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16. Abstract

From April through October 1977, a new sub surface irrigation system design was tested and evaluated in an applied situation. The purpose of this research was to study the practical application of the design and the collection of data for development of design, construction and maintenance guidelines.

The study has proved the practical applicability of the "Sub Surface Infiltration System."

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"SUB-SURFACE INFILITRATION SYSTEM"

FOR

TREE IRRIGATION

By

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Roadway Development Division

Washington State Department of Transportation

Final Report

Research Project HR 475

Prepared for

Washington State Department of Transportation

Division of Highways

OCTOBER, 1977

INTRODUCTION

Highway Development includes both roadway and roadside development. Roadside development takes into consideration impacts on the environment caused by the highway facility, with particular interest in the mitigation of adverse impacts. One means of mitigation is through roadside planting of trees, shrubs, ground covers and erosion control grasses.

Climatic and soil conditions are such that in many areas supplemental irrigation is required to ensure plant survival during the establishment period. Once the plant has established a good root system, irrigation can often be terminated or limited to a reduced watering schedule during the driest period only.

Irrigation systems and materials have evolved from strictly agricultural applications. From this a market has developed for application to golf courses, cemetaries, parks, homes, etc. The commercial and refined ornamental nature of these applications allows for a relatively high degree of maintenance contrary to that required by roadside irrigation systems. In contrast to the commercial and ornamental applications, roadside irrigation represents a small market, with increasingly different requirements for the following reasons:

(a) Roadside development and maintenance is of secondary priority to the roadway requirements.

(b) Increasing demands on available water, large scale application and remoteness of systems necessitates low water usage of the individual units.

(c) Lack of surveillance requires vandal resistant equipment.

(d) Irrigation in arid locations often creates a visual and maintenance nuisance by the abundant weed growth that flourishes under the ideal soil moisture and climatic conditions.

(e) The present concept for roadside planting follows a trend towards the use of large trees, spaced at greater than normal intervals, with a low emphasis on shrubs and ground covers.

Analysis of these concerns resulted in the following criteria for a roadside-tree-irrigation system.

(a) Low maintenance.

(b) Low water usage.

(c) High degree of vandal resistance.

(d) Produce zero or little increase in surface soil moisture.

(e) Sensitive to varying plant needs caused by soil exposure, etc.

(f) Visually unobtrusive.

(g) Components of system to be readily available.

(h) Favorable cost-benefit ratio.

It was surmised that a subsurface system would satisfy the criteria of b, c, d and f, however, presently available subsurface irrigation systems were found to have the following disadvantages.

A. Drip/Trickle Systems:

1. Require complex, costly filtration systems to ensure water quality in order to prevent clogging of the orifices.
2. Polyethylene tubing used as supply lines is often subject to rodent damage, and damaged areas are difficult and costly to locate and repair.
3. Water is applied in small quantities and from pin point emitter sources, which produce small wetted areas, thereby restricting root development.

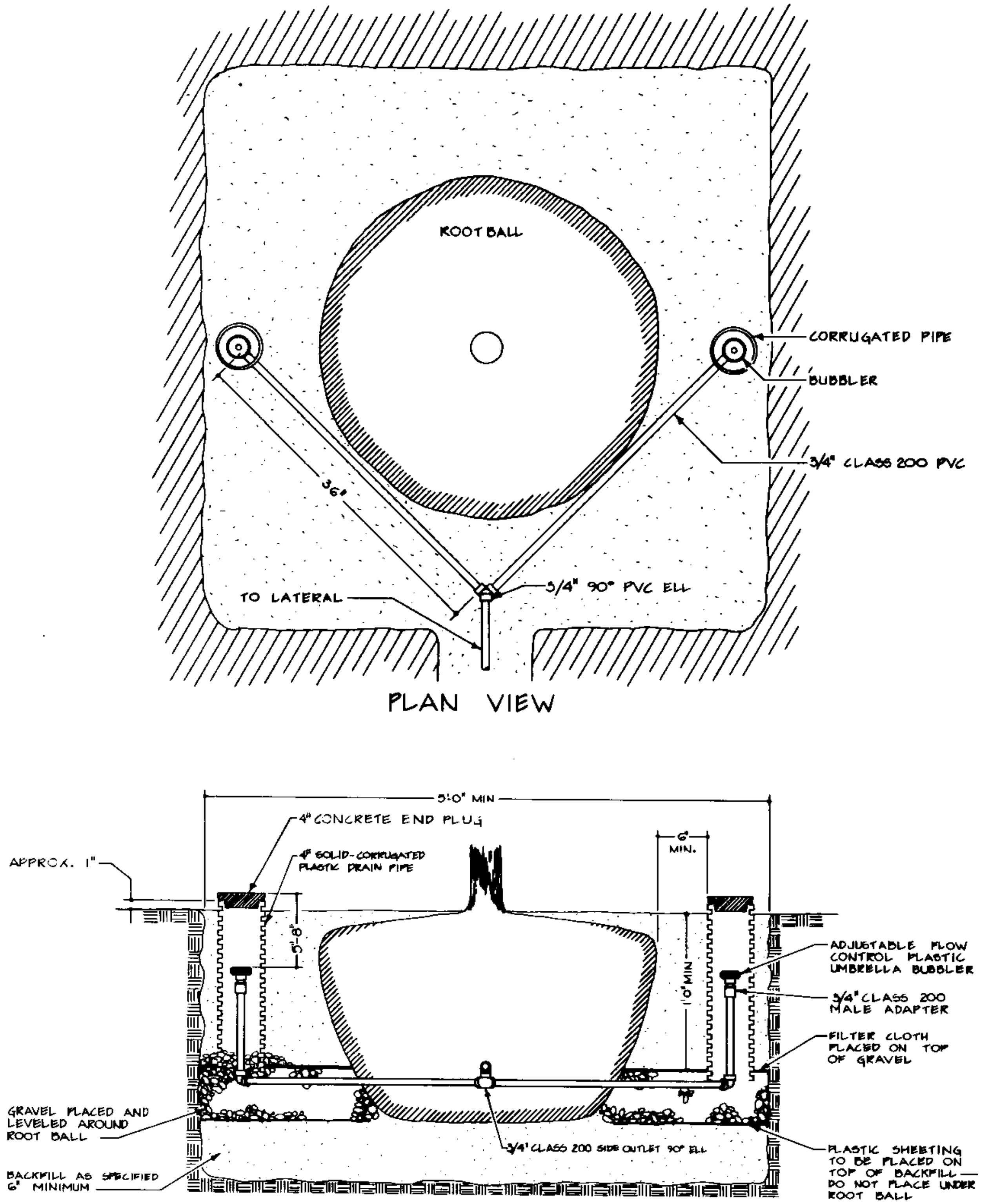
B. Mechanical subsurface irrigator tend to fail after a period of use. Repairs are costly due to difficulties encountered in locating points of failure, uncommon parts, etc.

C. Visual inspection is extremely difficult to perform on either of the systems discussed above.

Figure 1 shows the "Sub-Surface Infiltration System" design that was used in this study.

The design was reviewed extensively by various disciplines within the department as well as outside irrigation specialists, resulting in the general concensus that the system should work. A decision was then made to field test the system prior to actual, statewide application.

SUB-SURFACE INFILTRATION SYSTEM



NOTES TO DESIGNER:

QUANTITY OF GRAVEL TO BE PLACED AROUND ROOT BALL VARIES BETWEEN 2 AND 6 CUBIC FEET DEPENDING ON PERCOLATION RATE OF PLANTING AREA.
GRAVEL MUST CONFORM TO STANDARD SPECIFICATIONS 9-03.1(3)C FOR #5 CONCRETE AGGREGATE.

THIS SYSTEM IS DESIGNED FOR TREES HAVING A ROOT BALL DEPTH OF 16" OR MORE

Figure 1

SUBSURFACE IRRIGATION DESIGN

The SUBSURFACE INFILTRATION SYSTEM is designed to be placed in a planting hole with a 5'0" minimum diameter. This diameter is selected to accommodate the root ball of most tree sizes commonly used, as well as having a sufficient reservoir for water storage and distribution for use as a permanent system. The system is designed for trees having root balls up to 36" in diameter and root ball *depths no less than sixteen inches.* This sixteen inch root ball depth is necessary to ensure that the gravel blanket used is a minimum of twelve inches below the surface and that the water is supplied to the root ball. Depth of the planting hole is equal to the depth of the root ball, plus six inches for back-filling as specified in the state planting specifications.

The system uses three quarter inch Class 200 PVC or polyethylene pipe and schedule 40 PVC or "Turnseal" fittings in its design with adjustable flow control plastic bubbler heads to dispense the water. The use of the adjustable bubblers allows fine funing to eliminate wet and dry spots. These bubblers operate under a wide range of water pressure, from 10 PSE to 80 PSE and have large orifices that don't require fine filitration.

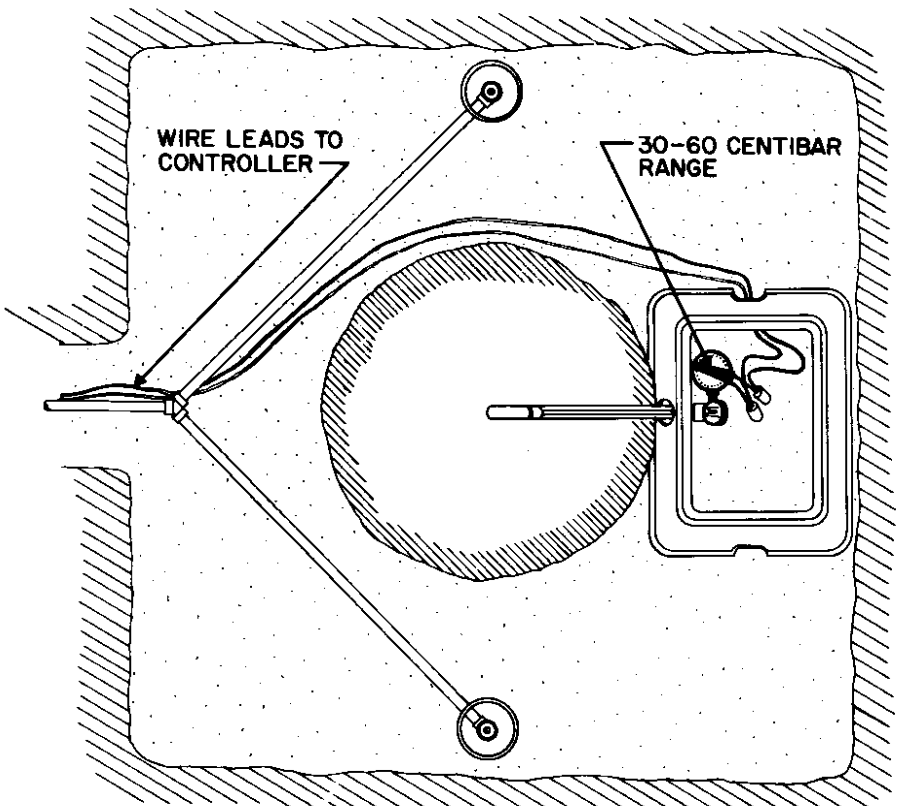
A four inch diameter, non-perforated, corrugated plastic drainpipe used as a sleeve, is then placed over the riser and bubbler head assembly. This sleeve channels the water directly to the gravel blanket, and permits visual inspection of the water flow by removal of the concrete end plug at the surface. Filter cloth is placed on top of the gravel blanket, to reduce the possibility of silt carried by normal precipitation from filling the voids in the blanket. The gravel blanket serves two main purposes. First, the gravel provides adequate storage of the water while the system is on. (The water will not back up the sleeve and flood the surface). Secondly, the gravel blanket allows the water to infiltrate through its voids and be dispersed over a larger area. The percolation rate of the surrounding soil determines the quantity of gravel to be used. An area 5'0" in diameter requires approximately 12 gallons of water to yield one inch over the entire planting hole area. One cubit foot of No. 5 concrete aggregate will hold 2.7 gallons of water. This system is designed for extremes in percolations rates. Areas of high percolation rates require very little gravel for storage. Areas having low percolation rates require a sufficient quantity of gravel to hold the entire 12 gallons. This system is, therefore, designed for a minimum of two cubic feet to a maximum of six cubic feet of gravel. Two cubic feet of gravel will store approximately five and one-half gallons of water, and when placed in a planting hole with a twelve inch diameter root ball, will form a blanket approximately one and one quarter inches thick. Six cubic feet of gravel will store approximately 16 gallons of water, and when placed in a planting hole with a thirty-six inch diameter root ball, will form a blanket approximately five and three quarters inches thick.

Plastic sheeting is used under the gravel blanket to produce a wider dispersion of the water being applied. The plastic sheeting should lie relatively flat on top of the layer of backfill placed in the bottom of the hole. The plastic should be thick enough (4 mil minimum) to resist tearing and puncturing during installation and backfilling.

