

THE RELATIONSHIP OF
TRICKLE IRRIGATION TO GROWTH AND
ROOT DISTRIBUTION OF SHADE TREES
AND TO FERTILIZER INJECTION

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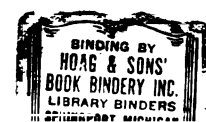
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ABSTRACT

THE RELATIONSHIP OF TRICKLE IRRIGATION TO GROWTH AND ROOT DISTRIBUTION OF SHADE TREES AND TO FERTILIZER INJECTION

By

Harry Glenn Ponder

In spring of 1972, 3-year-old liners of Pin Oak (Quercus palustris L.) and Common Honey Locust (Gleditsia triacanthos L.) and 4-year-old liners of Sugar Maple (Acer saccharum Marsh.) and White Ash (Fraxinus americana L. cv. Autumn Purple) were planted in a uniform Coloma loam soil near Albion, Michigan. Trickle irrigation was installed during July and August of 1972.

The relationship of trickle irrigation to root distribution was evaluated with Sugar Maple, Common Honey Locust, and Pin Oak. Treatments were 5.7 liters per hour and no supplemental water. Trees were dug with a 66" tree spade October 17, 1974. The root system of each tree was divided into 15 cm concentric cylinders around the trunk. Roots were divided into those greater than 2 mm and those less than 2 mm in diameter. Fresh weight determinations were made with each root size classification in each zone.

Irrigation did not alter root system depth. Irrigated Sugar Maple had more fibrous roots (on a weight basis) and

irrigated Common Honey Locust had more large roots than check trees. Irrigated Pin Oak had more fibrous roots and more large roots. Root systems of irrigated and non-irrigated trees were distributed in the same volume of soil.

The effect of trickle irrigation on trunk diameter increase was studied with 4 shade tree species in 1973 and 1974.

Irrigation treatments consisted of 5.7 liters per hour and no supplemental water on Sugar Maple and Common Honey Locust. White Ash treatments were no water, 1.4 liters per hour, and 2.8 liters per hour. Irrigated Pin Oak trees received 5.7 liters per day at application rates of 5.7, 2.8, and 1.4 liters per hour and application time per day was 1, 2, and 4 hrs respectively. Leaf analysis was performed each year.

In 1973 there was a doubling in increase in diameter of irrigated Pin Oak, White Ash, and Sugar Maple with the higher flow rate per hour over that of checks. Irrigated Common Honey Locust trunk diameter increase was greater than checks. In 1974 1 hr and 2 hr irrigated Pin Oak and irrigated White Ash again outgrew checks but irrigated Common Honey Locust and Sugar Maple did not.

Leaf N and K were the only elements to show consistent changes with all species. Leaf N was lower in 1974 compared to 1973 while K was higher. Trickle irrigation did not promote any consistent significant change in nutrient composition of leaves.

A fertilizer injection system based on hydraulic displacement of tank fertilizer solution was developed for trickle

irrigation systems. A portion of the water in the irrigation line is by-passed through a tank containing fertilizer solution. Displacement of the fertilizer solution occurs over time and results in a constant dilution of the fertilizer solution.

Fertilizer turnover rate for the system was determined. Sixty-six percent of the fertilizer was lost during each cycle (cycle is the movement of a volume of water equal to the volume of the tank through the tank). As tanks were connected in series, the depletion rate was reduced. This system is amenable to field trickle irrigation plots.

THE RELATIONSHIP OF TRICKLE IRRIGATION
TO GROWTH AND ROOT DISTRIBUTION OF SHADE
TREES AND TO FERTILIZER INJECTION

By

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INTRODUCTION

Trickle irrigation is based on the prevention of drought stress. This is accomplished by consistent applications of small quantities of water directly to the area of the root zone.

Dr. Blass, of England, is credited with discovering trickle irrigation in the late 1940's. He and other English researchers developed a trickle irrigation system for use on greenhouse tomatoes. In the late 1950's, researchers in Israel adapted trickle irrigation to field production of vegetable crops and by the mid 1960's Australian workers were using trickle irrigation in orchards and vineyards.

To date, most of the research with trickle irrigation has been with fruit and vegetable crops in arid regions. The research has shown in many cases increased yield and increased vegetative growth with trickle irrigation as compared to sprinkler irrigation. Little research has evaluated trickle irrigation under temperate climatic conditions and research evaluating trickle irrigation on ornamental horticulture crops is almost non-existent.

The purpose of this research was to determine the effect of trickle irrigation on root distribution and growth of several shade tree species under temperate climatic conditions and to develop a non-electrical fertilizer injection system for use with trickle irrigation systems.

REVIEW OF LITERATURE

Root distribution. Historically, several factors have been reported as affecting root distribution. Some of these factors are nitrogen quantity (7,10), nitrogen carrier (2,6,8), cultural practices (1,3,13), temperature (15), soil type (5,9,12), and water (4,7,11,16).

Research reports evaluating root distribution with respect to trickle irrigation are limited and are for arid climates almost exclusively. At this time no clear picture of the effect of trickle irrigation on root distribution has emerged.

Some of the work with fruit crops under trickle irrigation in arid regions suggested that roots directly under the trickle emitter died and new roots developed further away in the transition-zone between water-saturated soil and dry soil (17). Yet work with greenhouse carnations indicated greater root growth around the emitter (11), and research comparing sprinkler and trickle-irrigated 'Valencia' oranges suggested no difference in horizontal or lateral root development (18).

Growth. Middleton et. al. (14) showed no difference in trunk area increase of trickle-irrigated prunes the first year with varying quantities of water applied each day. A significant

increase in trunk diameter was found the second year with the higher quantities of water applied each day. There are few, if any, other research reports that show the effect of trickle irrigation to trunk diameter increase on trees.

SECTION I

RELATIONSHIP OF TRICKLE IRRIGATION
TO ROOT DISTRIBUTION OF THREE
SHADE TREE SPECIES

Harry Glenn Ponder

Abstract: The relationship of trickle irrigation to root distribution was evaluated with Sugar Maple, Common Honey Locust and Pin Oak. Treatments were 5.7 liters per hour and no supplemental water. Trees were dug with a 66" tree spade in 1974. The root system of each tree was cut into 15 cm concentric cylinders around the trunk. Roots were divided into those greater than 2 mm and those less than 2 mm. Fresh weight determinations were made with each root size classification in each zone.

Irrigation did not alter root system depth. Irrigated Sugar Maple had more fibrous roots (on a weight basis) and irrigated Common Honey Locust had more large roots than check trees. Irrigated Pin Oak had more fibrous roots and more large roots. Root systems of irrigated and non-irrigated trees were distributed in the same volume of soil.

Numerous factors have been implicated as influencing root distribution. Nitrogen quantity (7,11), nitrogen carrier (2,6,8), cultural practices (1,3,16), temperature (17), soil type (5,9,14), and water (4,7,13,18,20) are some primary factors that have been studied.

No data have been found to show any relationship of trickle irrigation to root development on any crop under temperate climatic conditions. Some data on fruit trees from arid regions suggest that roots directly under the trickle emitter die and new roots develop further away in the transition zone between water-saturated soil and dry

soil (19). Goldberg et al. (13) using greenhouse carnations indicated a greater root growth at the emitter decreasing with distance from the emitter. They also suggested that trickle irrigation promoted a shallow root system. Other arid region data suggest no difference in lateral or horizontal root development between trickle-irrigated 'Valencia' oranges and sprinkler-irrigated 'Valencia' oranges (22). Furuta et al. (12) working on eucalyptus in containers found a heavier root system and more roots were in the center of the ball with fewer roots at the bottom with trickle irrigation as compared to sprinkler irrigation.

The objective of this research was to study the effect of trickle irrigation on root development of three shade tree species under temperate climatic conditions.

