University of Jordan
Faculty of Graduate Studies

OPTIMAL DEPLETION WITH SUPPLEMENTAL IRRIGATION FOR NECTARINE IN RAINFED AREAS

By
MARWAN ANTON THALJI HATTAR

Supervised By
Dr. AHMAD ABU-AWWAD

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This thesis was defended successfully on 14 /12/1994

1. Dr. Ahmad Abu-Awwad.

   (Assistant Prof. of Irrigation Engineering).

   ....

2. Dr. Ibrahim Ghawi.

   (Associate Prof. of Soil Physics).

   ....

3. Dr. Mohammed Shatanawi.

   (Associate Prof. of Irrigation Engineering).

   ....

4. Dr. Jamal Sawwan.

   (Associate Prof. of Horticulture).

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DEDICATED

TO

MY
MOTHER
FATHER
FAMILY
HOME

ACKNOWLEDGEMENTS

THANKS TO GOD

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ABSTRACT

OPTIMAL DEPLETION WITH SUPPLEMENTAL IRRIGATION FOR NECTARINE IN RAINFED AREAS

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Field experiment was conducted during 1991/1992 on a two-year old "Stark Red Gold" nectarine trees (*Prunus persica nectarina*) at the University of Jordan, Al-Jubeiha. The experiment was initiated to determine optimal management allowable depletion that maximizes water use efficiency, derive soil-water extraction patterns in two dimensions, study the effect of supplemental irrigation on growth and yield and study the effect of partially covered soil surface on crop water requirements.

The experiment consisted of two main treatments; management allowable depletion (MAD); three treatments: 25, 50 and 75 percent of the total available water and partial covering of soil surface with black plastic mulch; two treatments: presence and absence of mulch.

Relative contributions to crop water use decreased as the vertical depth increased from soil surface. Increasing MAD increased relative contributions of the deep layers.

Variations in the relative contributions to crop water use were slight and negligible among the 0-50, 50-100, and 100-150 cm horizontal distance intervals from tree stem.

In the unmulched treatments, the relative holding, total stem growth, periodic shoot elongation, leaf relative water content, and leaf clorophyll content were greater in the 25% MAD treatment than the same parameters in 50% and 75% MAD treatments. Increasing MAD from 25% to 50% and from 50% to 75% decreased consumptive use significantly. Thus, water use efficiency decreased as MAD was decreased below 50%.

In the mulched treatments, almost all plant-related parameters studied, namely total and relative tree growth, total and relative stem growth, periodic and seasonal shoot elongation, leaf relative water content, and leaf chlorophyll content, were significantly higher in the 25% and 50% MAD treatments as compared to same parameters in the 75% MAD treatment. However, the 25% and 50% MAD treatments were not significantly different in their influence on plant-related parameters. Consumptive use increased significantly as MAD decreased from 75 to 50% and from 50 to 25%. Also, water use efficiency in the 25% MAD treatment was significantly lower than water use efficiency in the 50% and 75% MAD treatments.

Most plant-related parameters and water use efficiency increased significantly upon partial covering of soil surface with mulch. The greatest increases occurred in the 50% MAD treatment. Also, with mulch, consumptive use increased significantly in the 25% MAD treatment as compared with unmulched treatment. While, no significant difference occurred in consumptive use at the 50% and 75% MAD treatments with mulch.

Under the conditions of this experiment, or similar conditions, partial covering of soil surface with mulch is recommended. Also, the 50% MAD is recommended to be used with supplemental irrigation of nectarine trees.

1- INTRODUCTION

Dangers of food shortage is increasing in the world. This may be attributed to many reasons among which is that the rate of population increase exceeds the parallel increasing rate in food production. Therefore, increasing agricultural production is a must to avoid food shortages .

Water supply is a permanent constraint in arid and semi-arid regions. Thus, adoptation of some methods of water management to overcome such a problem is necessary. In Jordan, about 90% of the total agicultural area receives an annual rainfall of 200mm or less. Nevertheless, approximately 93% of that area is rainfall dependent and contributes only around 30% of the total agricultural production (1). This low contribution of rainfed areas is due, primarily, to defficient effective precipitation, its improper distribution both in time and space, and the large fluctuations from year to year. To increase crop yield in such rainfed areas, supplemental irrigation has to be supplied.

Needed amount of supplemental irrigation for any crop is the difference between the crop water requirements and the effective precipitation. So, supplemental irrigation requires a knowledge of crop water requirements (2) and the relationships between water use, water application rate, and crop yield (3 and 4).

With the limited water resources available for irrigation, the value of saved water by efficient scheduling of supplemental irrigation is of considerable interest. Supplemental irrigation should be designed with longest possible interval and lowest possible water amount, considering that long interval and low water amount will not adversely affect plant growth or economical yield. However, irrigation scheduling is usually based on the total allowable depletion of crop and optimal management allowable depletion.

Root growth and development and, consequently, the water extraction patterns are highly affected by soil water content and water management practices (5). The size and depth of the crop root zone can be approximated from the water extraction patterns in two dimensions.

Optimal utilization of the rainfall requires adequate amount of rainfall to infiltrate to the root zone for direct use by crops and diverting the excessive water to a storage reservoir or aquifer for later use with supplemental irrigation (6). This can be achieved by water harvesting through application of impervious ground covers to a non-cultivated portions of soil surface. Ground covers are beneficial also in reducing evaporation from soil, preventing soil erosion, and in weed control.

Use of supplemental irrigation and water harvesting can remove or alleviate the climatic risk factors in arid and semi-arid regions by increasing the choices for soil and crop water management, which in turn can stabilize yields (6).

Generally, the information of water relations and water requirements of fruit crops in the mediterranean region is very limited. This problem is most detectable in peach crops, particularly the nectarine (*Prunus persica nectarina*), since nectarine cultivation started in the mediterranean region just recently. Therefore, it was planned to conduct an experiment with nectarine trees aiming to :

1-determine the optimal management allowable depletion that maximize water use efficiency.

2-derive soil-water extraction patterns in two dimensions.

3-study the effect of supplemental irrigation on crop growth and yield.

4- study the effect of partially covered soil surface on crop water requirements .

2- Literature Review

To fully understand crop water use, the soil-plant-water continuum should be studied as a whole and not in its individual components. So, under field conditions, we must consider the response of both above ground parts of the plant and its roots to the different water management practices (7).

2-1) Water management and plant growth :

In arid and semi-arid regions, where precipitation is varied in amount and distribution, supplemental irrigation is needed (8), especially for summer crops (9). While in humid areas, supplemental irrigation may be used to increase crop yield in terms of quantity and quality (10).

Huguet et al. (1992) divided fruit trees according to their reactions to water stress into peach trees and apple trees(11). In peach trees , water stored in tissue reservoirs is well protected against transpiration and released gradually as water stress becomes more severe. While in apple trees, water stored in tissue reservoirs is easily transpired at early stages of water stress.

Several researchers indicated that increasing water stress reduced apples, pears and peaches fruit production (10, 12, 13 , 14); shoot elongation and stem growth of apples and peaches (15, 16, and 17); and increased defoliation and failure of pears and peaches flower buds (13). Others showed that reducing water stress increased apples and avocadoes fruit production (18 , 19); shoot growth and trunk expansion (18 , 20); and strengthened flower buds in the following spring (21).

In relative to fruit quality, fruits of irrigated apple trees were larger and contain less dry matter and soluble sugars than none irrigated trees(10).

Many investigators found a favourable effects of supplemental irrigation on growth and yield of peach trees either through increasing fruit set and reducing fruit drop (22 , 23) or by increasing fruit size (22 , 24). Also, they observed an enhancement in trunk growth with supplemental irrigation. Shoot elongation of peach and pear trees increased 9 cm (about 40%) to 12 cm (about 60%) by irrigation (13).

The different organs of peach trees vary in their tolerance to drought (16). They classified organs sensitivity to water stress in a decreasing order: limb diameter increase, shoot elongation, fruit growth, then expansion of leaf area .

Nevertheless, fruit production is dependent on the growth of other organs such as shoots, roots, and trunk (25 , 26). Thus, irrigation treatments affect the yield indirectly through their influence on tree growth (14). A relationship between trunk size and peach tree growth was noted by Chalmers et al. (15) and Mitchell and Chalmers (27).

Leaf water potential and transpiration rate were demonstrated by Brun et al. (28) and Tan and Buttery (29). The two parameters were reduced as water stress was increased. Reduction in transpiration rate as a result of water stress is usually accompanied by a decrease in photosynthesis as reported by Lang and Gardner (30). They attributed this interrelation to the reduction in CO_2 uptake due to stomatal closure as a result of water stress.

In the other hand, late in the growing season, a scheduled water deficits improved apricots and pears fruit quality (31). Suppressing vegetative vigor by regulated deficit irrigation at certain growth stages increased peach and pear fruit production (15, 27, 32, 33 , 34). Li et al. (16) reported a 14% to 18% increase in peach yield with regulated deficit irrigation during the first phase of rapid fruit growth and / or the second phase of slow fruit growth. However, a reduction of 18% to

27% occurred due to regulated deficit irrigation during the third phase of final accelerated fruit growth.

Chalmers et al. (35) indicated that the vegetative growth of irrigated pear and peach trees reduced about 70% and 80% as daily water allocations reduced to 1/4 and 1/8 of the theoretical needed amount of water during the early stages of fruit growth, respectively. However, no reduction occured in fruit size, number, or yield.

Nevertheless, Blanko (36) implicitely rejected the regulated deficit irrigation technique in peach and nectarine trees since the fruits are carried on one year old shoots which affects the management practices toward increased shoot growth.

Mitchell et al. (37) highlighted the importance of precise irrigation scheduling of peach. It is unlikely to use irrigation interval rather than that indicated by the volume of water required in irrigation scheduling to avoid water stress for a long period (34). Irrigation scheduling usually is determined by amount of water that can be safely extracted from the soil (allowable depletion) which is varied according to the crop, soil and climate (38).

With the same water amount, frequent irrigation produced a greater yield of peaches and avocadoes compared to low irrigation frequency (19 , 27). Also, more vegetative growth of avocado trees occurred with frequent irrigation (19).

Storchus and Kosykh (39) found that irrigation improved growth and yield of young peach trees and the best results were obtained from irrigation at 80% of field capacity. While, Mitchell and Chalmers (40) indicated that increasing irrigation rate enhanced vegetative growth of peach trees, but had no effect on the yield . Layne et al. (41) studied the effects of irrigation level and planting density of peach trees and found that using a 50% management allowable depletion and 536 trees per hectare dry soil conditions induced more extensive root growth at greater soil depths. Also, Levinson and Adato (19) detected that the roots of avocado trees were at 50-55 cm soil depth in wet treatment and at 70-75 cm soil depth in dry treatment .

In general, root distribution studies and soil water extraction patterns were related to each other (54). Also, many workers studied the relative effectiveness of water uptake by roots at successive depths (7). Depletion effectiveness of any given root layer increased with increasing soil moisture and the depth to that root layer from soil surface (53, 55 - 56). While, Proffitt et al. (7) and Al-Khafaf et al. (53) concluded that the influence of the depth to the root layer was related to water availability at that layer and the overlying layers.

Cohen et al. (57) concluded, from a two-year irrigation study on peach (3 years old) and apricot trees, that lateral root growth was extended to a horizontal distance of about 4m during the active growth period of the first year of study compared to the previous years due to water availability. Also, in peach, roots extended vertically through all the studied 30-cm depth intervals down to 1.8m within the horizontal distance interval of 0-2m from tree stem and through some depth intervals within the horizontal distance interval of 2-3m.

Arya et al. (58) and Al-Khafaf et al. (53) indicated that water extraction patterns were dynamically changing and time dependent due to change in drying soil hydraulic properties and continuous root growth.

2-3) Soil surface covering and water harvesting

Verplancke et al. (59) demonstrated the effects of mulch on water relations of several crops and obtained a reduction in water use and an increase in effective rainfall, water use efficiency, and yield by mulching

Improvements in plant growth and soil properties by mulch were attributed, primarily, to the role of ground cover in reduction of evaporation loss and conserving soil moisture (59, 60, 61 . 62).

Jones et al. (60) highlighted the value of under-tree covers in regulating soil and tree water status in orchards, and pointed out its usefulness in altering the soil moisture regimes. They indicated that the amplitude of diurnal changes tended to decrease by soil surface covering.

Maintaining a high soil moisture in young orchards is necessary for rapid peach and grape canopies development (43). Gregoriou and Rajkumar (63) found that mulch increased shoot growth, trunk diameter, plant height, and canopy spread of young avocado and mango trees. Vigorous roots were found on soil surface below the mulch, as such mulching increased root growth at all depths. The greatest growth of canopy and roots resulted under mulching with irrigation.

Glenn and Welker (5) found that young peach trees responded to the ground cover treatments. Covering 50% of soil surface affected root growth and water use of young peach trees not only under the soil cover, but also in the adjacent 50% of the root volume (under the unmulched area).

Some kinds of soil covers (impermeable kinds) are capable to increase the net quantity of water received by plants from natural rainfall through water harvesting or runoff harvesting. Karnieli et al. (64) defined runoff harvesting as a method of collecting surface runoff from a catchment area and storing it in a surface reservoirs or in the root zone of a cultivated area for direct consumptive use. While, Perrier (6) defined runoff harvesting as a process of collecting rainfall water from a modified or treated area to either maximize or minimize runoff.

The objective of runoff harvesting is to collect runoff to increase water availability in areas where rainfall amounts are limited. Also, runoff harvesting prevents soil erosion which is caused by runoff (65). So, two of the problems facing agriculture in semi-arid areas are addressed simultaneously.

A well-designed water harvesting system can help in the development of agriculture in most arid climates (6). Kowsar (66) used the accumulated runoff from a microwatersheds for establishment of greenbelts in Iranian cities without imposing a burden on water amounts allocated to the cities. Also, Fink and Ehrler (67) concluded that in arid and semi-arid climates, runoff farming methods for growing Christmas trees and many other crops were feasible. Many studies showed a crop yield response to runoff harvesting not only in seasons of below average rainfall (68), but also under good rainfall conditions (65) where runoff harvesting was valuable compared to the controlled plots of deep tillage alone.

Runoff (harvested water) can be used directly on cultivated fields, stored in the soil, or used with supplemental irrigation in direct runoff farming systems by placing a ridges around the cultivated area to retain water. The effectiveness of this system depends on the crop water requirements, amount and distribution of rainfall, soil infiltration rate, and water holding capacity (6).

At all circumstances, crop value should be high to compensate for the extra soil treatment costs and for the land sacrified for catchment (67).

However, development of an increased usage of rainfall harvesting is still necessary since precipitation is often the only available source of water, especially in arid and semi-arid regions (69).

3- Materials and Methods

Field experiment was conducted during 1991/1992 (November 1991 to October 1992) on a two-year "Stark Red Gold" nectarine trees (*Prunus persica nectarina*) at the University of Jordan, Al-Jubeiha. Al-Jubeiha lies within the western uplands of Amman at altitude of 980m above sea level, latitude of 32° north, and longitude of 35° east, with an average annual rainfall of about 467mm (70).

A preliminary study was carried out during the active period of 1991 to establish the experiment for the next year. Total irrigation amounts added to nectarine trees during 1991 are shown in Table 1 (Appendix B).

3-1) Experimental Design:

Two main treatments were applied to nectarine trees in randomized complete block design with four replications. Treatments were as follows:

I. Irrigation was practiced at management allowable depletion (MAD) 25, 50, and 75 percent from total available water (field capacity-permanent wilting point).

II. Plastic mulch on soil surface in a square shape around tree. Two treatments; presence and absence of mulch.

The six combination treatments; U-25% (unmulched 25% MAD), M-25% (mulched 25% MAD), U-50%, M-50%, U-75% and M-75%, were completely randomized within each block (Figure 1). Twenty four trees were selected, according to their appearance, from about fifty trees planted at 4m×5m.

