrigation. The purpose of irrigation is to supplement the rainfall, thereby achieving optimal tree performance. An important aspect of irrigation that is often overlooked by farmers, is that one should not irrigate to wet the tree, but to replenish the water that was lost from the soil, through surface evaporation and that used by the plant (evapotranspiration). In order to irrigate optimally, certain soil and plant characteristics should be known. The purpose of this paper is to discuss these parameters using data from research done in the more important avocado growing areas of the world.

Relationship between irrigation and *Phytophthora*

According to Sterne, Kaufmann & Zentmyer (1978) the symptoms of root rot of avocado caused by *Phytophthora cinnamomi* Rands resemble water stress, i.e. wilting, leaf discolouration, dieback and reduced reproductive growth. Sterne, Zentmyer & Kaufmann (1977a) had shown that very wet conditions (a soil matric potential of -10 kPa or less) enhanced the occurrence of root disease caused by *Phytophthora cinnamomi.* Sterne *et al.,* (1977b) showed that at a matric potential of -25 kPa in a sandy loam soil, the incidence of *Phytophthora* was relatively low, whereas on a clayey soil the disease rating at this matric potential was still very high (50 — 100%). According to Borst (1984), the opportunity for infection of avocado feeder roots by root rot fungus can be reduced by improving the drainage of the soil and by lengthening the irrigation cycle. Lahav & Kalmar (1983) stated that due to the fact that avocados are often grown on heavy soils, the danger of overwetting exists. This condition leads to impaired aeration of the upper soil layer where most of the tree's roots occur. This in turn will affect the supply of oxygen to the roots, reduce the uptake of nutrients and increase the tree's susceptibility to root rot. The relationship between soil matric potential, water holding capacity of the soil and the norms set by Sterne *et al.,* (1977b) will be discussed later in this paper.

IMPORTANT PARAMETERS FOR IRRIGATION PURPOSES

Root depth

Abercrombie (1990) has shown that on a clay loam soil without any restricted layers only 21 % of avocado roots occurred in the top 300 mm of soil. When compacted layers occur, however, the root depth can be severely restricted, with 50% or more of the roots occurring in the top 300 mm of soil. The deeper the roots, the larger the volume of soil available for water storage purposes. Kalmar & Lahav (1976) claimed that most soil moisture changes occurred in the 0 to 600 mm zone in an avocado orchard. They also claimed that a longer irrigation cycle would enhance deeper root growth. Shalhevet, Mantell, Bielorai & Shimshi (1981) stated that 95% of the water taken up by avocados grown on a heavy soil, came from the 0 to 600 mm soil layer, while on a medium textured soil, the root system was deeper and water uptake from the top 600 mm of soil was only 80%.

It is thus obvious that the top 600 mm of soil should be considered for irrigation purposes. It is, however, always better to determine the root depth in every orchard because it could be restricted by compaction or it could be much deeper than 600 mm. It is logical that if 900 mm instead of 600 mm can be irrigated, the soil water reservoir will increase with 50%.

Water holding capacity of the soil

By definition, the easily available water is that portion of the total water holding capacity of the soil held between field capacity (-10kPa) and a matric potential (suction) of -100 kPa. Figure 1 presents a rough estimate of the capacity of easily available water of different textured soils, ranging from very sandy to more than 40% clay. From this graph one can easily ascertain the waterholding capacity of a soil if the clay content is known. Note that this graph refers to the top 600 mm of soil only. Where adequate roots occur, for example up to 800 mm deep, the capacity determined should be increased by a factor (800/600) of 1,33.

After irrigation, the tensiometer often falls back to 0 kPa, which indicates that a lot of free water is present in the soil. This, of course, will displace all air from the soil causing temporary waterlogged conditions. According to Setler & Belford (1990), a lack of oxygen is the major cause of limited plant growth in waterlogged soil. Even at field capacity (-10 kPa), the conditions for root disease are enhanced (Sterne *et al.,* 1977a). it is therefore advisable to let the soil dry out to a certain extent between irrigations to improve growing conditions. The extent of this "drying out" will be discussed later.

Allowable depletion of easily available water

Shalhevet *et al* (1981) recommended that irrigation should start when only 30% of the available water in the soil, to a depth of 600 mm, was left. Borst (1984) stated that irrigation should commence when 30 to 50% of the available water had been used. Many other researchers refer to a matric potential in the root zone that should not be exceeded, rather than a percentage depletion of available water. Bower (1985) recommended that -55 kPa at 250 mm depth should not be exceeded. Lahav & Kalmar (1983) showed that on a very heavy soil (60% clay) their wet treatment (irrigated when a tensiometer reading of -25 kPa at a depth of 300 mm was reached) was not much better than the dry treatment (irrigated at -40 kPa). Lyman (1982) recommended that -35 kPa should not be exceeded, whereas Peck (1985) recommended -25 kPa at 300 mm depth, -15 to -30 kPa at 600 mm depth and not lower than -40 kPa at 900 mm depth for avocado irrigation. Marsh, Branson, Davis, Gustafson & Strohman (1978) advised that tensiometer readings should be kept between -15 to -20 kPa at 300 and 600 mm depth and should not be allowed to exceed -40 kPa on a sandy loam soil. Whiley, Saranah, Cull & Pegg (1988) recommended that during spring tensiometer readings should not exceed -30 kPa for a sandy loam soil or -40 kPa for a clay loam soil at a depth of 300 mm within the dripline of the tree. These values should be lowered to -25 kPa and -30 kPa respectively, during the second fruit drop period (December/January).