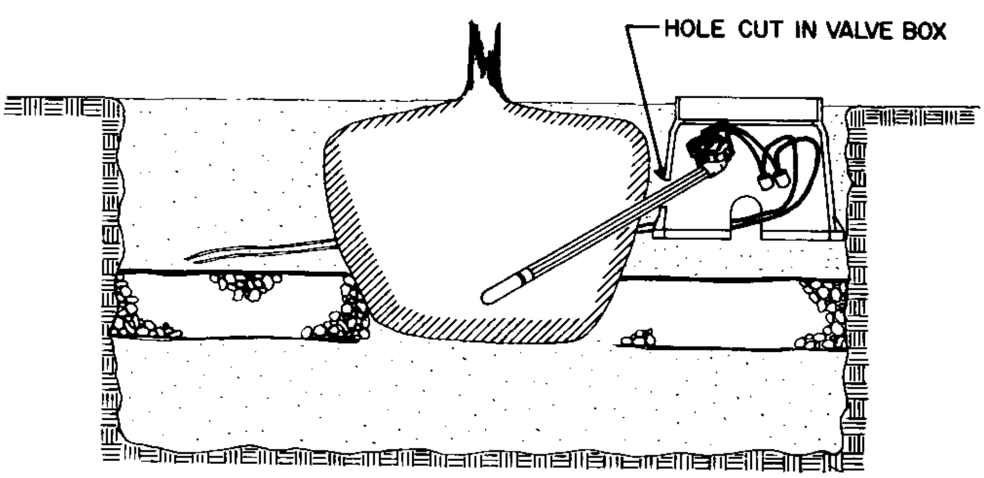
The use of an automatic controller permits selection of the time of day for which the system is allowed to come on, as well as the length of time allotted for the system to operate during each cycle. The use of tensiometers in conjunction with the electric automatic controller allows the system to come on only when the plants require water. The tensiometer should be installed as shown in Figure 2 and should be set to start the irrigation at the 30-60 centibar range depending upon the climate and soil conditions.

In order for the water to be distributed equally throughout the gravel, it is essential that the combined controller setting (timing) and the bubbler head output (GPM) result in rapid flooding of the gravel blanket. In comparison, slow delivery of water could result in the water seeping to low spots in the plastic sheeting, thereby causing unequal water distribution.

PLACEMENT OF TENSIOMETER



PLAN VIEW



ELEVATION

NOTE:
TIP OF TENSIOMETER LOCATED APPROXIMATELY IN THE CENTER AND NEAR THE BOTTOM OF THE ROOT SYSTEM

Figure 2

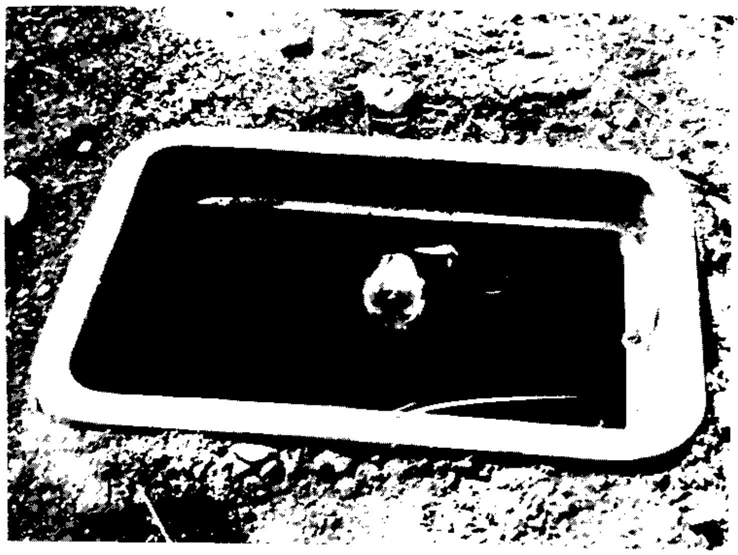


Figure 3
TENSIOMETER INSTALLATION

RESEARCH OBJECTIVES

The objective of this research was to evaluate the "Sub-Surface Infilitration System" for tree irrigation during design, construction, operation and maintenance. These major areas were then broken into the following areas of study:

A. Root Growth
B. Water Use
C. Sensitivity of System
D. Aesthetics
E. Weed Growth
F. Vandalism
G. Economics
H. System Components
I. Application of the System

The findings from this evaluation period were to aid in forming a design technique, setting guidelines for design, construction and maintenance in roadside development projects.

DESCRIPTION AND OBSERVATIONS

Site Selection

The site selection was subject to the following criteria:

(a) The soil to represent average statewide conditions in regards to drainage.

(b) Soil containing rocks, etc. in number or size to interfere with the flow of water or root growth is unacceptable.

(c) The climate preferably to represent the dry extremes of the State.

(d) Water supply available close by, relatively clean and of adequate pressure.

(e) Separated from heavily used pedestrian areas in order to avoid vandalism of test equipment.

Considerable difficulty was experienced in locating a suitable site. A shortage of irrigation water caused by the 1977 drought, canceled out several possible sites. Others were found to be unsuitable due to rocks or foreign materials wasted there during previous construction activities. The final **site** was selected on the Wenatchee Valley College Campus, in Wenatchee, Washington.

Plant Material

The plant material selected for the research were two trees each of two species that are representative of roadside planting projects in the research area. The species selected for the two deciduous trees was Honey Locust (Gleditsia triacanthos) and two evergreen trees, Common Douglas Fir (Pseudostuga taxifolia).

Problems encountered in locating a suitable test site resulted in a delay in planting until April 28. This date was much later than intended or desired, and with this lateness, the choice of satisfactory plant material was limited. The Honey Locust used in the study were of good quality; however, the quality of the Douglas Firs was poor due mainly to undersized root balls. Both Douglas Firs died shortly after planting, and were replaced; however, the quality of the replacement trees was no better than that of the first planting, and another fir died during the summer.

Irrigation System

The irrigation system was installed in accordance with the procedures described in Appendix "E". A tensiometer was used in conjunction with an electric controller to produce an efficient, and soil moisture sensitive, water supply to the trees. The tensiometer was installed to override the controllers "ON" position, and allow the system to come on only when the soil moisture level drops below the present moisture range.

Data Collection

Data collection indicating soil moisture content was accomplished by measuring changes in electrical resistance or conductivity in buried porous gypsum blocks. These gypsum blocks were installed at prescribed distances and depths from the point at which the water was dispersed. Measurements were taken at monthly intervals with the readings expressed graphically as shown in Appendix "B".

The final monitoring period in October 1977, included the excavation of approximately one half the root system of one of the Honey Locust and one of the Douglas Fir to evaluate root growth achieved during the research period.

RESULTS AND DISCUSSION

The results from this research period indicate that the "Sub-Surface Infiltration System" for tree irrigation is an efficient and workable design for use in new planting projects where permanent sub-surface systems are required.

Root Growth

Root growth of plants in arid areas is limited normally to the wetted area produced by the irrigation system. The smaller the wetted area, the smaller the root area of the plant, and the greater the plants dependency on the irrigation system. Conversely, it would appear that a greater wetted area would encourage more extensive root growth and would lessen the plants dependency on the irrigation system by providing a larger area from which moisture and nutrients, necessary to the plants survival, could be extracted.

Root growth found on the Honey Locust used in this study was extensive. Some fine, hair like roots were found in the soil above the filter cloth, and in the gravel blanket, see Figures 4 and 5.

Figure 4
ROOTS FOUND ABOVE FILTER CLOTH

Figure 5
ROOTS FOUND IN GRAVEL BLANKET

The majority of root growth appeared beneath the plastic sheeting as shown in Figure 6. Roots below the plastic sheeting were numerous, larger in diameter than those found above the plastic, and extended as far as the perimeter of the plastic.

One root in particular (see Figures 6, 7 and 8) extended to the edge of the plastic along a fairly uniform level and appears to follow the movement of water running off the outer edge of the plastic.

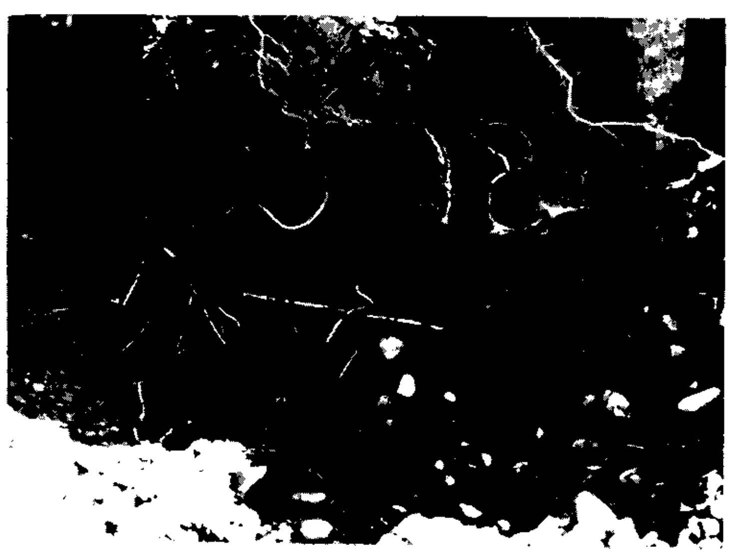


Figure 6
ROOTS FOUND BELOW THE PLASTIC SHEETING

Figure 7
LARGE ROOT FOUND BELOW PLASTIC SHEETING

Figure 8
PATTERN AND EXTENT OF LARGE ROOT FOUND
BELOW PLASTIC SHEETING

The extent and pattern of root growth found during the final evaluation period indicates that a beneficially deep root system resulted from this design.

Water Use

A considerable water saving potential exists with this design when compared with surface systems, since water is applied only and directly to the root ball area and is not lost to weed growth, evaporation, or run off. Possible future research will include water metering of this system to compare with water use of a traditional surface system under the same soil, plant, and climate conditions.

Sensitivity of System

The sensitivity of the test system to varying plant needs caused by differences in soil, exposure, temperature, etc. is the result of using adjustable bubbler heads at each tree, a tensiometer per each control valve section, and an automatic controller to allow for selection of the time of day for which the system is to come on, as well as limit the length of time the system is to operate during each cycle.

This combination of adjustable bubbler heads, tensiometer and automatic controller performed as anticipated during the research period, and soil moisture readings and visual observations indicated adequate levels of moisture for optimum root growth.

Aesthetics

Since only two, 4" diameter, concrete end plugs are visible at each tree, and weed growth is not promoted, the system has little significant adverse visual impact. (See Figure 9).

Figure 9
FINISHED INSTALLATION SHOWING VISUAL IMPACT ON AREA

The only forseeable adverse impact that this design has on the aesthetics is with the color of the concrete end plugs. The light gray color of the concrete is in harsh contrast to the surrounding soil. This impact could be lessened however by coloring the plugs to blend in with the surroundings.

Weed Growth

Weed growth was successfully discouraged by applying the water below the surface, thereby allowing the top 12 inches of soil to dry out. Weed growth observed at the research site appeared to be no greater than that of adjacent areas supported by natural precipitation only.

Vandalism

The probability of vandalism is significantly reduced by the fact that the system is below ground, and therefore out of sight with the exception of the concrete end plugs. The end plugs are the only items that could be easily vandalized from this system, and they would be less conspicuous if colored as discussed previously and therefore less likely to be vandalized.

Economics

The total economics of this design when compared with other irrigation systems is not fully evaluated at this time and may differ with application.

The cost of component parts and installation is expected to be greater with the test system than with most other systems; however, maintenance cost is anticipated to be lower.

While the "SUB-SURFACE INFILTRATION SYSTEM" is comprised mainly of components typical to most presently available surface and subsurface systems, additional parts are used such as filter cloth, gravel corrugated drain pipe, concrete end plugs and plastic sheeting. The cost of these additional parts combined with the labor cost involved in their installation, increased the component and installation cost of the complete system above that of most others.

The cost involved in maintenance appears to be less with the system than with commercially available sub surface systems for the following reasons:

A. Drip or trickle systems require complex filtration systems that necessitate periodic maintenance, emitters clog up easily, clogged emitters are difficult to locate, and rodents often cause extensive damage requiring frequent repairs. Each of these involve additional man hours and dollars to maintain.

B. Mechanical subsurface irrigators tend to fail after a period of use as any mechanical device will. They cannot be visually inspected to assure that they are operating, and frequently the first sign of failure is the tree drying out and turning brown. Often the tree cannot be saved at that point. Replacement cost of plants is high, and repair or replacement of the subsurface irrigator would be required.