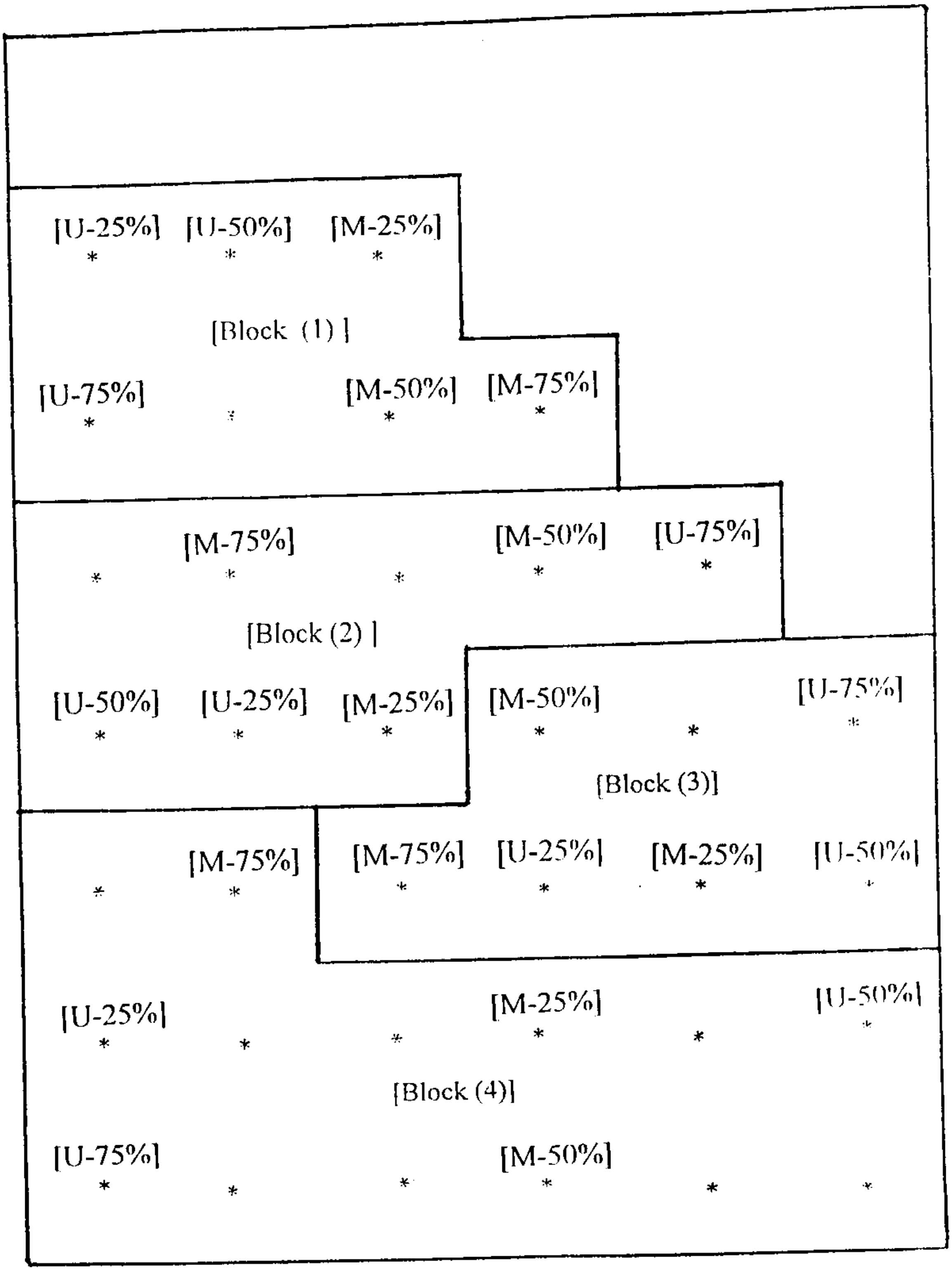

Figure 1: Experiment Layout

3-2) Access Tubes:

A square area of 3×3 m^2 with 1m depth were assumed to represent the tree active root zone. Two sets of three access tubes were installed around each tree to 1m depth in blocks 2 and 3. Three access tubes were installed along the tree rows; at 25, 75, and 125cm from tree stem, respectively, and the other three access tubes were installed perpendicular to the tree rows at the same respective distances (Figure 2).

Soil water content was measured at 20cm increments starting at depth of 10cm down to 90cm from soil surface using neutron probe. Neutron probe was calibrated for the surface layer and, separately, for the subsurface layers. Calibraion curves and equations are shown in Figures 1, 2, 3, and 4 (Appendix B).

3-3) Plastic Mulch:

Black plastic mulch was placed on the soil surface around the specific nectarine trees in a square shape with a total covered area of 6.75m^2. A 2.25m^2 square unmulched area was left around each tree in center of the mulch. Accordingly, the mulch covered 75% of the whole area (9m^2) as shown in Figure 2. Slope of plastic mulch was designed so that rainfall water was directed towards the unmulched area around the tree from all sides.

3-4 Rain Gauges:

Three rain gauges were distributed in the field and rainfall amounts were recorded at each rainfall event during 1991/1992 season. Rainfall amounts are shown in Table 2 (Appendix B).

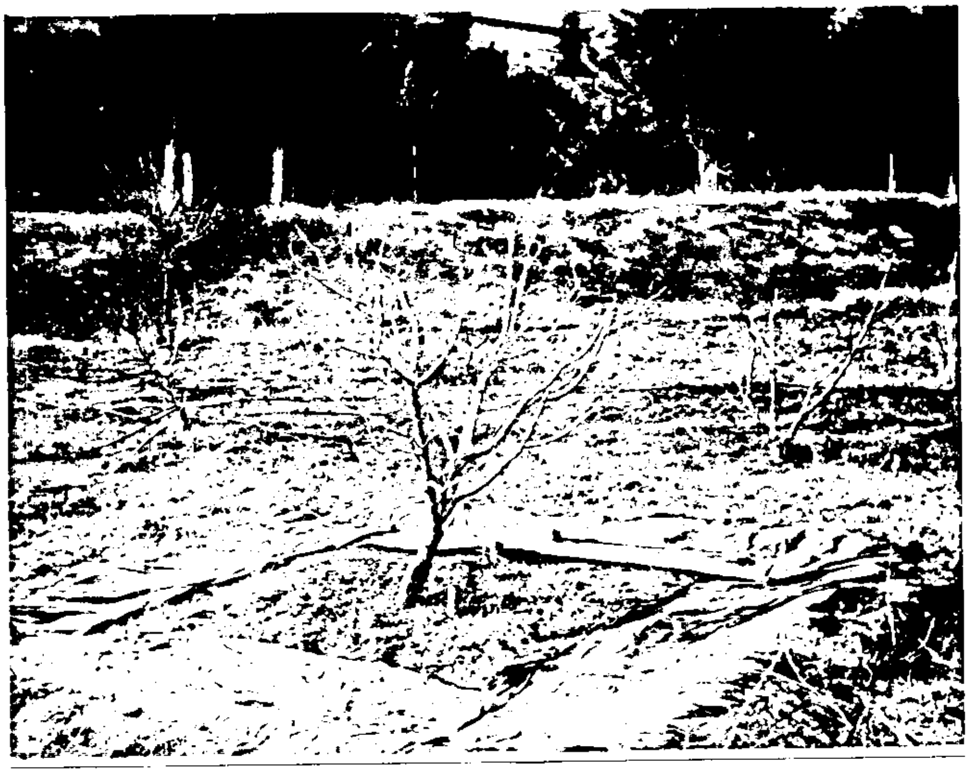

Figure 2: Plastic mulch and neutron probe access tubes around one tree.

3-5) Irrigation System:

One 16-mm trickle line with pressure compensating emitters was used for each treatment. Water quantities were regulated through irrigation duration according to number of emitters on each tree and emitter discharge. Emitters were evaluated every month during the irrigation period.

3-6) Fertigation:

Compound fertilizer (20:10:18) was applied at a rate of 1000g/tree (200g N/tree, 45g P/tree, and 150g K/tree) at two dozes during the active period; April 15 and June 15, 1992 .

3-7) Pesticides:

Anthio and Bayfidan were sprayed twice during the active period to control mites and powdery meldiew; on April 30 and June 30, 1992 .

3-8) Soil Analysis:

Three sets of composite soil samples were collected from three locations in the experiment area. Each set consisted of five soil samples for the five soil depth increments (0-20, 20-40, ..., 80-100cm). The following analyses were conducted for the composite samples:

Field capacity and permanent wilting point were determined at 0.33 bar (33kPa) and 15 bars (1500kPa), respectively, using ceramic plate pressure apparatus. Potassium and phosphorus were extracted by ammonium acetate and molybdate solutions, respectively, and quantified using flame photometer for potassium and spectrophotometer for phosphorus. Bulk density was determined using the core method. Pippette method was used to determine particle size distribution (Methods of soil analysis, 1965) .

3-9) Methodology:

3-9-1) Soil moisture measurements and irrigation:

Soil water content was measured once every two weeks during the inactive period and once a week during the active period for all trees in blocks 2 and 3. In the 25% management allowable depletion treatments, soil water content measurements were adjusted to two times a week from June 10, 1992 until the end of irrigation period.

Percentage of depleted soil water was determined using soil water content measurements. Irrigation was practiced when depletion was near or equal the designed value of each treatment. The weighted average of the depleted soil water depth, based on the relative areas represented by the access tubes of the tree, was used to quantify the required irrigation depth. Total area represented by the six access tubes per tree was $9m^2$, divided into 1, 3, and $5m^2$ for the access tubes representing 0-50, 50-100, and 100-150cm horizontal distance intervals from tree trunk, respectively.

Average depletion from total available water and amounts of irrigation water are presented in Tables 4, 5, and 6 (Appendix B).

3-9-2) Plant-related parameters:

Plant-related parameters were measured for all trees in the experiment. They were divided into seasonal and periodic measurements

I) Seasonal measurements; at the beginning and/or the end of the active period :

1- Stem circumferance (SC) at 10cm above grafting point. Total increase and relative increase of SC were calculated as follows:

$$\text{Total SC increase} = \text{Final SC} - \text{Initial SC}$$

$$\text{Relative SC increase} = \frac{\text{Total SC increase}}{\text{Initial SC}}$$

where initial SC, final SC and total SC increases are in centimeters.

Assuming tree trunk has a regular circular shape, trunk cross sectional area (TCA) was calculated using SC values as following:

$$TCA = r^2\pi = \frac{(SC)^2}{4\pi}, \text{ since } SC = 2r\pi$$

where r (cm) is the radius of tree trunk.

Total and relative increases of TCA were calculated as in SC.

Initial and final stem circumferance measurements are shown in Table 2 (Appendix D).

2- Tree volume, represented by the horizontal distance between the most far two points of tree in both row and inter-row directions and the height of the highest point of tree above the grafting point. Initial and final measurements of these dimensions are shown in Table 3 (Appendix D). Cubic volume of the tree was calculated by multiplying the values of these three dimensions.

Total increase and relative increase of tree volume were calculated, also, as in SC.

3- Yield, number of fruits, and the average fruit weight per tree were measured at harvest time.

II) Periodic measurements:

1. Leaf relative water content (LRWC) was measured on a two weeks basis all over the active period. A sample of five leaves was taken from each tree and their relative water content (%) was determined using relative turgidity method, (Kramer, 1969), as :

$$LRWC = \frac{FW - DW}{TW - DW} \times 100$$

where FW (g) and DW (g) are the fresh and oven-dried leaves weight, respectively. TW (g) is the weight of leaves after emersing them in distilled water for 4-6 hours.

2- Leaf chlorophyll content was determined every two weeks from mid-August to the end of active period. Chlorophyll was extracted from a representative one gram sample by 80% acetone and, then, it was quantified using spectrophotometric method and Arnon's equation (Gross, 1991) as:

$$\text{Total chlorophyll (mg/g of leaves)} = [20.21\, A_{645} + 8.02\, A_{663}]\ \frac{V}{1000 \times W}$$

where A_{645} and A_{663} are the absorbence values of chlorophyll extract solution at wavelengths 645 and 663 nm, respectively, V (ml) is the total volume of chlorophyll solution and W (g) is the fresh weight of leaf sample.

3- Shoot length : Five new shoots were selected and labeled on tree and their lengthes were measured every two weeks all over the active period.

4- Flowers and fruits were counted monthly starting from flowering stage until harvest time (Table 1, Appendix D). Relative holding at each counting date was calculated as following :

$$\text{Relative Holding at any date(i)} = \frac{\text{Number of fruits at date (i)}}{\text{Initial number of flowers}}$$

where i is the counting date; May 15, June 15, and July 15, 1992.

3-10) Calculations:

3-10-1) Water use and water extraction patterns:

Water use was estimated, separately, for both the active period (April 1 to October 31, 1992) and all over the year (November 1, 1991 to October 31, 1992). The following equation was used to estimate the water use during the period between any two successive soil moisture measurements:

$$WU = [(I+R) \cdot Pw] \pm \Delta S$$

where WU (mm) is the water use during the given period, I (mm) is the irrigation amount, R (mm) is the rainfall amount, Pw (%) is percentage area wetted under trickle irrigation at a depth of 15-30cm from the soil surface, and ΔS (mm) is the change in soil water content. Weighted average water use of tree was calculated as following :

$$WU_a = \frac{\Sigma(WU_i \times A_i)}{A}$$

where WU_a (mm) is the weighted everage water use of the tree, WU_i (mm) is the water use in a given horizontal distance interval ; 0-50, 50-100, or 100-150cm from tree trunk, Ai (m^2) is the area around tree represented by the given horizontal distance interval ; 1, 3, or 5 m^2 for 0-50, 50-100, or 100-150cm interval , respectively , and A (m^2) is the total area represented by the three horizontal distance intervals (9 m^2).

Horizontal and vertical water extraction patterns were derived from water use values of all soil moisture measuring locations of tree (30 locations) depending on the relative contributions of these locations in the overall water use of tree (sum for all locations). The best fit curve equations were constructed for each of the average vertical and average horizontal dimensions from the relative contribution values of both replicates.

3-10-2) Water use efficiency :

Water use efficiency was calculated for all trees in blocks 2 and 3 using water use (WU) during the active period .

$$1-\ WUE_y = \frac{\text{total yield per tree}}{\text{WU per tree}}$$

where WUE_y (g/mm/tree) is water use efficiency , total yield is in grams, and WU (mm) is the weighted average water use .

$$2-\ WUE_{se} = \frac{\text{average seasonal shoot elongation per tree}}{\text{WU per tree}}$$

where WUE_{se} (cm/mm/tree) water use efficiency and seasonal shoot elongation is in centimeters.

$$3-\ WUE_{sc} = \frac{\text{total increase in SC per tree}}{\text{WU per tree}}$$

where WUE_{sc} (cm/mm/tree) is the water use efficiency and SC(cm) is the stem circumference.

$$4-\ WUE_{tca} = \frac{\text{total TCA increase per tree}}{\text{WU per tree}}$$

where WUE_{tca} (cm^2/mm/tree) is the water use efficiency and TCA (cm^2) is the trunk cross-sectional area .

5- $WUE_V = \frac{\text{total V increase per tree}}{\text{WU per tree}}$

where WUE_V (m^3/mm/tree) is the water use efficiency and V (m^3) is the tree volume .

3-10-3) Statistical analysis :

Statistical analysis for randomized complete block design (RCBD) was performed for all the seasonal plant-related parameters, water use and water use efficiency considering the number of blocks from which the measurements were taken (four blocks for the seasonal plant-related measurements and two blocks for water use and water use efficiency).

Periodic plant-related parameters required interference of the time factor in the analysis as a less important factor than the main two treatments (management allowable depletion and covering of soil surface). Therefore, the design of the experiment was assumed as a split plot design in RCBD where the times of taking measurements were the main plots and the six combination treatments, composed from the three management allowable depletion and the two mulch treatments, were the subplots.

ANOVA tables are shown in Table 1 (Appendix E).

4- Results and Discussion

4-1) Water Extraction Patterns:

Vertical and horizontal water extraction patterns, as a percent of the total water use, during the whole year and the active period were determined from soil water measurements. Soil water measurements were conducted at fifteen locations in the soil profile; five depth increments at three horizontal distance intervals. In all treatments, water extraction patterns were about the same in both active period and the whole year. Vertical and horizontal water extraction patterns of the six treatments during the active period and the whole year are shown in Tables 1, 2, 3, 4, 5, and 6 (Appendix C).

