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A comparison of irrigation scheduling by tensiometer versus evaporation pan

MJ SLABBERT
Westfalia Estate, PO Box 14, Duivelskloof 0835, RSA

SYNOPSIS
An actual irrigation schedule as done by tensiometer was compared with an irrigation schedule as done wan an evaporation pan. The evaporation pan method of scheduling was found to be impractical under these conditions. A possible reason was that not all the factors influencing the evapotranspiration from an orchard were properly taken into account.

INTRODUCTION

Phytophthora root rot is of great economic importance on Westfalia Estate and over-irrigation is known to enhance this devastating disease. On the other hand production per unit area keeps the farmer in business. Obviously a high production level cannot be attained with trees suffering from moisture stress. Irrigation scheduling should thus take both of the above factors into consideration. In South Africa irrigation scheduling with an evaporation pan is a widely used method, probably more so with other crops than with the avocado. On Westfalia Estate tensiometers are used to schedule irrigation. The purpose of this paper is to compare these two methods for suitability under these specific conditions.

MATERIALS AND METHODS

Evaporation measurements were obtained with the help of a class A evaporation pan situated on Westfalia Estate. Tensiometer data were obtained from eighty sets situated in the orchards of the 'Westfalia section' of the Estate. A set consists of two tensiometers installed at 300 mm and at 600 mm on the shadow side (south east) of a representative tree. Evaporation readings were taken daily at 08h00 and tensiometer readings were taken on Mondays, Wednesdays and Fridays. Soil moisture retention curves were determined with the help of a pressure membrane at the University of Pretoria. These were used to check the tensiometer readings gravimetrically. As a basis for commercial irrigation the research of Bower (1979) was used. According to his results stomata close at a suction of between 50 centibar and 60 centibar, thus irrigation was carried out as close to the 50 centibar level as possible. The amount of water applied per irrigation round was usually 35 mm, but the amounts were adapted according to the 600 mm tensiometer, so as not to create an over-wet condition. The soil on Westfalia Estate is a red lateritic clay, with a clay content of between 35 and 60 per cent.

RESULTS

For the purpose of comparison an irrigation schedule was drawn up for the calendar year 1986 from the actual evaporation data. The formula used was:

$$Eo \times Pf = Et$$

with

- Eo = evaporation
- Pf = panfactor
- Et = evapotranspiration

The evapotranspiration was progressively accumulated until a total of 35 mm was reached. The value of 35 mm was chosen as this is representative of the water-holding capacity per 600 mm of the soil between 10 and 50 centibar soil suction. This has previously been established by pressure membrane studies. Figure 1 shows a moisture retention curve of a typical soil on Westfalia Estate. The rain that fell in this period was subtracted from the accumulated total. However, in practice some rain is considered as not enough to be effective, this level varying according to different authors.

