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Water extraction pattern and transpirational losses of peach trees under well-watered and drying cycles

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सार — मूल्यांकन लाइसीमीटरों में उगाए गए आड़ू के बड़े वृक्षों में सिंचाई बंद कर देने से मृदा नमी प्रतिबल होता है। आरम्भ में वाष्पोत्सर्जन सम्भावना के अनुरूप था जबकि सक्रिय जड़ों मे मृदा नमी उपलब्ध क्षेत्र की क्षमता के अनुसार थी। शुष्क समय में मृदा नमी में तीव्र परिवर्तनों के कारण वाष्पोत्सर्जनक दर में क्रमिक कमी आई। 0-60 सें.मी. की गहराई तक मिट्टी में नमी ठीक से घुलने पर पानी के उपयोग में तेजी से कमी आई है। बड़े आड़ू के वृक्षों को उनकी उपापचयी गतिविधि के लिए कम से कम 10 मि.मी. पानी की आवश्यकता होती है। मिट्टी के पार्श्वगत उपलब्ध जल से आड़ू में वाष्पोत्सर्जन क्षति का आकलन करने के लिए एक समाश्रयण निदर्श तैयार किया गया है।

ABSTRACT. Mature peach trees [*Prunus Persica (L.) Batsch*] grown in weighing lysimeters were subjected to soil moisture stress by shutting off irrigation. Initially transpiration (T) was at potential rate when available soil moisture in the active root zone was near field capacity. Rapid changes in soil moisture under drying cycles caused gradual decrease in transpirational rate. When 0 to 60 cm soil layer reached permanent wilting point, there was a sharp decline in water use. Mature peach trees require barest minimum of 10 mm of water for their metabolic activity. A regression model has been developed to estimate transpirational loss of peach from available soil profile water.

Key words — Prunus persica, Drought stress, Drying cycle, Transpiration.

1. Introduction

Water extraction by fruit trees is primarily governed by the evaporative demand of the atmosphere and soil water status in the root zone.The water balance in a given period can be expressed as the difference between the input and the output of water. The soil acts as a buffer receiving water intermittently through irrigation or precipitation and releasing it continuously through evapotranspiration, evaporation and drainage. The water holding capacity and status of different soil layers play an important role in meeting the evapotranspirational needs of plants. Under well-watered condition, plants extract water in a steady state where the water potential gradient between plant and soil as induced by atmospheric evaporative demand decides the water requirement of the plants, while under-stressed condition in the drying cycles, the water status and physiological processes of the plant are modified inducing more resistances to liquid flow in soil and plant vascular system. These modifications can be used not only to determine when irrigation is required (*e.g.* Schmueli 1967, Stegman *et al.* 1976) but also to determine the lower limit of soil water status up to which plant can survive under drought.

In this study drought tolerance of mature peach trees has been evaluated as affected by moisture deficit on transpirational (T) losses in a set of lysimeters.

2. Method

2.1. *Experimental site and plant material*

The research experiment was conducted at the University of Texas Agricultural Experiment Station, Stephenville, USA (98°13'W, 32°12'N) by the senior author during the period of his training in USA (June-August 1993). The soil in the lysimeters was Windthorst fine sandy loam, thermic udic paleustalf (Wagner *et al.* 1973). The transpirational losses of 8 years' old mature peach [*Prunus Persica (L) Batsch CV: sentinel*] trees under well-watered and under two successive drying cycles as measured by weighing lysimeters was determined. The evaporation loss was eliminated by placing 10 cm thick mulch uniformly on the soil surface. Tensiometers were placed at a depth of 15 cm.