4-1-1) Vertical water extraction patterns:

In the three management allowable depletion (MAD) treatments (25%, 50%, and 75%), relative contributions of the root layers to crop water use decreased as the vertical depth increased from soil surface (Fig. 3 and 4). In the 25% MAD, maximum contribution occurred at the second layer (20-40 cm), while, a negligible contribution (around 1%) resulted from the deepest layer (80-100 cm). However, with the 50% MAD and 75% MAD treatments, relative contribution of the deepest layer were about 4% and 12%, respectively.

In both unmulched and mulched treatments, increasing MAD increased relative contributions of the 60-80 cm and 80-100 cm layers, and decreased relative contributions of the 20-40 cm and 40-60 cm layers. However, with mulched treatments, relative contribution of the surface layer increased as MAD increased. Since increasing MAD increased the irrigation interval and water stress, so, the roots in the 60-80 and 80-100 cm layers were enhanced for more contribution in water use. Proffitt et al.

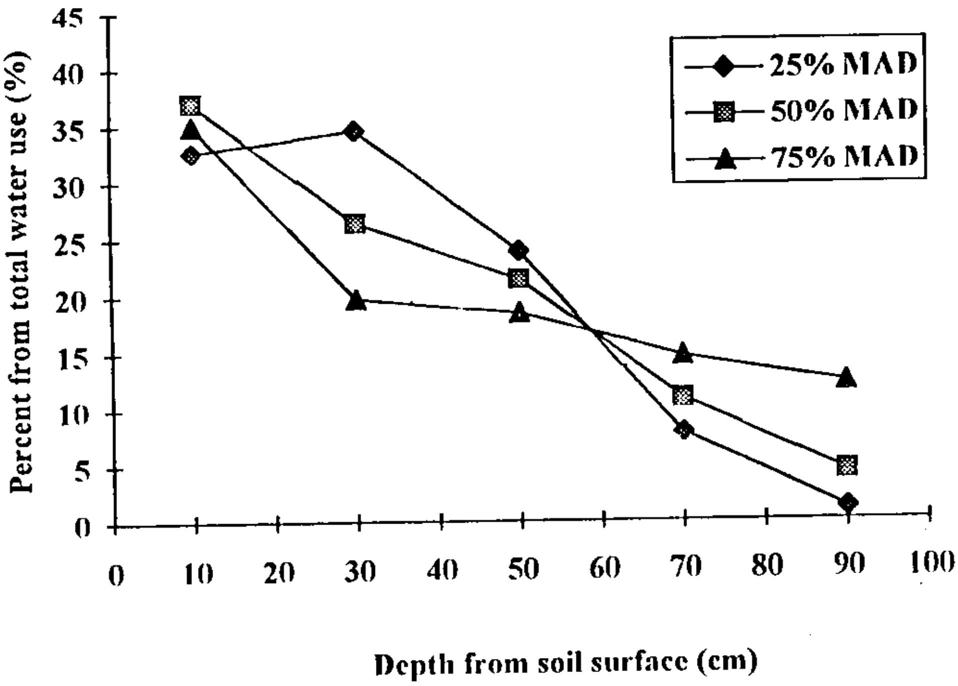

Figure 3: Average vertical water extraction patterns of the unmulched treatments during the active period as affected by management allowable depletion.

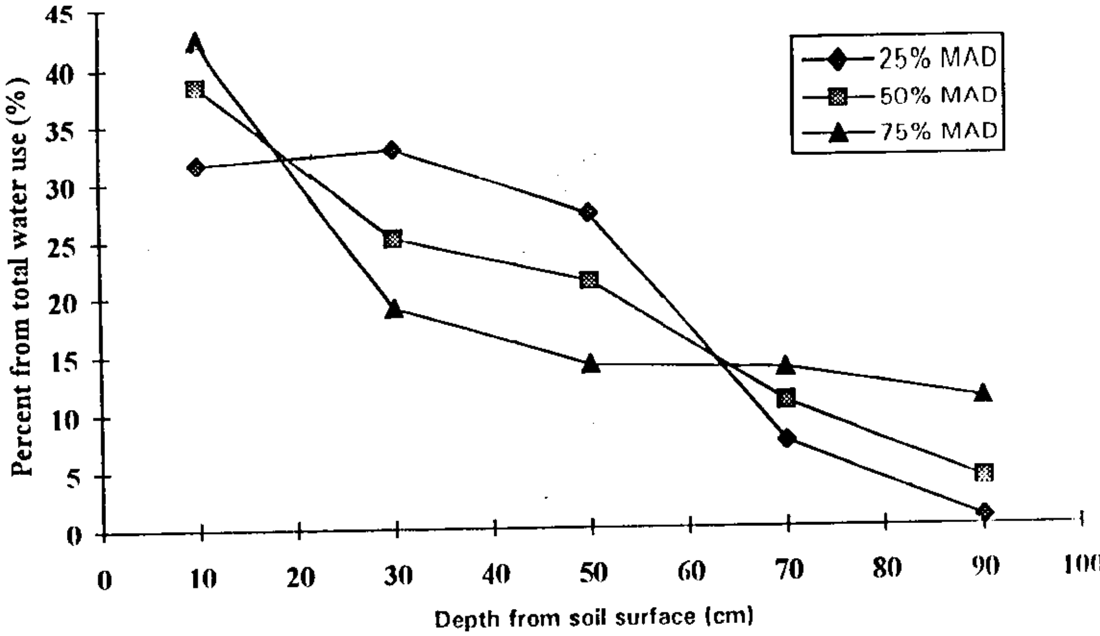

Figure 4: Average vertical water extraction patterns of the mulched treatments during the active period as affected by management allowable depletion.

(1985) attributed the reduction in relative contribution of the surface layer in total water use at frequent irrigation (low MAD) to the decrease in direct evaporation from soil surface because frequent irrigation increased plant canopy spread which resulted in more radiation interception and less surface evaporation.

In the mulched treatments (Fig. 4), relative contributions of the 0-20 cm, 60-80 cm, and 80-100 cm layers increased from about 32% to 42%, 8% to 14%, and 1% to 11%, respectively, as MAD increased from 25% to 75%. While, relative contributions of the 20-40 cm and 40-60 cm layers decreased from about 33% to 19% and 28% to 14%, respectively. Also, as MAD increased from 25% to 75%, about the same relative contributions of the root layers and the same variations in relative contributions occurred in the unmulched treatments. However, the increase in relative contribution occurred in the surface layer and the decrease in relative contribution occurred in the 40-60 cm layer were less in the unmulched treatments than in the mulched treatments (Fig.3 and 4).

The overall relative contribution of the upper 40% of the root zone (0-40 cm) was almost constant and near 65% in all MAD treatments. With the 25% MAD, relative contributions of the 0-20 cm and 20-40 cm layers were about the same. While, with 50% MAD and 75% MAD treatments, relative contribution of the 0-20 cm layer were about 1.5 and 2 times greater than the relative contribution of the 20-40 cm layer, respectively. Also, total contribution of the lower 60% of the root zone (40-100 cm) was about 35% in all treatments. In the 25% MAD and 75% MAD treatments, relative contribution of the 40-60 cm layer were about 25% and 5% greater than relative contribution of the 80-100 cm layer, respectively.

Covering soil surface with mulch increased irrigation interval in the 75% MAD treatments (Table 6, Appendix B). Thus, in the 75% MAD mulched treatment, relative contribution of the 0-20 cm layer increased about 7% and relative contribution of the 40-60 cm layer decreased about 5% as compared with relative contributions of the same layers in the 75% MAD unmulched treatment. However, mulch effect was almost negligible in the 25% MAD and 50% MAD treatments (Fig. 3 and 4).

In general, relative contributions of the successive root layers decreased with depth. The rate of decrease between the 0-20 cm and 20-40 cm layers was increased and that between the 20-40 cm and 80-100 cm layers was reduced as MAD increased.

4-1-2) Horizontal water extraction patterns:

In general, variations in the relative contributions in total water use were slight among the three horizontal distance intervals (0-50 cm, 50-100 cm, and 100-150 cm from tree stem) as shown in Fig. 5 and 6. Each horizontal distance interval contributed about one-third the total water use.

In the unmulched treatments (Fig. 5), relative contributions of the 0-50 cm, 50-100 cm, and 100-150 cm distance intervals in the total water use were 33%, 35%, and 32% for the 25% MAD treatment; 36%, 31%, and 33% for the 50% MAD treatment; 34%, 33%, and 33% with 75% MAD treatment, respectively. Variation between maximum and minimum relative contributions, among the three horizontal distance intervals, were around 3%, 5%, and 1% in the 25% MAD, 50% MAD, and 75% MAD treatments, respectively. Availability of soil water in the 25% MAD and 50% MAD treatments resulted in that the root distribution and , may be, the spatial variability in water intake by soil and the free water movement within soil were reflected on the horizontal water extraction patterns. While, water stress in the 75% MAD treatment enhanced roots within the three horizontal distance intervals to contribute about the same amounts in water use.

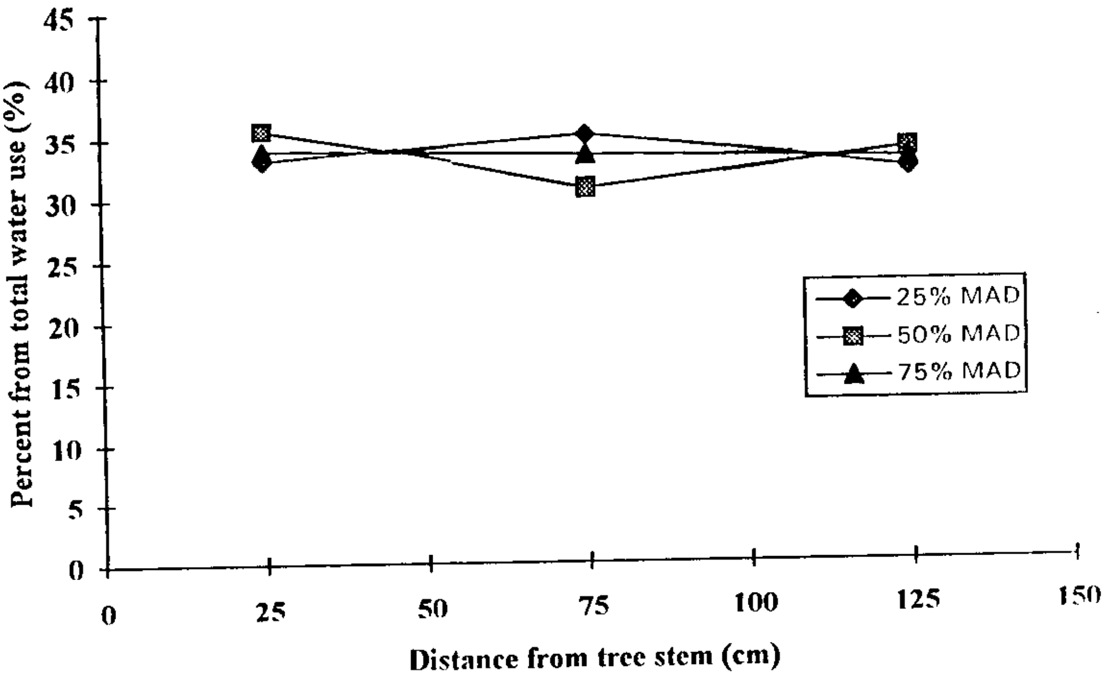

Figure 5: Average horizontal water extraction patterns of the unmulched treatments during the active period as affected by management allowable depletion.

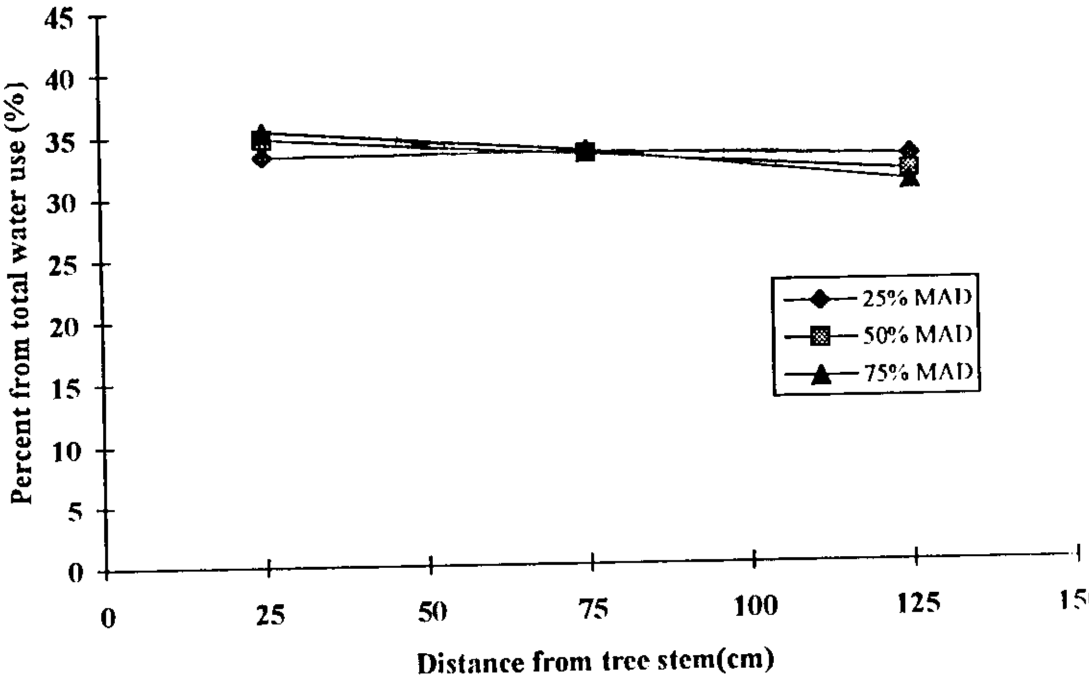

Figure 6: Average horizontal water extraction patterns of the mulched treatments during the active period as affected by management allowable depletion.

In the mulched treatments (Fig. 6), relative contributions of the three horizontal distance intervals were near 33% in the 25% MAD treatment. While, relative contribution decreased with distance in the 50% MAD and 75% MAD treatments, with a maximum variation in relative contribution among the three horizontal distance intervals of about 3% and 4%, respectively. Increasing irrigation interval in the 75% MAD treatment by mulch might resulted from conserving soil water under the mulch, while soil water under the adjacent unmulched surface reached very low values. Also, in the 50% MAD treatment, mulch reduced water loss underneath. Therefore, with mulch, the horizontal distribution of total water use decreased with increasing distance from tree stem in both 50% MAD and 75% MAD treatments.

4-1-3) Mathematical models:

For practical and more common application of the water extraction patterns, regression relationships were developed, separately, for vertical and horizontal directions for both the active period and the whole year.

For each treatment, 25 different relationships were tested using a computer program. The best equation was selected according to its correlation coefficient, logicity and the simplicity of understanding and application.

The general vertical water extraction patterns relationship can be described as :

$$Sme = A + (B \times Vd) + (C \times Vd^2) \quad \text{......................... (1)}$$

where Sme (%) is the soil moisture extraction as a percent of total water use. Vd (%) is the vertical depth from soil surface as a percent from total root zone depth. A, B, and C are empirical coefficients (Tables 1 and 2).

Increasing MAD from 25% to 75% increased the value of the empirical coefficient A. Also, in the 75% MAD treatments , the value of A increased with mulch. Thus, A is a function of MAD and mulch.

Also, as MAD increased, cofficient B decreased and coefficient C increased due to the reduction in the average variation between relative contributions of the various layers of root zone (Fig. 1 and 2).

With 25% MAD, equation (1) was applicable within the range 5%-90% of total root zone depth. The calculated Sme values at 5% and 90% of total root depth were about 0% and 100%, respectively. Results indicated that relative contribution of the lowest 20% of root zone depth was negligible in the 25% MAD treatment. However, equation (1) can be used for the whole depth of root zone in the 50% MAD and 75% MAD treatments.