MATERIALS AND METHODS

Three-year-old bareroot liners of Pin Oak (Quercus palustris L.) and Common Honey Locust (Gleditsia triacanthos L.) and 4-year-old liners of Sugar Maple (Acer saccharum Marsh.) were planted in a nursery near Albion, Michigan during late June of 1972. The soil type was a deep uniform Coloma loam. The late planting plus an extremely dry summer prevented noticeable growth on all genera that first summer and contributed to the death of many Pin Oaks.

Planting consisted of plowing furrows, putting liners in the furrows, and pushing the soil around each tree. Partially open furrows were left between trees.

Four hundred trees were planted per acre in twenty tree rows. A natural grass sod developed and was left the duration of the experiment. No fertilizer was applied during the experiment.

Trickle irrigation was installed in late July and early August of 1972. A four-inch well served as the water source. A flow regulating valve (valve designed to deliver a specific quantity of water if a 15 lb. water pressured differential is maintained across the valve) on each row and one microtube per tree controlled water flow rate to each tree. Microtubes were positioned 15 cm from tree trunks. Solenoid valves and time clocks were used to automate the system.

The irrigation treatments were 5.7 lph (liters per hour) per tree versus no supplemental water on each genus. In 1973, trickle irrigation began June 25 and was discontinued September 25. Water was applied 1 hr each day. The summer was not extremely dry.

In 1974, the trickle irrigation system ran June 10 - September 24. Water was applied 1 hr each day June 10 - July 1, 2 hrs each day July 1 - July 16, and 3 hrs each day July 16 - September 24. The summer was extremely dry. Evaporation data was collected during both summers.

Two trees per treatment were dug October 17, 1974 with a 66" tree spade. Trees selected reflected the trunk diameter average for the 20 trees under the treatment. Less than 2% of the roots were severed in the digging process. The soil

was carefully removed from the roots by hand and with a minimal loss of fibrous roots.

There were 2 replications per treatment, and both the .1 and .05 levels of significance were calculated. T test was used to determine treatment differences.

The root system was photographed and root system depth measured. Then the root system was cut into 15 cm concentric circles around the trunk. Roots were divided into those greater than 2 mm in diameter and those less than 2 mm. The smaller classification was considered the fibrous roots and probably included the major absorbing roots (10). Fresh weight was obtained on each root category.

RESULTS AND DISCUSSION

Tables 1, 3, and 5 show quantity on a weight basis and per cent of root system in relation to distance from trunk for Pin Oak, Common Honey Locust, and Sugar Maple respectively.

Regardless of treatment, over 90% of the root systems of the three genera were within 30 cm of the trunk. 10% of this total were fibrous roots. Cowart (10) working with 2-year-old peaches on a sandy loam soil in Georgia found only 67% of the root system within 30 cm of the trunk. This difference may indicate the importance of soil characteristics, soil moisture conditions, and the inherent nature of genera on root development.

In contrast to the statement by Goldberg et al (13) that trickle irrigation promoted a shallow root system, no difference was found in depth of root systems receiving supplemental water versus those without supplemental water (tables 2, 4, and 6). By digging a ball 28 cm deep and 60 cm in diameter, over 90% of the total root system and over 70% of the fibrous root system of Pin Oak would be retained. The ball would need be 40 cm deep for Common Honey Locust and Sugar Maple. These are not large balls for the tree size and should make for excellent livability after transplanting.

Total quantity of roots decreased with distance from the trunk of the tree. This is in agreement with previous work on peach (10) and apple (3,5). Boynton and Savage's work (5) on a mature Baldwin apple tree shows that the total quantity of fibrous roots did not decrease for some distance from the tree. Our data show that this was not true for all shade tree genera in this study.

Tables 1 and 2 and fig. 1 show the data and show visually the response of Pin Oak roots to the irrigation treatments.

Irrigated trees outgrew non-irrigated trees in top growth and root growth, but there was no difference in percent of roots, large or fibrous, in any zone. There was an increase in the quantity of large roots in the 0-15 cm and 30-45 cm zones and of fibrous roots in the 15-30 cm zone in the irrigated plot.

Trickle irrigation did not influence per cent of total root system in each zone. Trickle irrigation did result in a larger root system and a larger tree. The larger root system was distributed in the same volume of soil as the roots of the smaller non-irrigated trees.

Wyman (21) working with 7-year-old Pin Oaks averaging 1.6 cm in trunk diameter found that all new roots grew directly downward and none grew laterally beyond the original diameter of the root ball. The root balls ranged between 60-90 cm. The check and irrigated Pin Oaks of this study averaged 2.17 cm and 2.92 cm in trunk diameter respectively. Ball diameters were similar to those in Wyman's study, but our observation was that new roots did move beyond the original root ball diameter and that many of the new roots grew laterally.

Tables 3 and 4 and fig. 2 show the data and show visually the response of Common Honey Locust roots to the irrigation treatments.

There was no difference in total top or root growth between irrigated and non-irrigated trees. A higher percentage of fibrous roots in the 30-45 cm zone was found in the non-irrigated plot. This has little practical significance since these roots will probably be severed when the trees are transplanted from the nursery. In the irrigated plot, a greater quantity of large roots was discovered in the 0-15 and 15-30 cm zones. Kramer (15) pointed out that the large roots

of trees do absorb a sizable quantity of water indicating that the large root increase may be advantageous for transplanting and during the ensuing adjustment period.

Tables 5 and 6 and fig. 3 show the data and show visually the response of Sugar Maple roots to the irrigation treatments.

Irrigated trees had more fibrous roots in the 0-15 and 15-30 cm zones compared to checks. This should enhance transplantability of those trees. Irrigated trees also had a larger caliper.

The influence the grass sod may have had on tree growth was not determined. The sod removed some of the water applied. Beckenbach and Gourley (3) found little difference in root distribution of apple trees grown under sod, clean cultivation and cover crop methods.

No root rot or pathogenic situation was found on any of the root systems surveyed in the study. There was no evidence of roots dying under the trickle emitter as reported from arid regions (19), and no evidence of roots congregating around the emitters as has been reported (13). The root systems seemed to be uniformly around the tree regardless of emitter location.

The root systems of Pin Oak, Common Honey Locust, and Sugar Maple were beneficially altered by trickle irrigation as was the root system of eucalyptus in Furuta's work (12) and

in contrast to no alteration reported on citrus in arid regions (20).

The greater quantity of rainfall and higher quality water in temperate regions contrasted to arid regions may account for many of the differences in root distribution data from the two regions.

Table 1. Relationship of distance from the trunk to quantity and per cent of total root system of trickle-irrigated Pin Oak.

Treatment	Distance from Trunk (centimeters)						Total Weight (g)
	0-15		15-30		30 ⁺		
	g	%	g	%	g	%	
	Roots less than 2 mm Diameter						
5.68 lph check	143	8	58	4	341	2	234
	22	4	25	4	211	4	68
	N.S.	N.S.	**	N.S.	N.S.	N.S.	**
	Roots 2 mm Diameter or Larger						
5.68 lph check	1282	73	190	11	48	2	1520
	332	64	103	18	17	4	454
	**	N.S.	N.S.	N.S.	**	N.S.	**

*.1 level of significance
 **.05 level of significance

Table 2. Relationship of trickle irrigation to top and root growth of Pin Oak.

Treatment	Average Caliper (cm)	Trunk Diam. (cm)	Top Fresh Weight (g)	Rooting Depth (cm)	Total Fresh Root Weight (g)	Evaporation loss (cm)	
						1973 July-Sept.	1974 July-Sept.
5.68 lph check	3.75	1.44	2040.8	28	1755.0		
	2.03	0.47	476.2	28	521.0	6.70	23.10
		**	**	N.S.	**		

*.1 level of significance

** .05 level of significance

Table 3. Relationship of distance from trunk to quantity and percent of total root system of trickle-irrigated Common Honey Locust.