2.2. *Irrigation*

Prior to the commencement of drying cycles, both the lysimeters were irrigated upto soil water

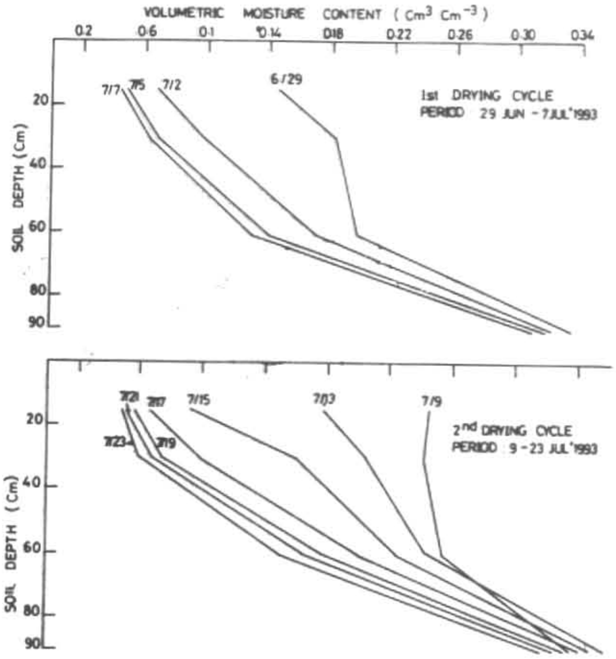


Fig. 1. Changes in soil moisture profile during the first and second drying cycles

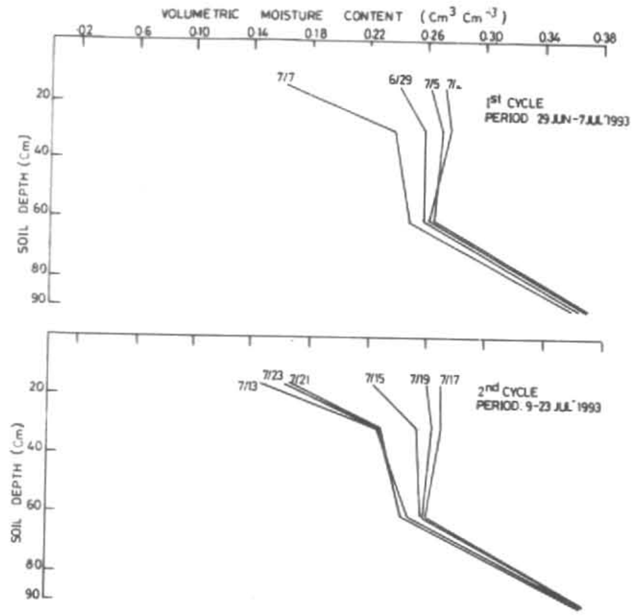


Fig. 2. Changes in soil moisture profile under well-watered condition

potential of −0.15 bar. Drip irrigation was applied with perforated plastic tubes. The study extended from last week of June 1993. Irrigation in one lysimeter was continued, while the second lysimeter was allowed to dry from 29 June 1993.

2.3. *Soil moisture*

This was measured daily during the study period except for 3-4 July and 9-12 July 1993 with a neutron probe (Model 503 DR Campbell Pacific Nuclear Crop.) in access tubes in each lysimeter. The tube was located 60 cm from the tree and 30 cm from the outer ring of the lysimeter. Measurements were made at 15, 30, 60, 90 cm depths. The neutron probe calibration was established from soil samples taken from both the lysimeters. Bulk density of the soil was 1.53 g/cm^3. The relationship between soil water content and the count number of the neutron probe was established.

2.4. *Soil water balance*

The general equation of the soil water balance can be written as :