The general horizontal water extraction patterns equation can be as:

$$Sme = A + (B \times Hd) \quad \text{.......................................(2)}$$

where Hd (%) is the horizontal distance from tree stem as a percent from the maximum expected horizontal root extension. A and B are empirical coefficients (Tables 3 and 4).

Using equations 1 and 2, relative contribution of any layer or horizontal distance interval of the root zone in total water use can be estimated.

4-2) Plant-Related Parameters:

Tree growth, physiological changes and yield of nectarine trees were investigated during 1992. Many researchers indicated that tree growth and its phyiological conditions of trees may affect crop yield either during same year or the following years.

Table 3 : Correlation of determination and the empirical coefficients of the horizontal water extraction patterns relationships during the active period.

Treatment	Coefficients		
	A	B	R^2
25% MAD -unmulched	- 0.07	1.01	9.93 E-1
25% MAD-mulched	0.15	9.99 E-1	9.99 E-1
50% MAD-unmulched	2.98	9.65 E-1	9.99 E-1
50% MAD-mulched	2.54	9.77 E-1	9.98 E-1
75% MAD-unmulched	0.75	9.93 E-1	9.99 E-1
75% MAD-mulched	3.60	9.69 E-1	9.99 E-1

Table 4: Correlation of determination and the empirical coefficients of the horizontal water extraction patterns relationships during the whole year.

Treatment	Coefficients		
	A	B	R^2
25% MAD -unmulched	0.53	1.00	9.94 E-1
25% MAD-mulched	0.48	9.96 E-1	9.99 E-1
50% MAD-unmulched	3.12	9.64 E-1	9.99 E-1
50% MAD-mulched	2.42	9.80 E-1	9.96 E-1
75% MAD-unmulched	1.76	9.87 E-1	9.99 E-1
75% MAD-mulched	4.78	9.57 E-1	9.97 E-1

4-2-1) Yield and fruit weight:

Yield, number of fruits per tree, and the average fruit weight are presented in Table 5. Fruit production in all trees was very low which may be attributed to the age of trees. Trees were young and it was the first year of production. Also, frost conditions which occurred during the budding stage (February and March) might cause a yield reduction due to the falling of flower buds. Nahlawi (74) stated that frost resistance threshold value of peaches is -4°C. This threshold value was reached during several nights at budding stage (Table 3, Appendix B).

In both unmulched and mulched treatments, statistical analysis showed insignificant differences in nectarine yield and average fruit weight in the different MAD treatments (Table 6). However, variations in nectarine yield resulted from changing MAD were greater in mulched treatments as compared with unmulched treatments. The 25% MAD treatment produced about 36% higher yield than yields in both mulched 50% and 75% MAD treatments. While, average fruit weight in the 25% MAD mulched treatment was around 48% and 61% less than that in the 50% and 75% MAD mulched treatments, respectively.

Mulch increased both yield and average fruit weight in the 25%, 50%, and 75% MAD treatments. In the 25% MAD treatment, a significant increase of about 1480% in yield and insignificant increase in average fruit weight occurred upon covering of soil surface. While, insignificant increase in yield and significant increase of about 820% and 1275% in average fruit weight occurred in the 50% and 75% MAD mulched treatments as compared with the yield and average fruit weight which occurred in the 50% and 75% MAD unmulched treatments, respectively. So, the increase of fruit number per tree rather than the increase in arverage fruit weight caused the yield increase.

Table 5: Yield, number of fruits per tree and average fruit weight.

Tree			Yield		
Soil Cover	**MAD (%)**	**Block**	**Total yield per tree (g)**	**No.of Fruits**	**Average Fruit Weight (g)**
Unmulched	25	1	0	0	0
	25	2	57	1	57
	25	3	0	0	0
	25	4	0	0	0
	50	1	0	0	0
	50	2	0	0	0
	50	3	36	1	36
	50	4	0	0	0
	75	1	90	3	30
	75	2	0	0	0
	75	3	0	0	0
	75	4	0	0	0
Mulched	25	1	335	9	37
	25	2	101	2	51
	25	3	315	8	39
	25	4	134	3	45
	50	1	0	0	0
	50	2	480	3	160
	50	3	173	1	173
	50	4	0	0	0
	75	1	61	1	61
	75	2	170	1	170
	75	3	165	1	165
	75	4	271	6	45

Table 6: Effect of MAD and mulch on plant-related parameters using DMRT at 5% confidence level.*

Unmulched MAD Treatments 25%	Unmulched 50%	Unmulched 75%	Mulched MAD Treatments 25%	Mulched 50%	Mulched 75%
Yield (g/tree)					
14b	9b	23ab	221a	163ab	167ab
Average Fruit Weight (g/fruit)					
14c	9c	8c	43abc	83ab	110a
Relative Holding					
0.23b	0.15c	0.19bc	0.34a	0.34a	0.33a
Stem Circumferance Total Increase (cm)					
4.9abc	3.8bcd	2.7d	5.4ab	6.5a	3.1cd
Stem Circumferance Relative Increase					
0.3ab	0.3ab	0.2b	0.5a	0.5a	0.3b
Trunk Cross-Sectional Area Total Increase (cm)					
13.2ab	9.1bc	5.4c	13.1ab	18.8a	7.5bc
Trunk Cross-Sectional Area Relative Increase					
0.9abc	0.7bc	0.6c	1.2a	1.2ab	0.6c
Tree Volume Total Increase (m^3)					
4.096b	4.126b	2.477b	7.155a	7.823a	3.673b
Tree Volume Relative Increase					
2.229b	3.195b	1.788b	3.414b	6.022a	3.124b
Leaf Relative Water Content(%)					
82.8a	81.8b	81.7b	82.4ab	82.6ab	80.6c
Chlorophyll Content (mg/g)					
1.238a	1.069c	1.089c	1.517b	1.347d	1.249a
Periodic Shoot Elongation (cm)					
3.2bc	2.5ab	2.3a	3.6c	4.4d	2.9abc
Seasonal Shoot Elongation (cm)					
38.0ab	30.2b	28.0b	42.8ab	52.8a	35.1b

* Values followed by the same letter are not significantly different.

4-2-2) Relative holding :

Table 7 shows the initial number of flowers and monthly relative holding in both unmulched and mulched treatments at the different MAD levels. Relative holding was affected by MAD only in the absence of mulch (Table 6). Comparison among relative holding means (Table 6) indicated that the 25% unmulched treatment resulted in a significant increase of about 54% in the relative holding as compared with relative holding in the 50% MAD unmulched treatment. While, the 75% MAD unmulched treatment produced an intermediate relative holding that was not significantly different from relative holdings in both 25% and 50% MAD unmulched treatments .

In the mulched treatments, no variations occurred in the relative holding among the three MAD treatments. Average relative holding during the season were the same and around 0.33 in all mulched MAD treatments. Also, mulch produced significant increase of about 48%, 130%, and 69% in relative holdings in 25%, 50%,, and 75% MAD treatments, respectively, as compared with the relative holdings in the unmulched treatments at the same respective MAD levels. With mulch, high water availability in the 25% MAD treatments and water stress in the 75% MAD treatments reduced relative holding increase as compared with relative holding increase in the 50% MAD treatments.

4-2-3) Stem circumferance and trunk cross-sectional area :

Total and relative increase of stem circumferance and trunk cross-sectional area as influenced by MAD and mulch during the active period are presented in Table 8.

In the unmulched treatments, both total and relative stem growth increased as MAD decreased (Table 6). Total stem growth was significantly higher in the 25% MAD treatment than total stem growth in

Table 7: Initial number of flowers and monthly relative holding.

Tree			Number of flowers	Relative Holding ---Date---		
Soil Cover	MAD (%)	Block	15/4/92	15/5/92	15/6/92	15/7/92
Unmulched	25	1	332	0.55	0.26	0.00
	25	2	96	0.47	0.38	0.01
	25	3	106	0.52	0.33	0.00
	25	4	92	0.16	0.04	0.00
	50	1	79	0.52	0.06	0.00
	50	2	100	0.37	0.17	0.00
	50	3	169	0.37	0.10	0.01
	50	4	123	0.13	0.03	0.00
	75	1	232	0.54	0.21	0.01
	75	2	48	0.33	0.08	0.00
	75	3	60	0.37	0.22	0.00
	75	4	172	0.33	0.24	0.00
Mulched	25	1	187	0.66	0.40	0.03
	25	2	191	0.63	0.24	0.02
	25	3	53	0.70	0.21	0.08
	25	4	86	0.69	0.35	0.04
	50	1	91	0.66	0.32	0.00
	50	2	76	0.55	0.38	0.04
	50	3	72	0.60	0.36	0.01
	50	4	44	0.71	0.41	0.00
	75	1	95	0.75	0.32	0.01
	75	2	69	0.65	0.32	0.02
	75	3	137	0.61	0.39	0.01
	75	4	43	0.47	0.28	0.14

Table 8: Total and relative increases of stem circumferance and trunk cross-sectioal area as influenced by MAD and mulch during the active period.

Tree			Circumferance		Cross-Sectional Area	
Soil Cover	**MAD (%)**	**Block**	**Total Increase (cm)**	**Relative Increase**	**Total increase (cm)**	**Relative Increase**
Unmulched	25	1	6.0	0.4	17.2	1.0
	25	2	5.5	0.3	18.4	0.7
	25	3	4.5	0.4	9.7	1.0
	25	4	3.5	0.3	7.5	0.7
	50	1	3.5	0.2	10.7	0.4
	50	2	3.7	0.3	8.3	0.7
	50	3	2.5	0.2	5.5	0.4
	50	4	5.5	0.5	12.8	1.3
	75	1	3.5	0.3	7.5	0.7
	75	2	3.2	0.3	6.2	0.7
	75	3	2.5	0.3	3.8	0.7
	75	4	1.5	0.1	3.8	0.2
Mulched	25	1	7.0	0.4	23.4	1.0
	25	2	5.5	0.6	10.4	1.6
	25	3	2.5	0.3	3.8	0.7
	25	4	6.5	0.6	14.6	1.6
	50	1	7.0	0.4	23.4	1.0
	50	2	6.5	0.4	20.2	1.0
	50	3	6.0	0.4	17.2	1.0
	50	4	6.5	0.6	14.6	1.6
	75	1	4.0	0.3	9.8	0.7
	75	2	3.5	0.3	7.5	0.7
	75	3	3.5	0.2	10.7	0.4
	75	4	1.5	0.2	2.0	0.4

the 75% MAD treatment. While, the 50% MAD treatment produced an intermediate total stem growth which was not significantly different from total stem growth in both 25% and 75% MAD treatments. However, insignificant increase occurred in the relative stem growth as MAD decreased.

In the mulched treatments, the 25% and 50% MAD treatments resulted in significant increase in both total and relative stem growth as compared with total and relative stem growth in the 75% MAD treatment. While, no significant differences in the total and relative stem growth occurred between the 25% and 50% MAD treatments. So, mulch promoted the influence of decreasing MAD in increasing the total and relative stem growth.

In general, covering soil surface with mulch increased both total and relative stem growth as compared with unmulched treatments in all MAD levels. The increase in total stem growth by mulch was significant in the 50% MAD treatment and insignificant in both 25% and 75% MAD treatments as compared with unmulched treatments at the same MAD levels. This may be attributed to high water availability in the 25% MAD treatments and to water stress in the 75% MAD treatments.

4-2-4) Tree volume :

Total and relative increases in tree volume (growth) as influenced by MAD and mulch during the active period are shown in Table 9. In the absence of mulch, statistical analysis indicated that no significant differences occurred in tree growth among the three MAD treatments (Table 6). Maximum tree growth occurred in the 50% MAD treatment, while, the minimum tree growth occurred in the 75% MAD treatment.

With mulch, the 75% MAD treatment produced significant decrease of about 49% and 53% in total tree growth as compared with total tree

Table 9: Total and relative increases of tree volume as influenced by MAD and mulch during the active period.

Tree			Tree Volume	
Soil Cover	MAD (%)	Block	Total Increase (m^3)	Relative Increase
Unmulched	25	1	6.743	2.754
	25	2	5.116	1.903
	25	3	3.571	3.341
	25	4	0.954	0.919
	50	1	4.330	3.149
	50	2	5.273	2.669
	50	3	3.179	3.045
	50	4	3.722	3.918
	75	1	2.042	1.416
	75	2	2.519	2.399
	75	3	2.865	1.856
	75	4	2.482	1.481
Mulched	25	1	8.296	3.081
	25	2	7.423	2.032
	25	3	6.324	4.358
	25	4	6.576	4.183
	50	1	9.157	3.847
	50	2	10.716	5.755
	50	3	9.190	6.440
	50	4	2.229	8.047
	75	1	4.036	4.118
	75	2	4.142	4.884
	75	3	4.780	2.567
	75	4	1.734	0.927

growth which occurred in the 25% MAD and 50% MAD treatments. respectively. While, no significant difference occurred in total tree growth among the 25% and 50% MAD mulched treatments. Significant increase of about 76% and 94% in relative tree growth occurred with 50% MAD mulched treatment as compared with relative tree growth in the 25% and 75% MAD mulched treatments , respectively. While, no significant difference occurred in relative tree growth between the 25% and 75% MAD mulched treatments.

Mulch increased both total and relative tree growth in the three MAD treatments. In comparison with the unmulched treatments, significant increase of about 76% and 90% in total tree growth occurred with mulch in the 25% and 50% MAD treatments, respectively. While, the 50% MAD mulched treatment resulted in a significant increase of about 88% in relative tree growth as compared with relative tree growth in the 50% MAD unmulched treatment. However, no significant increase was occurred in both total and relative tree growth in the 75% MAD mulched treatment. Also, no signifcant increase in the relative tree growth occurred in the 25% MAD mulched treatment as compared with relative tree growth in the 25% MAD unmulched treatment.

Thus, an interrelation occurred between the MAD and mulch treatments. Mulch enhanced the improving effects of decreasing MAD on tree growth, and increasing water availability maximized the effect of mulch on tree growth.

4-2-5) Leaf relative water content :

Table 10 presents the leaf relative water content as affected by MAD and mulch during the active period. In the absence of mulch, the 25% MAD treatment produced the highest significant leaf relative water content among the three MAD treatments (Table 6). The difference in leaf

Table 10: Leaf relative water content as affected by MAD and mulch during the active period.