In South Africa it is generally accepted that not more than 50 to 60% depletion of easily available water in the root zone should be allowed. This corresponds to a soil matric potential of about -50 kPa for a clayey soil and -30 kPa for a sandy soil. This is well within the 'safe' range indicated by Sterne *et al.,* (1977b) as regards *Phytophthora* control.

Critical irrigation stages

Several researchers have commented on this subject. Whiley *et al.,* (1988) speculated that the second fruit drop stage of the growth cycle (December/January in Australia), is the most critical period for water management. They summarised their recommendations as follows: Management of water in the orchard during flowering can be critical for fruit-set, whereas during the latter part of spring it is not so critical. During the final period of rapid fruit growth and maturity, effective irrigation management reduces fruit drop and increases final fruit size. Lahav & Kalmar (1983) claimed that the effect of irrigation on yield and fruit size was small, with autumn water stress sometimes causing a decrease in fruit size. Furthermore, flowering was not induced by autumn water stress. They recommended that the irrigation interval be shortened in summer when fruit growth rate is rapid to ensure maximum fruit size, whereas in autumn fruit growth is slower and a shortening of the irrigation interval will have no advantage. A short irrigation cycle in spring may cause reduced aeration and cooling of the soil with the possibility of root destruction. According to Bower (1985) the period prior to and during early fruit growth is the most important time to ensure adequate irrigation. He also claimed that a dry period during autumn and winter will not ensure good flowering in spring. Bower & Cutting (1987) suggested that a pre-harvest water stress would increase post-harvest browning potential.

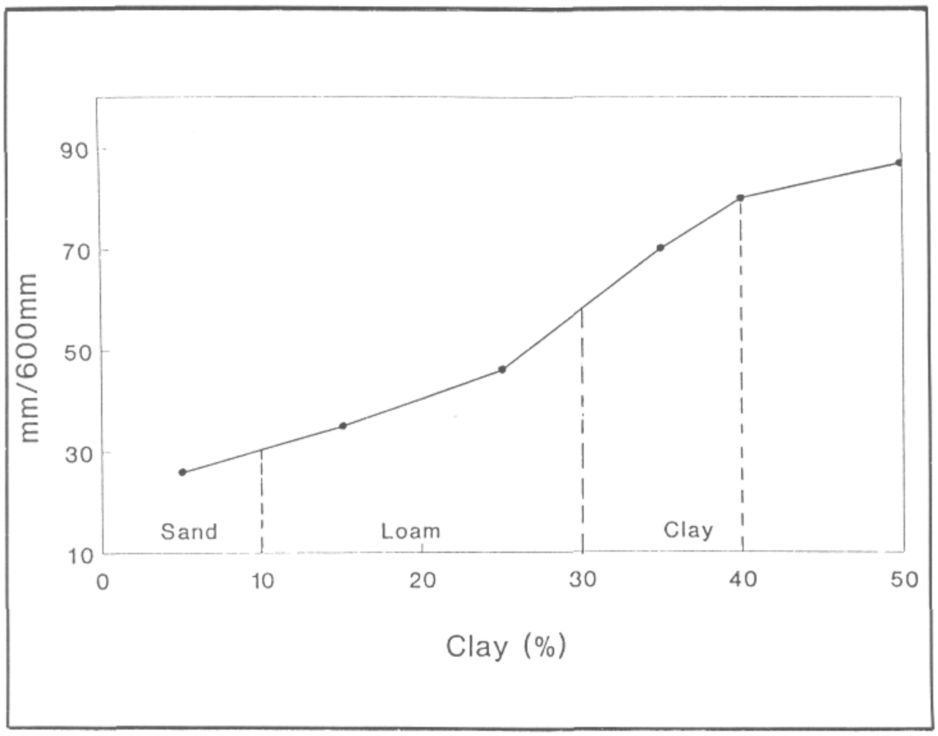

Fig 1 Easily available water for different textured soils.

Irrigation cycle length

The length of the irrigation cycle is determined by the water holding capacity of the soil, the water requirement of the plant and the season. Therefore, the irrigation cycle length will vary throughout the season, being relatively short in summer and long in winter. This implies that the volume of water to be applied will always be the same for a specific orchard. Using the water holding capacities given in Figure 1, a soil with a clay content of 40% will have 80 mm available water in the root zone (600 mm depth). If a depletion of 50% is allowed it means that 40 mm (plus 10 — 15% depending on the efficiency of the irrigation system) should be applied per irrigation. In the case of a soil with only 20% clay, this value would be 20 mm (39 mm x 50%) per application. Therefore, the trees on a lighter soil will have to be irrigated more often than those on a heavy soil. By using tensiometers the farmer does not have to guess as the tensiometer will indicate when water is needed. The farmer will, however, have to determine the volume of water required to replenish the soil water in the root zone to field capacity.

