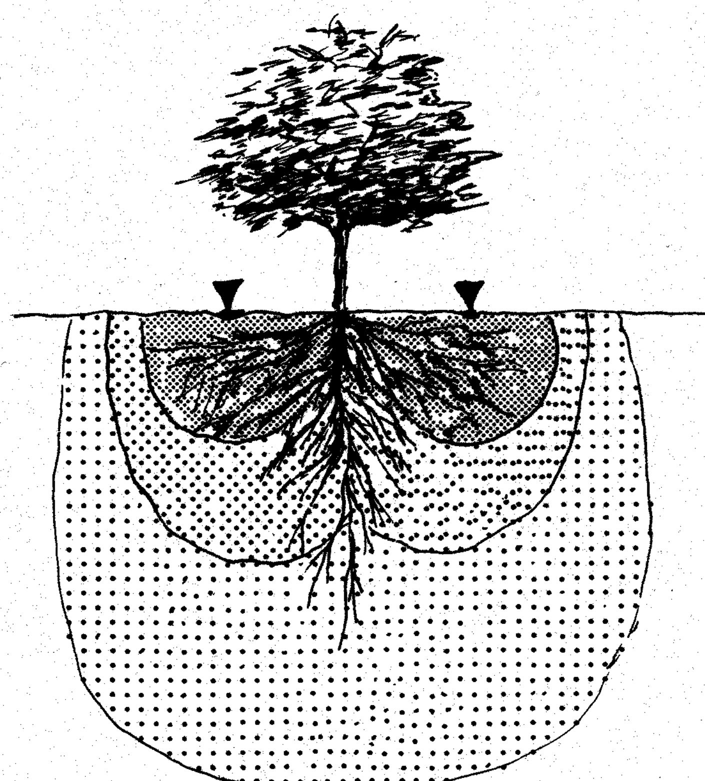
Drip Irrigation Research in Oregon

a progress report



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Oregon State University, Corvallis

FOREWARD

Trickle irrigation is a method of applying water to individual plants at a low rate from a network of small pipes, tubes, and emitters. Water moves from the discharge points, largely through capillary movement, to plant root systems. Soil moisture content varies considerably between locations in root zones, but is relatively constant at specific locations throughout the growing season when compared to variations in soil moisture under other methods of irrigation. Because of the complete control of water during irrigation, this technique potentially offers considerable opportunities for water savings, labor savings, and the benefits derived from precise soil moisture control.

Trickle irrigation was first introduced to the United States from Israel within the last five years. Many questions relating to crop adaptability, design, scheduling, and system conversions need to be answered before it can be recommended for general use.

In 1972 a system was installed in a hedgerow planting of apples at the Mid-Columbia Experiment Station. In 1973 cooperative research projects were initiated by the Agricultural Engineering Department, Mid-Columbia Experiment Station, North Willamette Experiment Station, and Southern Oregon Experiment Station. This 1973 report summarizes results of the first year's work.

For additional information, contact Marvin Shearer, Extension Irrigation Specialist, Department of Agricultural Engineering, who edited this report and is coordinating the research described in it.

J. R. Davis

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ACKNOWLEDGEMENT:

Appreciation is expressed to the following companies who donated equipment or provided other services to this project: Controlled Water Emission Systems, Micro Trickle Irrigation Systems, WAICO Northwest, and Perma Rain Irrigation, Inc.

For purposes of clarification, trade names have been used in this report. This is not to imply endorsement of products named or criticism of those not included.

ABSTRACT

Trickle systems were installed on pears, apples, and blackberries in 1973. Comparisons were made with conventional surface and sprinkler irrigation systems. Trickle irrigated pared pears had lower pressure test values than surface irrigated pears, however, little difference was measured in fruit size and yield. No apparent difference in maturity or storage characteristics was found between fruit that had been trickle irrigated and sprinkler irrigated.

Substantial water savings were made with trickle systems in place of sprinkler or surface systems. It appeared that K values relating water loss from a class A pan to crop water requirements may be closer to 1.0 than 0.6 or 0.7 which are generally used.

CONTENTS

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Use of Pan Evaporation as a Guide to Scheduling Drip Irrigation in Blackberries

Lloyd W. Martin, Marvin N. Shearer, and Kenneth F. Kangas

'Thornless Evergreen' blackberries are grown almost exclusively in the Northwest, with the major production in Oregon. They account for approximately 75 percent of the total processed pack of blackberries in the Northwest and 60 percent of the total pack in the United States.

Most of the acreage is grown under sprinkler irrigation due to the very low summer rainfall. Sprinkler irrigation is a production practice that has not been thoroughly evaluated in 'Thornless Evergreen' blackberries nor compared with drip irrigation. The work reported here was based on use of pan evaporation as a guide to scheduling drip irrigation and compares plant growth and fruiting of blackberries under drip irrigation and sprinkler irrigation.

Procedure

The experiment was established in 1972 in a six-year-old planting of 'Thornless Evergreen' blackberries grown in a sandy shot loam soil. Data collection began the following May. Design of the experiment was a split plot with six replicates each. One-half the experimental area was irrigated with conventional solid set 14V sprinklers spaced 40 feet by 40 feet. Water pressure at the sprinklers varied from 45 to 65 psi. The other half of the experimental area was irrigated with a Drip-Eze trickle system. One in-line emitter was placed adjacent to each plant and operated at a constant line pressure of 16 psi discharging approximately one gallon per hour. A three row buffer area was maintained between main treatment areas. Main treatments were each about one-sixth acre in area.

Water application schedules for the drip system were designed to apply a depth of water equal to the depth of water evaporated from a class A pan since the last irrigation to the ten square feet area allotted each plant. Evaporation was measured daily. Plants were spaced 5 feet apart in the row with rows 10 feet apart. Plants were grown in a hedgerow which was approximately 2 feet wide in May. Intervals between drip irrigation applications varied from three to six days.

Water applications in the sprinkler plots were designed to apply approximately one inch of water per week during May and June and one-and-one-half inches per week from June until the end of the picking season. This schedule approximated the "rule of thumb" guidelines followed by better blackberry growers.

Soil moisture was monitored with tensiometers. Measurements were made at the 12, 24, and 36 inch depths at two locations in each of the main plots. Tensiometer readings were recorded at about 8:30 a.m. daily throughout the season.

Results and Discussion

Tensiometer readings in the sprinkler irrigated area (figure 1) did not exceed 40 centibars throughout the growing season at the 24 and 36 inch depths; however, tensiometer readings at the 12 inch depth was 50 or greater on two days each in July and August. The effects of these brief periods of moderate stress in the upper root zone could not be identified within the limits of this experiment.

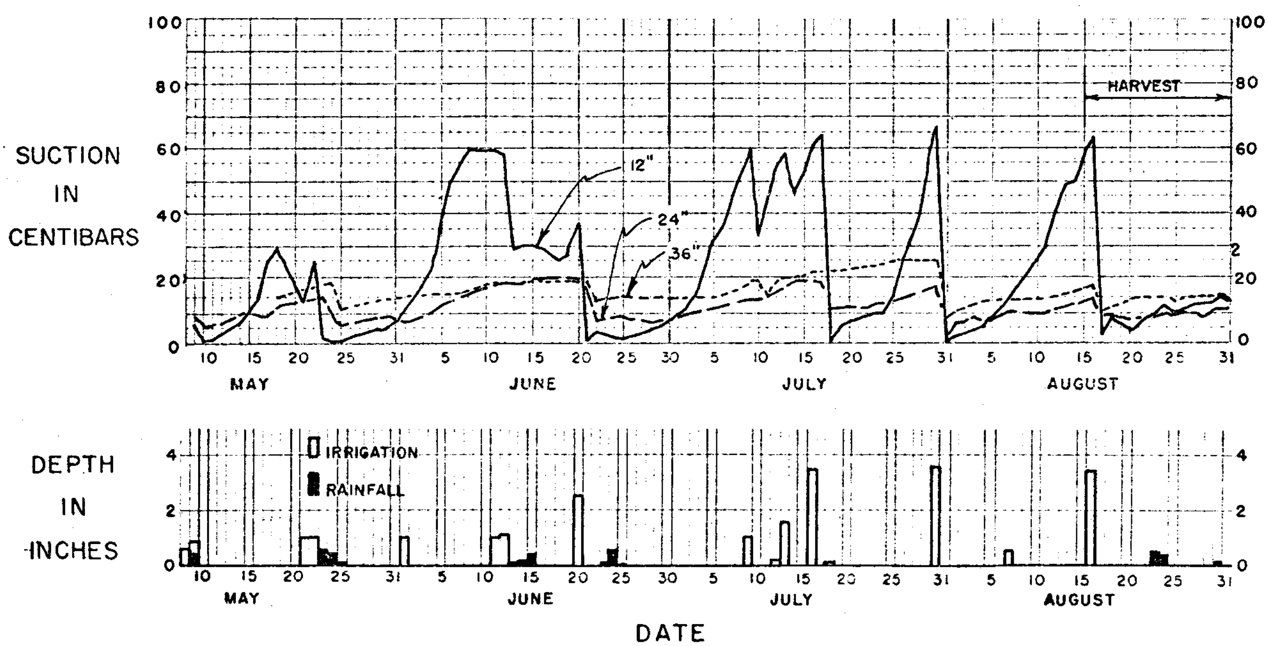


Figure 1. Soil moisture and irrigation records, average of two stations, solid set sprinkler system, 'Thornless Evergreen' blackberries, North Willamette Experiment Station, 1973.

Tensiometer readings in the drip irrigation plot (figure 2) were relatively stable through May and June. Readings at each of the three depths stayed below 25 centibars for this two month period. For the remainder of the season the tensiometer readings steadily increased. At the last picking, on September 1, tensiometer readings were 55 or greater at the 12, 24, and 36 inch depths.

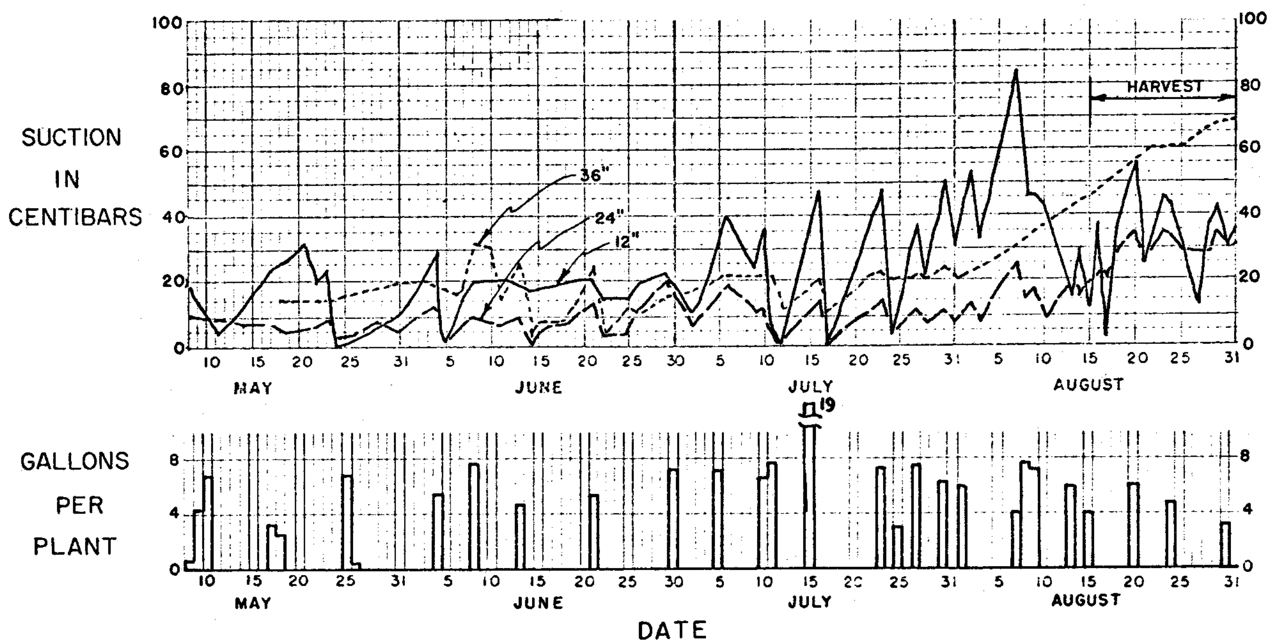


Figure 2. Soil moisture and irrigation records, average of two stations, drip irrigation system, 'Thornless Evergreen' blackberries, North Willamette Experiment Station, 1973.