Treatment	Distance from Trunk (centimeters)						Total Weight (g)
	0-15		15-30		30 ⁺		
	g	%	g	%	g	%	
	Roots less than 2 mm Diameter						
5.68 lph check	39	4	44	4	16	1	99
	75	8	47	5	28	4	149
	N.S.	N.S.	N.S.	N.S.	N.S.	**	N.S.
5.68 lph check	Roots 2 mm Diameter or Larger						
	902	75	159	13	48	3	1109
	741	80	4	1	30	3	774
	**	N.S.	*	*	N.S.	N.S.	*

*.1 level of significance

** .05 level of significance

Table 4. Relationship of trickle irrigation to top and root growth of Honey Locust Trees.

Treatment	Average Caliper (cm)	Trunk Diam. Inc. (cm)	Top fresh Weight (g)	Rooting Depth (cm)	Total Fresh Root Weight (g)
5.68 lph	2.82	0.79	1215.2	30	1208
check	2.46	0.59	1020.4	40	924
		*	N.S.	N.S.	N.S.

*.1 level of significance

**.05 level of significance

Table 5. Relationship of distance from the trunk to quantity and per cent of total root system of trickle-irrigated Sugar Maple.

Treatment	Distance from Trunk (centimeters)						Total Weight (g)
	0-15		15-30		30 ⁺		
	g	%	g	%	g	%	
	Roots less than 2 mm Diameter						
5.68 lph check	208	9	176	8	56	2	441
	36	2	60	4	32	2	128
	*	*	*	N.S.	N.S.	N.S.	*
5.68 lph check	Roots 2 mm Diameter or Larger						
	1301	56	448	19	109	4	1858
	1012	75	218	16	35	2	1264
	N.S.	**	N.S.	N.S.	N.S.	N.S.	N.S.

*.1 level of significance

** .05 level of significance

Table 6. Relationship of trickle irrigation to top and root growth of Sugar Maple Trees.

Treatment	Average Caliper (cm)	Caliper Increase (cm)	Top Fresh Weight (g)	Depth (cm)	Total Fresh Root Weight (g)
5.68 lph	4.80	1.43	2607.6	38	2298.5
check	4.20	1.17	2516.9	38	1392.0
		**	N.S.	N.S.	N.S.

*.1 level of significance

** .05 level of significance

Figure 1. Root distribution of Pin Oak. Top and bottom:
left, irrigated and right, non-irrigated.

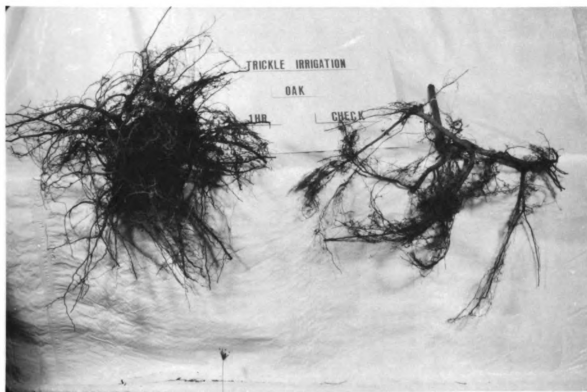
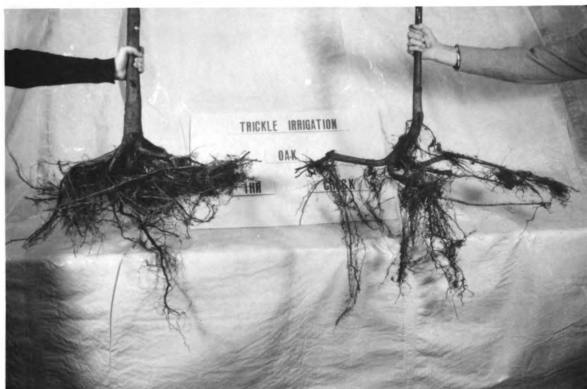


Figure 2. Root distribution of Sugar Maple. Top and bottom:
left, irrigated and right, non-irrigated.

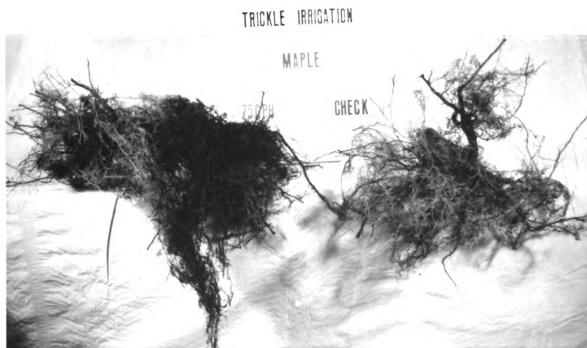
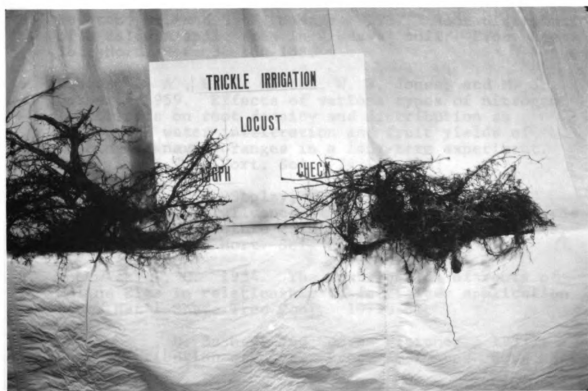
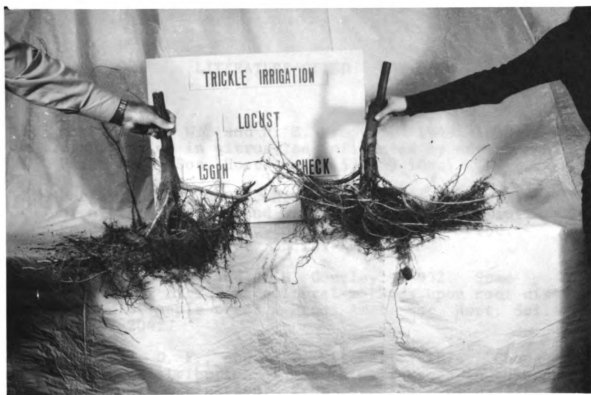


Figure 3. Root distribution of Common Honey Locust. Top and bottom: left, irrigated and right, non-irrigated.



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SECTION II

RELATIONSHIP OF TRICKLE IRRIGATION TO GROWTH OF FOUR SHADE TREE SPECIES

Harry Glenn Ponder

Abstract: The effect of trickle irrigation on trunk diameter increase was studied with four shade tree species in 1973 and 1974. Irrigation treatments consisted of 5.7 liters per hour and no supplemental water on Sugar Maple and Common Honey Locust. White Ash treatments were no water, 1.4 liters per hour, and 2.8 liters per hour. Irrigated Pin Oak trees received 5.7 liters per day at application rates of 5.7, 2.8, and 1.4 liters per hour and application time per day was 1, 2, and 4 hrs respectively. Leaf analysis was performed each year.

In 1973 there was a doubling in increase in diameter of irrigated Pin Oak, White Ash, and Sugar Maple with the higher flow rate per hour over that of checks. Irrigated Common Honey Locust trunk diameter increase was greater than checks. In 1974 1 hr and 2 hr irrigated Pin Oak and irrigated White Ash again out grew checks but irrigated Common Honey Locust and Sugar Maple did not.

Leaf N and K were the only elements to show consistent changes with all species. Leaf N was lower in 1974 compared to 1973 while K was higher. Trickle irrigation did not promote any consistent significant change in nutrient composition of leaves.

Shade trees are priced in accordance to trunk diameter. Research on trickle irrigated prunes showed no difference in trunk area increase the first year with varying quantities of water each day but a significant increase the second year with the higher quantities of water each day (3).

This research was performed to determine the relationship of trickle irrigation to trunk diameter increase and nutrient composition of leaves of Sugar Maple(Acer saccharum Marsh.),

Common Honey Locust (Gleditsia triacanthos L.), White Ash (Fraxinus americana L. cv. Autumn Purple), and Pin Oak (Quercus palustris L.).