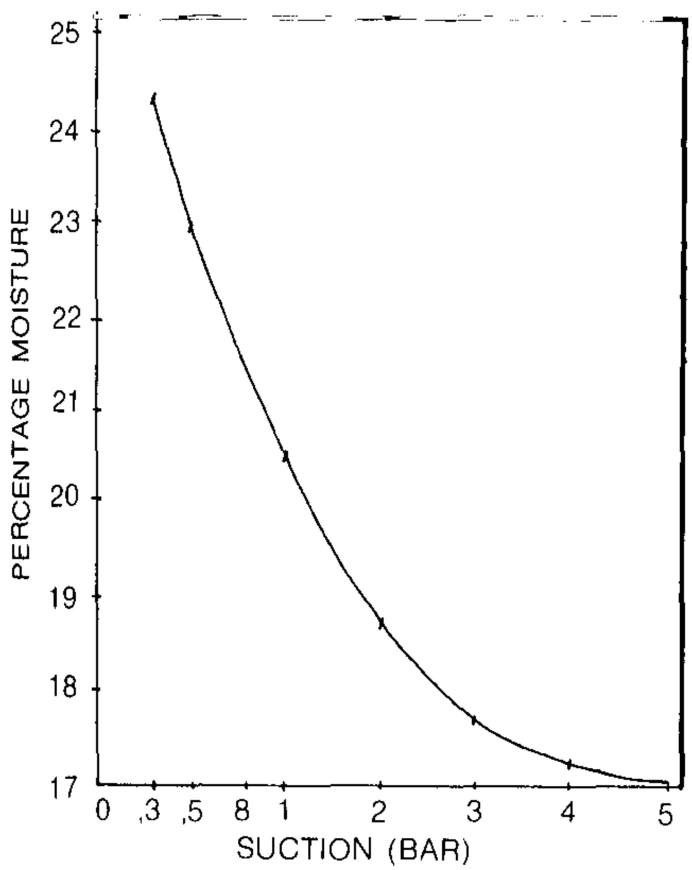


Fig 1 A typical moisture retention curve of the soil on Westfalia Estate

In Table 1 the number of irrigation rounds for 1986 is given for different panfactors and the exclusion of different amounts of rain. The difference in schedule is not very marked whether small amounts of rain are excluded in the calculation or not. As can be seen in the table, the biggest difference depends on the panfactor that is used. According to Bredell and Barnard (1972) and also Scheepers the panfactor for avocados in the sandy soil of Nelspruit should be 0,65.

Figure 2 gives the number of irrigation rounds made on the 80 irrigation blocks during 1986 according to the requirements indicated by the tensiometer readings. These varied from 3 to 25 rounds. It can clearly be seen that according to the evaporation pan schedule, a panfactor of 0,5 would have required at least 19 irrigation rounds, thus being too high for 143 ha of the 145 ha on Westfalia section. In terms of number of rounds as shown in Table 1, no less than 17 different panfactors would have had to be used in order to have obtained the same results as those achieved using tensiometers.

TABLE 1 Number of irrigation rounds in 1986 as scheduled by evaporation pan, for different panfactors and exclusion of different rainfall levels

Rainfall excl.	Panfactor		
	02	05	10
none	7	19	42
6 mm	7	21	43
11 mm	8	21	44

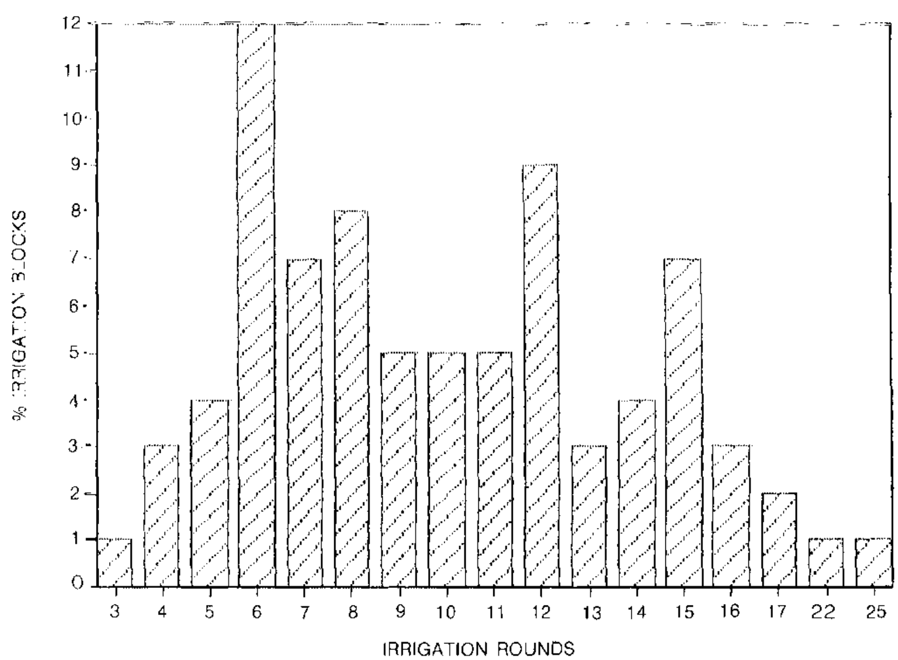


Fig 2 Actual number of irrigation rounds in 1986 on 80 irrigation blocks (totalling 145 ha) scheduled according to the tensiometers