Increased moisture stress in the drip irrigation plots in July and August apparently resulted in the reduction in fruit size (table 1). Fruit from the drip irrigation plot averaged 2.7 grams each compared to 3.4 grams for fruit from the sprinkler irrigated area. The difference in fruit size resulted in a corresponding difference in total fruit yield - a 26 percent increase in size and 28 percent increase in yield on the sprinkler irrigated plots.

Growth of new fruiting canes was not adversely affected by the lower moisture level in the drip irrigation plots (table 2). The number of canes per hill and their length and diameter were approximately the same under both systems of irrigation. Growth was adequate for an optimum set of fruit buds.

Table 1. Effect of Irrigation Systems on 'Thornless Evergreen' Blackberry Yield and Fruit Size

	Yield (T/A)	Size (g)
Drip	3.9	2.7
Sprinkler	5.0	3.4
Percent Increase	28	26

Table 2. Effect of Irrigation Systems on Cane Growth of 'Thornless Evergreen' Blackberries

	Cane length (ft.)	Diameter (1 1/16")	No./hill
Drip	19.5	8.35	9.8
Sprinkler	19.2	8.57	9.3

The total amount of water applied during the season through the sprinkler system was 22.19 inches (table 3). This approximates the 20.3 inches of evaporation that occurred during the same period. Only 5.14 inches of water was applied with the drip irrigation system and as noted above, was obviously insufficient during the later part of the growing season. Rainfall during this period was 3.10 inches.

Table 3. Total Moisture, May 8 - August 31, 1973

	Inches	(Gallon/plant)
Evaporation	20.3	632.7
Rainfall	3.10	96.6
Drip applied	5.14	160.2
Sprinkler applied	22.19	691.7

Distribution of water under the sprinkler system was quite variable (table 4). The amount of water reaching the soil surface in the center of the row was approximately two-thirds of that measured at the soil surface midway between the rows and was approximately one-third of that measured beneath the edge of the plant canopy. This disparity of water reaching the soil surface under blackberries being sprinkler irrigated must be considered in making comparisons with the drip system. Placement of tensiometers and correlation of their readings to calculated water application must also be considered with caution.

Table 4. Water Distribution Under Sprinkler Irrigation in 'Thornless Evergreen' Blackberries

	Catch			
	July 17		July 30	
	Depth in can	Percent of theoretical application	Depth in can	Percent of theoretical application
	inches	percentage	inches	percentage
Center of row	.054	36	.078	47
Edge of canopy	.145	97	.202	122
Midway between rows	.086	57	.114	69
Theoretical average application[a]	.150	100	.165	100

[a]Theoretical application was based on 50 psi estimated water pressure on July 17 and 61 psi actual measurement on July 30, and 14V sprinklers with a 7/64 inch orifice on a square spacing of 40 feet by 40 feet.

Distribution of water in the root zone under the drip irrigation system was measured on July 6 with tensiometers placed 18 inches deep. Tensiometers were spaced at 1 foot intervals between plants in the row and at 1 foot intervals on a line perpendicular to the rows (figure 3). They were read after 4 hours of continuous irrigation. Tensiometer readings increased as the distance from the emitters increased.

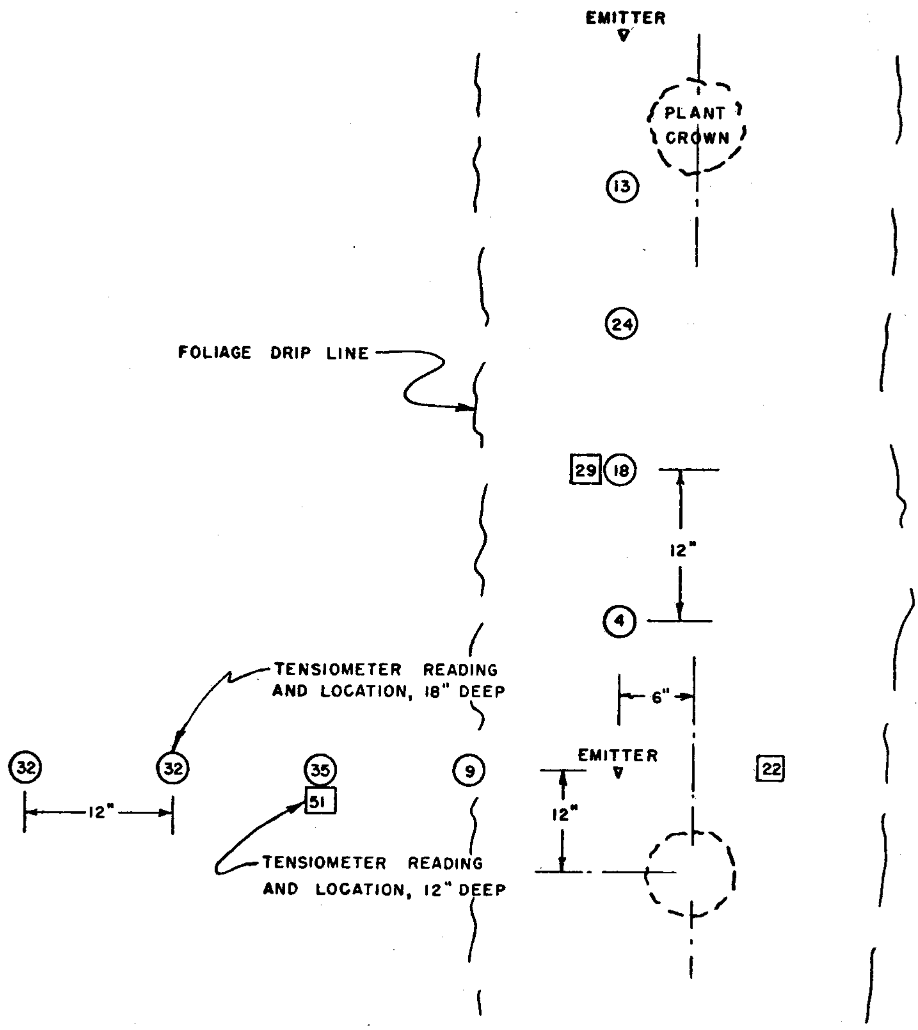


Figure 3. Soil moisture suction values recorded July 6 under 'Thornless Evergreen' blackberries.

Summary

A drip irrigation system was installed in a mature planting of 'Thornless Evergreen' blackberries and performance of the system and plant response were compared to that in an adjacent planting irrigated with solid-set sprinklers. Water applications with the drip system were designed to apply water quantities equivalent to the depth of water lost from a class A pan since the last irrigation to the area under the drip line of a 2 foot wide hedgerow with plants spaced 5 feet apart. This scheduling was maintained throughout the growing season.

Water applications with the sprinkler system were designed to apply approximately 1 inch of water per week during May and June and one-and-one-half inches of water per week from June until the end of the picking season. Trickle irrigated berries were under-irrigated. They received 78 percent less water than those sprinkler irrigated.

Tensiometer readings indicated that plants irrigated with the sprinkler system were never subject to severe moisture stress; however, plants watered with the drip system were excessively dry in August. At the end of the growing season tensiometer readings under the drip system were above 30 centibars tension at the 12, 24, and 36 inch depths.

Size of fruits and total yield were less from plants watered with the drip system than from sprinkler irrigated plants. Current season cane growth was not adversely affected.

If pan evaporation data are to be used as a guide for scheduling drip irrigation on 'Thornless Evergreen' blackberries, adjustments must be made for seasonal changes in drip line areas due to plant growth when calculating water application requirements.

Pear Tree Response to Trickle Irrigation on Carney Clay Soil

Porter B. Lombard

Objectives

1. To evaluate pear tree response to trickle irrigation on Carney clay soil.
2. To evaluate adequacy of trickle irrigation scheduling based on evaporation pan measurements and tensiometer monitoring.
3. To evaluate water intake problems and soil moisture distribution in a pear orchard in Carney clay soil under trickle irrigation.

Procedures

A Drip-Eze trickle irrigation system was installed in one acre of forty-year-old trees of Anjou, Bartlett, Bosc, and Comice cultivars on OHxF seedling root stocks for evaluation at the Southern Oregon Experiment Station on April 30, 1973. The trees were spaced 25 feet by 25 feet with weed-free tree rows and sodded middles. Drip zone diameters varied from 17 feet to 24 feet.

Four emitters were placed 7 feet apart around each tree trunk. Total water applications were measured by a water meter. An in-line fertilizer applicator and cartridge water filter was placed between the pressure regulator and the trickle system. Fifteen pounds per square inch pressure was maintained at the discharge side of the cartridge filter. Tensiometers for monitoring soil moisture were installed at three trees and were located 1 foot from the southwest emitter at depths of 1, 2, and 3 feet.

The amount of water applied at each irrigation was based upon the evaporation from a class A U.S. Weather Bureau pan as applied to the drip line area under the trees using a "K" factor of 1. The application was adjusted when the need for such adjustment was indicated by the tensiometer monitoring stations. Tensiometers were read almost daily.

Discussion and Conclusions

Various irrigation schedule intervals were tried during May and early June while consumptive use was low to determine whether or not there would be problems in getting the required amount of water into the soil without excessive runoff and ponding. Continuous irrigation lasting more than 24 hours produced some runoff. It was also observed that continuous irrigation for as much as six days did not bring the soil moisture suction at the 2 and 3 foot tensiometer depths below 10 centibars as was hoped. It remained higher than desired throughout the growing season. In order to meet consumptive use, daily irrigations were scheduled after June 13, from 12 to 22 1/2 hours per day dependent on the evaporation pan readings. Figures 1, 2, and 3 show daily water applications and the moisture suction values in response to those applications for Bartlett and Anjou pears.