MATERIALS AND METHODS

Three-year-old liners of Pin Oak and Common Honey Locust and 4-year-old liners of Sugar Maple and White Ash were planted in a nursery near Albion, Michigan during late June of 1972. The soil type was a deep uniform Coloma loam. The late planting plus an extremely dry summer prevented noticeable growth on all species that first summer and contributed to the death of many Pin Oaks.

Planting consisted of plowing furrows, putting liners in the furrows, and pushing the soil around each tree. Partially open furrows were left between trees.

Four hundred trees were planted per acre in twenty tree rows. A natural grass sod developed and was left the duration of the experiment. No fertilizer was applied during the experiment.

Trickle irrigation was installed in late July and early August of 1972. A four-inch well served as the water source. A flow regulating valve (valve designed to deliver a specific quantity of water provided a 15 lb. pressure differential can be maintained across the valve) on each row and one microtube per tree controlled water flow rate to each tree. Microtubes were positioned 15 cm from trees. Solenoid valves and time clocks were used to automate the system.

Irrigation treatments consisted of 5.7 lph versus no supplemental water on Sugar Maple and Common Honey Locust. White Ash treatments were no water, 1.4 lph, and 2.8 lph. All Pin Oak trees except check trees received the same total amount of water per day. Application rate varied and consequently application time. The 1 hr. treatment was 5.7 lph; the 2 hr. treatment, 2.8 lph; and the 4 hr. treatment, 1.4 lph. Each time treatment on Pin Oak was further split into 1 versus 2 microtubes per tree. Microtubes were positioned in the row 15 cm on either side of the tree trunk. There were at least 20 trees under each treatment for all genera.

In 1973 trickle irrigation began June 25 and was discontinued September 25. Water was applied 1 hr. each day.

In 1974 the trickle irrigation system ran June 10 - September 24. Water was applied 1 hr. per day June 10 - July 1, 2 hrs. per day July 1 - July 16, and 3 hrs. per day July 16 - September 24. The summer was extremely dry.

Leaf samples were collected on August 15 of both summers. Leaf N content was analyzed by the Kjeldahl method and K content by flame photometer. Other elements were determined spectrographically.

Leaf water content was determined using the relative turgidity method described by Weatherly (4). The leaf disks were collected during the noon period of September 4, 1973.

Randomized block designs were employed and comparisons among treatment means were made using Duncan's test.

RESULTS AND DISCUSSION

Table 1 shows net water loss from an evaporation pan and rainfall data for 1973 and 1974. 1974 was much drier. August was the driest month both years.

Sugar Maple, White Ash, Common Honey Locust, and Pin Oak trunk diameter increase related to trickle irrigation in 1973 and 1974 is shown in tables 2 and 3. Tables 4 and 5 show leaf nutrient-element composition for the 4 shade tree species in 1973 and 1974.

1973. Trickle irrigated trees showed a greater trunk diameter increase than check trees for all species. Trunk diameter increase doubled, except for Common Honey Locust, with the higher flow rate per hour on each species compared to check trees. Leaf composition values are thought to represent acceptable levels based on growth obtained.

Relative turgidity studies revealed a higher water content in the leaves of irrigated Sugar Maple and Common Honey Locust. Ash and Pin Oak showed no difference in relative turgidity. This may be related to leaf structure.

Pin Oak axillary shoot number increased with increasing flow rate.

1974. There was no difference in trunk diameter increase between check and irrigated trees of Sugar Maple and Common Honey Locust.

The reduced growth of irrigated Sugar Maple, relative to 1973, may have been due to lower leaf N compared to check trees. Davidson (2) reported 2.98, 2.41, and 1.71% as high,

average, and low leaf N values respectively for Norway Maple (Acer platanoides, L.). In comparison irrigated Sugar Maple had low leaf N. There were no treatment differences in any other nutrient composition values. Cole and Till (1) found a N deficiency and reduced growth on 'Valencia' oranges under trickle when fertilizer was not applied for 18 months.

Common Honey Locust had the highest leaf nutrient composition variability between years. N, P, Ca, Mg, Fe, B, and Al were lower and K, Na, Mn, Cu, and Zn were higher in 1974 compared to 1973. Compared to the high, low and average values reported by Davidson (2), Common Honey Locust had low leaf N, P, Ca, Ma, and Fe and high leaf Mn. Reduced growth may have resulted from low nutrient composition values having reached a threshold level that reduced tree response to water.

Trunk diameter increase was twice as great on irrigated White Ash as on check trees. Irrigated trees trunk diameter increase was greatest in July and August (figure 1). No difference in rate of trunk diameter increase was found between the two flow rates. Leaf N was lower and K and P higher in 1974 compared to 1973.

Pin Oak trunk diameter increase doubled in the 1 and 2 hr. irrigation treatments compared to the check. Trunk diameter increased most rapidly in July and August (Figure 2). This was the driest period of 1974.

Axillary shoot number was significantly increased on Pin Oak in the 1 hr. plot

Little trunk diameter increase occurred on any species after August 24. This suggests that trickle irrigation was probably not beneficial after August.

1973 and 1974. A tendency for checks to outgrow or at least grow as fast as irrigated trees before the irrigation treatments were implemented in 1974 was found with all species. This may suggest that the irrigated trees, larger at the end of 1973, required more water for growth and/or that the root system of irrigated trees became sensitive to the irrigation and grew less rapidly when there was no irrigation. Turning the trickle system on earlier in the spring might eliminate this situation.

Trunk diameter increase of check trees of White Ash, Pin Oak, and Common Honey Locust was about the same both years even though 1974 was much drier. It is hard to explain this on a nutritional basis. Possibly the sporadic nature of drought stresses on a plant during the year partially account for it. It is hard to evaluate the long term effect of a short stress period versus a longer stress period. Perhaps in 1973 the drought stresses were simply shorter in nature.

Pin Oak had significantly more axillary shoots in the 1 hr. treatment. Wider and taller heads resulted in these trees, increasing their commercial acceptability.

There was no difference in growth with 1 versus 2 emitters per tree on Pin Oak for any treatment in either year. Figure 3 shows the data for 1974.

Observation showed that irrigated Pin Oak had greater twig elongation than check trees. Wyman (5) working on 5-year-old Pin Oak discovered a high correlation between twig growth and trunk diameter increase.

The reduced trunk diameter increase of Pin Oak in the 4 hr. treatment may have been due to the slow application rate coupled with the competition of the sod for water. It was also difficult to maintain accurate delivery rates at the low flow rate. Constant maintenance and adjustment was required on this treatment during both summers.

It seems that N should not be left off Sugar Maple for more than 1 year if a substantial growth rate is to be maintained. This statement probably applies to Common Honey Locust and to the other species to a lesser extent. With trickle irrigation Middleton et al.(3) showed significantly higher leaf N on prunes within 1 year after application of N fertilizer at the water discharge point. This suggests that low leaf N such as found in Sugar Maple in this study can be corrected quickly with the addition of N fertilizer in conjunction with the trickle system.

Tables 4 and 5 show some differences in nutrient-element values between treatments in 1973 and/or 1974, but there seem to be few trends that would explain the growth responses obtained. N and K seem to be the only elements showing consistent changes in all species with time. Leaf N was lower, regardless of treatment, while K was higher in 1974 compared to 1973. Other than N

the deletion of fertilizer did not seem to affect growth during the experiment with the possible exception of Common Honey Locust. The data indicate that trickle irrigation does not promote consistent significant changes in nutrient content of leaves.

Tree hardiness did not seem to be adversely affected by trickle irrigation. No winter injury was observed on any of the trees. Even with continued irrigation in 1974 growth was halted by August 24 on all species studied. Some factor, environmental and/or genetic, must override the promotive effect of water on growth at this time of year.

Per cent increase in trunk diameter has a yearly additive effect and the increases due to trickle irrigation result in a more profitable tree for the nurseryman.

Table 1. Net pan evaporation and rainfall data for 1973 and 1974.