$$\Delta S = P + I - R - T - E - D \qquad (1)$$

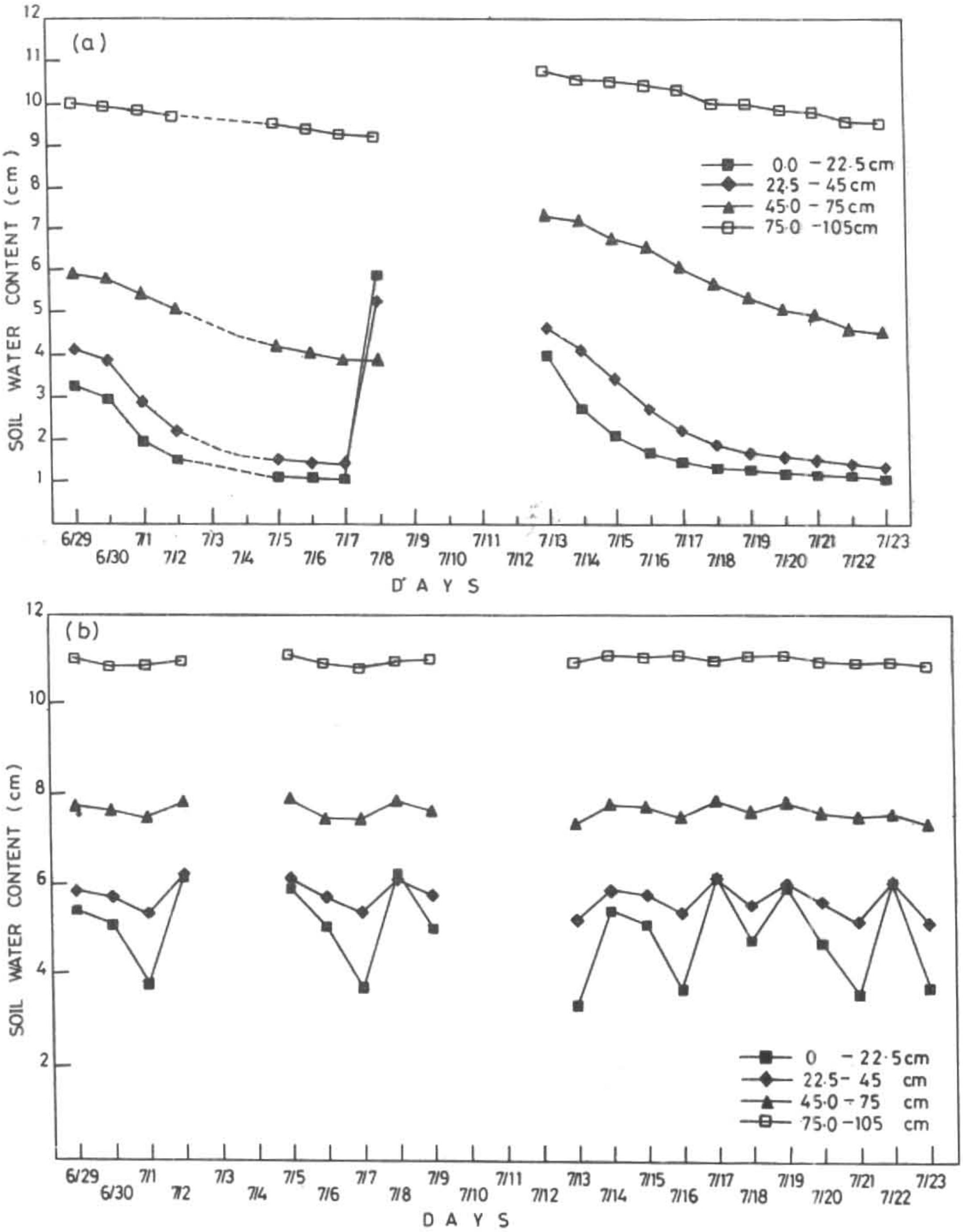
where, ΔS is the change in stored water, P and I are precipitation and irrigation respectively, R is surface runoff, T is transpiration, E is evaporation and D is flow of water out the root zone. As irrigation was controlled through irrometer there were no drainage or runoff losses. Evaporation was eliminated by using thick mulch, thereby, R, D, E are neglected. Thus final equation is :