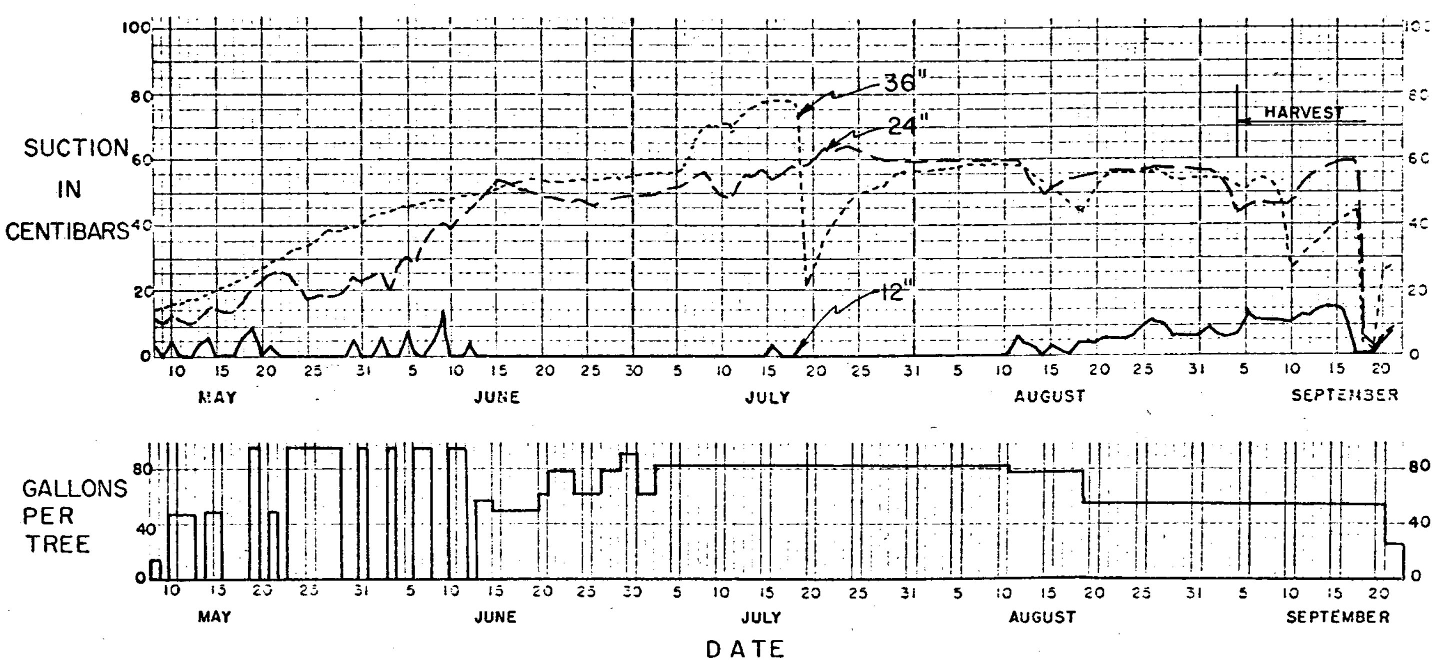


Figure 1. Soil moisture and irrigation records for station #1, Anjou pears, Southern Oregon Experiment Station, 1973.

The tensiometer readings indicate an abrupt change in suction between the 1 and 3 foot depths. On July 5, several tensiometers were installed 12 and 18 inches deep at 1 foot intervals from the emitter on the southwest corner of an Anjou tree and parallel to the tree row. The observed suction values are shown in figure 4.

Soil samples were taken under three trees on September 20, 1973 at horizontal intervals of 2 feet from the emitter in line with the tree trunk through the southwest emitter. Values of these samples are shown in figure 5 as percent available moisture in the soil. Moisture percentages relating to the 100 percent and 50 percent available moisture levels were determined in detailed irrigation studies on these soils at an earlier period. Soil moisture varied considerably in the profile at the close of the irrigation season. The distribution pattern indicates available soil moisture was above 50 percent in an area of from 68 to 200 square feet around each tree and to a maximum depth of 27 to 30 inches. Fifty percent available moisture in the top three feet of soil is considered adequate for good tree and fruit growth.

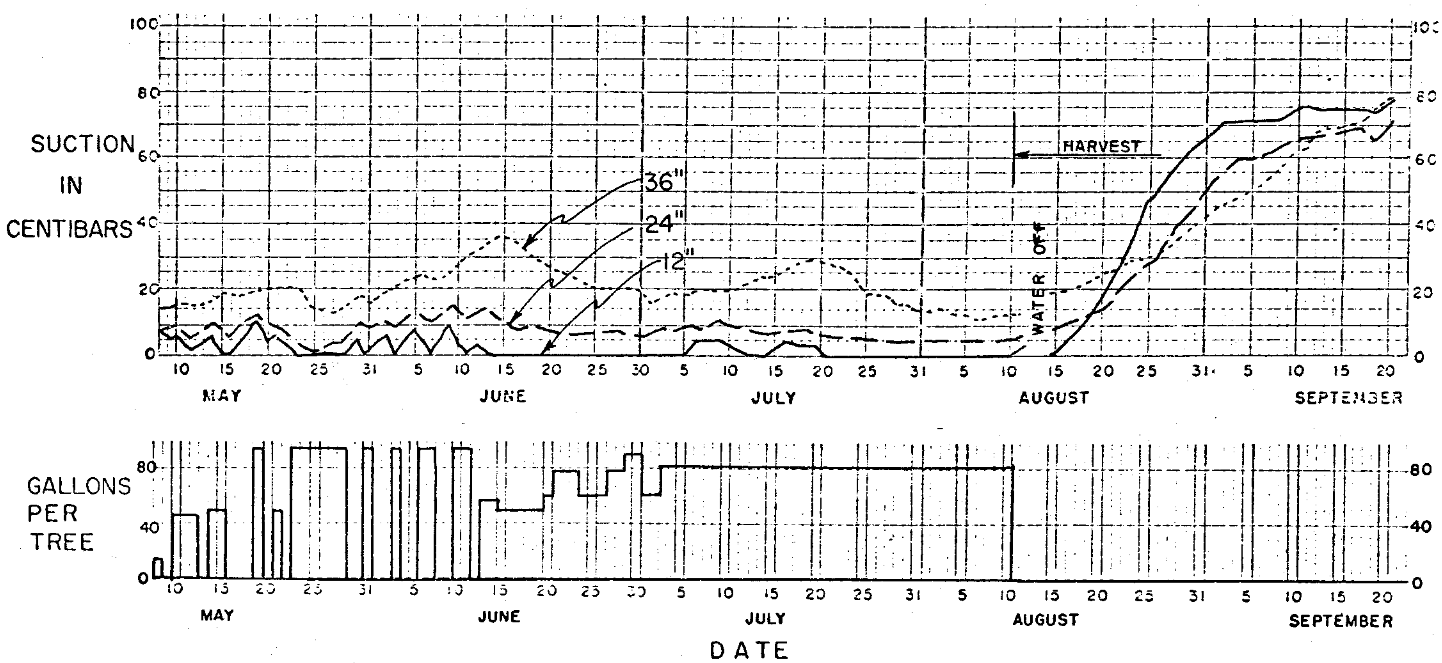


Figure 2. Soil moisture and irrigation records for station #2, Bartlett pears, Southern Oregon Experiment Station, 1973.

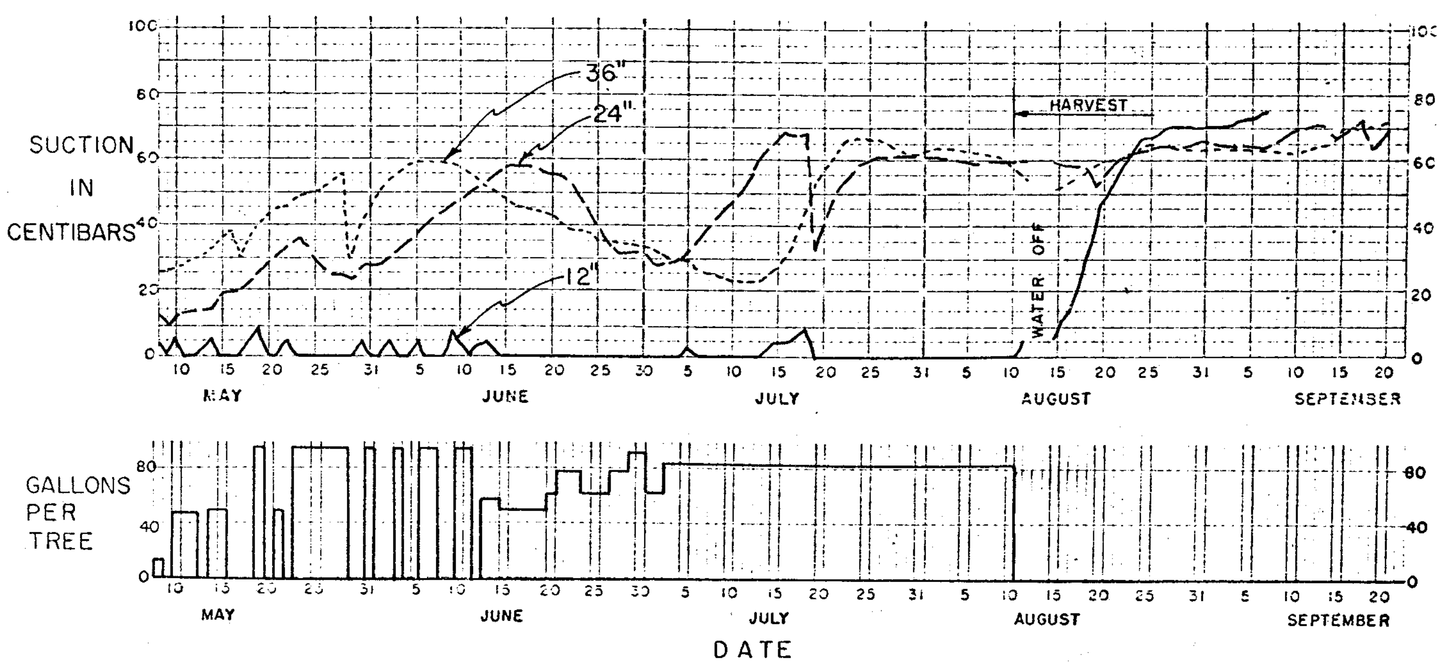


Figure 3. Soil moisture and irrigation records for station #3, Bartlett pears, Southern Oregon Experiment Station, 1973.

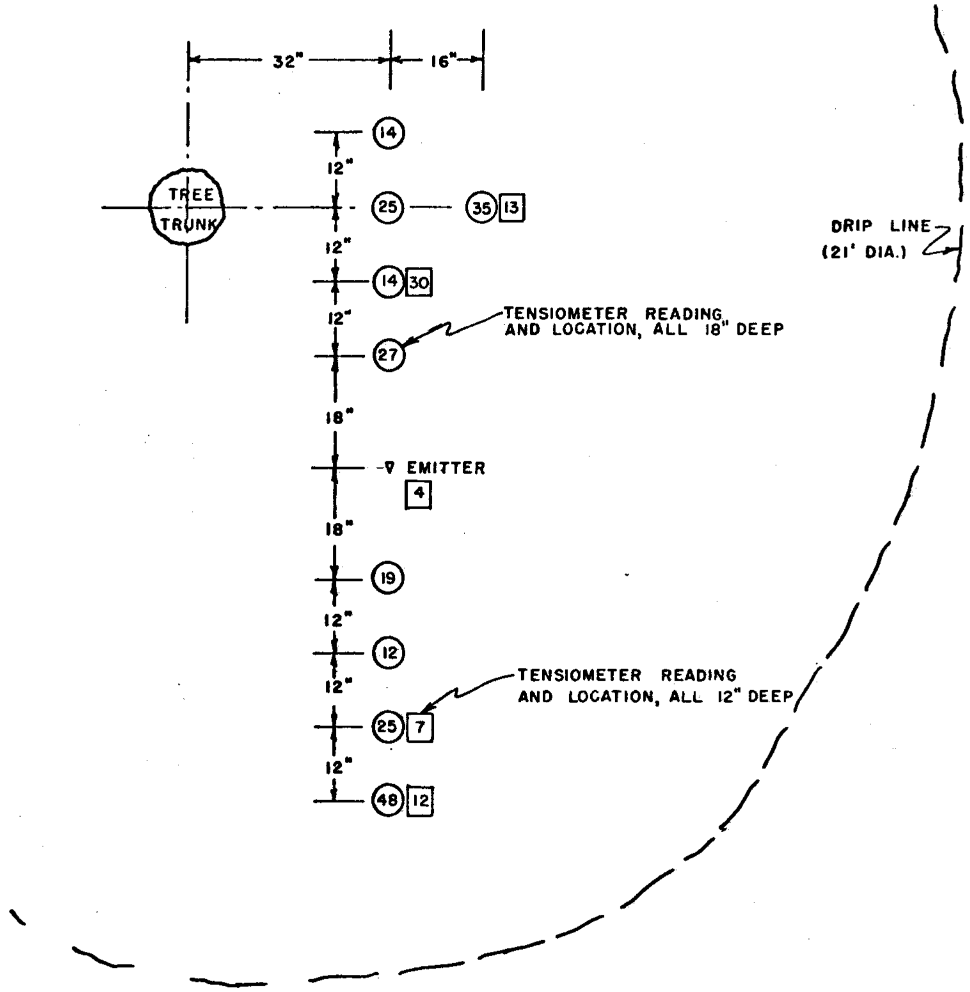


Figure 4. Soil moisture suction values recorded July 5 under an Anjou pear tree.