Year	July	August	Sept.
	Net Evaporation (cm)		
1973	- 1.02	- 8.38	+ 2.41
1974	-10.87	-12.24	
	Rainfall (cm)		
1973	13.94	6.15	11.10
1974	5.31	6.98	4.95

Table 2. Growth response of 4 shade tree species to trickle irrigation in 1973.^x

Species	Treatment Liters/hr	Trunk Diam. (cm) Jun. 24	Trunk Diam. Inc. (cm) Jun. 24-Sept. 24	Axill, Shoots	Relative Turgidity
Sugar Maple	check 5.68	2.92 3.20	0.28 0.61a		79.0b 93.2a
Ash	check 1.42 2.84	2.81 2.80 2.76	0.18c 0.30b 0.39a		86.0a 86.0a 87.0a
Honey Locust	check 5.68	1.97 1.97	0.26b 0.38a		80.1b 93.0a
Pin Oak	check 4 hr (1.42 lph) 2 hr (2.84 lph) 1 hr (5.68 lph)	1.63 1.67 1.73 1.85	0.18c 0.28b 0.39a 0.48a	0.50d 4.23c 9.98b 15.71a	82.4a 85.0a 83.0a 81.0a

^xMeans followed by different letters differ significantly at p=0.05.

Table 3. Growth response of 4 shade tree species to trickle irrigation in 1974.^x

Species	Treatment Liters/hr	Trunk Diam. (cm) Jun 24	Trunk Diam. Inc. (cm) ^y			Axill. Shoots
			Jul 24	Aug 24	Sept 24	
Sugar Maple	check 5.68	3.54	0.18a	0.36a	0.40a	
		4.07	0.18a	0.37a	0.40a	
White Ash	check 1.42 2.84	3.36	0.14b	0.17b	0.18b	
		3.41	0.21a	0.29a	0.31a	
		3.41	0.23a	0.30a	0.32a	
Honey Locust	check 5.68	2.41	0.14a	0.18a	0.21a	
		2.46	0.13a	0.17a	0.20a	
Pin Oak	check 4 hr (1.42 lph) 2 hr (2.84 lph) 1 hr (5.68 lph)	1.92	0.12a	0.23b	0.25b	0.0b
		2.03	0.17ab	0.29b	0.31b	1.6b
		2.23	0.20a	0.40a	0.43a	3.1b
		2.44	0.22a	0.45a	0.48a	14.8a

^xMeans followed by different letters differ significantly at p=0.05.^yValues represent accumulated totals during 1974.

Table 4. Nutrient-element composition of leaves of Sugar Maple and White Ash in 1973 and 1974.*

Species	Treatment lit./hr	N%	K%	P%	Na ppm	Ca%	Mg%	Mn ppm	Fe ppm	Cu ppm	B ppm	Zn ppm	Al ppm
Sugar Maple (1973)	check 5.68	2.36a	0.44a	0.18a	235.6a	1.23a	0.30a	363.2a	168.1a	1.7b	41.9a	11.8b	126.9a
		2.21a	0.38a	0.20a	223.7a	1.37a	0.33a	380.1a	149.9a	11.6a	41.9a	33.0a	124.3a
(1974)	check 5.68	1.96a	0.57a	0.26b	144.5a	1.38b	0.29a	383.3a	166.4a	7.9a	44.0b	37.7a	99.7a
		1.70b	0.55a	0.35a	177.3a	1.62a	0.32a	415.7a	142.4a	8.4a	50.5a	30.9b	100.3a
White Ash (1973)	check	2.44a	0.75a	0.16a	268.5a	1.23a	0.25a	52.2a	171.2a	14.4a	24.7a	32.0a	119.0a
	1.42	2.52a	0.69a	0.17a	389.5a	1.29a	0.31a	59.2a	168.0a	18.7a	28.4a	35.2a	108.3a
	2.84	2.36a	0.66a	0.16a	246.4a	1.23a	0.31a	45.2a	156.0a	15.6a	26.1a	30.1a	103.0a
(1974)	check	1.82a	1.10a	0.22a	340.4a	1.13a	0.21b	35.1a	147.9a	11.1a	25.4a	15.8a	98.4a
	1.42	1.81a	0.86b	0.22a	329.4a	1.05a	0.22b	41.1a	156.1a	13.6a	26.5a	13.4a	102.2a
	2.84	1.87a	0.84b	0.24a	288.0a	1.21a	0.26a	48.5a	155.8a	13.5a	27.2a	13.9a	103.4a

*Means followed by different letters differ significantly at p=0.05.

Table 5. Nutrient-element composition of leaves of Common Honey Locust and Pin Oak in 1973 and 1974*.

Species	Treatment	N%	K%	P%	Na ppm	Ca%	Mg%	Mn ppm	Fe ppm	Cu ppm	B ppm	Zn ppm	Al ppm
Honey-locust (1973)	check	2.21a	0.44a	0.26a	350.3b	1.01a	0.25a	76.3a	140.8a	2.1a	29.8a	8.6a	81.7a
	5.68	1.95a	0.57a	0.28a	639.7a	0.99a	0.24a	67.8a	154.4a	2.5a	30.8a	10.8a	94.9a
(1974)	check	1.82a	1.20a	0.12b	708 b	0.57a	0.15a	116.3b	23.8a	20.6b	5.3b	32.5a	50.0a
	5.68	1.77a	1.26a	0.14a	758 a	0.62a	0.14a	134.7a	29.4a	26.4a	9.6a	31.6a	47.6a
Pin Oak (1973)	check	1.78a	0.40c	0.17a	502 a	0.63a	0.21a	1017 a	131.8a	1.2b	24.3a	17.3b	103.0a
	4 hr	2.18a	0.44b	0.17a	370 a	0.66a	0.20ab	841 a	125.8ab	1.2b	23.6a	19.3b	90.2ab
	(1.42 lph)												
	2 hr	2.17a	0.46b	0.18a	369 a	0.60a	0.18ab	954 a	116.1abc	7.6a	23.4a	33.3a	75.7b
	(2.84 lph)												
(1974)	1 hr	2.00a	0.53a	0.17a	348 a	0.54a	0.16b	993 a	106.9c	7.1a	22.8a	33.8a	72.9b
	(5.68 lph)												
	check	1.78a	0.61c	0.18b	504 a	0.63a	0.15a	1247 a	118.7a	5.2a	36.7a	33.4a	62.0a
	4 hr	1.80a	0.66b	0.19ab	468 a	0.60a	0.18a	933 b	107.2ab	5.2a	29.5b	26.6b	59.0a
	(1.42 lph)												
(1974)	2 hr	1.98a	0.61c	0.21a	380 b	0.56a	0.17a	1258 a	103.4b	4.7a	29.2b	30.0ab	57.4a
	(2.84 lph)												
	1 hr	1.87a	0.71a	0.19ab	371 b	0.59a	0.17a	1241 a	101.9b	3.8a	27.1b	33.9a	66.9a
	(5.68 lph)												

*Means followed by different letters differ significantly at p=0.05.

Figure 1. Trunk diameter increase of White Ash related to date and treatment. Differing letters on a particular date indicate differences due to treatment at $p=0.05$.