The maintenance cost is expected to be less with this system than with commercially available surface systems for the following reasons:

A. Water is applied a minimum of 12 inches below the surface, thereby discouraging weed growth and in turn eliminating the need for and cost of *weed control.*

B. Since water is dispersed below the surface, none is lost to evaporation, run off or weed growth. In addition, the system uses a moisture detection device such as a tensiometer, which allows water to be applied only when the plants require it. These two features result in the system having *low water use.*

C. *Reduction in vandalism* - With the system having a low visual profile, repair and replacement costs are expected to be greatly reduced.

D. *Impacts by the elements* - Elements on the surface, whether they be sand, leaves, mud, weather, etc., do not affect this system as they do surface types. Orifices are not plugged by blowing sand, leaves, etc. Components are not affected, as surface systems are, by continual exposure to the weather. These and other items of concern to surface systems do not apply to this design, and should therefore result in less maintenance required and less cost.

System Components

Components of the design are low in cost, readily available and easy to assemble, requiring no special tools or training to construct.

Adjustable bubbler heads operate with water pressures ranging from as low as 10 PSI to 80 PSI, thereby making it possible to use this design in areas that have low water pressure.

The use of polyethylene pipe and "Turnseal" fittings makes an economical and quick installation; however, the use of polyethylene should be avoided in areas known to have rodent problems.

IMPLEMENTATION OF THE SUB-SURFACE INFILTRATION SYSTEM

The following are several areas where implementation of the "SUB-SURFACE INFILTRATION SYSTEM" would appear to be beneficial:

A. Street trees.

B. Plants that require perpetual watering.

C. Trees in a naturalized urban setting.

D. Trees located in an arid setting.

Construction Guidelines to aid in the systems implementation can be found in Appendices "E".

SOIL MOISTURE MEASURING METHODOLOGY

Soil moisture content was measured during the research period using Gypsum Blocks and a model KS-1 moisture tester manufactured by the Delmhorst Instrument Company.

These gypsum blocks (see Figure 10) were placed at specified depths and distances from the planting hole as shown in Appendix A.

The ends of the gypsum block wire leads were left protruding a few inches above the surface of the soil as shown in Figure 11 and were knotted to make future identification possible.

Figure 10
GYPSUM BLOCKS USED IN MEASURING MOISTURE CONTENT OF THE SOIL

Figure 11
WIRE LEADS FROM GYPSUM BLOCKS

Monthly readings were taken at the numerous test points, (see Figure 12) with the soil moisture content readings plotted on graphs to illustrate water movement through the soil profile (see Appendix B).

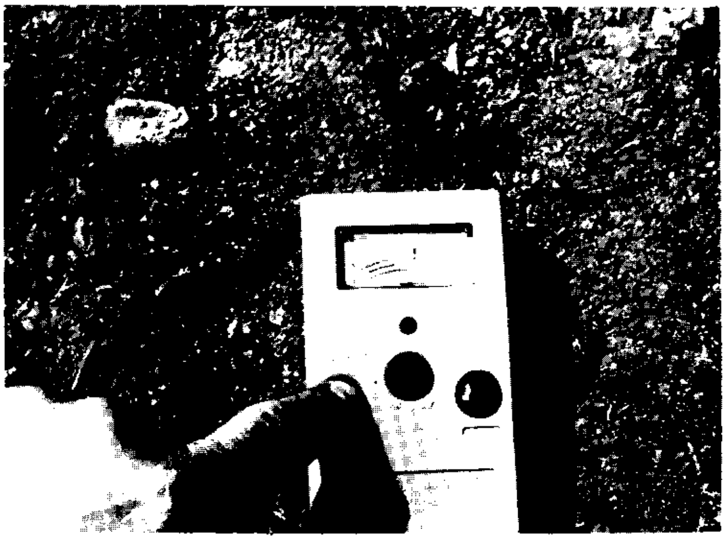
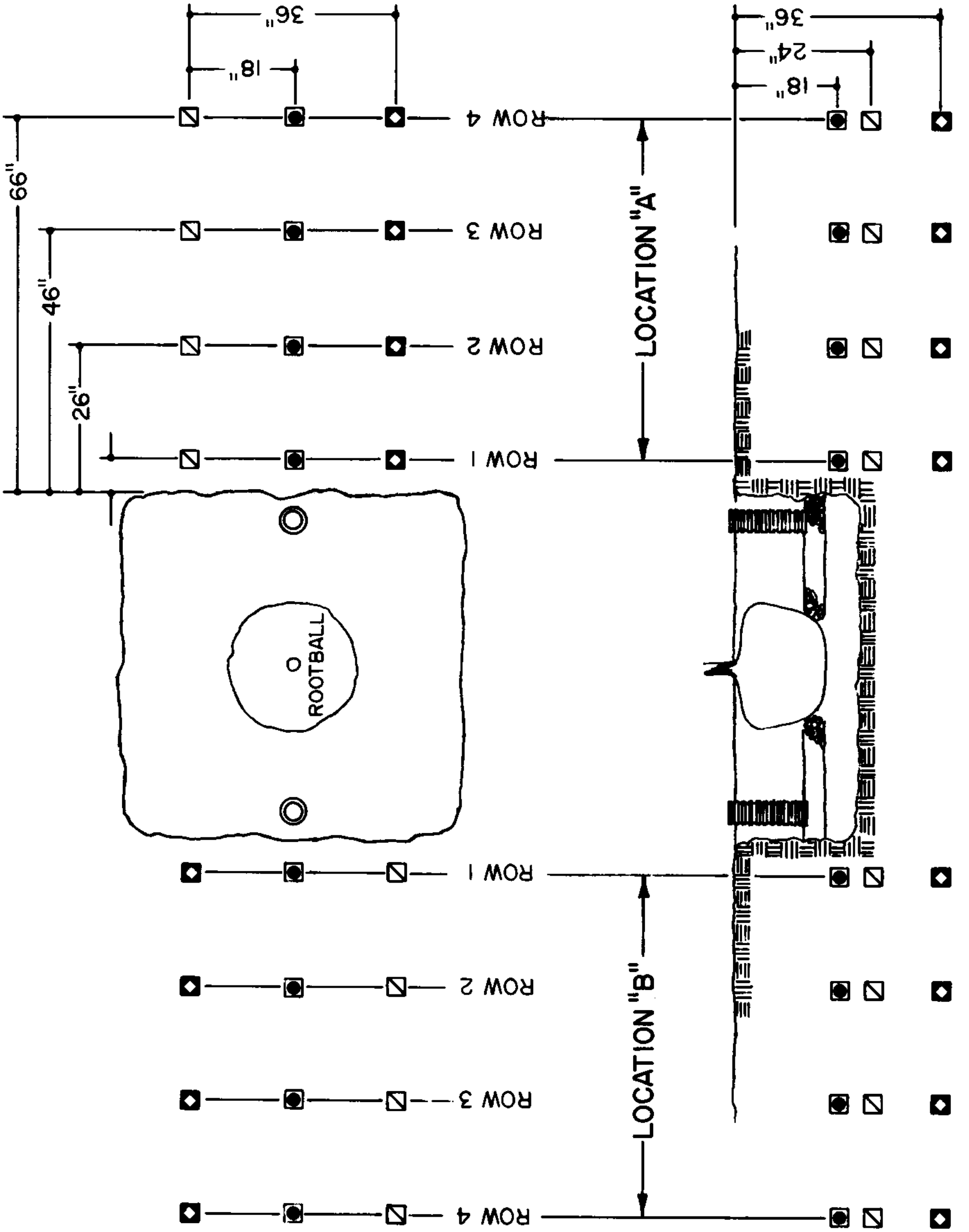


Figure 12
KS-1 METER, READING SOIL MOISTURE CONTENT

APPENDIX

APPENDIX A



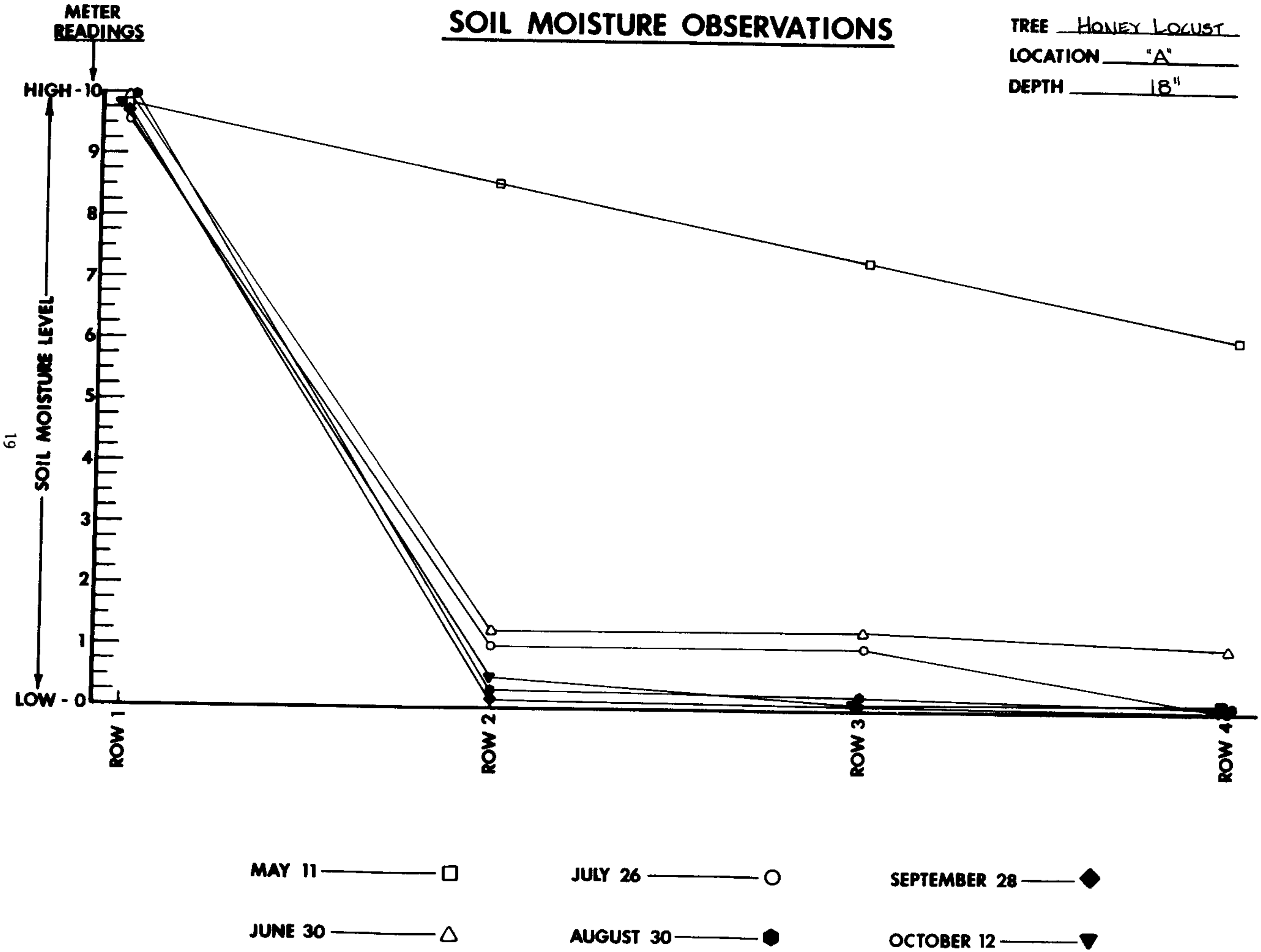
GYPSUM BLOCK LAYOUT

APPENDIX B

Based upon observations of the following graphs, it is concluded that lateral movement of moisture was achieved with this system, under the selected test site conditions. These graphs reflect that soil moisture levels greater than 3.4 extend to approximately the 2nd row of gypsum blocks in most cases, and to nearly the 3rd row in others. A meter reading of 3.4 as shown on the conversion chart for the Delmhorst Moisture Tester, (see Appendix C) shows that approximately 50% of the available moisture in the soil has been used at this point, or inversly 50% remains. This 50% level indicates that an area at least 8 1/2 to 12 feet across contains sufficient moisture to sustain plant life.