Comparable trees in an adjacent furrow irrigated orchard were used to evaluate fruit growth and fruit maturity response to the trickle irrigation trees of Bartlett and Bosc cultivars. The furrow irrigation was applied three times at monthly intervals with about 4 inches of water per irrigation. Tensiometers stationed in this orchard indicated that the water penetrated 18 to 24 inches at each irrigation. Due to the swelling and cracking nature of this soil, the water found its way under furrow irrigation throughout this portion of the profile through the cracks.

Ten fruit per tree on two trees of each cultivar on both furrow and trickle irrigation plots were measured every two to three days and converted to fruit volume. Results are shown in figures 6 and 7. Accumulative fruit volume in both plots were the same by harvest, although the daily rate of fruit growth on the furrow irrigated trees was reduced prior to and was increased following an irrigation in comparison with those on the trickle irrigation plots. Also the daily growth rate of the Bartlett fruit continued to increase until harvest while the Bosc daily growth rate leveled during July 18 through August 27 and then decreased slightly thereafter.

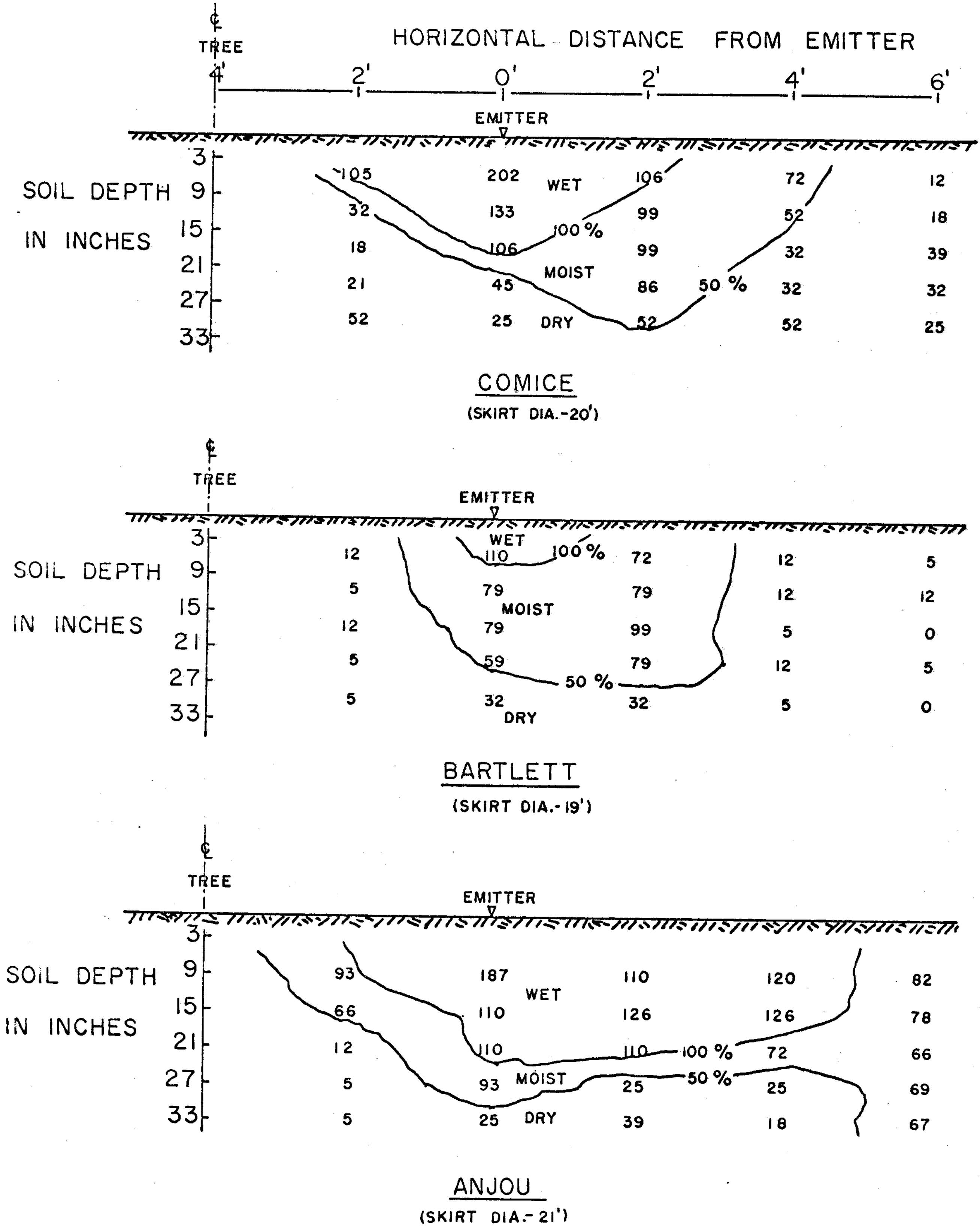


Figure 5. Soil moisture distribution under Comice, Bartlett, and Anjou trees on September 20, 1973.

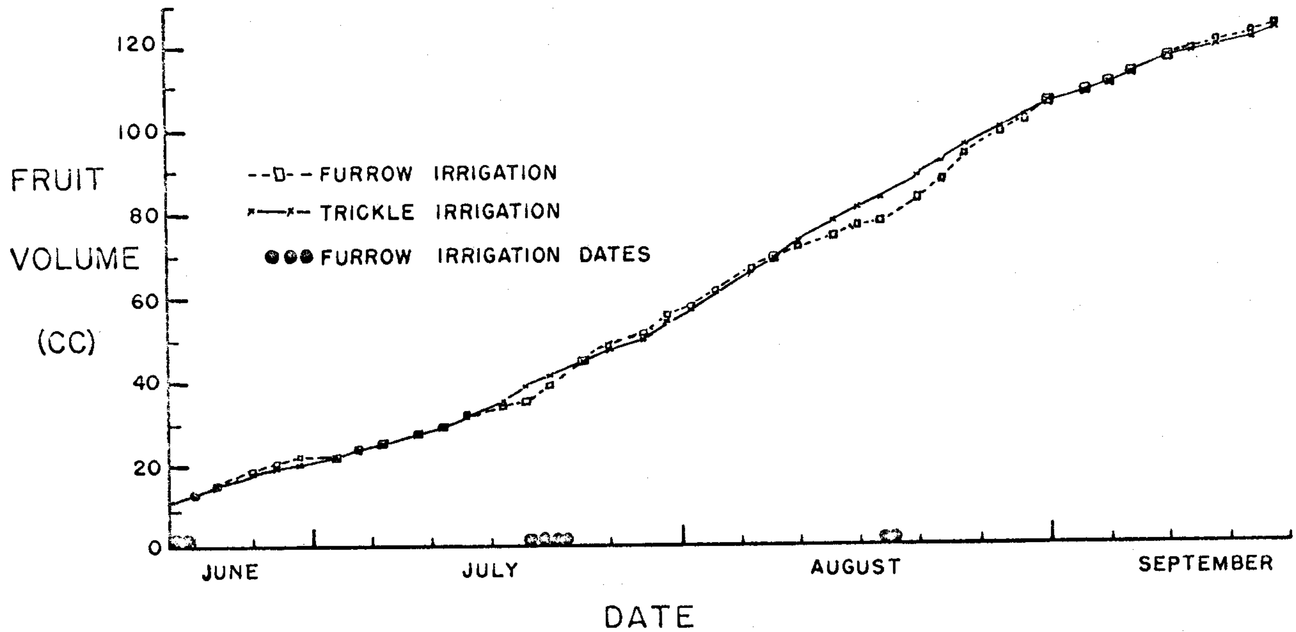


Figure 6. Comparison of accumulative fruit growth of furrow and trickle irrigated Bosc pears.

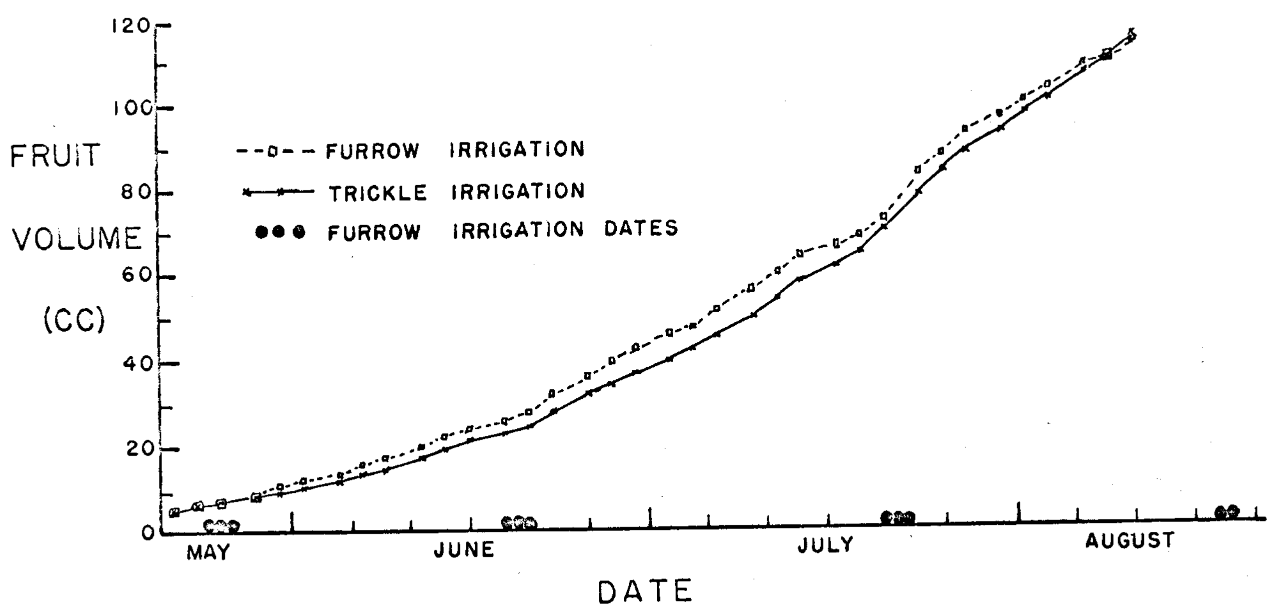


Figure 7. Comparison of accumulative fruit growth of furrow and trickle irrigated Bartlett pears.