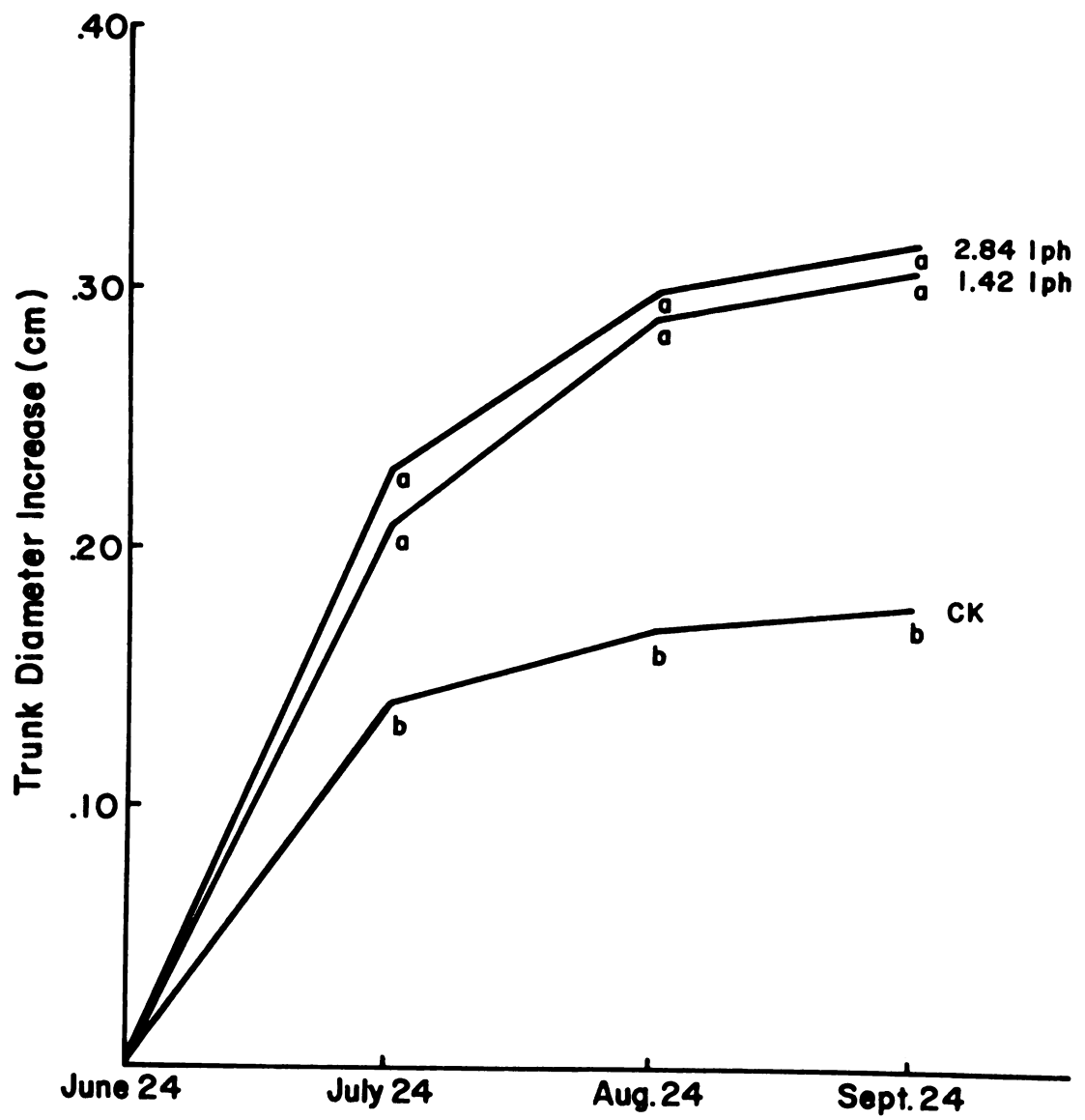


Figure 2. Trunk diameter increase of Pin Oak related to date and treatment. Differing letters on a particular date indicate differences due to treatment at $p=0.05$.

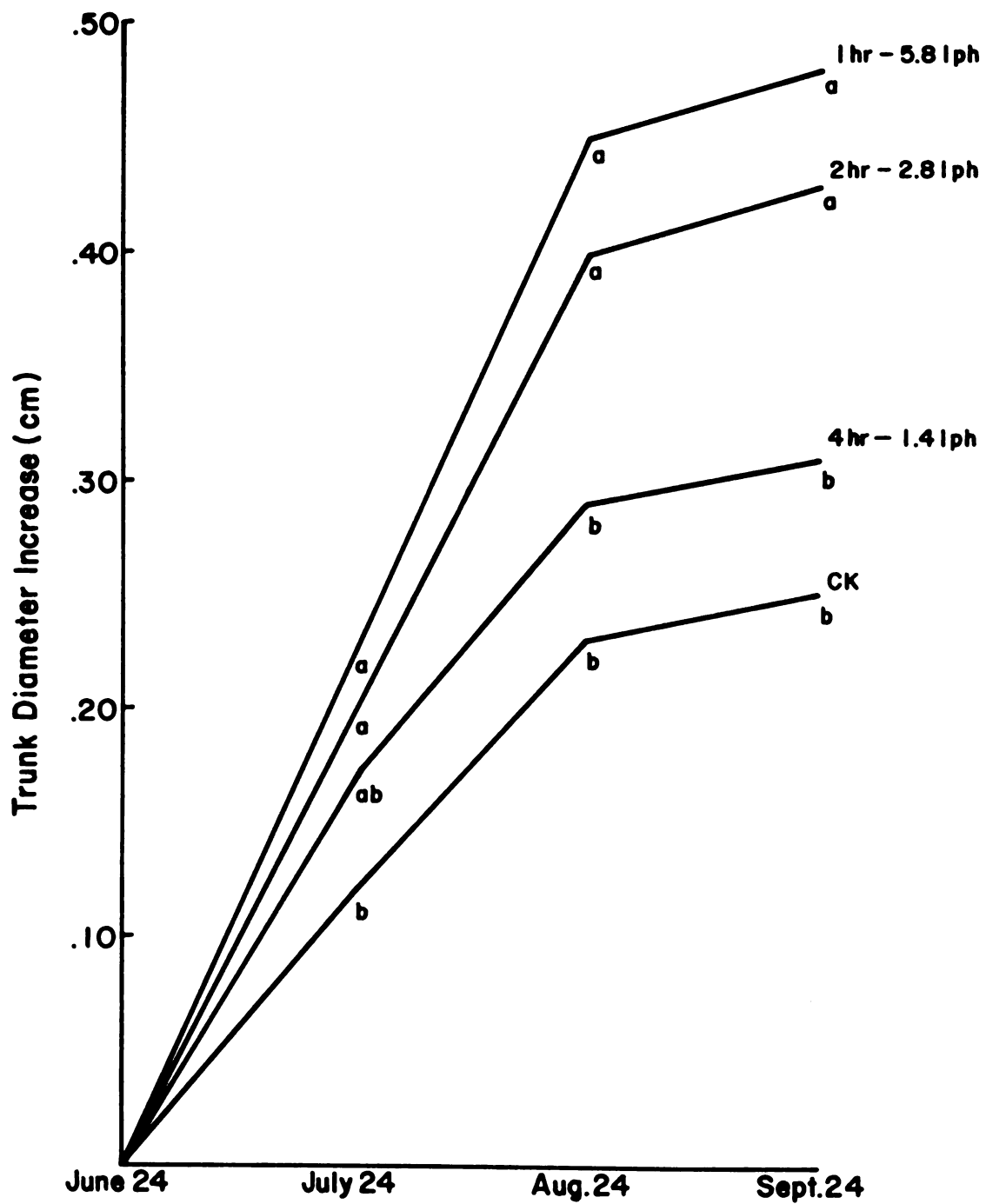
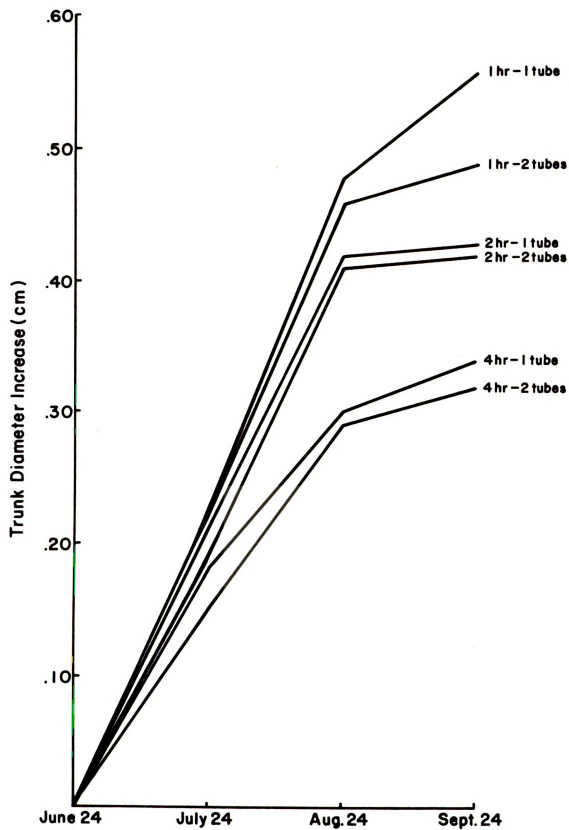


Figure 3. Trunk diameter increase of Pin Oak related to 1 and 2 emitters per tree on each treatment. There was no difference between 1 and 2 microtubes on any date for any treatment at $p=0.05$.