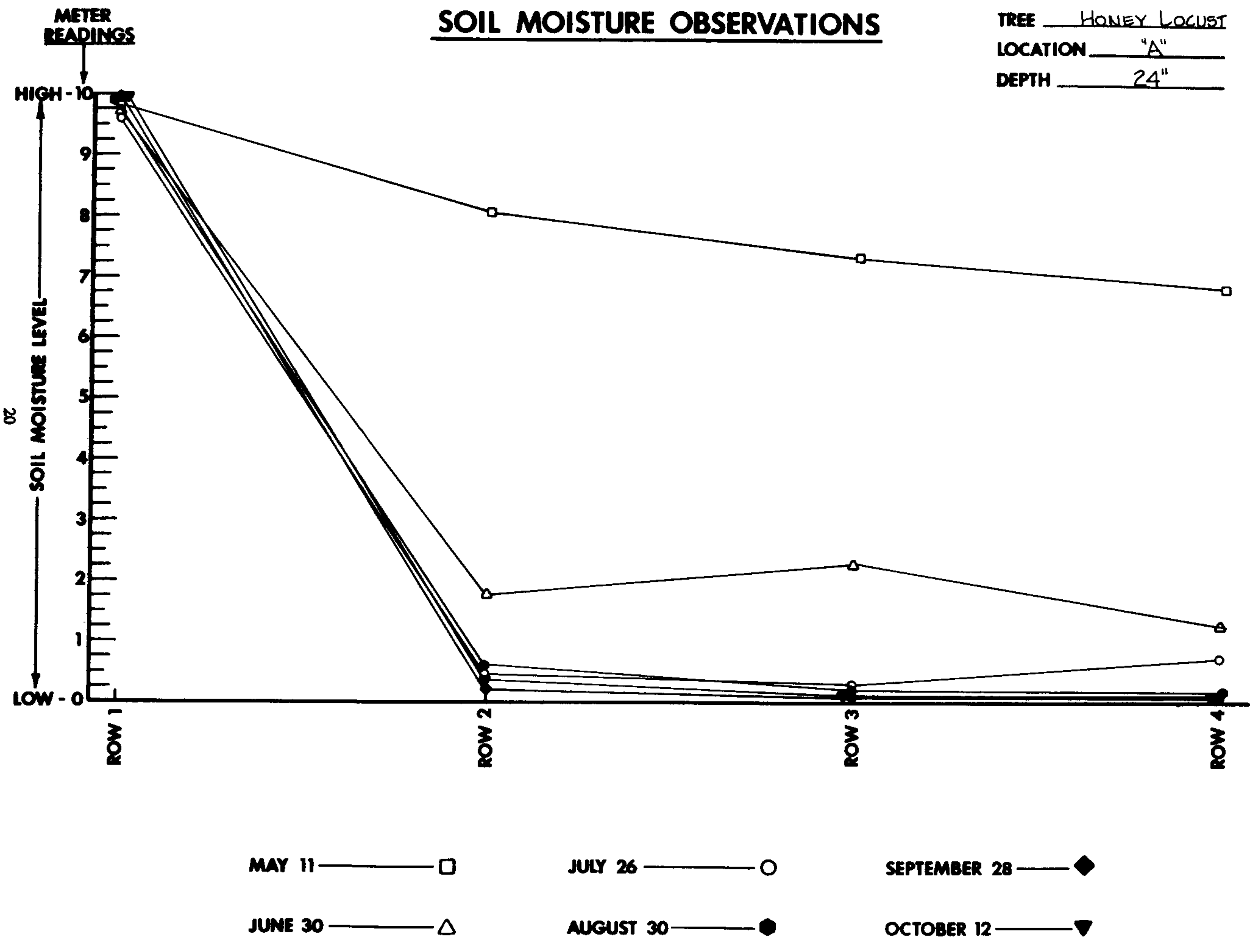
The graphs also show that moisture levels diminish as the distance increases from the planting hole, until in most cases, row 4 moisture levels are nearly "0". This reading of nearly "0" is assumed to approximate the moisture level of the soil in the immediate test areas, supplied only by natural precipitation.

Soil moisture levels found along rows 1, 2 and 3 were normally higher than on row 4, thereby reflecting that these moisture levels are produced by the test system, and the system therefore appears to be responsible for the pattern and extent of root growth found.

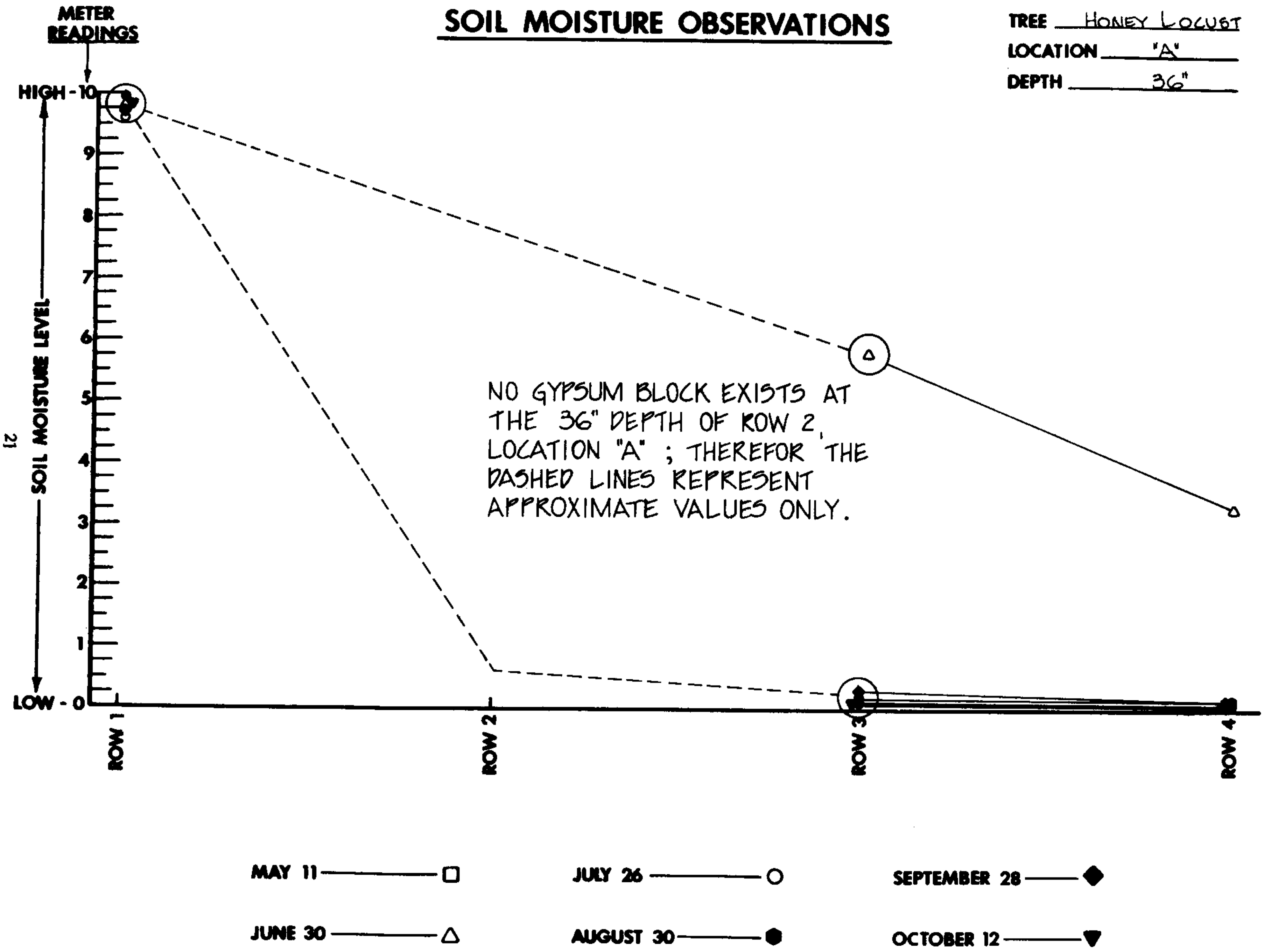

SOIL MOISTURE OBSERVATIONS
TREE Honey Locust
LOCATION "A"
DEPTH 18"
METER READINGS
HIGH - 10
9
8
7
6
5
4
3
2
1
LOW - 0
SOIL MOISTURE LEVEL
ROW 1
ROW 2
ROW 3
ROW 4
MAY 11
JUNE 30
JULY 26
AUGUST 30
SEPTEMBER 28
OCTOBER 12

SOIL MOISTURE OBSERVATIONS

TREE Honey Locust
LOCATION "A"
DEPTH 24"