At harvest, fruit sizes and maturity tests were measured on four trees in each cultivar plot and these averages are presented in table 1. Average fruit size was greater in the Bartlett trickle plot than the furrow irrigated plot but little, if any, difference was found in Bosc. Flesh pressures were considerably reduced while juice soluble solids were only slightly reduced by trickle irrigation on both cultivars.

Table 1. Effect of Trickle Irrigation on Fruit Size and Maturity of Bartlett and Bosc Pears, 1973

Irrigation method	Percent of fruit larger than 2 & 3/8" diameter (Average 4 trees)		Fruit maturity: U.S.D.A. pressure tester (skin pared)		Fruit maturity: Soluble solids	
	Bartlett	Bosc	Bartlett	Bosc	Bartlett	Bosc
Trickle	61(±20)	78(±7)	22.6(±2.4)	17.9-(±.4)	13.8(±.2)	14.7(±.2)
Furrow	43(±19)	74(±9)	25.3(±1.4)	19.8 (±.5)	13.9(±.2)	15.5(±.5)

Note: Numbers in parenthesis indicate range of values for individual trees. Measurements were made on Bartlett pears 8/9/73 and on Bosc pears 9/21/73.

Summary

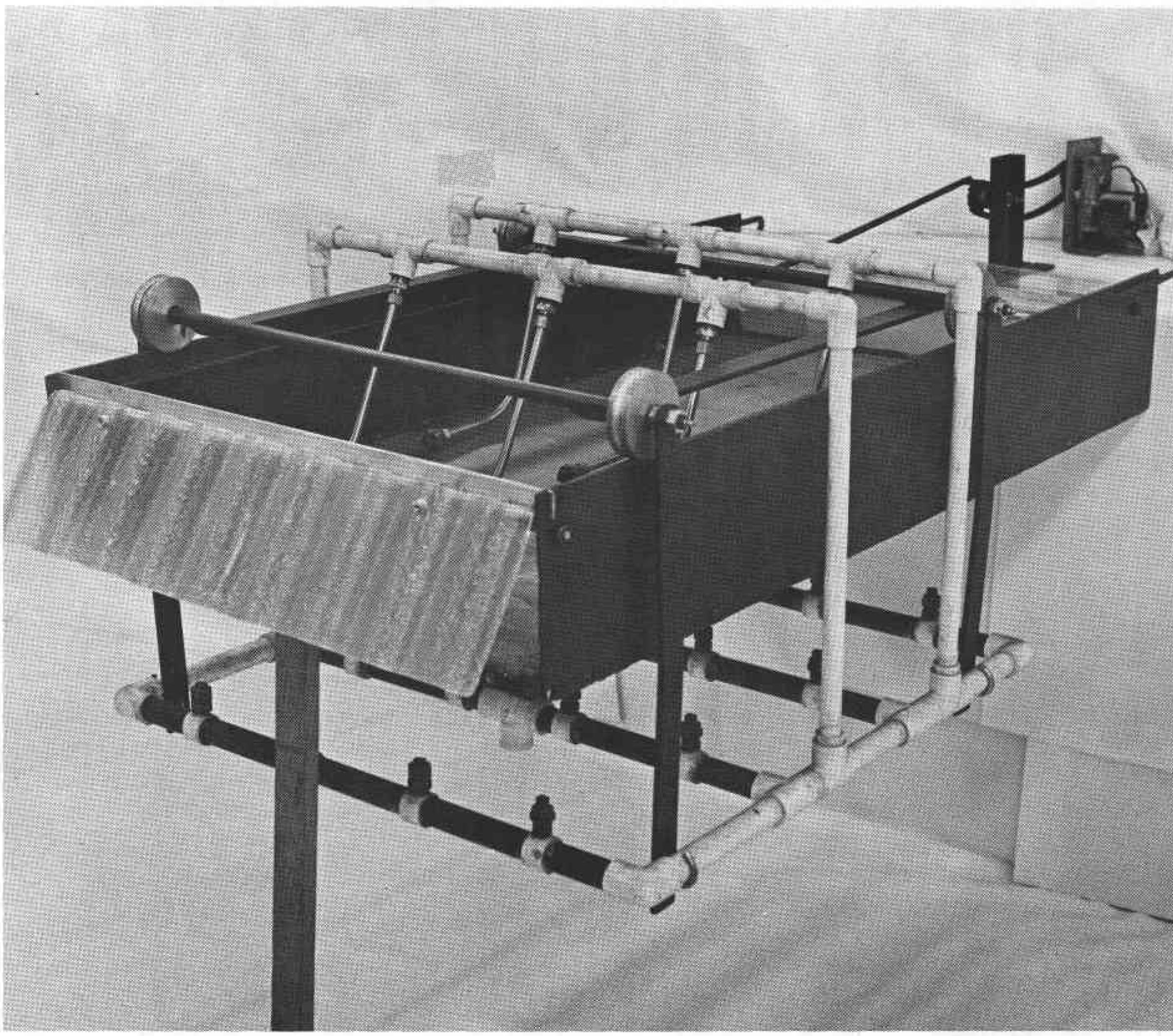
A trickle irrigation system was installed in one acre of forty-year-old pears and performance of the system and plant response was compared to that in an adjacent planting that was furrow irrigated. Water applications were designed to apply to the area within the drip line of the tree an amount equivalent to that lost by a standard U.S. Weather Bureau evaporation pan.

Three water applications of an estimated 4 inches each were made to the surface irrigated block on a monthly interval.

Rate of fruit growth between the two blocks varied during the season with greatest variation in the surface irrigated block. At maturity little, if any difference in fruit size was found in the Bosc cultivars, however, the trickle irrigated Bartletts were larger than those surface irrigated. Flesh pressures were considerably reduced while soluble solids were only slightly reduced by trickle irrigation. These differences, however, could be due to tree variation.

Water volume applied to the trickle block was 40 percent less than that applied to the surface irrigated block.

Water movement through soil was restricted, however, there was no problem providing adequate water to the root system when the soil moisture in the upper 12 inches was kept wet around the emitters; and four emitters were used on mature trees having 16 to 24 feet drip line diameters.



This 200 mesh self-cleaning screen was developed by the personnel of the Mid-Columbia Experiment Station at Hood River, Oregon. It effectively cleans water containing debris and glacial silt that is conveyed in open canals. Eighty percent of material passing through this screen is smaller than 50 microns and 99 percent is smaller than 100 microns.

Trickle Irrigation Progress Report in the Mid-Columbia Area

Walter M. Mellenthin, Scott Kelly, and C. Y. Wang

Objective

Numerous studies have been published relative to trickle or drip irrigation systems in newly planted or young non-bearing orchards. The objective of the current project underway at the Mid-Columbia Experiment Station is to obtain information on problems during the transition from sprinkler applications to trickle systems on bearing pear trees.

Procedure

A trickle system was installed in a mature pear block (45 years old) planted 20 feet by 20 feet in the early spring of 1973 on the experiment station. This system consisted of one-half inch polyethylene lateral lines from a one-and-one-fourth inch P.V.C. main line at the edge of the block. The 'in row' laterals were buried approximately three to four inches below ground level with two micro tube emitters per tree. These emitters were spaced five feet from each tree and about three feet on the uphill side of the tree row. The system was designed to emit one-half gallon water per hour per emitter at ten to twelve psi pressure. Different micro tube diameters and lengths were used to balance the discharge rates of the emitters. In one part of the block three emitters were installed per tree and in another section four emitters were installed per tree. All emitters had the same discharge rate. This allowed for a comparison of seasonal fruit growth and packing sizes at harvest to different water applications. An adjacent section of the same planting received normal sprinkler applications. Fruit from this block was used for comparing growth with the trickle systems.

A primary factor in the successful operation of a trickle irrigation system is the supply of clean water. Much of the irrigation water in the Mid-Columbia area contains varying amounts of debris with a considerable quantity of glacial silt. Thorough filtering or screening is essential if the system is to operate with a minimum of maintenance. All irrigation water used at the station passes through a 200 mesh stainless steel screen. Below the screen a series of water jets continually oscillate back and forth keeping particles from plugging the screen as the water moves through it to the pumping tank. On top of the screen two water jets keep the debris moving to the discharge end of the screen and to the overflow or waste pipe. The jets are operated at 45 to 50 psi. Since the water is pumped to each plot in old existing underground lines containing silt and rust, a sand filter was installed to remove debris from the pipes and to provide additional filtering.

The sprinkler applications were based on tensiometer readings which were read twice weekly and the trickle plots were irrigated according to evaporation rates from a class A evaporation pan. Sufficient water was applied to replace the previous week's evaporation loss. It was felt that using weekly pan evaporation to schedule irrigations was more practical for a commercial orchardist than daily evaporation rates because of the water delivery systems in the Hood River area.

Certain assumptions must be made in the operation of a drip system until more reliable data are available. On the 20 foot by 20 foot pear block it was assumed that it was necessary to apply the pan evaporation values to only 50 percent of the area in calculating irrigation needs. Weekly pan evaporation was, therefore, multiplied by 0.5 in arriving at the weekly net soil moisture loss for the block. This assumed a one to one ratio between pan evaporation and soil moisture loss from the designated area. Tensiometers were installed 18 inches from emitters in the trickle blocks to monitor soil moisture but irrigations were applied on the evaporation loss basis.

Discussion

A comparison of seasonal tensiometer readings from the sprinkler plot with readings from the two emitter per tree drip system is shown in figures 1 and 2. The readings from the sprinkler plot clearly show the effect of three seasonal irrigations on the moisture levels at three soil depths. It appears the period between sprinkler applications could be lengthened, but since fruit growth and size data were compared with trickle plots it was desirable not to allow the blocks to dry down further before sprinkling. The soil is a fine sandy loam texture and well drained. The Bartletts were harvested on August 15, about twelve days following the August 3 irrigation. Anjou harvest began on September 7 or seven days following the third and last irrigation.

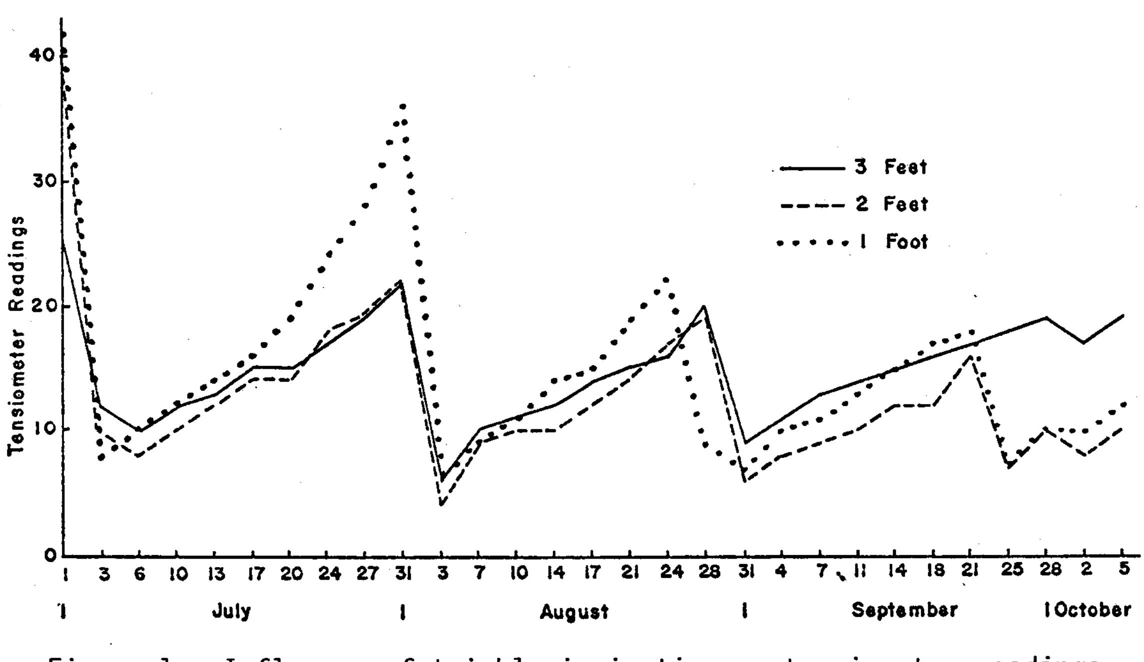


Figure 1. Influence of trickle irrigation on tensiometer readings in Bartlett and Anjou pears, 1973.