According to research done by Rowell (1979) the panfactor in Nelspruit should be closer to 0,5 for young trees and 0,2 for old trees. To indicate the effect of age of the trees on the irrigation rounds, Table 3 gives the irrigation rounds, applied according to the tensiometers for block 10 which was five years old in 1986. All the trees were Hass grafted on Duke 7 rootstocks. The rounds varied from 6 to 14 although there was no difference according to evaporation scheduling parameters. The data in Table 2 demonstrate that the same panfactor in the same area does not necessarily apply even if the trees are of the same scion, rootstock and age, and planted in the same soil.

The irrigation rounds that match both the evaporation pan schedule and the tensiometer schedule are 7 and 8 rounds respectively. In Table 3 the blocks that achieved 7 rounds according to the tensiometer schedule are compared with the evaporation data. The actual days on which irrigation was carried out, were taken and the panfactor calculated, taking into account the total rainfall.

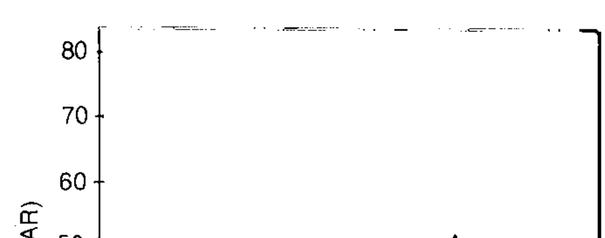
The panfactors vary from 0,06 to 0,92 and they are not correlated with the different rounds which might have indicated a different panfactor for different times of the year. Although the number of irrigation rounds was the same, the actual dates of irrigation differ substantially. It can be seen that the panfactor varies between irrigations to such an extent that no workable correlation can be derived from it. Figure 3 gives an example of two different sets of tensiometer readings for different irrigation blocks.

TABLE 2
Actual irrigation rounds for eight irrigation blocks within block 10. All the trees are of the same age, scion and rootstock.

Block no	A-1	A-2	A 3	A 4	B 1	B 2	B 3	B-4
Rounds	6	7	7	11	14	11	7	6

TABLE 3 Panfactor calculated from evaporation data for blocks that received seven rounds of irrigation in 1986.

Irrigation block no	Irrigation Round						
	1	2	3	4	5	6	7
31-4	0 08	0 34	0 37	0 48	0 24	0 54	0,36
36C-2	0 07	0 33	0 59	017	0 31	0 92	0,47
1 OA-3	0 06	0 24	0 74	0 44	0 44	0 32	0,35
1513-1	0 07	0 82	0 30	0 33	0 22	0 84	0,21
10B-3	0 07	0 27	0 52	0 82	0 29	0 27	0,48
30-1	0 07	0 32	0,28	0 45	0 26	0 45	0,26
1 OA-2	0,08	0,44	0,42	0,44	0,34	0,69	0,27



DISCUSSION

With the amount of variability shown in Table 3 the conclusion is reached that under these circumstances a tensiometer is bound to give better results than an evaporation pan. On Westfalia Estate the production per hectare has been increasing significantly over the last four years. However, this is related to many different factors of which irrigation is but one. These results confirm those of Du Plessis (unpublished data) in which he found that by using a tensiometer, far less irrigation rounds were required and yet there was no decline in yield or fruit size of citrus. This will be true on condition that the tensiometers are functioning properly and are well maintained and are consistently read.

The question arises as to why such variability in panfactors was found. The panfactor is supposed to simulate the difference between evaporation from a free water surface and evapotranspiration from the orchard. The factors which influence transpiration and moisture loss from an orchard are numerous and can vary independently. Moisture losses from an orchard are made up of two main components: a part lost from the tree as well as a part evaporated directly from the soil surface.