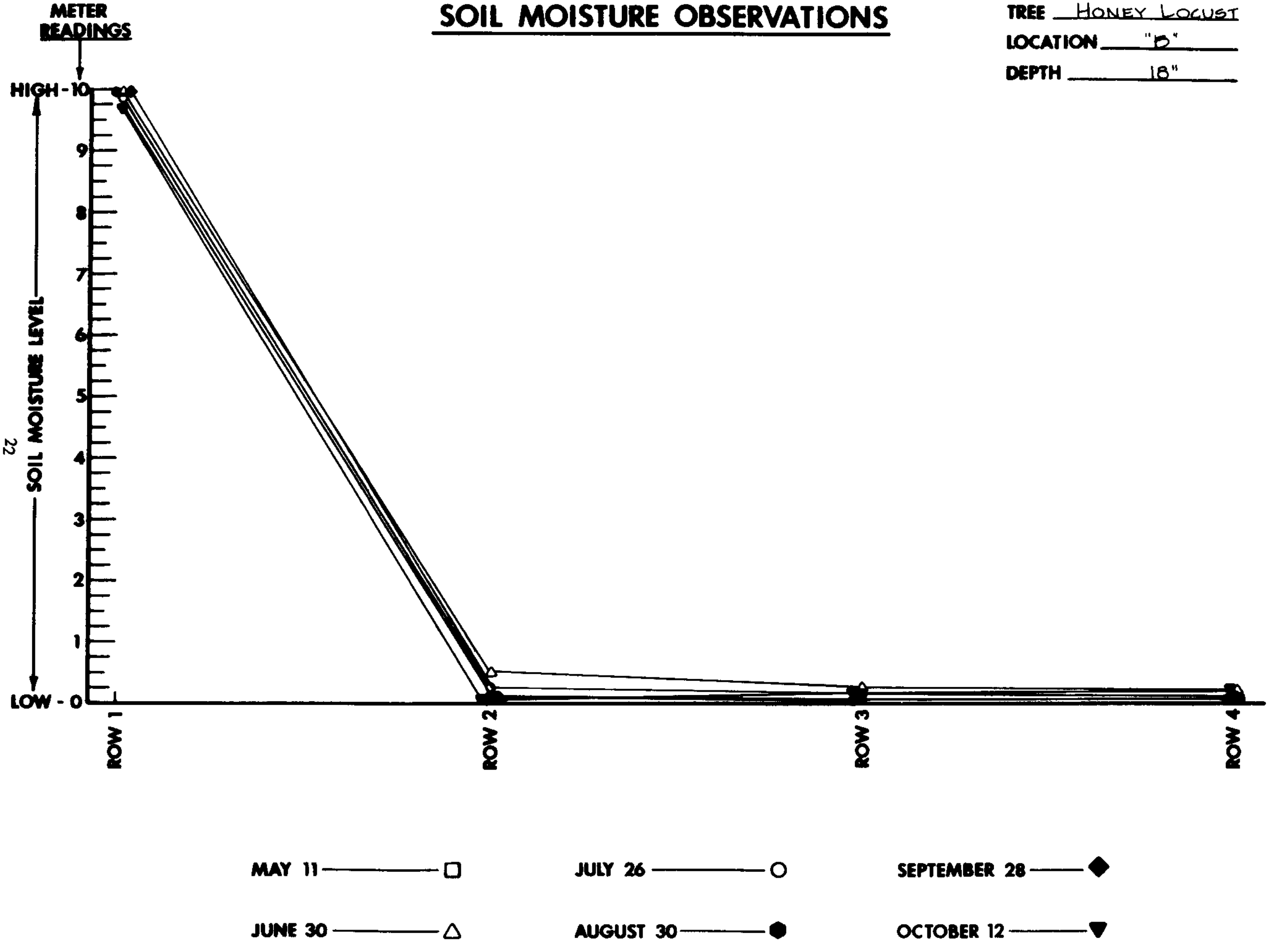


SOIL MOISTURE OBSERVATIONS



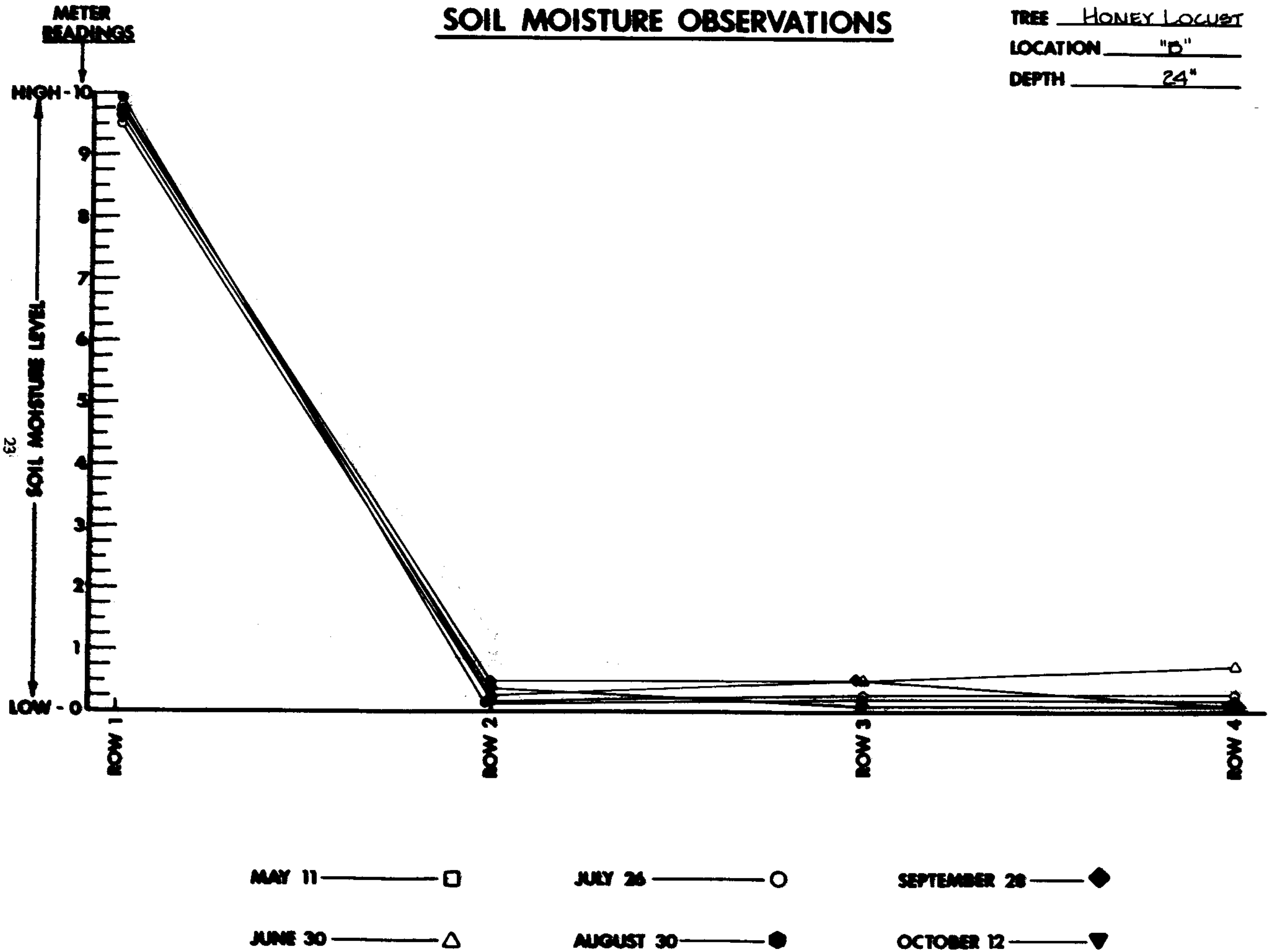
SOIL MOISTURE OBSERVATIONS

TREE Honey Locust
LOCATION "B"
DEPTH 18"



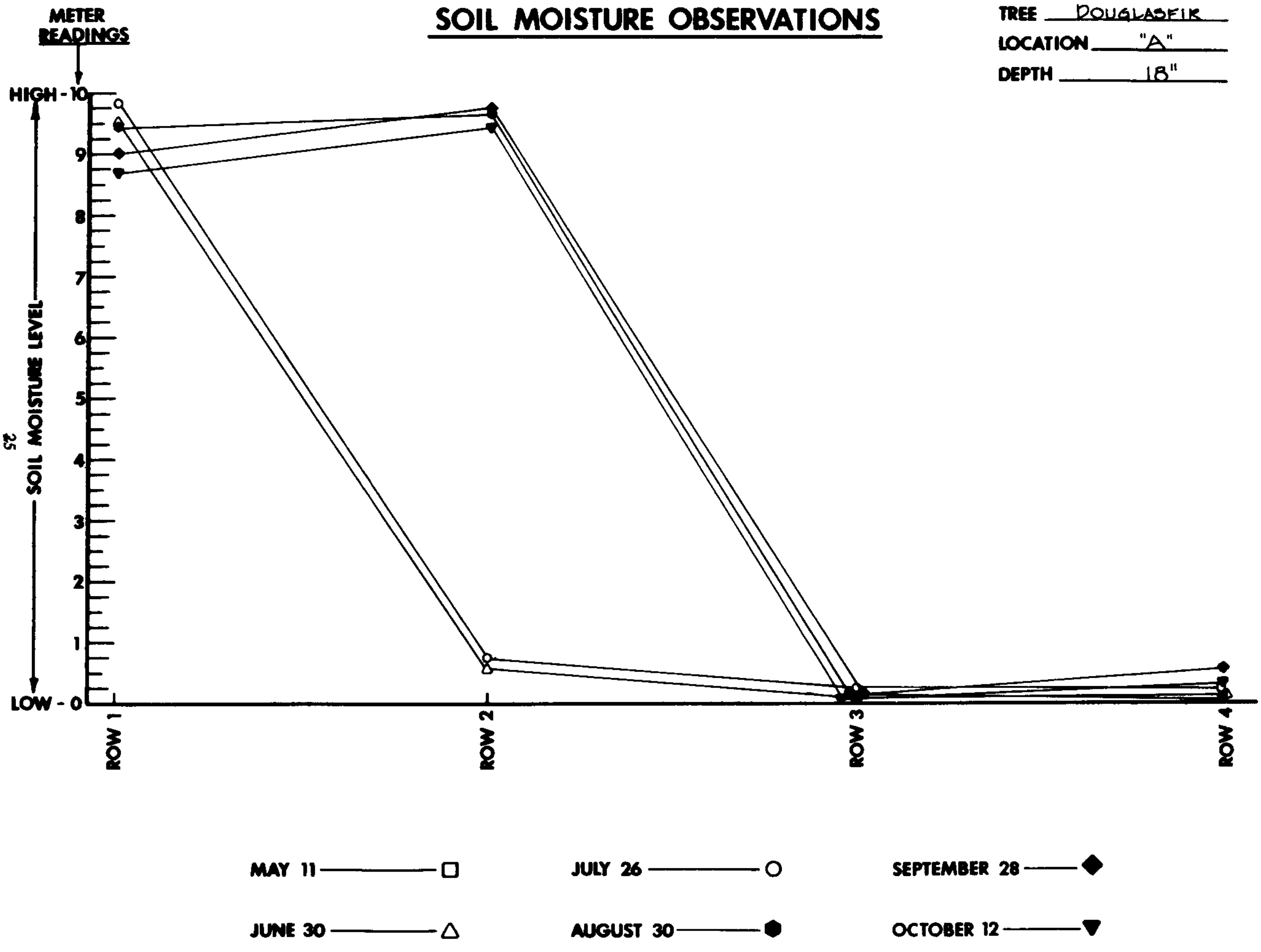
SOIL MOISTURE OBSERVATIONS

TREE Honey Locust
LOCATION "B"
DEPTH 24"



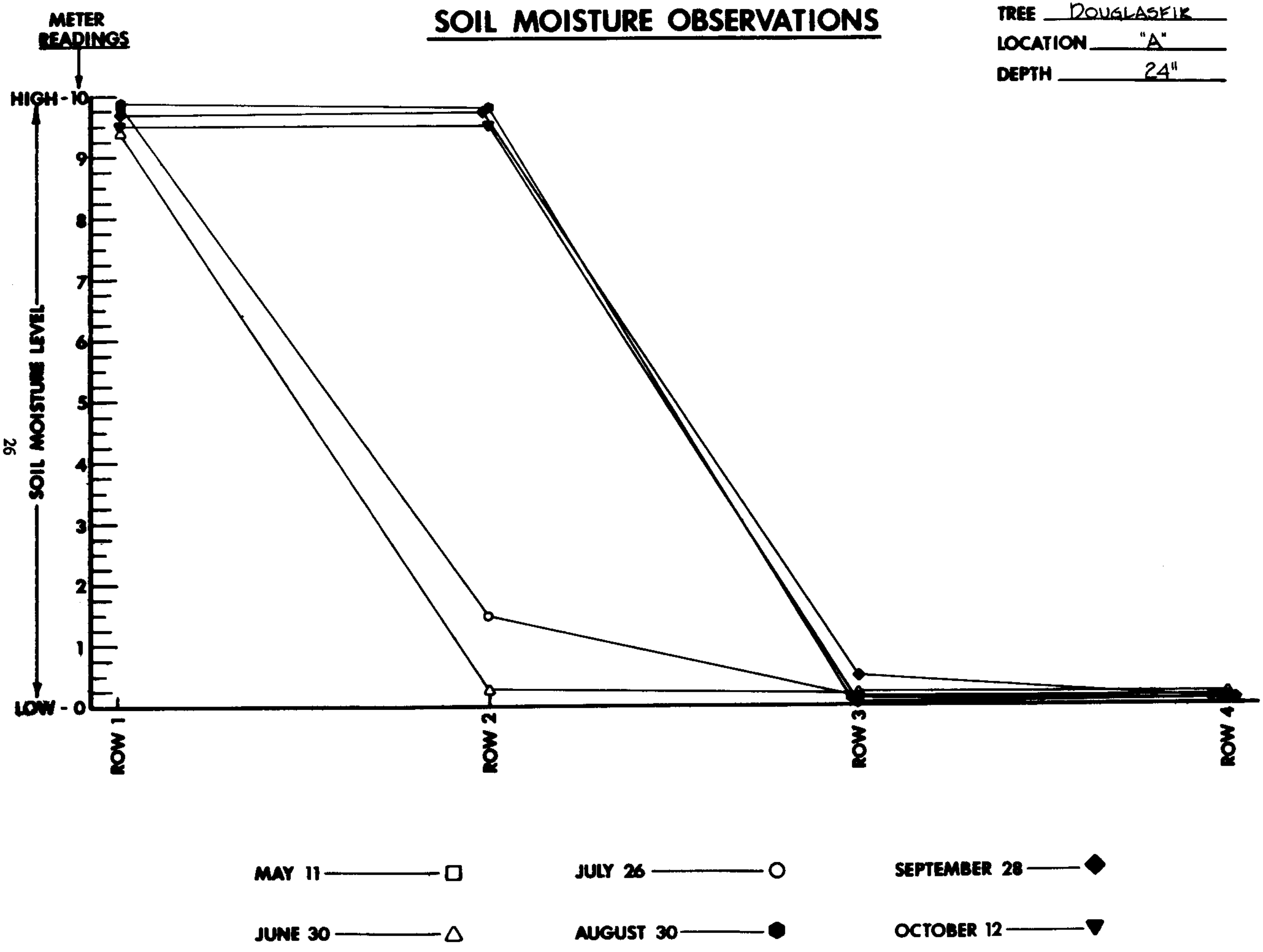
SOIL MOISTURE OBSERVATIONS

TREE DOUGLASFIR
LOCATION "A"
DEPTH 18"

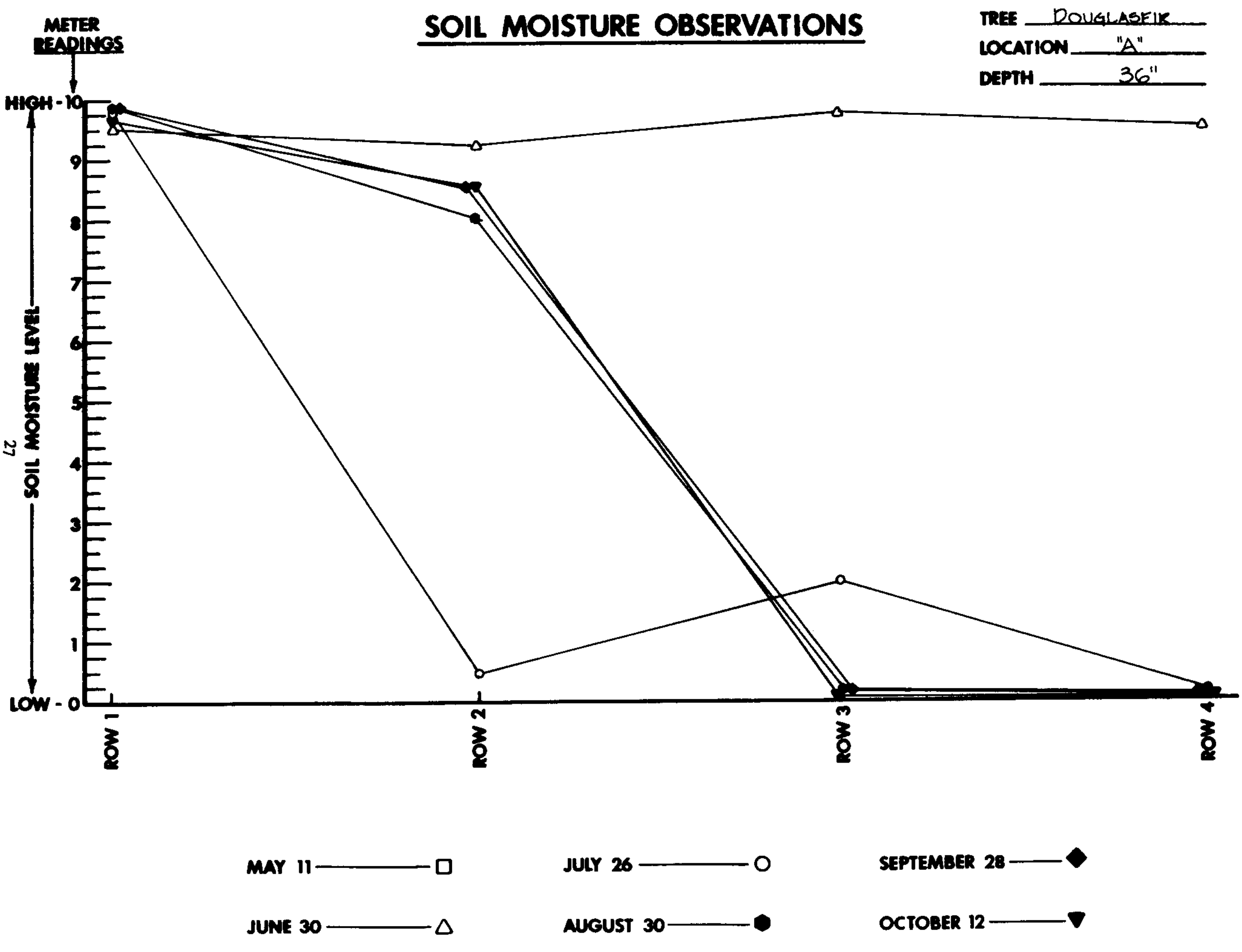


SOIL MOISTURE OBSERVATIONS

TREE Douglasfir
LOCATION "A"
DEPTH 24"