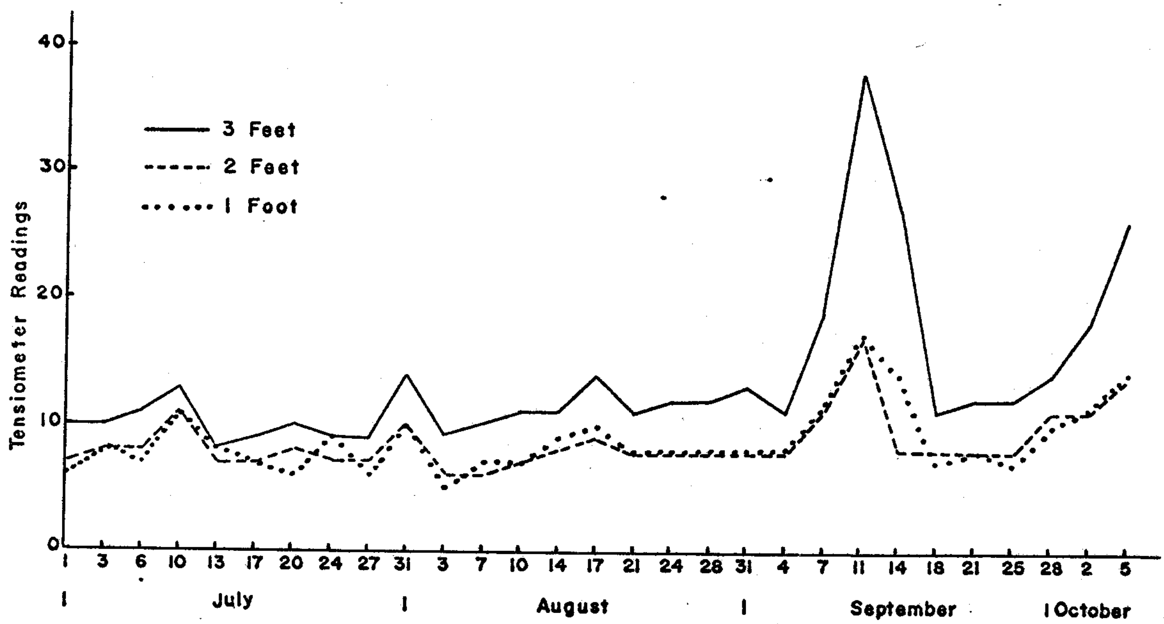


Figure 2. Influence of sprinkler irrigation on tensiometer readings in Bartlett and Anjou pears, 1973.

Drip applications based on evaporation losses shown in figure 2 indicate that soil moisture at the three depths was maintained near field capacity throughout the irrigation season. It is interesting to note the "drying down" effect which began on September 4 when the system was turned off at the start of Anjou harvest. The system was operated again at completion of harvest and continued until fall rains began.

The influence of sprinkler versus trickle irrigation methods on weekly d'Anjou fruit measurements is shown in figure 3. There was no difference in seasonal growth rate of pears irrigated with the two systems. Figure 4 shows the effect of different water application obtained by increasing the number of emitters per tree. Considering that fruit size on the three emitter block was slightly larger at the beginning of the irrigation season, it appeared there was no significant difference in size at harvest.

During Bartlett harvest, a 100 fruit sample was taken from every other Bartlett tree in the plot and sized (figure 5). This shows an eight percent reduction in the number of fruits attaining a number one size (2 1/4" dia.) and a slight increase in the percent of number two and three sizes. However, this was probably not significant since these blocks were thinned by seasonal workers. Yields were not compared in 1973 since the bloom and fruit set periods were before the irrigation systems were started. Yields will be taken in subsequent crop years. There was no apparent difference in maturity or storage characteristics of fruit from the two systems.

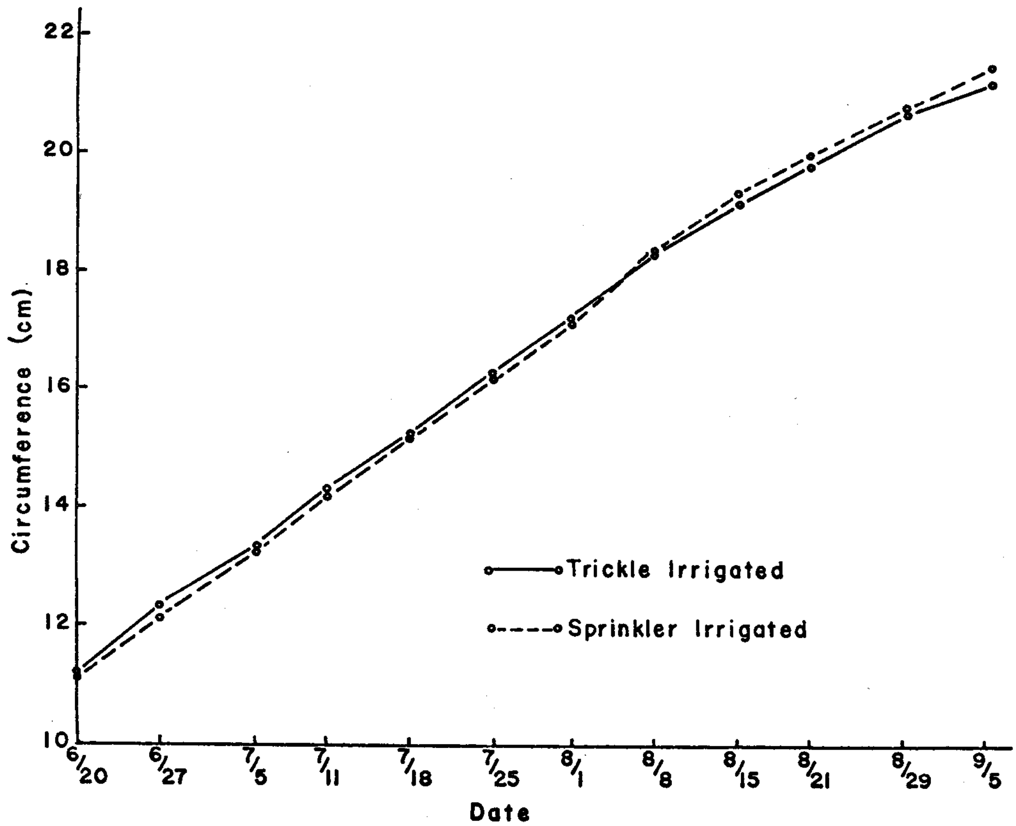


Figure 3. 1973 d'Anjou pear fruit growth.

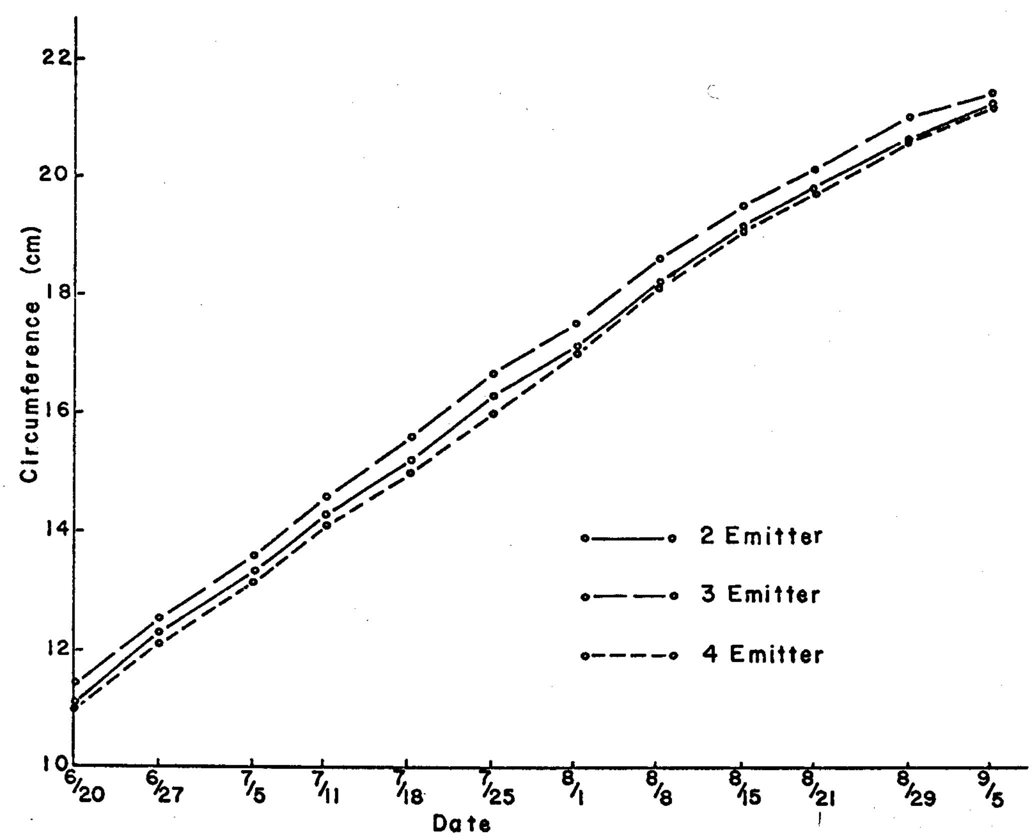


Figure 4. Influence of irrigation on d'Anjou pear fruit size.

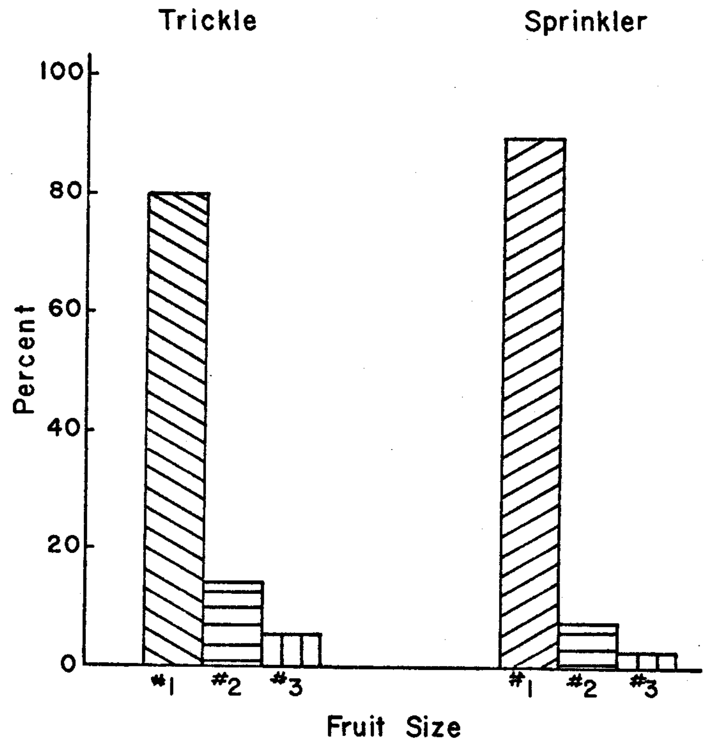


Figure 5. Influence of irrigation systems on Bartlett pear size. Number 1, 2, and 3 sizes are 2 1/4 inches, 2 1/3 to 2 1/4 inches, and less than 2 1/8 inches, respectively.