$$\Delta S = P + I - T \qquad (2)$$

3. Results and discussion

3.1. *Changes of soil moisture in the drying cycle*

Soil moisture variations as a function of depth and time were evaluated for well-watered as well as moisture deficient lysimeters during the drying cycles and are presented in Figs. 1 & 2 respectively. The soil water content in the well-watered lysimeter fluctuated between 0.15 to 0.28, 0.23 to 0.28, 0.25 to 0.26 and 0.36 to 0.37 cm^3/cm^3 respectively at 15, 30, 60 and 90 cm depths whereas in the dry lysimeter soil water content varied between 0.10 to 0.31, 0.06 to 0.23, 0.13 to 0.25 and 0.31 to 0.36 cm^3/cm^3 respectively at 15, 30, 60 and 90 cm depths. Thus the average soil water content in the well-watered lysimeter fluctuated between the estimated field capacity (0.24 cm^3/cm^3) and the lower limit of the readily available water (29% of field capacity). In the dry lysimeter the moisture content decreased with time and wilting point reached on 1 and 4 July in the first drying cycle and 16 and 19 July in the second drying cycle respectively for 0 to 22.5 and 22.5 to 45 cm



Figs. 3 (a & b). Soil water content at four layers (a) during two successive drying cycles and (b) under no-stress condition. An irrigation was applied on 8 August 1993 (Soil water content is expressed as the depth of water)

depths. Average soil moisture at lower depths did not reach wilting point as water extraction from deeper depths was restricted due to shallow rooting pattern of peach. The average soil water content at 60 and 90 cm depths generally remained high and decrease in moisture content is gradual which indicates that water either moved by capillary action or a fewer roots have extracted the water from this depth.

3.2. *Water storage depletion*

The progressive depletion pattern of water storage in different soil profile layers especially under two successive drying cycles is presented in Fig. 3 (a). The total profile water stored at the beginning of the drying cycles was 24 cm and 29 cm respectively in the first and second drying cycles. During the first drying cycle (29 June-7 July 1993)

TABLE 1

Water extraction pattern from different soil layers under well-watered and under drying cycles (Percent of total depletion)

Date	Dry soil layer (cm)				Well-watered soil layer (cm)			
	0-22.5	22.5-45	45-75	75-105	0-22.5	22.5-45	45-75	75-105
30 Jun	—	—	—	—	71	20	9	−1
1 Jul	41	41	16	3	—	—	—	—
2	26	42	22	10	—	—	—	—
6	3	20	45	32	74	18	2	7
14	59	24	7	9	—	—	—	—
15	35	37	24	3	69	20	12	−1
16	29	50	15	6	—	—	—	—
17	16	38	38	8	—	—	—	—
18	13	27	33	26	—	—	—	—
20	16	14	45	25	67	28	5	1
21	8	25	50	17	—	—	—	—
22	3	13	50	33	—	—	—	—

water storage in 0-22.5 and 22.5-45, 45-75 and 75-105 cm layers decreased respectively from 3.3 to 1.0, 4.1 to 1.4, 5.9 to 3.9 and 10.0 to 9.3 cm. Similar extraction pattern was also observed during the second drying cycle (9-23 July 1993). In a period of 12 days following irrigation, water storage in the same layers decreased respectively from 5.5 to 1.1, 5.5 to 1.3, 7.6 to 4.5 and 10.1 to 9.3 cm. Fig. 3 (b) shows the change of soil water storage under well-watered condition during the same period. The daily water reserves used (*i.e.,* changes in water storage during 24 hours) in the well-watered lysimeter is more or less uniform compared to that in dry lysimeter. Under well-watered condition with average irrigation frequency of 2-3 days, water storage in 0-22.5, 22.5-45, 45-75, 75-105 cm layers fluctuated as follows : 6.2 to 3.1, 6.1 to 5.2, 7.8 to 7.3 and 11.0 to 10.9 cm respectively during the study period.