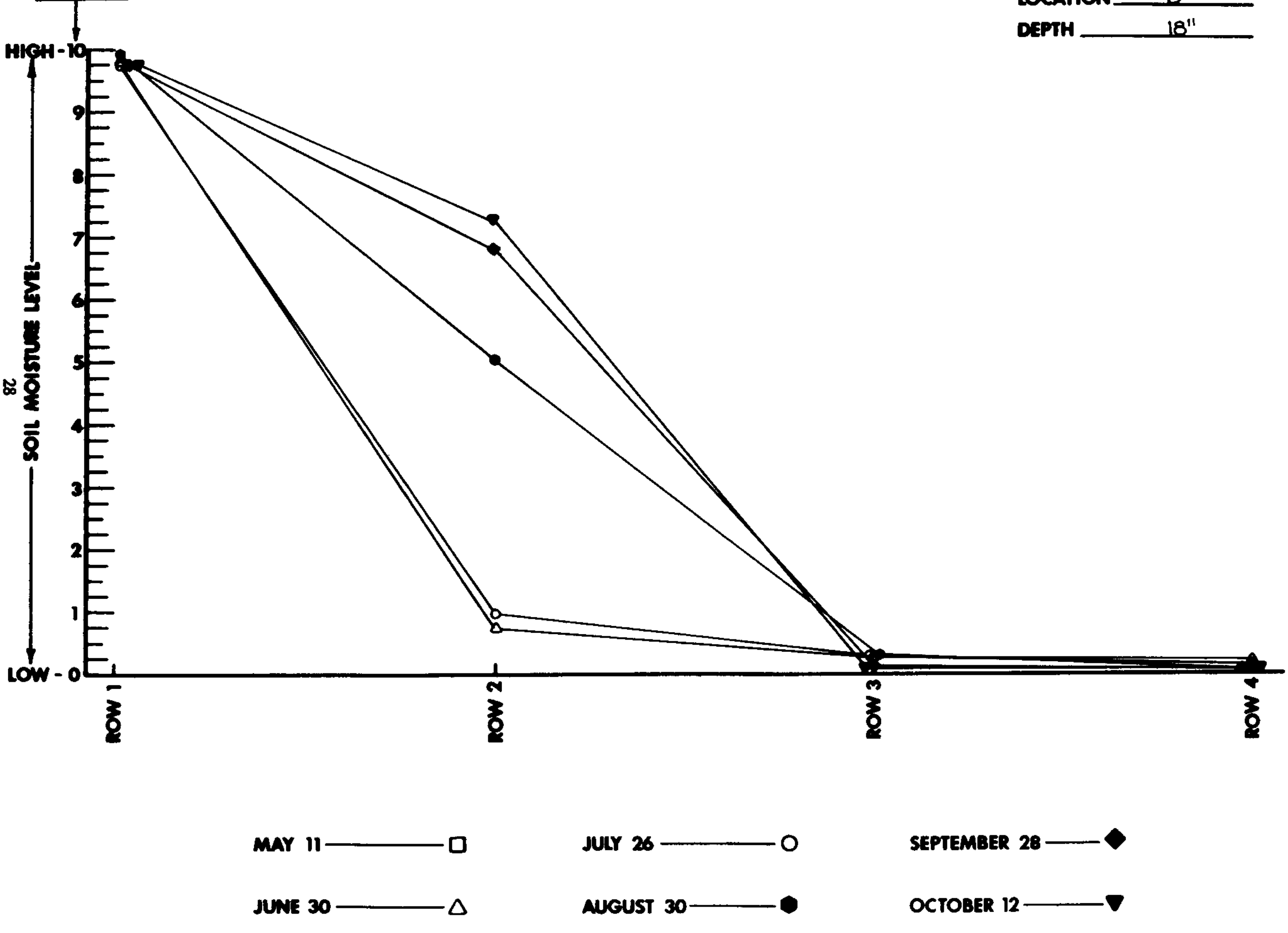


SOIL MOISTURE OBSERVATIONS



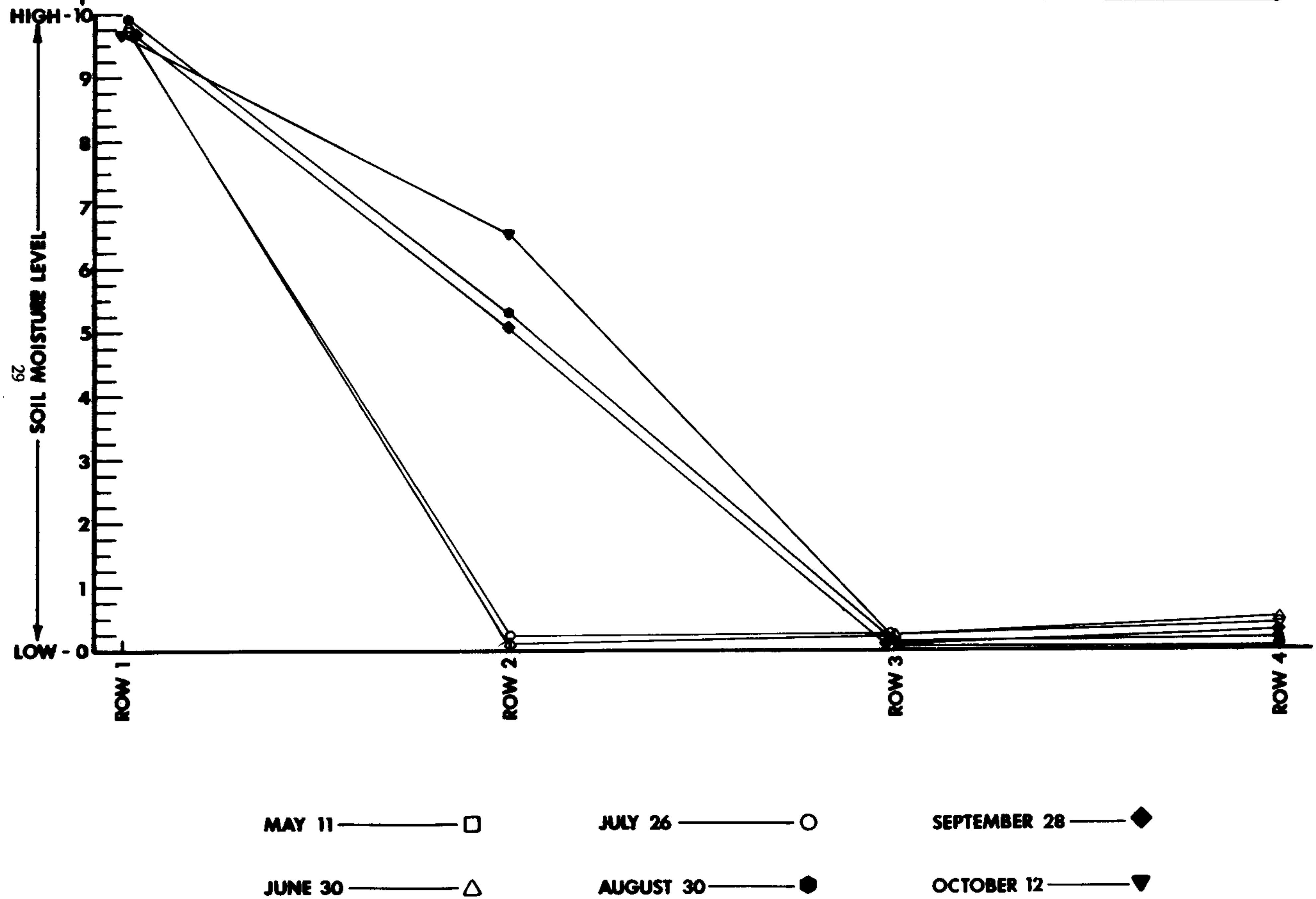
SOIL MOISTURE OBSERVATIONS

TREE: Douglasfir
LOCATION: "B"
DEPTH: 18"



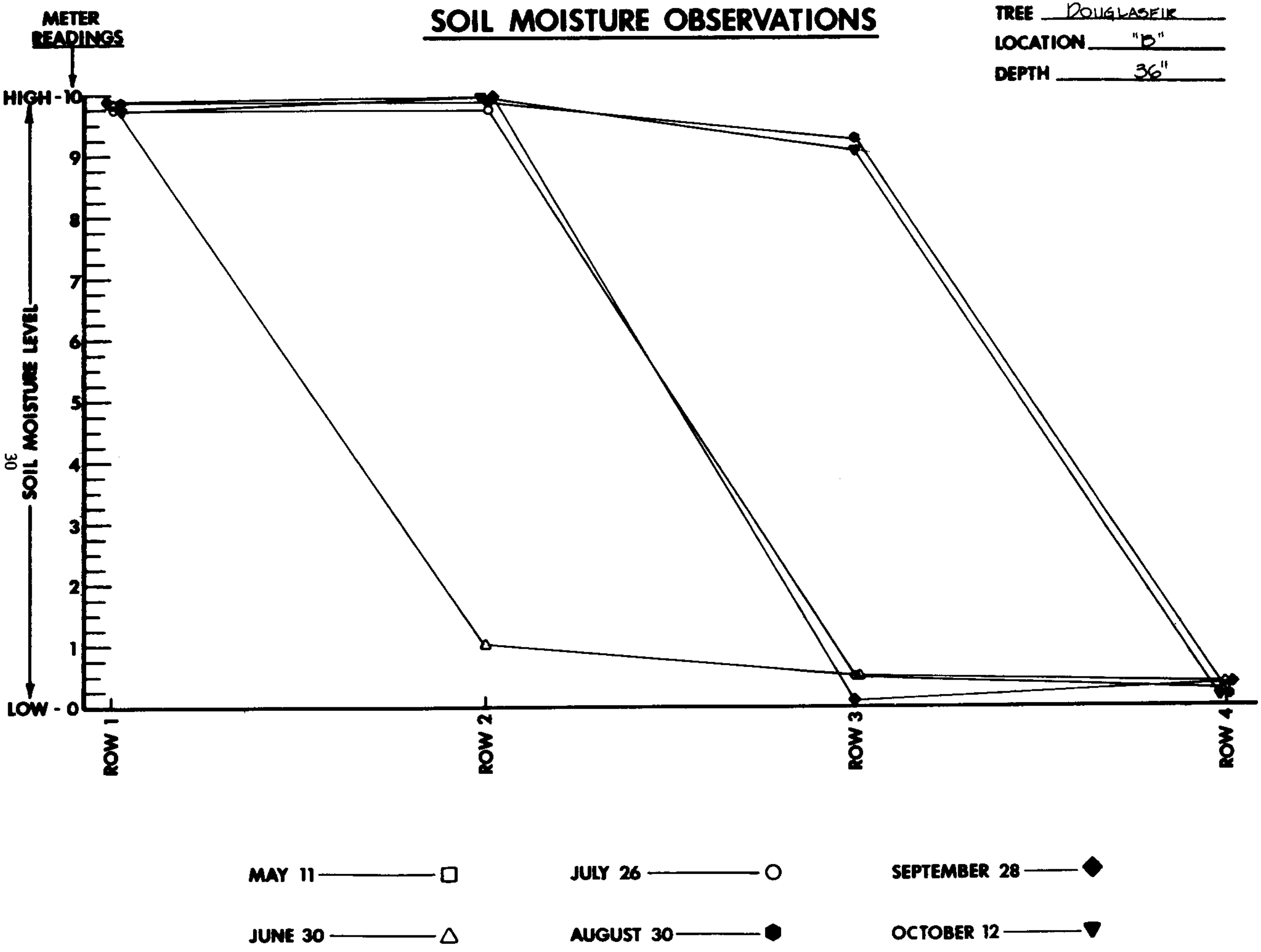
SOIL MOISTURE OBSERVATIONS

TREE Douglasfir
LOCATION "D"
DEPTH 24"



SOIL MOISTURE OBSERVATIONS

TREE Douglasfir
LOCATION "B"
DEPTH 36"



APPENDIX C

Soil moisture content was measured during the research period using Gypsum Blocks and a Model KS-I Moisture Tester manufactured by the Delmhorst Instrument Company.