A comparison of the influence of varying number of emitters per tree and the sprinkler plot on the percent packout of commercial size groups of Anjou pears is shown in figure 6. There was practically no effect of varying the number of emitters per tree on premium sizes (90-135). The sprinkler block had a lower percentage of premium sizes but had a greater percentage of large sizes (80's and larger). This indicates a slight decrease in sizing on Bartletts and Anjous under trickle irrigation in 1973. Further studies are needed to better understand the effects of converting from sprinkler to trickle irrigation systems on mature pear trees.

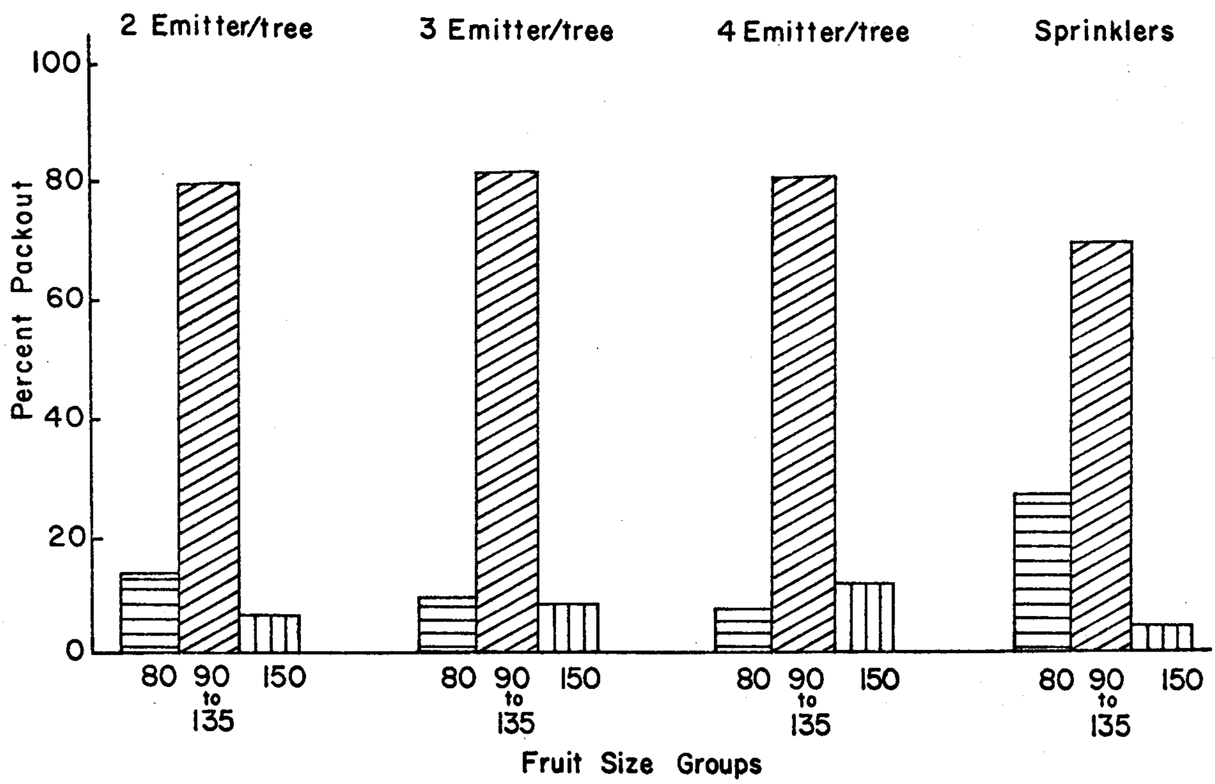


Figure 6. Influence of irrigation systems on d'Anjou fruit size.

Summary and Conclusions

Preliminary studies have shown that trickle irrigation is a practical method of applying water to tree fruit crops providing a source of clean water is available or an adequate screening or filtering device is installed. Plugged emitters are just as serious as plugged sprinklers and more labor is required to keep a system operating if the water is not clean.

If trickle applications are based on evaporation losses, the design of new systems should allow for water applications based on the highest anticipated daily or weekly evaporation rates.

No problems were encountered in maintaining adequate water to mature pear trees of 16 to 18 feet drip line diameter with a trickle system having only two emitters per tree, however, two emitters appeared to be marginal. Water volume applied through the trickle system was equivalent to that lost by a standard U.S. Weather Bureau evaporation pan. Fruit size was slightly reduced by trickle irrigation.

Initially, water cleaning was a problem. A self-cleaning 200 mesh overflow screen was developed. This screen with a scheduled flushing program eliminated plugging problems for the remainder of the season.

Interpreting Evaporation from Class A Weather Bureau Pan for Irrigation Scheduling of Crops Grown Under Trickle Irrigation

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The use of class A evaporation pans for scheduling irrigations with trickle systems is generally accepted but the procedures and K values used for relating to estimated consumptive use vary widely. (Pan Evap. x K = consumptive use)

Jensen and Middleton (1) suggest K values of 1.00 for peach orchards with grass cover and 1.05 for apple orchards with grass cover in Washington state for predicting sprinkler and surface irrigation requirements. They indicate, however, that these values were 0.05 larger than average measured values.

Howell and Hiler (2) report that consumptive use values have been shown to be nearly equal to 0.6 of the maximum mean evaporation of a class A evaporation pan for trickle irrigation in Israel. In another paper by Hiler and Howell (3) they reported one could expect a high water use efficiency with grain sorghum using K values of 0.6 to 0.7 but it would not be adequate if highest yields were desired.

DeRemer (4) used K values of 0.5 but provided for a small safety factor by calculating the area covered by individual trees as a square rather than as a circle. (i.e. $A = D^2$ instead of $A = \pi r^2$)

New (5) suggests a K value of 0.7.

March (6) states that most pans will register evaporation greater than evapotranspiration from a growing crop even though the crop covers 100 percent of the area.

Stevenson (7) reports that trickle systems can be operated at 70 to 80 percent of peak demand periods without adverse effects if they operate continuously. He recommends adjusting the flow rate periodically to meet average monthly consumptive use by adjusting line pressure but never shutting the system off during the growing season.

Controlled Water Emission Systems (8) recommends using a K value of 0.7 but applies it to the established tree spacing rather than the area covered by the drip line when converting to trickle systems on mature trees.

Nearly all recommendations suggest the use of tensiometers for monitoring soil moisture to indicate the need for adjustments in irrigation scheduling when evaporation pans are used.

It would seem logical that if, through trickle irrigation, a more uniform and wetter soil moisture condition exists in the root zone because of very frequent irrigations, plants will transpire more water than when grown with more widely spaced irrigations. The low K values (0.5 to 0.7) associated most often with trickle irrigation, therefore, are difficult to reconcile with K values of Jensen and Middleton.

Objective

To develop and field test a simple procedure using a class A evaporation pan for scheduling trickle irrigation.

Procedure

Trickle irrigation research plots at the North Willamette, Southern Oregon, and Mid-Columbia Experiment Stations were scheduled according to class A pan evaporation. Charts similar to tables 1 and 2 were used to estimate how many hours the systems should operate. The tables are entered for the left and top as indicated. All references to "pan evaporation" refer to net losses from a class A pan. (Pan evaporation = class A pan evaporation plus rainfall). Tensiometers were used to monitor soil moisture in the field.

Water applied through the trickle systems was measured with recording water meters at the Southern Oregon and the North Willamette Stations. Applications were calculated by volumetric measurements at the Mid-Columbia Station.

Yields were compared to plots irrigated with conventional irrigation systems and schedules, but otherwise were treated identically. If production under trickle irrigation equaled that under the conventional system, it was assumed that water was not limiting and irrigations were adequate. If production under the trickle system was reduced, it was assumed that irrigations were not appropriate. Tensiometer readings were then studied to determine if irrigations had been excessive or deficient.

The amount of water applied was then compared to the calculated "amount required" to determine reasonableness of the K value used.

Discussion

Comparisons of the water applied to 'Thornless Evergreen' blackberries at the North Willamette Station and the calculated requirements based on Pan evaporation x 1.0 and Pan evaporation x 0.7 are shown in figure 1. The calculated requirements were based on foliage widths of 2.29 feet in June,

Table 1. Hours to Run Trickle System to Replace Estimated Crop Use Since Last Irrigation, Hedgerow

Width of hedge row feet	Single line emitter spacing feet	Net pan evaporation or estimated consumptive use in inches[a]										
		.18	.20	.22	.24	.26	.28	.30	.32	.34	.36	.38
		Hours to run at 1 gallon/hour/emitter										
2	4	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
	5	1.1	1.3	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.3	2.4
	6	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.9
3[b]	4	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.9
	5	1.7	1.8	2.1	2.3	2.5	2.6	2.8	3.0	3.2	3.4	3.6
	6	2.0	2.3	2.5	2.7	2.9	3.2	3.4	3.6	3.8	4.1	4.3
4	4	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8
	5	2.2	2.5	2.7	3.0	3.2	3.5	3.7	4.0	4.2	4.5	4.7
	6	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7
5	4	2.2	2.5	2.7	3.0	3.2	3.5	3.7	4.0	4.2	4.5	4.7
	5	2.8	3.1	3.4	3.7	4.1	4.4	4.7	5.0	5.3	5.6	5.9
	6	3.4	3.7	4.1	4.5	4.9	5.2	5.6	6.0	6.4	6.7	7.1
6	4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7
	5	3.4	3.7	4.1	4.5	4.9	5.2	5.6	6.0	6.4	6.7	7.1
	6	4.0	4.5	4.9	5.4	5.8	6.3	6.7	7.2	7.6	8.1	8.5

[a]Pan evaporation equals class A pan evaporation plus rainfall.

[b]Example: Width of hedge-row 3 feet, single line emitters spaced 5 feet, emitter discharge 1 gallon/hour, pan evaporation since last irrigation 32 inches--run system 3.0 hours.