Soil Cover	Tree MAD (%)	Block	Leaf Relative Water Content (%) Date (9/5)	(23/5)	(6/6)	(21/6)	(4/7)	(18/7)	(2/8)
Unmulched	25	1	88.1	84.4	87.2	85.3	86.2	83.2	83.1
	25	2	87.6	81.5	88.5	86.2	89.3	85.3	86.6
	25	3	87.4	81.8	86.3	85.0	87.9	83.4	85.4
	25	4	88.2	80.9	87.7	83.0	86.1	83.2	82.8
	50	1	88.1	84.6	88.9	85.1	90.8	85.7	84.7
	50	2	89.1	86.1	87.3	82.7	89.0	84.4	83.8
	50	3	86.8	80.1	86.4	76.9	81.9	83.2	83.0
	50	4	85.7	78.6	87.5	85.4	85.1	78.8	79.1
	75	1	89.2	81.6	86.8	85.6	87.7	84.8	84.1
	75	2	87.8	83.8	85.1	76.5	88.0	86.6	83.6
	75	3	88.0	83.3	86.6	87.2	87.1	85.8	83.5
	75	4	88.4	79.9	86.6	82.0	87.2	83.1	80.1
Mulched	25	1	88.8	85.9	86.1	83.2	88.9	83.1	82.8
	25	2	86.1	86.2	87.3	77.7	86.5	85.9	83.7
	25	3	90.4	82.4	85.8	80.2	85.7	78.7	77.6
	25	4	90.1	82.0	89.0	82.1	85.7	86.4	86.3
	50	1	90.5	83.2	87.2	85.4	87.9	86.3	85.7
	50	2	88.3	83.6	86.5	85.3	87.9	85.8	84.2
	50	3	88.7	85.6	88.6	81.7	85.9	86.2	83.1
	50	4	87.2	81.2	88.6	84.5	85.6	84.9	84.3
	75	1	88.6	82.7	85.1	82.5	86.7	84.2	83.5
	75	2	87.1	83.5	87.0	84.3	83.8	86.1	82.9
	75	3	89.4	81.7	84.5	80.7	84.7	80.8	83.1
	75	4	85.7	78.0	86.9	75.4	84.8	79.2	78.8

Table 10: cont

Tree			Leaf Relative Water Content (%)						
			Date						
Soil Cover	MAD (%)	Block	(16/8)	(29/8)	(12/9)	(3/10)	(17/10)	(5/11)	(19/11)
Unmulched	25	1	80.0	79.5	81.6	78.8	83.8	82.2	81.3
	25	2	78.8	77.0	83.9	80.1	80.1	81.9	77.4
	25	3	78.5	79.4	79.2	79.0	79.0	81.3	78.6
	25	4	78.4	80.3	78.7	78.5	78.5	79.9	79.2
	50	1	80.0	81.1	80.5	75.6	75.6	82.1	81.9
	50	2	79.5	80.3	81.6	78.6	78.6	80.1	78.5
	50	3	79.3	81.0	81.8	78.8	78.8	81.0	80.0
	50	4	76.7	74.1	76.4	79.9	79.9	72.2	68.5
	75	1	76.6	79.6	80.9	74.7	74.7	79.3	77.6
	75	2	76.0	80.8	80.5	79.7	79.7	78.3	78.0
	75	3	78.6	78.4	80.4	76.5	76.5	79.0	77.2
	75	4	74.3	74.1	80.1	78.2	78.2	78.2	81.2
Mulched	25	1	80.5	80.3	82.3	75.4	84.3	83.2	78.4
	25	2	79.7	81.5	83.6	82.7	84.7	82.2	78.9
	25	3	78.1	77.3	76.5	77.1	80.6	78.3	76.6
	25	4	79.3	80.2	82.5	82.0	82.9	80.2	77.3
	50	1	80.5	70.4	80.9	80.4	84.8	80.9	79.0
	50	2	78.7	78.8	83.1	75.4	83.6	82.0	76.5
	50	3	81.9	78.8	80.8	75.6	82.8	78.3	73.9
	50	4	76.6	78.4	79.6	81.1	80.3	80.3	79.9
	75	1	78.7	72.0	75.9	79.0	82.2	80.1	77.4
	75	2	77.9	78.5	77.6	75.2	82.6	79.6	76.5
	75	3	76.8	78.0	78.0	75.4	79.7	77.1	76.1
	75	4	74.4	74.1	79.8	73.3	77.7	79.7	78.4

relative water content between the 50% and 75% MAD unmulched treatments was negligible and insignificant.

With mulch, leaf relative water content in the 25% MAD treatment was not significantly different from that in the 50% MAD treatment. While, the 75% MAD mulched treatment produced significantly lower leaf relative water content than both 25% and 50% MAD mulched treatments.

This indicated that an interaction between MAD and mulch treatments occurred in influencing the leaf relative water content. High water availability in the 25% MAD treatments was the limiting factor in determining the leaf relative water content in both unmulched and mulched treatments. In the 50% MAD treatment, mulch resulted insignificant increase of about 0.8% in leaf relative water content as compared with leaf relative water content in the 50% MAD unmulched treatment. While, in the 75% MAD mulched treatment, a significant decrease of about 1.1% in leaf relative water content occurred as compared with leaf relative water content in the 75% MAD unmulched treatment. This decrease in leaf relative water content may be attributed to the longer irrigation interval and greater water stress in the 75% MAD mulched treatment.

4-2-6) Chlorophyll content :

Leaf chlorophyll content as affected by MAD and mulch during the active period are presented in Table 11. In general, decreasing MAD increased chlorophyll content (Table 6).

In the absence of mulch, the 25% MAD treatment produced a significant increase of about 16% and 14% in chlorophyll content as compared with chlorophyll content values in the 50% and 75% MAD treatments, respectively. While, chlorophyll content in the 50% MAD unmulched treatment was not significantly different from that in the 75% MAD unmulched treatment.

Table 11: Leaf chlorophyll content (mg/g of fresh leaves) as affected by MAD and mulch during the active period.

Tree			Leaf Chlorophyll Content (mg/g) --Date--						
Soil Cover	MAD (%)	Block	(22/8)	(5/9)	(19/9)	(3/10)	(17/10)	(5/11)	(19/11
Un mulched	25	1	1.643	1.876	1.666	1.129	0.954	0.791	0.710
	25	2	1.950	1.952	1.954	1.160	1.161	0.875	0.732
	25	3	1.610	1.854	1.744	0.883	0.886	0.713	0.627
	25	4	1.519	1.658	1.602	0.860	0.848	0.687	0.607
	50	1	1.600	1.811	1.434	1.031	0.991	0.810	0.720
	50	2	1.616	1.813	1.459	0.970	0.984	0.661	0.500
	50	3	1.632	1.442	1.463	0.839	0.727	0.566	0.485
	50	4	1.422	1.382	1.221	0.664	0.771	0.538	0.451
	75	1	1.608	1.765	1.714	1.146	0.958	0.577	0.387
	75	2	1.725	1.995	1.664	0.995	1.002	0.863	0.586
	75	3	1.440	1.713	1.628	0.796	0.795	0.536	0.407
	75	4	1.173	1.219	1.400	0.628	0.737	0.558	0.469
Mulched	25	1	1.883	2.317	2.099	1.284	1.240	0.988	0.862
	25	2	2.087	2.156	2.075	1.510	1.279	0.996	0.854
	25	3	1.810	2.208	1.919	1.029	0.965	0.856	0.801
	25	4	2.378	2.234	2.206	1.333	1.331	0.996	0.829
	50	1	1.814	2.127	1.898	1.139	1.083	0.948	0.880
	50	2	1.787	2.152	2.035	1.206	1.243	0.942	0.791
	50	3	1.821	2.188	2.200	1.278	1.123	0.954	0.870
	50	4	1.463	1.511	1.471	0.721	0.964	0.631	0.465
	75	1	1.862	2.257	2.140	1.224	1.148	0.939	0.834
	75	2	1.866	2.087	1.962	1.025	1.111	0.929	0.838
	75	3	1.700	1.717	1.731	0.880	0.767	0.579	0.485
	75	4	1.287	1.745	1.485	0.664	0.685	0.546	0.477

With mulch, chlorophyll content increased significantly from 1.249 to 1.347 mg/g and from 1.347 to 1.517 mg/g as MAD decreased from 75% to 50% and from 50% to 25%, respectively.

Mulch increased chlorophyll content significantly in the three MAD treatments as compared with chlorophyll content at the same unmulched MAD levels. Chlorophyll content increases due to mulch were about 23%, 26%, and 15% in the 25%, 50%, and 75% MAD treatments, respectively. Increasing irrigation interval in the 75% MAD mulched treatment, as compared with irrigation interval in the 75% MAD unmulched treatment, reduced the effect of mulch in increasing chlorophyll content. Therefore, an interaction occurred between the MAD and mulch treatments in affecting the chlorophyll content.

4-2-7) Shoot elongation :

Average periodic and seasonal shoot elongations as affected by MAD and mulch are presented in Table 12. Mulch and MAD treatments were highly related to each other in influencing the periodic shoot elongation (Table 6).

In the unmulched treatments, average periodic shoot elongation increased as MAD decreased. The 50% MAD unmulched treatment produced an intermediate value of average periodic shoot elongation, among the three MAD treatments, which was not significantlly different from the average periodic shoot elongations resulted in both 25% and 75% MAD unmulched treatments. While, a significant increase of about 36% in average periodic shoot elongation occurred in the 25% MAD unmulched treatment as compared with average periodic shoot elongation in the 75% MAD unmulched treatment.

With mulch, the 50% MAD treatment resulted in significant increase of about 22% and 51% in average periodic shoot elongation as

Table 12: Average periodic and seasonal shoot elongation as affected by MAD and mulch during the active period.

Tree			Average weekly Shoot Length Increase (cm)						
			Date						
Soil Cover	MAD (%)	Block	(10/5)	(22/5)	(4/6)	(19/6)	(2/7)	(16/7)	(30/7)
Un mulched	25	1	8.3	5.8	9.2	13.3	6.4	1.5	0.5
	25	2	9.4	8.9	13.2	10.6	4.3	0.4	1.8
	25	3	5.6	7.2	10.3	6.7	1.9	0.3	0.3
	25	4	6.1	6.7	6.6	3.1	0.8	0.3	0.0
	50	1	11.4	6.6	12.6	10.8	2.7	0.5	0.0
	50	2	9.3	7.1	5.2	3.1	1.3	0.1	0.1
	50	3	6.4	7.2	7.3	4.8	1.8	0.2	0.0
	50	4	8.1	6.5	4.9	1.0	0.2	0.0	0.0
	75	1	6.5	4.3	4.8	3.8	0.8	0.3	0.3
	75	2	8.8	7.3	7.1	4.2	3.7	3.6	1.1
	75	3	6.0	8.0	10.9	8.2	5.8	0.9	0.3
	75	4	5.2	4.3	2.4	0.9	0.1	0.0	0.0
Mulched	25	1	11.8	8.2	6.9	9.5	1.6	0.9	0.0
	25	2	11.4	8.6	7.9	4.9	2.3	0.8	1.0
	25	3	13.6	12.0	13.8	3.6	2.5	1.9	0.9
	25	4	10.0	10.3	11.2	7.2	3.2	1.2	0.4
	50	1	11.8	10.8	13.6	9.7	2.2	0.7	0.4
	50	2	12.4	13.4	20.1	14.1	7.3	2.5	1.2
	50	3	10.6	9.8	12.9	10.3	5.0	1.4	0.8
	50	4	13.3	9.4	10.0	3.8	0.4	0.1	0.1
	75	1	11.6	8.3	10.6	7.8	2.2	0.4	0.3
	75	2	11.8	10.8	13.8	7.3	1.0	0.1	0.1
	75	3	6.6	6.3	6.3	3.2	0.8	0.1	0.3
	75	4	11.9	6.8	5.7	1.4	0.3	0.0	0.0

compared with average periodic shoot elongations which occurred in the 25% and 75% MAD treatments, respectively. While, insignificant increase of about 22% in the average periodic shoot elongation occurred in the 25% MAD mulched treatment as compared with that resulted from the 75% MAD mulched treatment.

In the unmulched treatments, increasing MAD from 25% to 50% and from 50% to 75% resulted insignificant decrease in the average seasonal shoot elongation (Table 6). With mulch, the 50% MAD treatment resulted in significant increase of about 50% in average seasonal shoot elongation as compared with the average seasonal shoot elongation in the 75% MAD treatment. While, the 25% MAD mulched treatment resulted an intermediate value of average seasonal shoot elongation that was not significantly different from the average seasonal shoot elongations in both mulched 50% and 75% MAD treatments.

A significant increase of about 75% in both average periodic and seasonal shoot elongations occurred in the 50% MAD mulched treatment as compared with the same parameters in the 50% MAD unmulched treatment. While, insignificant increase was recorded in the average periodic and seasonal shoot elongations from covering the soil surface in both 25% and 75% MAD treatments with mulch. High water availability in the 25% MAD treatment and water stress in the 75% MAD treament reduced the effect of mulch in increasing the periodic and seasonal shoot elongations when compared with the 50% MAD.

4-2-8) Consumptive use :

Consumptive use during the whole year and the active period as affected by MAD and mulch are presented in Table 13. In both unmulched and mulched treatments, consumptive use increased as MAD decreased (Table 14). In yearly consumptive use, the 25% MAD treatment produced

Table 13: Consumptive use as affected by MAD and mulch during the whole year and the active period.

Tree			Total Consumptive Use (mm)	
Soil Cover	MAD (%)	Block	During Whole Year	During Active Period
Unmulched	25	2	1065.4	853.6
	25	3	1096.1	897.1
	50	2	581.1	422.9
	50	3	488.1	357.9
	75	2	404.0	284.9
	75	3	472.2	286.4
Mulched	25	2	1193.1	998.1
	25	3	1126.5	936.2
	50	2	510.2	375.2
	50	3	513.4	373.3
	75	2	388.6	280.3
	75	3	447.4	324.3

Table 14: Effect of MAD and mulch on both yearly and active period consumptive use using DMRT at 5%. confidence level*.

Unmulched MAD Treatments			Mulched MAD Treatments		
25%	50%	75%	25%	50%	75%
-------------Yearly Consumptive Use (mm)-------------					
1080.8a	534.6b	438.1b	1159.8a	511.8b	418.0b
-----------Active Period Consumptive Use (mm)------					
875.4b	390.4c	285.7d	967.2a	374.3cd	302.3cd

* Values followed by the same letter are not significantly different.

the highest significant consumptive use among the three MAD treatments. During the active period, consumptive use decreased significantly as MAD increased in the unmulched treatments. Also, consumptive use in the 25% MAD mulched treatment was significantly higher than consumptive use occurred in both 50% and 75% MAD mulched treatments.

During the active period, consumptive use increased significantly (about 10%) with mulch treatment compared with consumptive use in the unmulched treatment in 25% MAD. Thus, indicated that the increase in tree yield and growth due to mulch resulted in a greater consumptive use. Mitchell et al. (1991) stated that increasing tree growth under high water supplies enhances vegetative growth to use additional water.

In the other hand, since the differences in tree yield and growth in the 25% and 50% MAD treatments were not significant, then the increase in consumptive use in the 25% MAD treatments as compared with consumptive use in the 50% MAD treatments can be considered as a luxury consumption.

4-2-9) Water use efficiency:

Water use efficiencies with respect to crop yield (WUE_y), stem circumferance (WUE_{sc}), trunk cross-sectional area (WUE_{tca}), tree volume (WUE_v), and the average seasonal shoot elongation (WUE_{se}) as affected by MAD and mulch are presented in Table 15. In general, water use efficiency decreased as MAD decreased below 50% (Table 16).

In the unmulched treatments, variations in WUE_y and WUE_{tca}, among the three MAD treatments, were not significant. The WUE_{sc} decreased significantly as MAD decreased from 75 to 50% and from 50 to 25%. The 25% MAD unmulched treatment resulted in a significant decrease of about 53% and 47% in WUE_v as compared with WUE_v in the 50% and 75% MAD unmulched treatments, respectively. While, WUE_v

Table 15: Water use efficiency with respect to crop yield (WUE_y), stem circumferance (WUE_{sc}), trunk cross-sectional area (WUE_{tca}), tree volume (WUE_v) and shoot elongation (WUE_{se}) as affected by MAD and mulch.

Tree			Water Use Efficiency				
Soil Cover	MAD (%)	Block	WUE_y (g/mm)	WUE_{sc} (cm/cm)	WUE_v (m^3/mm)	WUE_{se} (cm/mm)	WUE_{tca} (cm^2/mm)
Un mulched	25	2	0.0668	0.0064	0.0060	0.0581	0.0216
	25	3	0.0000	0.0050	0.0040	0.0366	0.0108
	50	2	0.0000	0.0087	0.0125	0.0617	0.0196
	50	3	0.1006	0.0070	0.0089	0.0796	0.0154
	75	2	0.0000	0.0112	0.0088	0.1316	0.0218
	75	3	0.0000	0.0087	0.0100	0.1404	0.0133
Mulched	25	2	0.1012	0.0055	0.0074	0.0374	0.0104
	25	3	0.3365	0.0027	0.0068	0.0528	0.0041
	50	2	1.2802	0.0173	0.0286	0.1896	0.0539
	50	3	0.4634	0.0161	0.0246	0.1433	0.0461
	75	2	0.6065	0.0125	0.0148	0.1666	0.0268
	75	3	0.5088	0.0108	0.0147	0.0737	0.0330

Table 16: Effect of MAD and mulch on the water use efficiency using DMRT at 5% confidence level*.