CONVERSION FOR DELMHORST MOISTURE TESTER MODEL KS-I AND CYLINDRICAL GYPSUM BLOCKS			
MOISTURE TENTION (BARS)	OHMS	METER READING	APPROXIMATE H_2O USED (%)
.2	140	9.8	FIELD CAPACITY
.3	220	9.4	
.4	350	8.5	
.6	700	7.2	25 %
.8	1100	6.1	
1.1	1500	5.2	
1.5	2600	3.8	
1.8	3100	3.4	50 %
2.0	3600	3.0	
3.0	5500	2.2	
6.0	9000	1.5	
15.0	28000	0.6	WILTING POINT

APPENDIX D

RECORD OF EVALUATION AND CLIMATOLOGICAL OBSERVATION CHARTS

The following charts are included in this report only to illustrate the drought conditions that prevailed in the research area during the test period.

This data was recorded at the W. S. U. Tree Fruit Research Center located near the test site, in Wenatchee. Recorded temperatures ranged from a low of 30° to a high of 104°, with over 41 inches total evaporation measured and only 3.31 inches of precipitation accumulated. Transpiration of water through the trees was not included in the total water loss stated above and would compound the dry condition if it were.

STATION W.S.U. TREE FRUIT RESEARCH CENTER (W.S.O. WENATCHEE) | COUNTY CHELAN | STATE WASHINGTON | DATE (Month and Year) APRIL, 1977

WS FORM B-22 (8-74) | U. S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL WEATHER SERVICE

RECORD OF EVAPORATION AND CLIMATOLOGICAL OBSERVATIONS

TIME OF COMPLETE OBSERVATION (Local time): MIDNT — MIDNT | STANDARD TIME IN USE: PACIFIC

DATE	AIR TEMPERATURE °F: 24 Hours Ending at Observation Max.	Min.	At Observation Dry-bulb	Wet-bulb	Dew Point	Supplemental Readings at ___ Dry-bulb	Wet-bulb	Dew Point	WATER TEMP. °F: 24 Hours Ending at Observation Max.	Min.	PRECIPITATION: Time of beginning	Time of ending	Time of beginning	Time of ending	24 Hour Amounts: Rain, Melted snow, etc. (in. & hundredths)	Snow, Ice Pellets, Hail (in. & tenths)	At Obsn. Snow, Ice Pellets, Hail, Ice on ground (in.)	WIND: Anemometer Dial Reading	24 Hour Movement	EVAPORATION (inches & hundredths): Gage Reading or Amount Added +	Reading When Tank Filled or Amount Removed −	Amount of Evaporation	ADDITIONAL DATA/REMARKS: TOTAL SINCE 4-1-77
1	61	35							61	38								9414	51	.07		.07	
2	68	31							63	38								9549	135	.12		.12	.19
3	75	46							72	40								9615	66	.45		.45	.64
4	81	36							75	42								9631	16	.09		.09	.73
5	79	36							76	44								9645	14	.27		.27	1.00
6	82	37							75	45								9660	15	.13		.13	1.13
7	82	39							78	46								9695	35	.21		.21	1.33
8	68	37							63	48					.07			9753	58	.09		.16	1.49
9	58	31							55	38								9796	43	.10		.10	1.59
10	62	34							62	38								9835	39	.13		.13	1.72
11	66	42							68	40								9915	80	.24		.24	1.96
12	68	32							63	38								9947	32	.17		.17	2.13
13	60	42							65	41								0053	106	.25		.25	2.38
14	61	38							65	38								0088	35	.16		.16	2.54
15	64	43							70	41								0172	84	.24		.24	2.78
16	56	37							60	44								0252	80	.19		.19	2.97
17	60	30							64	37								0299	47	.18		.18	3.15
18	56	31							62	36								0389	90	.17		.17	3.32
19	58	32							64	42								0465	76	.27		.27	3.59
20	63	30							66	38								0480	15	.13		.13	3.72
21	69	42							70	39								0502	22	.15		.15	3.87
22	81	45							82	47								0517	15	.18		.18	4.05
23	89	43							85	53								0529	12	.21		.21	4.26
24	94	46							88	54								0540	11	.24		.24	4.50
25	85	50							87	56					.01			0602	62	.15		.16	4.66
26	68	45							71	47					.04			0643	41	.26		.30	4.96
27	74	38							77	44								0656	13	.17		.17	5.13
28	82	38							80	45								0700	44	.24		.24	5.37
29	75	54							73	52								0757	57	.27		.27	5.64
30	80	42							79	49								0770	13	.19		.19	5.83
31																							
Sum	2120	1160													.12								
Avg.	70.7	38.7												Greatest	.07					Adjusted Total			

OBSERVER | STATION | DATE (Month and Year)

WS FORM B-22 (8-74) SUPERSEDES PREVIOUS EDITION

STATION: WSU TREE FRUIT RESEARCH CENTER | COUNTY: CHELAN | STATE: WASHINGTON | DATE (Month and Year): MAY 1977

WS FORM E-22 (8-74) — U. S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL WEATHER SERVICE

RECORD OF EVAPORATION AND CLIMATOLOGICAL OBSERVATIONS

TIME OF COMPLETE OBSERVATION (Local time): MIDNT — MIDNT | STANDARD TIME IN USE: PACIFIC

DATE	Air Temp. °F 24 Hours Ending at Observation Max.	Min.	At Observation Dry-bulb	Wet-bulb	Dew Point	Supplemental Readings at Dry-bulb	Wet-bulb	Dew Point	Water Temp. °F 24 Hours Ending at Observation Max.	Min.	Precipitation Time of beginning	Time of ending	Time of beginning	Time of ending	24 Hour Amounts Rain, melted snow, etc. (in. & hundredths)	Snow, ice pellets, hail (in. & tenths)	At Obsn. Snow, ice pellets, hail, ice on ground (in.)	Wind Anemometer Dial Reading (448)	24 Hour Movement	Evaporation (inches & hundredths) Gage Reading or Amount Added +	Reading When Tank Filled or Amount Removed −	Amount of Evaporation	Additional Data/Remarks: TOTAL SINCE 4-1
1	84	46							62	53								825	55	.23		.23	6 06
2	64	49							64	50					.01			843	18	.04		.05	6 11
3	61	46							62	48					.15			891	48		.02	.13	6 24
4	59	42							59	43					.01			929	38	.11		.12	6 36
5	64	33							69	38								974	45	.21		.21	6 57
6	65	33							61	40					.02			998	24	.03		.05	6 62
7	65	42							66	41					.08			1014	16		.01	.07	6 69
8	72	38							80	46								1031	17	.20		.20	6 89
9	80	38							81	48								1049	18	.15		.15	7 04
10	63	49							58	51					.11			1109	60	0	0	.11	7 15
11	65	44							73	44								1146	37	.20		.20	7 35
12	71	36							72	43								1163	17	.15		.15	7 50
13	74	45							72	45								1193	30	.20		.20	7 70
14	65	47							72	48								1262	69	.29		.29	7 99
15	68	42							65	45					T			1300	38	.13		.13	8 12
16	67	38							65	45								1365	65	.12		.12	8 24
17	72	53							75	46								1457	92	.27		.27	8 51
18	72	53							72	45					T			1489	32	.11		.11	8 62
19	73	43							77	49								1567	78	.33		.33	8 95
20	77	48							77	50								1618	51	.22		.22	9 17
21	69	56							74	49								1699	81	.36		.36	9 53
22	76	43							80	46								1735	36	.24		.24	9 77
23	63	48							57	48					.25			1776	41		.13	.12	9 89
24	70	40							71	45								1804	28	.16		.16	10 05
25	74	36							76	45								1840	36	.27		.27	10 32
26	64	49							72	53								1894	54	.23		.23	10 55
27	64	38							69	43								1935	41	.19		.19	10 72
28	67	41							65	44					T			1996	61	.20		.20	10 92
29	72	47							77	45								2055	59	.32		.32	11 24
30	69	39							66	46					T			2069	14	.08		.08	11 32
31	67	52							66	48					.03			2087	18	.04		.07	11 39
Sum	2132	1354													.66								
Avg.	68.8	43.7												Greatest	.25					Adjusted Total			

OBSERVER | STATION | DATE (Month and Year)

SUPERSEDES PREVIOUS EDITION

STATION WSU TREE FRUIT RESEARCH CENTER | COUNTY CHELAN | STATE WASHINGTON | DATE (Month and Year) JUNE 1977

WS FORM E-22 (8-74)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

TIME OF COMPLETE OBSERVATION (Local time): MIDNT-MIDNT

STANDARD TIME IN USE: PACIFIC

RECORD OF EVAPORATION AND CLIMATOLOGICAL OBSERVATIONS

DATE	AIR TEMPERATURE °F: 24 Hours Ending at Observation: Max.	Min.	At Observation: Dry-bulb	Wet-bulb	Dew Point	Supplemental Readings at ___: Dry-bulb	Wet-bulb	Dew Point	WATER TEMP. °F: 24 Hours Ending at Observation: Max.	Min.	PRECIPITATION: Time of beginning	Time of ending	Time of beginning	Time of ending	24 Hour Amounts: Rain, melted snow, etc. (in. & hundredths)	Snow, Ice Pellets, Hail (in. & tenths)	At Obsn. Snow, Ice Pellets, Hail, Ice on ground (in.)	WIND: Anemometer Dial Reading (Miles)	24 Hour Movement 3007	EVAPORATION (inches & hundredths): Gage Reading or Amount Added +	Reading When Tank Filled or Amount Removed −	Amount of Evaporation	ADDITIONAL DATA REMARKS: TOTAL SINCE 4-1-77	
1	70	46							69	57					0.21			2127	40		-.07	.14	11.53	
2	70	39							73	45								2154	27	.22		.22	11.75	
3	69	50								47					.02									
4	72	52							•	54					.08									
5	88	48							92									2196	42	.29		.39	12.14	3 DAY TOTAL
6	94	58							91									2234	38	.29		.29	12.43	
7	97	71							96	64								2305	71	.39		.39	12.82	
8	72	57							77	56								2400	95	.39		.39	13.21	
9	82	51							86	49								2422	22	.26		.26	13.47	
10	87	46							90	51														
11	86	61													.02									
12	80	53													.11			2514	92	.59		.72	14.19	3 DAY TOTAL
13	78	50							73	58					.34			2527	13		-.21	.13	14.32	
14	86	49							87	57								2565	38	.29		.29	14.61	
15	84	54							83	57								2596	31	.23		.23	14.84	
16	88	53							91	57								2610	14	.27		.27	15.11	
17	94	54							94	59								2621	11	.28		.28	15.39	
18	99	56							96	63								2659	38	.35		.35	15.74	
19	94	65							90	64								2728	69	.44		.44	16.18	
20	83	63							84	57								2803	75	.37		.37	16.55	
21	87	64							89	58								2851	48	.30		.30	16.85	
22	84	61							87	60								2907	56	.41		.41	17.26	
23	92	52							89	56								2944	37	.22		.22	17.48	
24	93	62							91	57								2997	53	.40		.40	17.88	
25	91	64							89	56								3071	74	.45		.45	18.33	
26	86	63							84	56								3144	73	.42		.42	18.75	
27	84	62							84	56								3223	79	.42		.42	19.17	
28	84	62							83	56								3300	77	.35		.35	19.52	
29	86	60							86	54								3352	52	.34		.34	19.86	
30	72	54							91	54								3385	33	.35		.35	20.21	
31																								
Sum	2554	1681													.78									
Avg.	85.1	56.1												Greatest	.34						Adjusted Total		8.82	

OBSERVER | STATION | DATE (Month and Year)