Daily water extraction patterns from different soil layers are better revealed by the data on daily contribution of each layer to total water use (Table 1). It is seen from Table 1 that top layers (0-22.5 and 22.5-45 cm) having higher rooting densities used more water both under well-watered and under drying cycles. The highest contribution of the top soil layer (0-22.5 cm) occurred on all the days under well watered treatment but under drying cycles it was only on those days when soil water content of the top layer was near field capacity. The relative contribution of 0-22.5 cm layer dropped from 41 to 3% and 59 to 3% respectively during first and second drying cycles. It is interesting to note that the contribution of 22.5-45 cm layer first increased to about 42 and 50% at the end of the first quarter of the drying cycles and then dropped as low as 20 and 13% at the end of the first and second drying cycles respectively. With progressive drying the relative contribution of 45-75 and 75-105 cm layers increased respectively from 16 to 45 and 3 to 32% during the first drying cycle and respectively from 7 to 50 and 9 to 33% during the second drying cycle.

Higher contribution of deeper layer especially at the end of the drying cycles confirms that peach roots extracted more water from deeper layer when the upper layers dried during the prolonged drying cycle. Such an uptake of water from the deeper soil layers when drying occurs has been reported for herbaceous crops (Taylor and Klepper 1973); Woody crops (Levin *et al.* 1972, Chalmers *et al.*

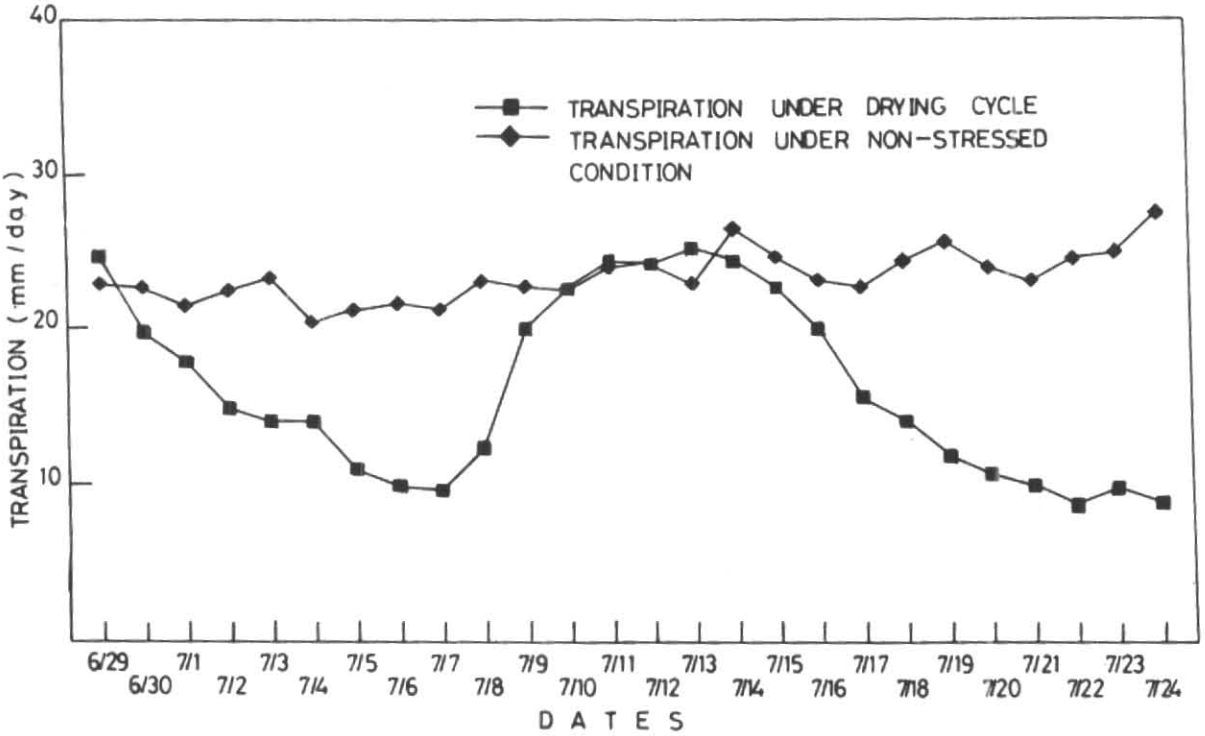


Fig. 4. Transpiration losses from peach tree under well-watered condition and drying cycle. Transpiration loss was computed from day-to-day weight changes of lysimeters