Unmulched MAD Treatments			Mulched MAD Treatments		
25%	50%	75%	25%	50%	75%
WUE_y (g/mm/tree)					
0.0334b	0.0503b	0.0000b	0.2188ab	0.8718a	0.5576ab
WUE_{sc} (cm/mm/tree)					
0.0057e	0.0079d	0.0100c	0.0041f	0.0167a	0.0116b
WUE_{tca} (cm^2/mm/tree)					
0.0162c	0.0175c	0.0175c	0.0072c	0.0500a	0.0299b
WUE_v (m^3/mm/tree)					
0.0050d	0.0107c	0.0094c	0.0071cd	0.0266a	0.0148b
WUE_{se} (cm/mm/tree)					
0.0473c	0.0707bc	0.1360ab	0.0451c	0.1665a	0.1202abc

* Values followed by the same letter are not significantly different.

in both 50% and 57% MAD unmulched treatments were not significantly different. The 50% MAD unmulched treatment produced an intermediate value of WUE_{se} that was not significantly different from WUE_{se} in the 25% and 75% MAD unmulched treatments. However, the 75% MAD unmulched treatment produced a significant increase of about 188% in WUE_{se} as compared with the WUE_{se} in the 25% MAD unmulched treatment.

In the mulched treatments, WUE_y had not affected significantly by MAD treatments. The 50% MAD mulched treatment produced the highest significant values of WUE_{sc}, WUE_{tca}, and WUE_v among the three mulched MAD treatments. While, the 75% MAD mulched treatment resulted in a significant increase of about 183%, 109%, and 315% in WUE_{sc}, WUE_{tca}, and WUE_v, respectively, as compared to the same parameters in 25% MAD mulched treatment. Also, the 75% MAD mulched treatment produced an intermediate value of WUE_{se} that was not significantly different form WUE_{se} in both 25% and 50% MAD mulched treatments. However, a significant increase of about 269% in WUE_{se} occurred as MAD increased from 25 to 50%.

In the 50% and 75% MAD mulched treatments, mulch increased WUEsc, WUEtca, and WUEv significantly as compared with the same parameters in the unmulched treatments at same MAD levels. Also, mulch increased WUE_y and WUE_{se} significantly in the 50% MAD treatment. While, in the 25% MAD treatment, mulch resulted in a none significant increase in WUEy and WUEv, significant decrease in WUE_{sc}, and insignificant decreases in WUEtca and WUEse as compared with unmulched treatment. Thus, the significant increase in yield and tree growth, and the insignificant increase in stem growth and seasonal shoot elongation could be attributed to mulch in the 25% MAD.

In general, the decrease in water use efficiency in the 25% MAD treatments, as compared with the water use efficiencies in both 50% and 75% MAD treatments, can be attributed to the luxury water consumption in the 25% MAD treatment.

Conclusions

I- Water extraction patterns:

1) Relative contribution of the root layers to crop water use decreased as the vertical depth increased from soil surface.
2) Increasing MAD increased the relative contributions of the deep layers.
3) In all MAD treatments, overall relative contributions of the upper 40% and lower 60% of the root zone were almost constant and about 65% and 35%, respectively.
4) In all MAD treatments, variations in the relative contributions in crop water use were slight and negligible among the 0-50, 50-100, and 100-150 cm horizontal distance intervals from tree stem.

II- Plant-related parameters:

1) In the unmulched treatments, the 25% MAD treatment was better than 50% and 75% MAD treatments in respect to the relative holding, total stem growth, periodic shoot elongation, leaf relative water content, and leaf chlorophyll content.
2) In the mulched treatments, although most of plant-related parameters in the 25% MAD treatment were not significantly different from those in the 50% MAD treatment, results indicated a positive responses in the 25% and 50% MAD treatments when compared with the 75% MAD treatment.
3) Partial covering of soil surface with mulch improved the plant-related parameters in all MAD treatments. The improvements were greatest in the 50% MAD treatment.

III- Consumptive use:

1) Consumptive use decreased as MAD increased from 25 to 50% and from 50 to 75%.
2) Mulch increased consumptive use significantly in the 25% MAD treatment as compared with consumptive use in the unmulched treatments.

IV- Water use efficiency:

1) In general, water use efficiency decreased as MAD decreased below 50%. The 25% MAD treatment resulted in a significant decrease in water use efficiency as compared to water use efficiencies in the 50% and 75% MAD treatments.
2) Mulch increased water use efficiency significantly in both 50% and 75% MAD treatments as compared with water use efficiency in the unmulched treatments at same MAD levels.

Recommendations

1) Partial covering of soil surface with mulch improves yield and growth of nectarine trees. Therefore, under-tree mulch is recommended in arid and semi-arid regions.
2) Most of tree growth parameters in the 25% and 50% MAD treatments increased significantly as compared with the same parameters in the 75% MAD treatment. While, water use efficiency was significantly greater in both 50% and 75% MAD treatments than that in the 25% MAD treatment. Therefore, the 50% MAD is recommended for supplemental irrigation scheduling with nectarine trees.
3) Experimenting several soil surface covering percentages is suggested to be conducted in the future with supplemental irrigation at 50% MAD.

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APPENDIX (A)

Table (1): Some physical and chemical soil properties.

Soil Depth [cm]	Bulk Desity [g/cm^3]	Field Capasity [Pv(%)]	Wilting Point [Pv (%)]	Phosphorus Content [ppm]	Potassium Content [ppm]
0-20	1.36	42.4	21.1	17.2	493.8
20-40	1.37	42.0	20.6	8.8	388.1
40-60	1.33	41.3	20.1	2.9	336.5
60-80	1.39	41.8	21.4	3.8	296.2
80-100	1.40	42.8	21.9	4.2	307.0

Table (2): Perticle size distribution and textural classes of the five soil depth increments.

Soil Depth [cm]	Clay [%]	Silt [%]	Sand [%]	Texture Class
0-20	52.5	14.7	32.8	Clay
20-40	58.7	29.4	11.9	Clay
40-60	46.3	33.6	20.1	Clay
60-80	65.6	6.3	28.1	Clay
80-100	50.8	14.8	34.4	Clay

$Pv = (37.05338 \times C.R) - 6.89864$ $R^2 = 0.81$

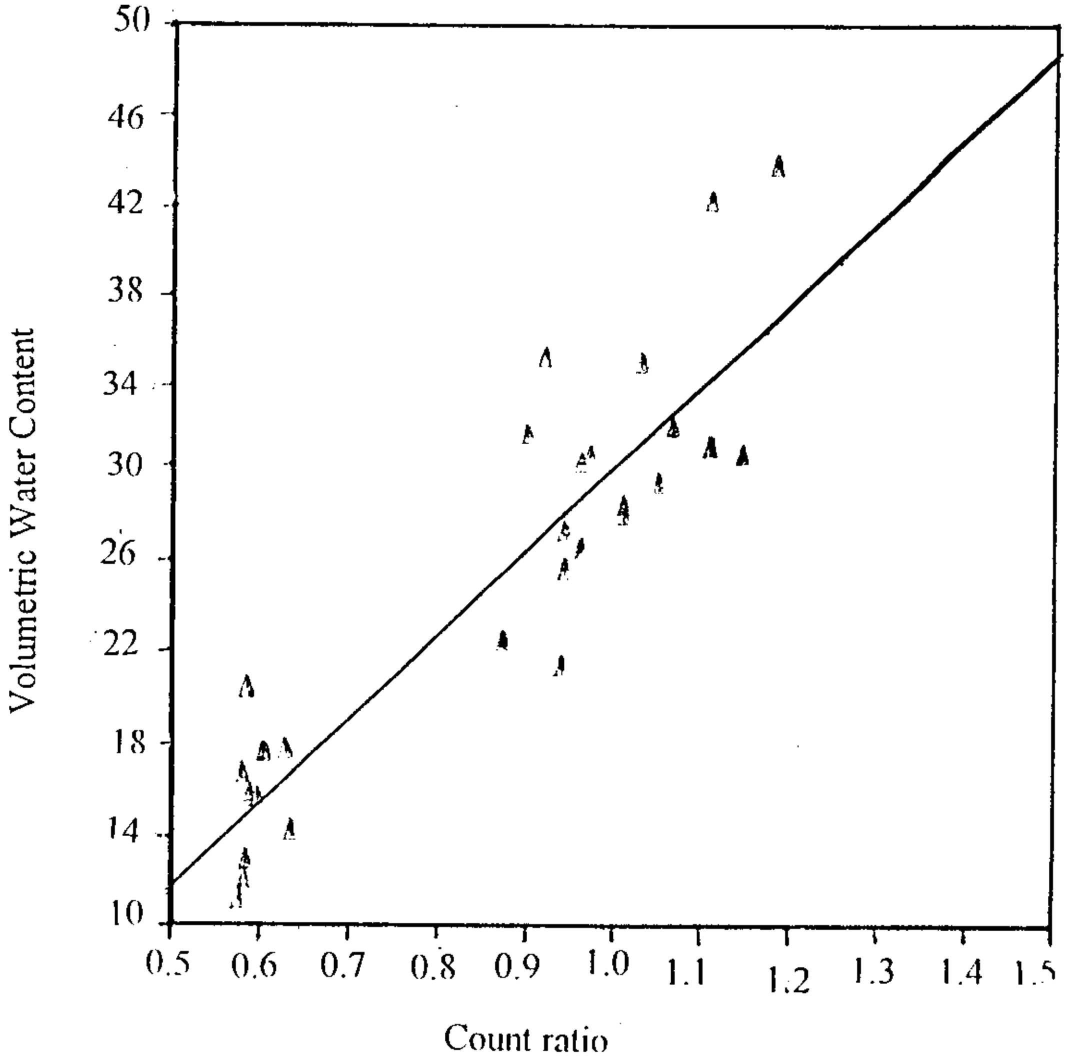

Figure (1): Neutron probe calibraion curve for 0-20 cm soil layer.

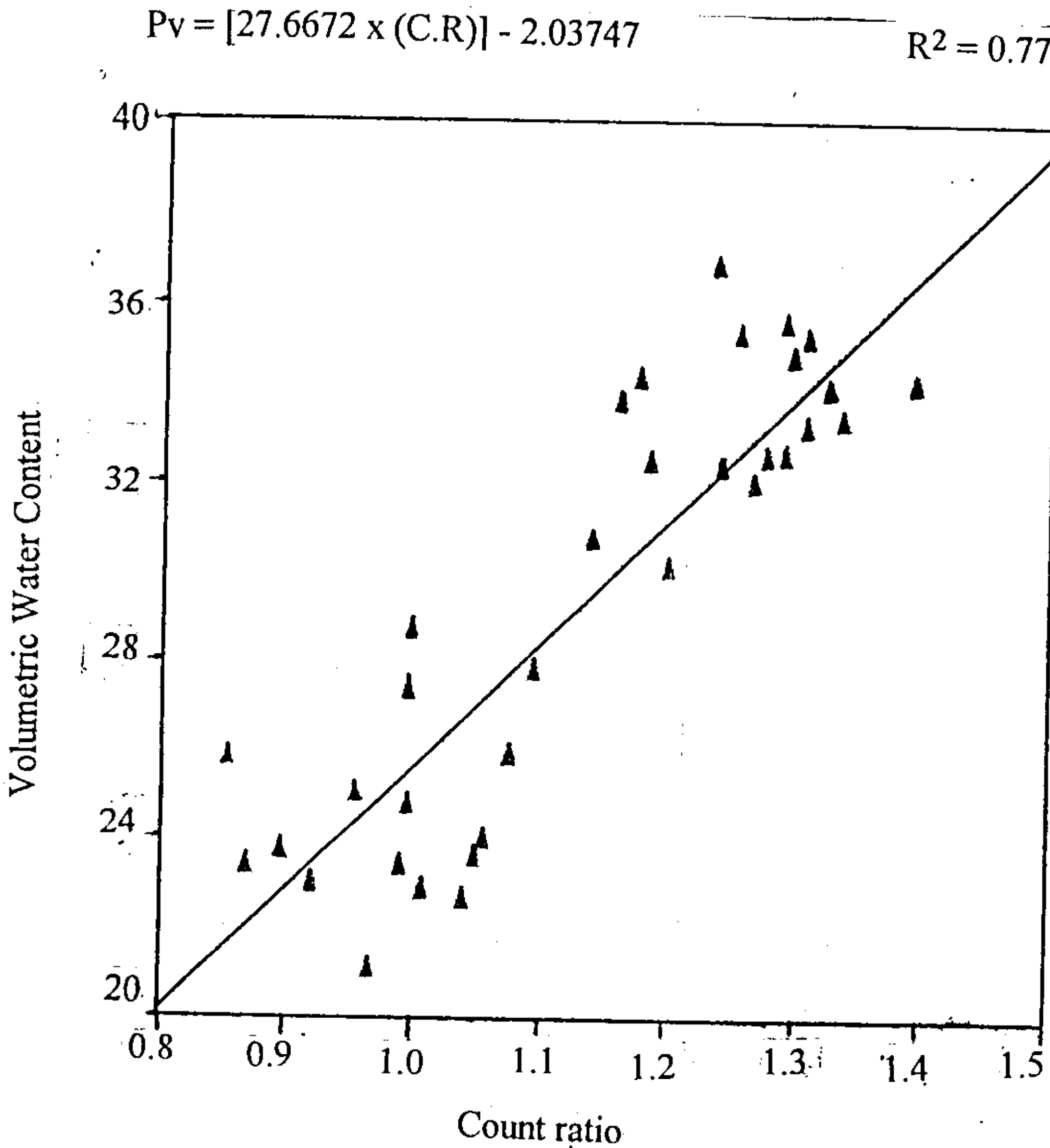

Figure (2): Neutron probe calibraion curve for 20-40 cm soil layer.

$$Pv = [29.77 \times (C.R)] - 6.0 \qquad R^2 = 0.87$$

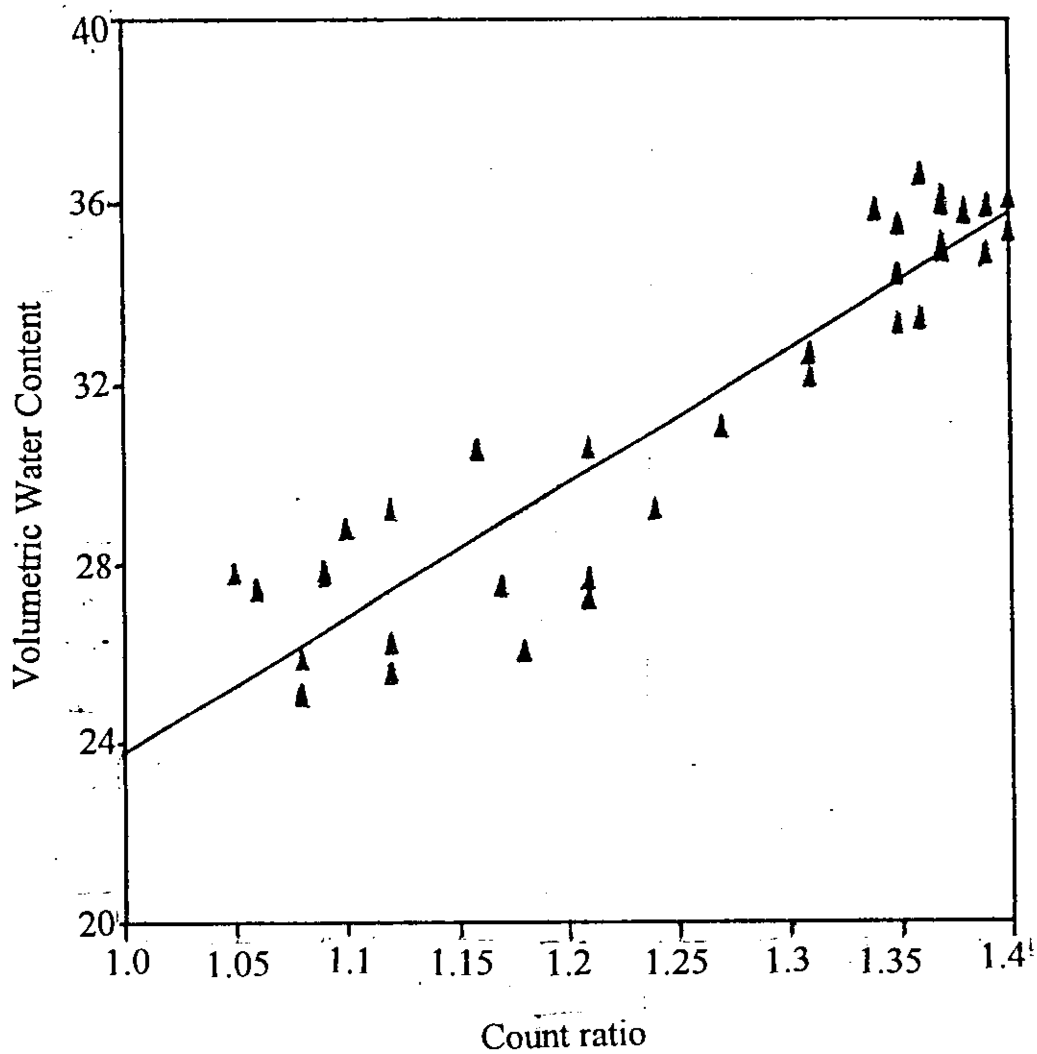

Figure (3): Neutron probe calibraion curve for 40-60 cm soil layer.