WS FORM E-22 (8-74) SUPERSEDES PREVIOUS EDITION

WS FORM E-22 (6-74)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF EVAPORATION AND CLIMATOLOGICAL OBSERVATIONS

STATION: TREE FRUIT RESEARCH CENTER
COUNTY: CHELAN
STATE: WASH.
DATE (Month and Year): JULY, 1977

TIME OF COMPLETE OBSERVATION (Local time): MID'N'T – MID'N'T
STANDARD TIME IN USE: PACIFIC

DATE	Air Temp. °F 24 Hours Ending at Observation Max.	Min.	At Observation Dry-bulb	Wet-bulb	Dew Point	Supplemental Readings at ___ Dry-bulb	Wet-bulb	Dew Point	Water Temp. °F 24 Hours Ending at Observation Max.	Min.	Precipitation Time of beginning	Time of ending	Time of beginning	Time of ending	24 Hour Amounts Rain, Melted snow, etc. (in. & hundredths)	Snow, Ice Pellets, Hail (in. & tenths)	At Obsn. Snow, Ice Pellets, Hail, Ice on ground (in.)	Wind Anemometer Dial Reading (Miles) 3385	24 Hour Movement	Evaporation (inches & hundredths) Gage Reading or Amount Added +	Reading When Tank Filled or Amount Removed −	Amount of Evaporation	Additional Data Remarks TOTAL SINCE 4-1-77 20.21
1	89	58							88	58								3458	73	.45		.45	20.66
2	72	55							78	52								3531	73	.36		.36	21.02
3	72	56							71	54								3586	55	.22		.22	21.24
4	75	51							75	51								3636	50	.25		.25	21.49
5	73	50							75	50								3679	43	.22		.22	21.71
6	79	50							85	51								3721	42	.30		.30	22.01
7	86	45							85	53								3740	19	.30		.30	22.31
8	90	49							85	56								3794	54	.30		.30	22.61
9	77	62							78	58								3905	111	.34		.34	22.95
10	84	60							86	53								3965	60	.41		.41	23.36
11	86	59							88	55					T			4017	52	.37		.37	23.73
12	74	59							78	58								4118	101	.41		.41	24.14
13	84	59							87	53								4188	70	.30		.30	24.44
14	89	60							90	55								4237	49	.32		.32	24.76
15	93	63							92	59								4290	53	.36		.36	25.12
16	88	64							84	61								4347	57	.30		.30	25.42
17	81	59							80	58								4407	60	.28		.28	25.70
18	82	57							86	53								4456	49	.35		.35	26.05
19	84	53							86	53								4481	25	.27		.27	26.32
20	83	48							85	55								4495	14	.18		.18	26.50
21	92	59							90	56								4544	49	.42		.42	26.92
22	94	58							93	61								4595	51	.35		.35	27.27
23	99	61							95	61								4610	15	.29		.29	27.56
24	94	56							86	62								4618	8	.15		.15	27.71
25	94	62							84	62								4635	17	.15		.15	27.86
26	94	63							92	62								4652	17	.27		.27	28.13
27	97	58							91	63								4696	44	.25		.25	28.38
28	79	61							84	64					.03			4773	77	.30		.33	28.71
29	77	56							81	55								4839	66	.32		.32	29.03
30	90	53							89	55								4859	20	.33		.33	29.36
31	97	57							96	57								4879	20	.30		.30	29.66
Sum	2658	1761																					
Avg.	85.7	56.8												Greatest						Adjusted Total			

OBSERVER: MEAN = 71.3
STATION
DATE (Month and Year)

WS FORM E-22 (6-74) SUPERSEDES PREVIOUS EDITION

STATION WSU TREE FRUIT RESEARCH CENTER | COUNTY CHELAN | STATE WASHINGTON | DATE (Month and Year) AUGUST 1977

TIME OF COMPLETE OBSERVATION (Local time) MIDNT – MIDNT | STANDARD TIME IN USE PACIFIC

WS FORM E-22 (8-74)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF EVAPORATION AND CLIMATOLOGICAL OBSERVATIONS

DATE	AIR TEMPERATURE °F: 24 Hours Ending at Observation Max.	Min.	At Observation Dry-bulb	Wet-bulb	Dew Point	Supplemental Readings at ___ Dry-bulb	Wet-bulb	Dew Point	WATER TEMP. °F: 24 Hours Ending at Observation Max.	Min.	PRECIPITATION: Time of beginning	Time of ending	Time of beginning	Time of ending	24 Hour Amounts: Rain, Melted snow, etc. (in. & hundredths)	Snow, Ice Pellets, Hail (in. & tenths)	At Obsn. Snow, Ice Pellets, Hail, Ice on ground (in.)	WIND: Anemometer Dial Reading (Miles)	24 Hour Movement 4879	EVAPORATION (inches & hundredths): Gage Reading or Amount Added +	Reading When Tank Filled or Amount Removed −	Amount of Evaporation	1966 ADDITIONAL DATA REMARKS: TOTAL SINCE 4-1-77
1	101	60							99	64								4911	32	.38		.38	30 04
2	102	64							99	65								4940	29	.33		.30	30 37
3	100	67							95	61								4977	37	.36		.36	30 73
4	93	64							89	66								5005	28	.29		.29	31 02
5	89	57							83	66					.01			5019	14	.13		.14	31 16
6	97	53							90	58								5037	18	.17		.17	31 33
7	98	59							92	60								5062	25	.39		.39	31 72
8	92	62							87	62								5123	61	.42		.42	32 14
9	97	61							94	61								5141	18	.25		.25	32 39
10	97	61							95	62								5155	14	.50		.30	32 69
11	100	59							95	63								5168	13	.27		.27	32 96
12	101	61							94	64								5192	24	.33		.33	33 29
13	104	62							96	65								5220	28	.36		.36	33 65
14	101	66							95	66								5240	20	.32		.32	33 97
15	96	59							92	65								5255	15	.28		.28	34 25
16	100	56							94	62								5266	11	.26		.26	34 51
17	101	57							94	62								5280	14	.24		.24	34 75
18	102	58							91	63								5316	36	.40		.40	35 15
19	103	63							95	63								5328	12	.24		.24	35 39
20	103	59							96	66								5350	22	.27		.27	35 66
21	93	64							87	65	0900	1000			T			5414	64	.25		.25	35 91
22	87	67							94	52	~~0600~~							5492	78	.42		.42	36 33
23	81	60							76	59	0600	0700	0900 / 1900	1000 / 2359	.04			5523	31	.11		.15	36 48
24	75	53							74	58					.04			5550	37	.16		.20	36 68
25	71	50							67	53					.04			5572	22	.04		.08	36 74
26	74	50							77	53					T			5618	46	.24		.24	36 98
27	76	47							72	51								5640	22	.14		.14	37 12
28	76	55							78	52					T			5674	34	.19		.19	37 31
29	70	48							67	53					.17			5700	26		-.08	.09	37 40
30	74	51							77	53					.23			5756	56	.18		.41	37 81
31	79	46							81	49								5766	10	.16		.16	37 97
Sum	2835	1799													.53								
Avg.	91.4	58.0												Greatest	.23					Adjusted Total			

OBSERVER | STATION | DATE (Month and Year)

WS FORM E-22 (8-74) SUPERSEDES PREVIOUS EDITION

STATION: W.S.U TREE FRUIT RESEARCH CENTER	COUNTY: CHELAN	STATE: WASHINGTON	DATE (Month and Year): SEPT. 1977	WS FORM B-32 (8-74)
TIME OF COMPLETE OBSERVATION (Local time): MIDNT — MIDNT	STANDARD TIME IN USE: PACIFIC			U. S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE

RECORD OF EVAPORATION AND CLIMATOLOGICAL OBSERVATIONS

DATE	AIR TEMPERATURE °F: 24 Hours Ending at Observation Max.	Min.	At Observation Dry-bulb	Wet-bulb	Dew Point	Supplemental Readings at Dry-bulb	Wet-bulb	Dew Point	WATER TEMP. °F 24 Hours Ending at Observation Max.	Min.	PRECIPITATION Time of beginning	Time of ending	Time of beginning	Time of ending	24 Hour Amounts Rain, Melted snow, etc. (in. & hundredths)	Snow, Ice Pellets, Hail (in. & tenths)	At Obsn Snow, Ice Pellets, Hail, Ice on ground (in.)	WIND Anemometer Dial Reading (Miles)	24 Hour Movement 5766	EVAPORATION (inches & hundredths) Gage Reading or Amount Added +	Reading When Tank Filled or Amount Removed −	Amount of Evaporation	ADDITIONAL DATA/REMARKS TOTAL SINCE 4-1-77
1	78	47							79	52								5780	14	.16		.16	38 13
2	75	53							75	54								5796	16	.07		.07	38 20
3	82	50							80	55								5808	12	.15		.15	38 35
4	79	58							76	55	1000	1230			.03			5823	15	.07		.10	38 45
5	82	57							82	57								5857	34	.30		.30	38 75
6	83	49							82	53								5871	14	.12		.12	38 87
7	76	47							69	53	1830	1900			.03			5919	48	.19		.22	39 09
8	78	47							79	48								5937	18	.21		.21	39 30
9	81	42							79	49								5947	10	.15		.15	39 45
10	84	46							82	49								5955	8	.15		.15	39 60
11	85	45							82	52								5963	8	.12		.12	39 72
12	87	45							82	52								5971	8	.15		.15	39 87
13	86	46							82	52								5989	18	.22		.22	40 09
14	80	58							78	54								6029	40	.24		.24	40 33
15	73	48							70	48								6042	13	.09		.09	40 42
16	66	46							63	48					.01			6048	6	.06		.07	40 49
17	69	39							68	44								6056	8	.06		.06	40 55
18	63	50							60	50					T			6059	3	.01		.01	40 56
19	68	49							66	51	0100	1115			.03			6073	14	.01		.04	40 60
20	70	43							71	48					T			6111	38	.22		.22	40 82
21	70	44							69	47					T			6125	14	.10		.10	40 92
22	71	38							71	44								6137	12	.08		.08	41 00
23	54	45							54	44					.35			6139	2	–	−.32	.03	41 03
24	67	41							67	45								6151	12	.07		.07	41 10
25	52	41							51	45					.44			6153	2		−.44	0	41 10
26	67	37							66	40								6160	7	.08		.08	41 18
27	61	43							58	43					T			6163	3	.01		.01	41 19
28	56	50							55	47					.30			6164	1		−.28	.02	41 21
29	66	45							64	47					T			6177	13	.06		.06	41 27
30	66	42							64	44								6199	22	.12		.12	41 99
31																							
Sum	2175	1393													1.19							3.42	
Avg.	72.5	46.4												Greatest	.44						Adjusted Total		

OBSERVER	STATION	DATE (Month and Year) 9/25/77

WS FORM B-32 (8-74) SUPERSEDES PREVIOUS EDITION

APPENDIX E

CONSTRUCTION GUIDELINES
FOR
"SUB-SURFACE INFILTRATION SYSTEMS"

First the planting hole is dug to proper specifications. A sufficient amount of specified backfill is placed in the hole and leveled to position the tree at the correct depth. The entire area is then covered with plastic sheeting. The plastic is smoothed out and a hole is cut out of the center equal to the diameter of the root ball. REMOVE ALL BURLAP OR SUBSTITUTE MATERIAL FROM THE ROOT BALL, and position tree in the center of the hole. Care shall be taken to insure that the plastic does not extend under the root ball. Rounded rock (No. 5 concrete aggregate as specified in standard specifications 9-03.1(3)(c) is placed and leveled in the hole.

The PVC risers and male adapters are assembled next and connected to the reconstructed pipe assembly. Risers should be of suitable length to allow a space of 5 - 8 inches between the top of the bubbler head and the finished height of the concrete end plug. Place pipe assembly in the top portion of the gravel blanket and connect to the lateral pipe, as shown in Figure 13.

Figure 13
PRECONSTRUCTED PIPE ASSEMBLY PLACED IN TOP PORTION OF GRAVEL BLANKET

Next, the system is flushed, capped and tested according to standard specifications 8-03.3(3), and the entire gravel area is covered with filter cloth. (see Figure 14).

Figure 14
FILTER CLOTH PLACED ON TOP OF GRAVEL BLANKET

Plastic sleeves are to be placed over risers and imbedded in the top portion of gravel as shown below in Figure 15.

Figure 15
PLASTIC SLEEVES PLACED OVER RISERS

The sleeves should extend approximately 1 inch above the surface of the ground, and a minimum of 6 inches shall remain between the sleeve and the root ball, when properly placed. The remainder of the planting hole shall be backfilled and compacted as specified (standard specifications 8-02.3(4).

Bubbler heads should be adjusted to approximately mid range, prior to installation to allow for future adjustments. Caps are then removed, bubbler heads installed and end plugs replaced in sleeves. Care shall be taken to prevent any foreign matter from entering the sleeve and clogging the drainage.

Prior to the start up of the system, cycle the controller through all control stations. At each station, check the water pressure available at the head located furthest from the control valve. The rate of flow per head can be estimated once the pressure at the head is known, and the controller timing can then be set. The station timing should be adjusted to prevent the quantity of water being supplied from exceeding the built in storage capacity of the system.