Table 2. Hours to Run Trickle System to Replace Estimated Crop Use Since Last Irrigation, Orchard, Individual Trees

Diameter of tree feet	Number of emitters per tree	Net pan evaporation or estimated consumptive use in inches[a]									
		.18	.20	.22	.24	.26	.28	.30	.32	.34	.36
		Hours to run at 1 gallon/hour/emitter									
10	2	4.4	4.9	5.4	5.9	6.4	6.9	7.4	7.9	8.4	8.9
	3	3.0	3.3	3.6	3.9	4.3	4.6	4.9	5.3	5.6	5.9
15	3	6.6	7.4	8.1	8.8	9.6	10.3	11.0	11.8	12.5	13.2
	4	5.0	5.5	6.1	6.6	7.2	7.7	8.3	8.8	9.4	9.9
20[b]	3	11.7	13.0	14.4	15.7	17.0	18.3	19.6	20.9	22.2	23.5
	4	8.8	9.8	10.8	11.7	12.7	13.7	14.7	15.7	16.6	17.6
	5	7.1	7.8	8.6	9.4	10.2	11.0	11.7	12.5	13.3	14.1
25	4	13.8	15.3	16.8	18.4	19.9	21.4	23.0			
	5	11.0	12.2	13.5	14.7	15.9	17.1	18.4	19.6	20.8	22.0
	6	9.2	10.2	11.2	12.2	13.3	14.3	15.3	16.3	17.4	18.4
	7	7.9	8.8	9.6	10.5	11.4	12.2	13.1	14.0	14.9	15.7
30	6	13.2	14.7	16.2	17.6	19.1	20.6	22.0	23.5		
	7	11.3	12.6	13.9	15.1	16.4	17.6	18.9	20.2	21.4	22.7
	8	9.9	11.0	12.1	13.2	14.3	15.4	16.5	17.6	18.7	19.8
	9	8.8	9.8	10.8	11.8	12.7	13.7	14.7	15.7	16.7	17.6

[a]Pan evaporation equals class A pan evaporation plus rainfall.

[b]Example: Diameter of tree 20 feet, emitters per tree 4, emitter discharge 1 gallon/hour, pan evaporation since last irrigation 0.30 inches --run system 14.7 hours.

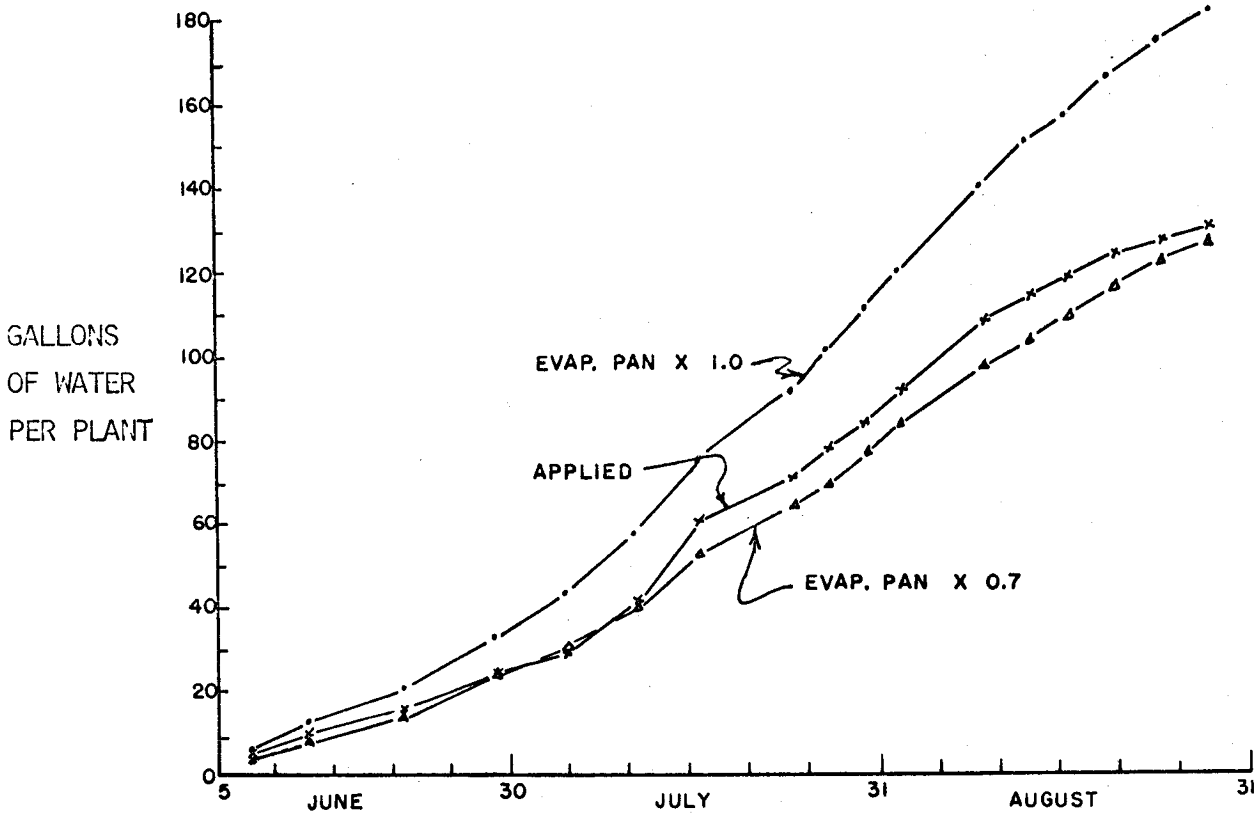

Figure 1. Comparison of calculated water required using K values of 1.0 and 0.7, and actual water applied to 'Thornless Evergreen' Blackberries at the North Willamette Station in 1973.

2.87 feet in July, and 3.45 feet in August. However, no adjustment was made for the changes in foliage width in determining the amount that was applied during the summer.

Yields were reduced one ton per acre under the trickle system due to insufficient water applied. Tensiometer readings support this conclusion. Water applications, however, were always greater than Evaporation x 0.7 when related to the adjusted width of the plant foliage.

Comparison of water applied to Anjou pears at the Southern Oregon Experiment Station and the calculated requirements are shown in figure 2 for two tree diameters found in the plots. Yield from trickle irrigated trees was equal to yields from surface irrigated trees. It is assumed, therefore, that the crop was not adversely affected by water applications greater than Evaporation x 1.0, even though Carney clay has poor internal drainage. There was no runoff although there was some slight surface ponding. This may have resulted in slightly higher surface evaporation losses than normal. Tensiometer readings showed no excessive moisture at the 2 and 3 foot depths.

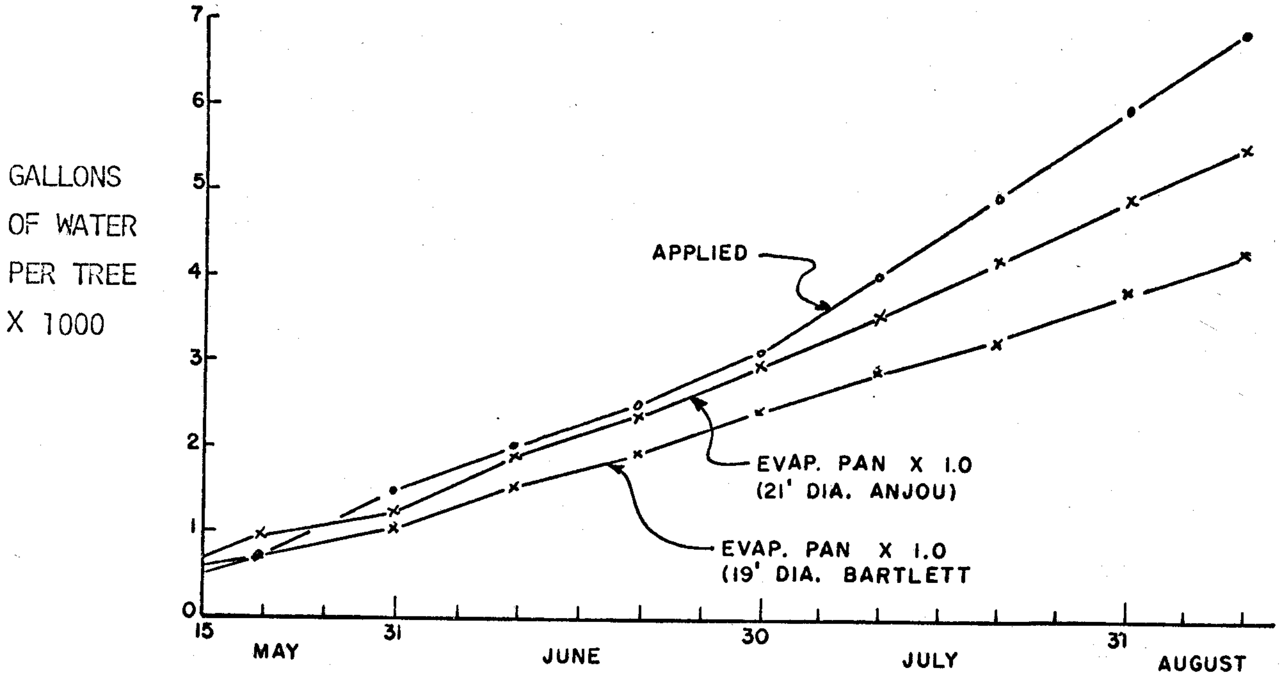

Figure 2. Comparison of calculated water required for two tree diameters using a K value of 1.0, and actual water applied to pears at the Southern Oregon Station in 1973.

A comparison of water applied to Anjou and Bartlett pears at the Mid-Columbia Station and calculated requirements are shown in figure 3. There appeared to be a slight decrease in sizing of both Bartletts and Anjous compared to an adjacent sprinkler irrigated block at harvest time. Weekly size measurements on Anjous that were trickle irrigated showed a slightly lower growth rate than those sprinkler irrigated, however, these differences might not be significant. No statistical analysis was made. It is assumed, therefore, that the water applications were adequate or only slightly deficient.

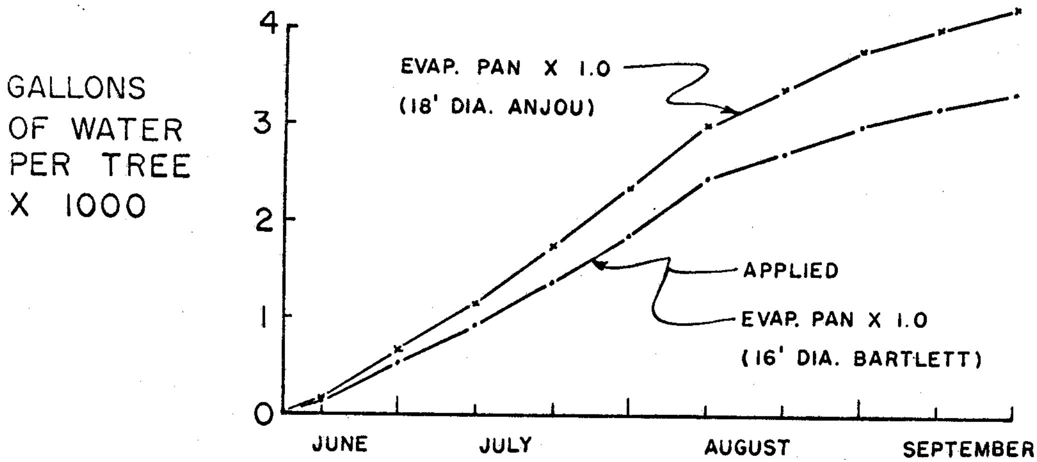

Figure 3. Comparison of calculated water required for two tree diameters using a K value of 1.0, and actual water applied to pears at the Mid-Columbia Station in 1973.

Summary

A simple procedure for scheduling trickle irrigation of crops not completely covering all the soil surface with plant canopy was field tested at three experiment stations. Technicians experienced no difficulty in using the procedures for determining how long to run their trickle systems, however, it was apparent that drip lines of plants and trees should be measured, not estimated, to determine foliage width and drip line areas. Additional study is necessary to validate K values for estimating drip irrigation schedules.

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