The transpiration rate of a tree can be influenced by many factors that will consequently change the panfactor. Probably the most important factor affecting the transpiration rate is root rot which at Westfalia Estate, is usually due to Phytophthora cinnamomi. However, no matter what the cause, if the roots of a tree are affected, the capacity to use soil moisture will also be affected. The extent to which moisture usage by the tree is affected, will depend on the degree of root destruction. Physical properties of the soil affecting aeration can have a marked influence on the efficiency of the roots without killing them. An example of such a condition is compaction in clay soils. This can adversely affect the capacity of the roots to supply the moisture demand of the leaves. The reaction of the tree if the demand cannot be met is the closing of the stomata in the leaves, Closing of stomata can thus occur even if adequate moisture is available in the soil.

Nutritional status and other diseases can also have an influence on the efficiency of the leaves and their transpiration rate.

The amount of moisture evaporating directly from the soil will depend on the size of the area shaded by the trees as well as the covering on the soil. Different methods of weed control will therefore also have different effects on the degree of exposure of the soil surface. A covercrop like velvet beans (Prosopis velutina) keeps the soil shaded in summer and provides a dry mulch in winter. However, they must be re-sown every season and the time of planting will make a difference to the cover obtained. The orchard practice of mulching will also have an influence which will further vary according to the nature and extent of the mulch. The physical condition of the soil surface that can influence the capillary movement of moisture will also significantly influence evaporation. If the soil surface is disturbed by tilling the capillary movement of soil moisture is disrupted, preventing loss until such time as the soil has settled again. This is a well-known method of moisture management employed by wheat farmers on the Springbok flats of South Africa.

Planting distances and patterns will determine what percentage of the area is not shaded by trees and for what period of time. This can change rapidly through orchard practices such as thinning and top working.

The evaporation pan also does not properly take into consideration movement of water into and through the soil. Physical properties of the soil will dictate the infiltration rate of the rain water but the evaporation pan method of scheduling does not take precipitation rate into consideration. In South Africa the rate of precipitation during thunderstorms can frequently exceed the soil's infiltration rate, thus giving rise to miscalculation of the moisture deficit in the soil.

If there is a layer in the soil that impedes the movement of moisture through the profile, the soil can stay wetter for a longer period. This can go undetected if an evaporation pan is being used, and can result in irrigation being carried out on already wet soil, thus aggravating root rot. During 1982 a newly planted orchard on Westfalia Estate was declining rapidly without the presence of Phytophthora. The reason for this was found to be the existing practice of installing only a 300 mm tensiometer for the first year after planting. In this case a compaction layer at 600 mm depth caused an overwet condition below the 300 mm tensiometer thus causing the death of the roots. The condition was rectified by installing a tensiometer at a depth of 600 mm and refraining from irrigation until it reached a reading of 60 cb.

It becomes clear that the factors that can influence the rate of moisture loss in an orchard are numerous and the possibilities of different variations are vast. It is theoretically possible to take all these factors into account in calculating a panfactor for a specific set of circumstances, but this becomes increasingly impractical.

A tensiometer also has its shortcomings and problems and is known to take a lot of effort to maintain properly. The main problem is that the tensiometer gives a reading for a small portion of the soil surrounding the porous cup. The art, therefore is to install the tensiometer in such a position that the reading is representative of the orchard.

In a long-term experiment in Israel as described by Lahav and Kalmar (1969) and Kalmar and Lahav (1976), using tensiometers to apply the correct amount of water, they found a marked influence on fruit size caused by the interval between irrigations. Although the author is certain that the tensiometers are well adapted to the conditions on Westfalia Estate, research should be done on irrigation interval to ascertain the optimum one for conditions on the Estate, thus further optimising irrigation and drawing the maximum effect possible for conditions on the Estate.

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