TABLE 2

Correlation between water use (Transpiration = T) available soil moisture (ASW) and pan evaporation (EVAP) for lysimeter-grown peach trees under well-watered and under drying cycle

Well-watered Parameter	Parameter			Stressed (Drying cycle) Parameter
	EVAP	ASW	T	
T	−0.023	0.133	1.000	
ASW	−0.220	1.000		
EVAP	1.000			
			1.000	T
		1.000	0.971**	ASW
	1.000	−0.480	−0.478	EVAP

** Significantly correlated ($P < 0.01$)

1983), forests (Nnyamah and Black 1977). Singh and Russel (1979) also recorded greater contribution from deeper layers towards the transpiration of sorghum crop with the drying of top soil.

3.3. *Transpiration*

Daily transpiration of water from the well-watered lysimeter was in the range of 21 to 28 mm of

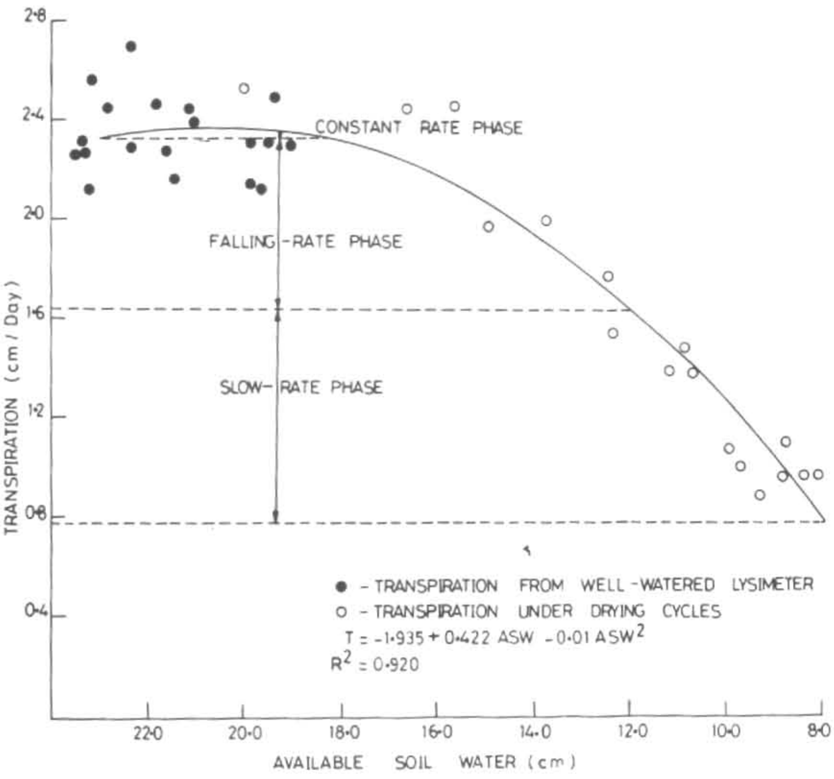


Fig. 5. Relationship between transpiration rate and available soil water in the soil profile (0-105 cm) during drying cycle