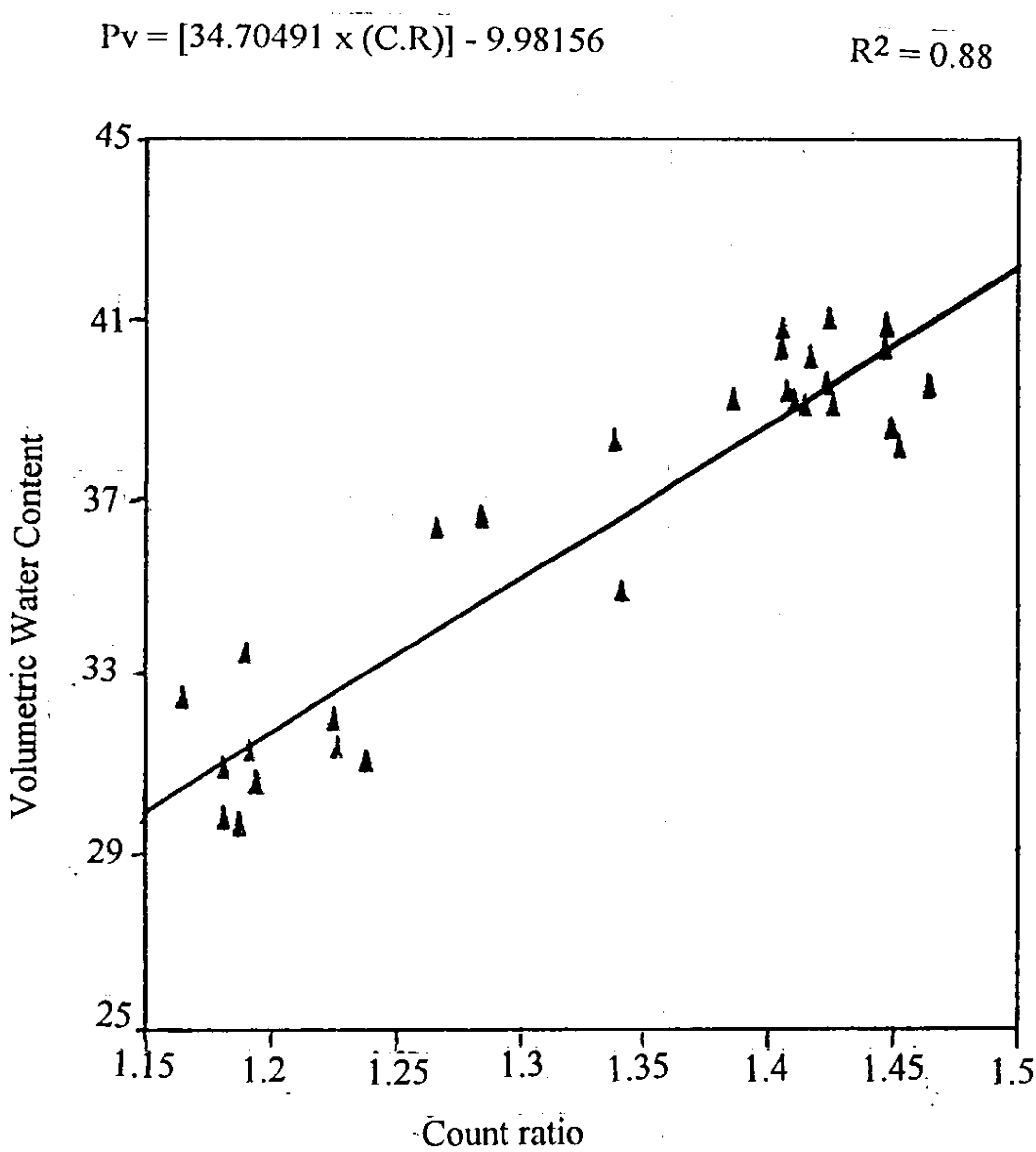

Figure (4): Neutron probe calibraion curve for 60-80 and 80-100 cm soil layers.

Table (1): Total irrigation water amounts applied during 1991 season.

Treatment	Total Water Amount (mm/tree)
25% MAD-Unmulched	467.9
50% MAD-Unmulched	290.2
75% MAD-Unmulched	174.6
25% MAD-Mulched	473.3
50% MAD-Mulched	253.6
75% MAD-Mulched	79.6

Table (2): Rainfall amounts recorded in the field during 199/ 1992 season.

Date	Rainfall Amount (mm)
13/10/91	8.9
3-4/11/91	21.6
28/11-1/12/91	62.1
2-5/12/91	124.1
12-13/12/91	80.8
19/12/91	2.9
24-25/12/91	7.7
17/12/91-2/1/92	49.0
13-15/1/92	8.9
15-16/1/92	22.8
17-21/1/92	24.5
21-22/1/92	3.2
30-31/1/92	17.0
31/1-2/2/92	58.6
2-3/2/92	6.4
3-7/2/92	119.0
9-11/2/92	33.2
11-12/2/92	3.4
17/2/92	3.8
20/2/92	16.2
22-24/2/92	21.3
24-25/2/92	39.8
4/3/92	6.2
21-22/3/92	43.5
16/4/92	2.5
7/5/92	1.0
8/5/92	1.5
16/5/92	0.3
17/5/92	4.0

Table (3): Minimum daily air temperature (^{o}C) during the first four months of 1992.

Day	Month			
	January	February	March	April
1	1.8	2.0	-1.0	5.0
2	-1.0	0.8	-3.0	2.0
3	-1.0	4.0	0.0	2.0
4	-4.0	0.5	0.0	6.5
5	-4.0	1.0	3.0	4.5
6	-2.0	3.0	4.0	6.5
7	1.0	2.0	1.5	11.0
8	2.0	3.0	1.5	13.5
9	1.5	1.8	2.5	9.5
10	1.5	-4.0	0.0	8.0
11	0.0	-1.0	1.0	11.0
12	5.0	-0.5	2.0	17.5
13	2.0	4.5	5.0	10.0
14	7.0	1.0	1.0	7.5
15	7.0	2.0	4.8	6.0
16	5.0	5.0	2.0	6.0
17	5.0	4.9	4.0	7.0
18	5.0	0.0	3.0	6.5
19	6.0	4.0	4.0	9.0
20	7.0	4.0	3.8	13.9
21	5.0	2.0	3.0	5.5
22	3.5	3.0	2.0	7.0
23	3.0	4.0	2.0	4.0
24	2.0	-1.8	1.0	6.5
25	1.5	-2.5	4.0	7.0
26	-1.0	-3.5	5.5	6.0
27	-0.5	-1.0	10.0	8.5
28	-2.0	-4.0	11.0	9.0
29	-0.8	-5.0	6.0	10.0
30	3.0		7.0	11.3
31	4.0		5.5	

Table (4) : Depletion and applied irrigation water amounts to 25% MAD treatments during 1992 season.

Date	Unmulched Treatment		Mulched Treatment	
	Depletion (%)	Irrigation Amount (mm)	Depletion (%)	Irrigation Amount (mm)
4/4/92	31.2	0.0	33.5	0.0
10/4/92	37.2	75.5	38.6	76.9
17/4/92	26.6	58.2	28.0	59.8
24/4/92	25.6	54.3	29.7	62.6
1/5/92	28.4	59.7	31.2	64.1
9/5/92	28.0	61.2	30.1	63.7
15/5/92	27.7	61.1	30.1	63.4
22/5/92	31.5	65.8	34.8	71.6
29/5/92	32.2	67.8	33.0	70.9
6/6/92	29.7	65.0	31.7	66.6
10/6/92	22.5	47.5	27.1	55.6
13/6/92	21.7	46.2	25.8	54.9
16/6/92	22.2	46.2	26.6	55.1
19/6/92	14.6	0.0	15.1	0.0
22/6/92	28.3	58.4	31.7	65.0
26/6/92	24.4	50.8	28.5	58.6
30/6/92	27.3	47.9	31.4	63.7
3/7/92	22.5	48.4	26.1	54.6
6/7/92	26.9	55.7	32.1	65.5
11/7/92	26.1	53.8	30.9	63.3
14/7/92	20.0	42.6	24.3	50.2
17/7/92	22.2	47.2	26.7	55.9
21/7/92	24.4	50.8	29.1	59.2
24/7/92	22.3	47.7	27.2	56.1
28/7/92	27.9	58.3	32.2	66.2
4/8/92	21.9	46.1	26.4	54.3
8/8/92	18.6	39.3	25.2	52.5
11/8/92	23.4	48.9	28.5	58.4
15/8/92	19.2	39.7	25.8	52.2
18/8/92	20.7	43.8	26.4	54.7
21/8/92	21.3	45.1	27.6	57.9
25/8/92	20.5	42.7	25.6	52.7
28/8/92	20.2	42.9	25.8	53.9
1/9/92	23.8	49.0	29.3	59.0
4/9/92	19.8	41.7	25.0	52.7
7/9/92	20.6	43.8	24.8	51.8
11/9/92	21.0	44.2	25.9	52.9
15/9/92	20.3	42.4	23.0	47.9
18/9/92	21.3	45.0	24.4	50.6
22/9/92	21.9	46.5	26.1	53.7
25/9/92	24.2	50.8	28.9	60.0

Table (5): Depletion and applied irrigation water amounts to 50% MAD treatments during 1992 season.

Date	Unmulched Treatments		Mulched Treatments	
	Depletion (%)	Irrigation Amount (mm)	Depletion (%)	Irrigation Amount (mm)
4/4/92	34.5	0.0	35.5	0.0
10/4/92	40.4	84.5	39.6	78.1
17/4/92	26.7	0.0	26.3	0.0
24/4/92	34.7	0.0	34.1	0.0
1/5/92	42.2	0.0	39.1	0.0
9/5/92	48.4	100.2	42.7	0.0
15/5/92	34.9	0.0	49.0	96.8
22/5/92	40.8	0.0	31.4	0.0
29/5/92	48.7	99.9	40.1	0.0
6/6/92	27.0	0.0	47.6	92.9
13/6/92	39.9	0.0	33.7	0.0
19/6/92	41.7	0.0	39.5	0.0
26/6/92	49.3	98.7	50.4	0.0
3/7/92	33.7	0.0	57.0	112.5
11/7/92	45.7	0.0	42.6	0.0
17/7/92	51.9	104.8	49.9	0.0
24/7/92	33.1	0.0	55.6	113.5
4/8/92	46.0	0.0	43.5	0.0
8/8/92	48.2	100.4	49.9	0.0
15/8/92	33.4	0.0	54.8	108.9
21/8/92	45.2	0.0	35.9	0.0
28/8/92	52.0	106.6	47.4	0.0
4/9/92	32.6	0.0	56.3	86.1
11/9/92	44.3	0.0	38.0	27.8
18/9/92	50.4	102.9	38.2	0.0
25/9/92	40.1	0.0	53.7	113.4

Table (6): Depletion and applied irrigation water amounts to 75% MAD treatments during 1992 season.

Date	Unmulched Treatment		Mulched Treatment	
	Depletion (%)	Irrigation Amount (mm)	Depletion (%)	Irrigation Amount (mm)
4/4/92	37.1	0.0	31.3	0.0
10/4/92	41.4	0.0	35.4	0.0
17/4/92	51.3	0.0	43.5	0.0
24/4/92	54.8	0.0	42.1	0.0
1/5/92	58.0	0.0	46.0	0.0
9/5/92	61.0	0.0	47.8	0.0
15/5/92	68.7	0.0	49.1	0.0
22/5/92	62.5	0.0	54.8	0.0
29/5/92	64.0	0.0	57.9	0.0
6/6/92	65.5	0.0	58.1	0.0
13/6/92	70.8	145.2	64.8	0.0
19/6/92	26.7	0.0	61.2	0.0
26/6/92	38.1	0.0	65.7	0.0
3/7/92	49.8	0.0	69.2	0.0
11/7/92	60.3	0.0	71.5	113.3
17/7/92	62.6	0.0	32.1	27.8
24/7/92	63.8	0.0	35.7	0.0
4/8/92	68.3	0.0	44.2	0.0
8/8/92	67.8	0.0	46.8	0.0
15/8/92	68.3	0.0	50.9	0.0
21/8/92	73.4	151.3	57.7	0.0
28/8/92	31.2	0.0	59.9	0.0
4/9/92	44.7	0.0	61.8	0.0
11/9/92	55.9	0.0	65.0	0.0
18/9/92	63.0	0.0	65.5	0.0
25/9/92	72.5	0.0	73.1	0.0

Table (1): Vertical and horizontal water extraction patterns of the 25% MAD-Unmulched treatment during a whole year and active period.*

Vertical Depth (cm)	---Horizontal Disance (cm)-------			
	0-50	50-100	100-150	Sum
0-20	10.76 (10.55)	10.70 (10.62)	10.93 (11.45)	32.39 (32.62)
20-40	11.22 (11.42)	11.62 (11.80)	11.19 (11.38)	34.03 (34.60)
40-60	7.84 (7.88)	8.86 (9.13)	6.88 (6.88)	23.58 (23.89)
60-80	2.82 (2.63)	3.09 (2.95)	2.34 (2.16)	8.26 (7.74)
80-100	0.56 (0.41)	0.74 (0.50)	0.44 (0.24)	1.74 (1.15)
0-100	33.21 (32.89)	35.01 (35.00)	31.78 (32.10)	100-00 (100-00)

Table (2): Vertical and horizontal water extraction patterns of the 25% MAD-Mulched treatment during a whole year and active period.*

Vertical Depth (cm)	---Horizontal Distance (cm)------			
	0-50	50-100	100-150	Sum
0-20	12.83 (12.69)	9.10 (8.88)	9.97 (9.94)	31.89 (31.51)
20-40	10.79 (10.83)	11.17 (11.17)	10.93 (10.92)	32.59 (32.92)
40-60	7.80 (7.90)	9.03 (9.20)	10.06 (10.31)	26.89 (27.40)
60-80	1.92 (1.84)	3.69 (3.72)	1.90 (1.90)	7.51 (7.46)
80-100	0.16 (0.15)	0.59 (0.52)	0.05 (0.04)	0.80 (0.71)
0-100	33.51 (33.40)	33.59 (33.50)	32.91 (33.10)	100-00 (100-00)

* Values in parenthesis are for the active period.

* All values are percentage.