WATER REQUIREMENTS OF AVOCADO TREES

Subtropical tree crops show a cyclic water use pattern through the season. Du Plessis (unpublished report) showed that mature citrus trees needed about 45 *ℓ/day* in August, increasing to a maximum of about 115 *ℓ/day* in summer and decreasing again to about 40 *ℓ/day* in winter. A similar pattern of water use by avocados was shown by Bekey (1989) in California. He indicated a water use of 45 *ℓ/day* in spring, increasing to 136 *ℓ/day* in mid-summer and decreasing again to 121 *ℓ/day* in autumn. For conditions in Israel, Shalhevet *et al (1975)* found the daily evapotranspiration to be 3,3 mm in June and July, increasing to 3,5 mm in August and decreasing again to 3,0 mm in October. Kalmar & Lahav (1976) also in Israel, showed that the irrigation cycle length influenced the evapotranspiration to a very large extent, ranging from a maximum of about 6 mm/day for a 7-day-cycle to about 2,5 mm/day for a 28-day-cycle. Gustafson *et al* (1979) found that by using drip irrigation, a six-year-old avocado tree will use a maximum of 114ℓ of water/day in the peak period, as compared to about *70ℓ/day* for a four-year-old tree. Furthermore, they showed that by using micro-rotating sprinklers, about 35% more water was needed than for drip irrigation. This difference (about 210 mm/season) was attributed mainly to evaporation from the much larger area of wet soil in the case of the sprinklers.

The total water use of avocados on a seasonal basis was found to be 668 mm in the Western Galilee (Kalmar & Lahav, 1976; and Lahav & Kalmar, 1983) in addition to 600 mm rainfall (mainly winter rainfall). In California, Gustafson *et al* (1979) found that six-year-old trees needed about 828 mm of irrigation during a season with 270 mm of rainfall.

IRRIGATION SCHEDULING

Generally, two methods of scheduling are used, namely tensiometers or an evaporation pan with specific crop factors. This review has thus far dealt extensively with the use of tensiometers and it will not be repeated again.

Crop factors

In an extensive investigation Adato & Levinson (1988) came to the conclusion that their 'dry' treatment, using a crop factor of 0,46, was just as good or even better in some aspects than the 'wet' treatment, using a crop factor of 0,64. This was ascribed to their wetting technique using daily intermittent drip irrigation. Previously, however, Lahav & Kalmar (1983) by using tensiometer scheduling, calculated the relevant crop factors: the 'dry' treatment had a crop factor of 0,39 versus 0,54 for the wet treatment. The differences in yield, fruit size and fruit growth between these two treatments were relatively small. They concluded that a combination of the two factors, namely wet in spring and dry in autumn can be recommended for Fuerte. In the case of Hass a relatively dry spring and wet autumn might be slightly better in Israel. Rowell (1979) recommended a very low crop factor of 0,2 for mature Fuerte trees in the Nelspruit area.

From a scientific point of view, tensiometers are ideal instruments for irrigation scheduling, because the water status in the root zone is directly measured. Crop or irrigation factors on the other hand are based on a relationship between the water needs of the crop and the climate over a particular period. Crop factors do not reflect the water status of the soil or plant, but are easy to apply in practice. The accuracy of using this method is dependent on research data. Very little work has been done in South Africa in this regard and crop factors obtained elsewhere will have to be used locally, or factors recommended for citrus (Du Plessis, 1987) may have to be considered in the meantime.

The main disadvantage when using a crop factor is that the soil could either be progressively dried out if the factor is too low or over wetted if the factor is too high. The only reliable way to prevent this is to make use of tensiometers to check on the crop factors used.

SUMMARY AND RECOMMENDATIONS

Although avocados seem to be insensitive to slight variations in irrigation regimes, water stress during flowering, fruit-set and early fruit growth should be avoided. The most important aspect of avocado growing is over irrigation, which should be avoided at all cost, as it will enhance root rot development and thus hamper the growth of the tree. It is therefore important that avocado trees only be planted on well drained soils without compacted layers, especially where high rainfall can cause over-wet conditions to prevail for a prolonged period. Tensiometer scheduling is essential and until more data becomes available, a maximum soil water potential of -30 kPa on sandy soil and -50 kPa on clayey soils at a depth of 300 mm, should not be exceeded. Furthermore, farmers should avoid a fixed cycle length and rather allow the tree to determine when irrigation should take place. The volume of water to be applied per irrigation can be determined by a soil analysis in the laboratory or by trial and error in the orchard, using tensiometers at different depths.

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