water (Fig. 4) during the hot summer days (Avg. Max. Temp. = 35.7°C and avg. pan evaporation = 12.4 mm). Under limiting soil water conditions transpiration dropped to as low as 10 mm of water at the end of the first drying cycle. During the first drying cycle, soil matric potential at 15 and 30 cm depths reached permanent wilting point respectively on 1 and 4 July thereby causing a drastic fall in transpirational losses. To verify results of first drying cycle, both the lysimeters were watered on 8 July to eliminate stress and assure that both peach trees were again using comparable amounts of water. It is interesting to note that peach tree recovered its full transpirational capacity after irrigation and transpirational loss was similar to that of well-watered peach tree. When irrigation was shut off and lysimeter was allowed to dry in the second drying cycle, transpiration gradually decreased from about 25 to 9 mm of water at the end of drying cycle on 23 July 1993. At the end of both the drying cycles when the peach tree was fully under stress, many leaves had begun to yellow and considerable exudation of gum appeared along the main scaffold branches. Thus a matured peach tree required minimum of 10 mm of water for maintaining its barest minimum metabolic activity under Texas conditions. When soil water in the root zone is unable to supply required water (transpiration = 10 mm), the plant starts showing wilting symptom and under severe drought the plant may even die.

3.4. *Relationship between transpiration and available soil water in the profile*

Statistical analysis of the data were made both for well-watered and stressed trees (Table 2). Correlation analysis of these data indicated that transpiration (T) was independent on both pan evaporation (EVAP) and available soil moisture (ASW) under well-watered condition. During the period of stress, transpiration was significantly affected by changes in available soil moisture in the root zone. Transpiration was found significantly correlated with ASW when the available soil moisture was extracted gradually in the drying cycles under limiting soil water supply. The value of r was 0.971 ($P < 0.01$).

The relationship between transpiration and available soil water in the root profile from well-watered and under drying cycles is presented in Fig. 5. The daily transpiration was measured from the weight loss recorded from both the lysimeters. The transpiration so obtained was assumed as a function of available soil moisture in the soil profile. It gave the following regression equation :

$$T = -1.935 + 0.422 \text{ ASW} - 0.01 \text{ ASW} \quad (3)$$
$$R^2 = 0.920 \text{ (significant at 1\% level)}$$

The empirical equation as well as Fig. 5 indicate that the transpiration rate decreased in a convex manner with decrease in available soil water content in the soil profile. The curve further shows some recognizable phases of decrease in transpiration rate, an initial constant rate phase, which occurred when available soil moisture in the profile was about 18 cm. Upto this limit the profile remained conductive enough to supply water to meet the potential transpiration demand. During this phase the transpiration was equal to potential transpiration and was limited by external meteorological condition (radiation, wind, temperature, vapour pressure deficit) rather than soil conductivity. An intermediate or second phase was the falling rate phase, during which the transpiration rate started falling progressively below the potential rate. In this phase the transpiration was limited by the rate at which the soil transmitted the water towards the root-extraction site. Hence it may be called the profile controlled phase and it persists for a longer period in contrast to the first phase (Dierckx *et al*, 1988).

The third phase (slow-rate phase), which was not easily recognizable, persists at a nearly steady rate for many days. The transpiration from the first to the second phase was generally sharp, as evident from Fig. 5, the second phase blends into third phase so gradually that the last two phases cannot be separated easily (Hillel 1980). This also confirms the findings of Ritchie (1981), Meyer and Green,(1980) that there is a critical point, somewhere between field capacity and wilting point moisture upto which the transpiration proceeds at potential rate and then drops. Hanks (1974) also produced evidence that the relative transpiration rate decreased linearly with reduction in available soil water.

4. Conclusions

(*i*) Under non-limiting water supply, mature peach tree requires about 25 mm/day water to meet atmospheric demand during summer months in Texas.

(*ii*) Water extraction in the root zone remains mostly restricted upto 60 cm depth. However, lower layers contribute significantly through capillary movement of water.

(*iii*) Mature peach tree needs a barest minimum of 10 mm per day for their survival under water-stressed condition in Texas.

(*iv*) Drop in transpiration during falling rate phase from that of constant rate phase though sharp yet the curve in falling rate phase blends with slow rate phase so gradually that they cannot be separated so easily.

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