Table (3): Vertical and horizontal water extraction patterns of the 50% MAD-Unmulched treatment during a whole year and active period.*

Vertical Depth (cm)	-----Horizontal Distance (cm)----			
	0-50	50-100	100-150	Sum
0-20	12.72 (13.17)	10.34 (10.71)	12.27 (13.12)	35.33 (37.00)
20-40	9.81 (9.46)	8.75 (8.55)	8.83 (8.31)	27.39 (26.32)
40-60	8.00 (7.83)	6.93 (6.71)	7.18 (6.80)	22.11 (21.34)
60-80	3.47 (3.33)	3.56 (3.57)	4.07 (3.96)	11.10 (10.87)
80-100	1.71 (1.78)	1.24 (1.28)	1.13 (1.40)	4.07 (4.46)
0-100	35.71 (35.58)	30.81 (30.82)	33.48 (33.60)	100-00 (100-00)

Table (4): Vertical and horizontal water extraction patterns of the 50% MAD-Mulched treatment during a whole year and active period.*

Vertical Depth (cm)	-----Horizontal Disance (cm)-----			
	0-50	50-100	100-150	Sum
0-20	12.70 (12.96)	12.73 (13.00)	11.85 (12.57)	37.28 (38.53)
20-40	9.32 (8.92)	9.24 (8.60)	8.22 (7.73)	26.78 (25.25)
40-60	7.16 (7.06)	7.59 (7.40)	7.00 (6.81)	21.75 (21.26)
60-80	3.88 (4.02)	3.12 (3.11)	3.44 (3.70)	10.44 (10.83)
80-100	1.63 (1.84)	1.15 (1.28)	0.98 (1.00)	3.76 (4.12)
0-100	34.69 (34.80)	33.82 (33.40)	31.49 (31.80)	100.00 (100.00)

* Values in parenthesis are for the active period.

* All values are percentage.

Table (5): Vertical and horizontal water extraction patterns of the 75% MAD-Unmulched treatment during a whole year and active period.*

Vertical Depth (cm)	-----Horizontal Distance (cm)----			
	0-50	50-100	100-150	Sum
0-20	11.14 (11.47)	12.13 (11.91)	10.85 (11.65)	34.12 (35.04)
20-40	8.06 (6.40)	8.10 (6.60)	7.69 (6.70)	23.85 (19.70)
40-60	6.91 (6.38)	6.53 (5.94)	6.60 (6.06)	20.04 (18.38)
60-80	4.62 (5.18)	4.38 (4.80)	3.87 (4.59)	12.88 (14.57)
80-100	3.47 (4.32)	3.11 (4.07)	2.52 (3.92)	9.10 (12.31)
0-100	34.20 (33.75)	34.26 (33.33)	31.54 (32.92)	100-00 (100-00)

Table (6): Vertical and horizontal water extraction patterns of the 75% MAD-Mulched treatment during a whole year and active period.*

Vertical Depth (cm)	-----Horizontal Distance (cm)----			
	0-50	50-100	100-150	Sum
0-20	14.02 (14.31)	12.35 (14.53)	11.70 (13.39)	38.07 (42.23)
20-40	8.81 (7.23)	8.15 (5.91)	7.80 (5.93)	24.76 (19.07)
40-60	5.81 (4.24)	6.29 (4.95)	6.23 (4.86)	18.34 (14.06)
60-80	4.01 (4.66)	4.16 (4.83)	3.51 (4.15)	11.68 (13.65)
80-100	3.45 (4.95)	2.28 (3.48)	1.41 (2.57)	7.15 (11.01)
0-100	36.10 (35.39)	33.25 (33.71)	30.65 (30.90)	100-00 (100-00)

* Volues in parenthesis are for the active period.
* All values are percentage.

Table (1): Monthly Counts of flowers and fruits for all trees.

Tree			Number of flowers	Number of Fruits ----------Date----------		
Soil Cover	MAD (%)	Block	15/4/92	15/5/92	15/6/92	15/7/92
Un mulched	25	1	332	182	86	0
	25	2	96	45	36	1
	25	3	106	55	35	0
	25	4	92	15	4	0
	50	1	79	41	5	0
	50	2	100	37	17	0
	50	3	169	63	17	1
	50	4	123	16	4	0
	75	1	232	125	49	3
	75	2	48	16	4	0
	75	3	60	22	13	0
	75	4	172	57	41	0
Mulched	25	1	187	123	75	6
	25	2	191	120	45	4
	25	3	53	37	11	4
	25	4	86	59	30	3
	50	1	91	60	29	0
	50	2	76	42	29	3
	50	3	72	43	26	1
	50	4	44	31	18	0
	75	1	95	71	30	1
	75	2	69	45	22	1
	75	3	137	83	53	1
	75	4	43	20	12	6

Table (2): Initial and final measurements of stem circumferance.

Tree			Stem Circumferance (cm)	
Soil Cover	MAD (%)	Block	Initial	Final
Un mulched	25	1	15.0	21.0
	25	2	18.3	23.8
	25	3	11.3	15.8
	25	4	11.7	15.2
	50	1	17.5	21.0
	50	2	12.3	16.0
	50	3	12.5	15.0
	50	4	11.0	16.5
	75	1	11.7	15.2
	75	2	10.7	13.9
	75	3	8.3	10.8
	75	4	15.0	16.5
Mulched	25	1	17.5	24.5
	25	2	9.2	14.7
	25	3	8.3	10.8
	25	4	10.8	17.3
	50	1	17.5	24.5
	50	2	16.3	22.8
	50	3	15.0	21.0
	50	4	10.8	17.3
	75	1	13.3	17.3
	75	2	11.7	15.2
	75	3	17.5	21.0
	75	4	7.5	9.0

Table (3): Initial and final measurements of the horizontal distance between the most far two points in both row and inter-row directions and the elevation of the highest point of tree.*

Tree			Row Direction		Inter-Row Direction		Height	
Soil Cover	MAD (%)	Block	Initial	Final	Initial	Final	Initial	Final
Un mulched	25	1	1.50	2.25	1.36	2.15	1.20	1.90
	25	2	1.57	2.15	1.25	1.65	1.37	2.20
	25	3	1.04	1.65	0.97	1.52	1.06	1.85
	25	4	1.02	1.15	0.87	1.22	1.17	1.42
	50	1	1.07	1.75	1.02	1.63	1.26	2.00
	50	2	1.22	1.75	1.35	2.18	1.20	1.90
	50	3	1.17	1.58	0.92	1.35	0.97	1.98
	50	4	1.00	1.60	0.95	1.46	1.00	2.00
	75	1	1.16	1.47	1.11	1.58	1.12	1.50
	75	2	1.03	1.43	0.98	1.60	1.04	1.56
	75	3	1.10	1.68	1.17	1.62	1.20	1.62
	75	4	1.34	1.53	1.06	1.58	1.18	1.72
Mulched	25	1	1.46	2.20	1.43	2.25	1.29	2.22
	25	2	1.39	2.15	1.80	2.43	1.46	2.12
	25	3	1.18	2.05	1.00	1.85	1.23	2.05
	25	4	1.18	1.93	1.20	2.02	1.11	2.09
	50	1	1.30	2.20	1.28	2.30	1.43	2.28
	50	2	1.47	2.60	1.03	2.15	1.23	2.25
	50	3	1.32	2.40	1.07	2.02	1.01	2.19
	50	4	0.53	1.28	0.60	1.35	0.87	1.45
	75	1	0.98	1.90	1.02	1.65	0.98	1.60
	75	2	0.85	1.65	1.05	1.80	0.95	1.68
	75	3	1.15	1.80	1.42	2.05	1.14	1.80
	75	4	1.27	1.68	1.27	1.49	1.16	1.44

* All values are in meter.

Table(1) : ANOVA tables of (a) seasonal plant-related measurements, (b) periodic plant-related measurements, (c) water use, and (d) water use efficiency.*

Yield			Average Fruit weight		
Source	df	MS	Source	df	MS
R	3	0.006	R	3	0.006
T	5	0.036	T	5	0.007
W	2	0.002	W	2	0.002
C	1	0.170	C	1	0.028
W*C	2	0.002	W*C	2	0.003
Error	15	0.014	Error	15	0.002
Total SC Increase			**Relative SC Increase**		
Source	df	MS	Source	df	MS
R	3	2.743	R	3	0.004
T	5	8.438	T	5	0.038
W	2	13.352	W	2	0.061
C	1	8.882	C	1	0.050
W*C	2	3.302	W*C	2	0.009
Error	15	1.259	Error	15	0.011
Total TCA Increase			**Relative TCA Increase**		
Source	df	MS	Source	df	MS
R	3	59.146	R	3	0.074
T	5	94.369	T	5	0.341
W	2	137.295	W	2	0.485
C	1	90.870	C	1	0.454
W*C	2	53.193	W*C	2	0.140
Error	15	15.735	Error	15	0.097
Total Volume Increase			**Relative Volume Increase**		
Source	df	MS	Source	df	MS
R	3	10.989	R	3	0.303
T	5	17.799	T	5	8.718
W	2	20.045	W	2	10.617
C	1	42.154	C	1	19.062
W*C	2	3.377	W*C	2	1.648
Error	15	2.602	Error	15	1.711
Relative Holding (Harvest)			**Total Shoot Elongation**		
Source	df	MS	Source	df	MS
R	3	426E-6	R	3	321.573
T	5	1523E-6	T	5	329.041
W	2	600E-6	W	2	241.045
C	1	5430E-6	C	1	789.251
W*C	2	492E-6	W*C	2	186.933
Error	15	947E-6	Error	15	92.126

(a)

Table (1): cont.

Relative Holding		
Source	df	MS
R	3	0.016
T	2	1.475
E(T)	6	0.013
WC	5	0.083
T*WC	10	0.019
E (WC)	45	0.005

Periodic Shoot Elongation		
Source	df	MS
R	3	28.330
T	11	378.178
E(T)	33	4.675
WC	5	27.388
T*WC	55	5.382
E (WC)	180	2.413

Leaf Relative Water Content		
Source	df	MS
R	3	0.0060
T	13	0.0299
E(T)	39	0.0006
WC	5	0.0037
T*WC	65	0.0005
E (WC)	210	0.0005

Chlorophyll Content		
Source	df	MS
R	3	0.698
T	6	6.258
E(T)	18	0.016
WC	5	0.781
T*WC	35	0.016
E (WC)	105	0.021

(b)

Yearly Water Use		
Source	df	MS
R	1	375
T	5	1182221
W	2	2870580
C	1	22698
W*C	2	73625
Error	5	14828

Active Period Water Use		
Source	df	MS
R	1	447
T	5	1175720
W	2	2867510
C	1	20950
W*C	2	61314
Error	5	9835

(c)

Table (1): cont.

WUEy		
Source	df	MS
R	1	0.0024
T	5	0.0791
W	2	0.0346
C	1	0.2472
W*C	2	0.0395
Error	5	0.0092

WUEv		
Source	df	MS
R	1	0.09E-8
T	5	3463E-8
W	2	4353E-8
C	1	6321E-8
W*C	2	1144E-8
Error	5	135E-8

WUEsc		
Source	df	MS
R	1	82E-8
T	5	1776E-8
W	2	3032E-8
C	1	1408E-8
W*C	2	7038E-8
Error	5	32E-8

WUEtca		
Source	df	MS
R	1	19E-7
T	5	1471E-7
W	2	1598E-7
C	1	1861E-7
W*C	2	1149E-7
Error	5	174E-7

WUEse		
Source	df	MS
R	1	263E-6
T	5	2147E-6
W	2	4551E-6
C	1	910E-6
W*C	2	360E-6
Error	5	317E-6

(d)

* Symbol R abbreviates Replicates.
Symbol T abbreviates Treatments.
Symbol W abbreviates MAD treatments.
Symbol C abbreviates soil surface covering treatments.
Symbol df abbreviates degrees of freedom.
Symbol MS abbreviates mean of squares.

الملخص

الاستنزاف الرطوبي الأمثل لأشجار النكتارين تحت ظروف الري التكميلي في المناطق المطرية

إعداد

مروان انطون حتر

إشراف

د. احمد ابو عواد

أجريت تجربة حقلية في الموسم ١٩٩٢/١٩٩١ في الحرم الجامعي للجامعة الاردنية في منطقة الجبيهة من ضواحي عمان على اشجار النكتارين (*Prunus persice nectarina*) من صنف"Stark Red Gold" لتحديد الاستنزاف الرطوبي الأمثل الذي يؤدي الى أعلى كفاءة ممكنة في استخدام الماء ومعرفة أنماط الاستنزاف الرطوبي بالاتجاهين الأفقي والعمودي ودراسة تأثير الري التكميلي على النمو والانتاج و دراسة تأثير التغطية الجزئية لسطح التربة على الاحتياجات المائية للنبات.

واشتملت التجربة على معاملتين رئيسيتين هما: الاستنزاف الرطوبي قبل الري، اذ تم تطبيق ثلاثة مستويات من الاستنزاف الرطوبي: ٢٥٪، ٥٠٪، و٧٥٪ من الماء المتاح الكلي. والتغطية الجزئية لما نسبته ٧٥٪ من سطح التربة تحت الأشجار بالملش الأسود، اذ تمت التغطية لنصف عدد الأشجار (١٢ شجرة) مع إبقاء النصف الآخر دون غطاء بلاستيكي.

وقد أظهرت الدراسة أن المساهمات النسبية لطبقات التربة المدروسة تقل بزيادة العمق من سطح التربة. كما أن زيادة الاستنزاف الرطوبي قبل الري يزيد من المساهمات النسبية للطبقات العميقة في الاستهلاك المائي الكلي. ولقد كانت الفروقات في المساهمات النسبية للمسافات الأفقية في الاستهلاك المائي الكلي تكاد تكون معدومة. 442341

وفي المعاملات التي يكون فيها سطح التربة مكشوفاً، كانت نسبة الاحتفاظ بالثمار والنمو الكلي للساق ومتوسط الامتداد الأسبوعي للأفرع و المحتوى النسبي للماء في الأوراق وكمية الكلوروفيل في الأوراق عند المستوى ٢٥٪ من الاستنزاف الرطوبي أفضل منها عند المستويات ٥٠٪ و ٧٥٪. أما الاستهلاك المائي فقد ارتفع عندما انخفض مستوى الاستنزاف الرطوبي من ٧٥٪ الى ٥٠٪ ومن ٥٠٪ الى ٢٥٪ من الماء المتاح الكلي. لذلك فان كفاءة استخدام الماء تناقصت بتناقص مستوى الاستنزاف الرطوبي لما دون ٥٠٪.

وأما في المعاملات ذات الغطاء البلاستيكي، فـان معظم المقـاييس المتعلقـة بالأشـجار، وهي: النمو الكلي والنسبي للساق والنمو الكلي والنسبي للشجرة و متوسـط الامتـداد الأسـبوعي والموسمي للأفرع والمحتوى النسبي للمـاء فـي الأوراق، وكميـة الكلوروفيـل فـي الأوراق كانت أعلى عند المستويات ٢٥٪ و ٥٠٪ من الاستنزاف الرطوبي منها عند المسـتوى ٧٥٪ من الاستنزاف الرطوبي. وكما في المعاملات المكشوفة، فقد ازدادت كميـة الاسـتهلاك المـائي وانخفضت كفاءة استخدام الماء بانخفاض مستوى الاستنزاف الرطوبـي من ٧٥٪ الـى ٥٠٪ ومـن ٥٠٪ الـى ٢٥٪ . وإن كفـاءات اسـتخدام المـاء عنـد المسـتويات ٥٠٪ و ٧٥٪ مـن الاسـتنزاف الرطوبـي غالبـاً مـا كـانت تزيـد وبمقـادير معنويـة عن كفـاءة استخدام المـاء عنـد المستوى ٢٥٪ من الاستنزاف الرطوبي.

وإن التغطيـة الجزئيـة لسـطح التربـة بـالملش الأسـود أدت الـى زيـادة معظـم المقـاييس المتعلقة بالأشجار وزيادة كفاءة استخدام الماء. وقد تركزت هذه الزيادات وبلغـت حدهـا الأكبـر عنـد المسـتوى ٥٠٪ مـن الاسـتنزاف الرطوبـي. كمـا نتـج عـن تغطيـة سـطح التربـة بالغطـاء البلاستيكي زيادة معنوية في الاستهلاك المائي عند المسـتوى ٢٥٪ مـن الاسـتنزاف الرطوبـي، بينما لم تؤدِّ تغطية سطح التربة بالغطاء البلاستيكي الى تغير معنوي في الاستهلاك المائي عنـد المستويات ٥٠٪ و ٧٥٪ من الاستنزاف الرطوبي.

ولذا يمكن التوصية باستخدام الغطاء البلاستيكي لسطح التربة، وبتطبيق المستوى ٥٠٪ من الاستنزاف الرطوبي عند برمجة الري التكميلي لأشجار النكتارين.