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SECTION III

HYDRAULIC DISPLACEMENT OF TANK
FERTILIZER SOLUTIONS(S) INTO A
TRICKLE IRRIGATION SYSTEM^{1/}

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ABSTRACT: Objectives were to develop a non-electrical field fertilizer injection system for trickle irrigation and to determine fertilizer turnover rates for the system. Materials included a plastic tank(s), a flow regulating valve, and small I.D. inlet, outlet connector lines. Flow from the tank(s) was created by a pressured differential across the flow regulating valve. With post valve line pressure known, microtubes for inlet, outlet lines were cut to lengths necessary for specific flow rates. Fertilizer turnover rates were determined by placing known quantities of KCl in the tank(s) and collecting aliquots released from the tank(s) at half-cycle intervals (1 cycle = volume of tank). K concentration was determined by flame photometer. For a one tank system, 66% of fertilizer solution was removed per cycle. As tanks were added in series the depletion rate was reduced. This system is amenable to field trickle irrigation plots.

Trickle irrigation has become an important cultural practice in fruit production in many areas. For example, since 1970 approximately 28,327 hectares of trickle irrigation has been installed in the United States. In Michigan, trickle irrigation has been installed in over 1618 hectares, primarily in deciduous fruit crops. This acreage is increasing daily.

2 & ^{1/}_{3/} Michigan Agricultural Exp. Station Journal Art. No. 7067
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The objective of this research was to develop an efficient, inexpensive, non-electrical fertilizer injection system for trickle irrigation and to determine fertilizer turnover for the system. The basic principle used was hydraulic displacement of fertilizer from a tank - or simply, forcing water into a tank thereby physically displacing fertilizer solution from the tank. Such a system results in continuous dilution of the fertilizer solution.

To determine if such a system could be accurately calibrated, a series of experiments were initiated to determine fertilizer turnover for the system. An 18.925 liter plastic tank was connected to a 1.27 cm polythene pipe. 1.14 mm I.D. (inside diameter) tubing was used as the connecting line. All tank and pipe connections were made via 1.90 mm I.D. grommets. The connecting tubing fitted tightly into a 2.54 cm sleeve of 1.90 mm I.D. tubing at the grommets. The sleeve permitted a piece of 1.14 mm I.D. tubing bent to 45 degrees to be extended down into the tank. This extension facilitated the mixing action in the tank. A pressure regulator in the 1.27 cm line allowed control of line pressure. By manipulating line pressure and length and/or I.D. of the connecting tube, flow thru the tank was regulated (1,2).

The tank must be air and water tight. To prevent leaks around the lid of the tank, the lid was sealed with Silastic JRTV Moldmaking Rubber^{1/}.

^{1/}Manufactured by Dow Corning Corp., Midland, Michigan.

225 g KCl was added to the tank. K concentration was determined with a flame photometer. Flow thru the tank was adjusted to the desired level. K concentration determinations were subsequently made at 1/2 cycle intervals - cycle is the movement of a volume of water equal to the volume of the tank through the tank. Cycle time was varied from 2 to 5 hours.

Data for a 1 tank system (Table 1) shows that 66.67% of the K was expelled during each cycle. So 33.33% of the K remained in the tank at the end of the first cycle. At the end of the second cycle 66.67% of the 33.33% was lost and 10.93% of the K remained. At the end of 4 cycles 1.2% of the K remained.

Anticipating that more fertilizer would be needed in some field plots than would be soluble in one tank, a concept of connecting tanks in series was developed. 1.90 mm I.D. tubing was used to make the connections.

For a 2 tank system - at the end of 4 cycles, in contrast to the 1.2% of the K remaining in a 1 tank system, 5.35% of the K remained. So not only was the fertilizer capacity of the system increased, but the fertilizer depletion rate was decreased.

For a 3 tank system - 16% of the K remained at the end of 4 cycles.

For a 4 tank system - 32% of the K remained at the end of 4 cycles.

And with a 5 tank system, 50 % of the K remained at the end of 4 cycles. With 7 cycles less than 10% of the K remained in a 5 tank system.

Fertilizer capacity could be increased and fertilizer depletion rate decreased simply by using a single larger tank while maintaining flow thru the tank at the same level as used with the smaller tank. However, one very large tank, at the head of each row in a research plot, could prove to be an obstacle to the normal flow of orchard traffic. Also maintaining flow thru the tank at a low level could hinder adequate mixing in the tank.

The data plotted on semilog paper (Fig. 1) illustrate how the addition of fertilizer tanks decreases the fertilizer depletion rate. (Each data point represents from 3 to 10 replications.) Varying cycle time did not affect this relationship, and it is believed that this K turnover rate data will hold true for any fertilizer material as long as the material is completely in solution.

For field research a constriction is needed in the 1.27 cm line everywhere a tank is to be located to force water thru the tank. A flow regulating valve, or a gate valve, can be used to provide the constriction. A flow regulating valve is a valve designed to deliver a specific quantity of water provided a 77.57 centim. mercury pressure differential can be maintained across the valve. Flow regulating valves were used in this study.

All tank and pipe connections were made via 1.90 mm I.D. grommets. For the inlet line (line from the high pressure side of the flow regulating valve to the tank) 0.89 mm I.D. tubing was used. The inlet line setup was the same as the connecting tube setup described earlier.

A check valve in the inlet line prevented fertilizer solution from siphoning from the tank into the header when the system was turned off (Fig. 2).

A second check valve was placed adjacent to the first one; positioned so as to let air into the tank when the system was turned off. This prevented collapsing of the tank due to suction created as each line drains thru its lowest outlet.

For the outlet line (line from tank to the low pressure side of the flow regulating valve) 1.90 mm I.D. tubing was used. The larger I.D. outlet line was to prevent buildup of pressure in the tank. An in-line screen (Fig. 3), placed in the outlet line, prevented any solid material from passing from the tank into the irrigation line.

For research, each tree row can be a plot with its own independent fertilizer injection system. This technique offers the researcher great flexibility in designing his fertilizer plots with trickle irrigation.

For commercial growers, one large tank on the water source line with a gate valve for a constriction could be used to fertilize an entire orchard. This technique offers the grower efficiency and economy.

Table 1. Percent K remaining as related to the number of cycles run.

<u>Cycle No.</u>	<u>% K Remaining</u>				
	<u>Tank 1</u>	<u>Tank 2</u>	<u>Tank 3</u>	<u>Tank 4</u>	<u>Tank 5</u>
.5	55.84	81.35	98.35	100	100
1.0	33.67	61.75	89.20	100	100
1.5	20.76	45.20	76.65	97.90	100
2.0	10.93	31.90	59.15	83.60	96.25
2.5	5.63	21.05	47.45	70.30	87.90
3.0	3.35	13.20	32.65	57.55	75.85
3.5	2.00	8.50	24.00	42.20	-----
4.0	1.20	5.45	16.15	32.00	50.45
4.5		3.45	11.55	24.55	40.00
5.0		2.15	7.75	17.70	31.45
5.5		1.32	5.17	12.50	24.33
6.0		.85	3.20	7.25	16.70
6.5			2.10	6.55	14.10
7.0			1.50	4.65	9.90

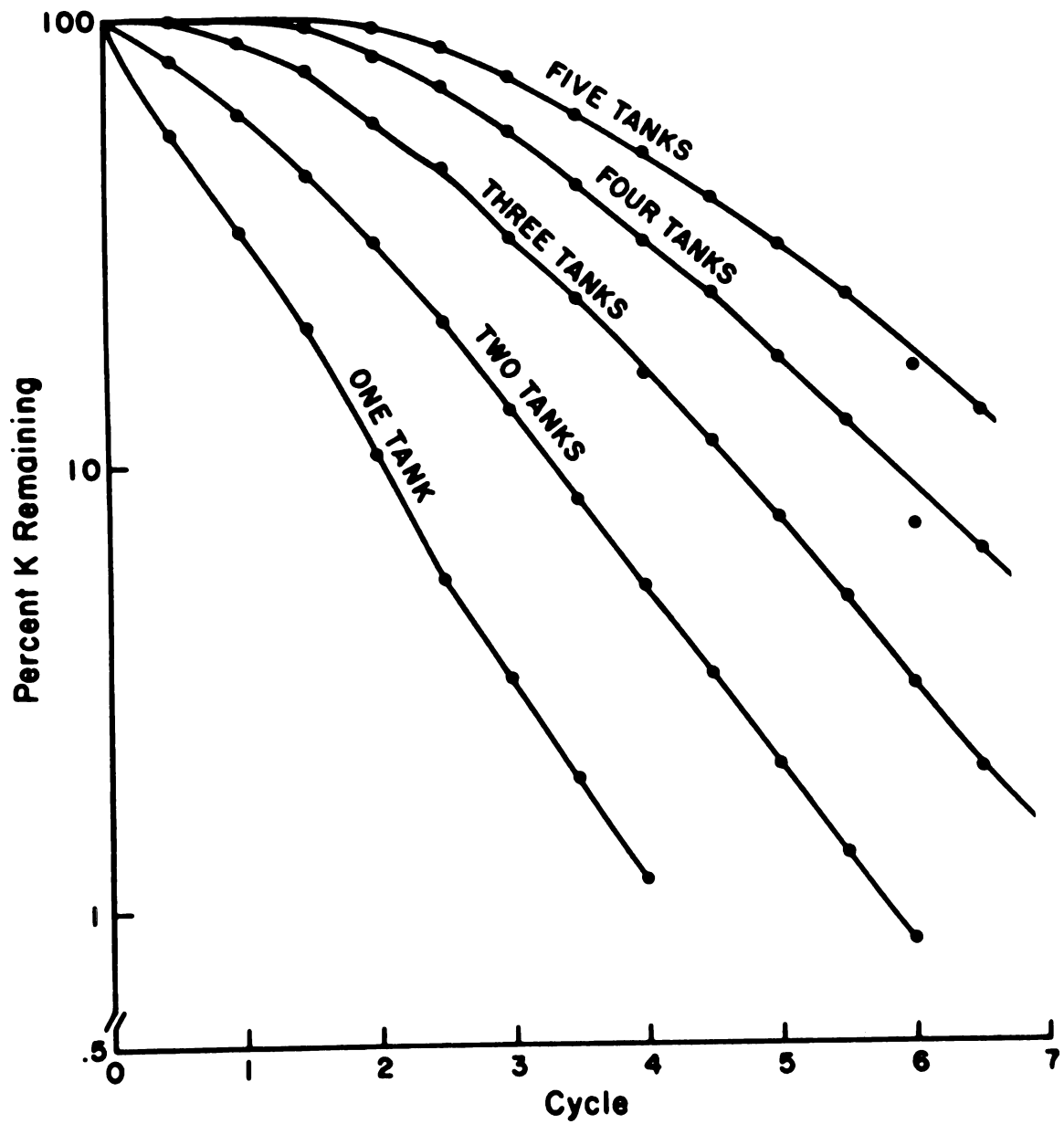
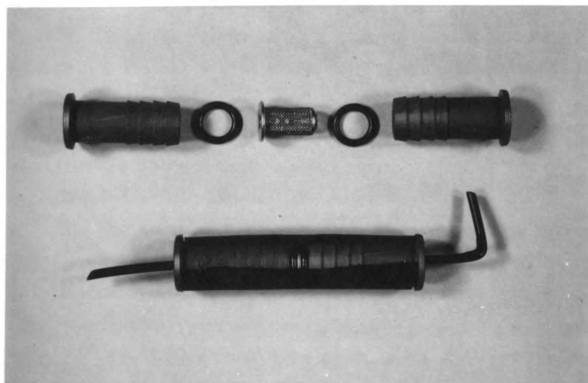
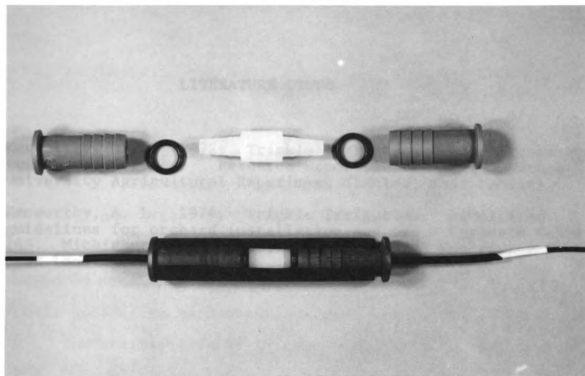


Fig. 1 Percent K remaining as related to the number of cycles run.

Figure 2. Top, L-R: 1/2" end plug, plastic 'o' ring, 3/8" check valve, plastic 'o' ring, 1/2" end plug.
Bottom: Check valve apparatus enclosed in 1/2" polyethylene pipe.

Figure 3. Top, L-R: 1/2" end plug, plastic 'o' ring, spray nozzle screen, plastic 'o' ring, 1/2" end plug.
Bottom: In-line screen apparatus enclosed in 1/2" polyethylene pipe.



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SUMMARY

In spring of 1972, 3-year-old liners of Pin Oak (Quercus palustris L.) and Common Honey Locust (Gleditsia triacanthos L.) and 4-year-old liners of Sugar Maple (Acer saccharum Marsh.) and White Ash (Fraxinus americana L. cv. Autumn Purple) were planted in a uniform Coloma loam soil near Albion, Michigan. Trickle irrigation was installed during July and August of 1972.

The relationship of trickle irrigation to root distribution was evaluated with Sugar Maple, Common Honey Locust, and Pin Oak. Treatments were 5.7 liters per hour and no supplemental water. Trees were dug with a 66" tree spade October 17, 1974. The root system of each tree was divided into 15 cm concentric cylinders around the trunk. Roots were divided into those greater than 2 mm and those less than 2 mm in diameter. Fresh weight determinations were made with each root size classification in each zone.

The following observations were made:

1. The irrigation treatments did not alter root system depth of Sugar Maple, Common Honey Locust, or Pin Oak.
2. On a weight basis, irrigated Sugar Maple had more fibrous roots and irrigated Common Honey Locust had more larger roots than check trees. The difference in response may reflect characteristic differences between the species.

3. Irrigated Pin Oak had more fibrous roots and more larger roots than check trees.
4. Root systems of irrigated and non-irrigated trees of all species were distributed in the same volume of soil.
5. In 1973, the higher flow rate of irrigation resulted in twice the increase in trunk diameter of Pin Oak, White Ash, and Sugar Maple trees. Trunk diameter increase for irrigated Common Honey Locust trees was also greater than check trees.
6. In 1974, 1 hr and 2 hr irrigated Pin Oak and White Ash trees again outgrew check trees but irrigated Common Honey Locust and Sugar Maple trees did not.
7. Leaf N and K were the only elements to show consistent changes (decrease) with all species. Trickle irrigation did not promote any consistent significant change in composition of leaves for other nutrients. This decrease in N may have caused the reduced response during the second year of trickle irrigation.
8. A fertilizer injection system based on hydraulic displacement of tank fertilizer solution was developed for trickle irrigation systems.

9. Fertilizer turnover for the system was determined. Sixty-six percent of the fertilizer was removed from the tank during each cycle (cycle is the movement of a volume of water equal to the volume of the tank thru the tank).

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