THE INFLUENCE OF TRICKLE IRRIGATION AND NITROGEN INJECTION ON APPLE, PEACH, SOUR CHERRY AND PLUM

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ABSTRACT

THE INFLUENCE OF TRICKLE IRRIGATION AND NITROGEN INJECTION ON APPLE, PEACH, SOUR CHERRY AND PLUM

By

Michael Wayne Smith

Trickle irrigation trials were established on peach (*Prunus persica* Batsch. cv. 'Redhaven'), plum (*Prunus domestica* L. 'Stanley'), sour cherry (*Prunus cerasus* L. 'Montmorency'), and apple (*Malus domestica* Bork. cvs. 'Wayne', 'Golden Delicious', and 'Rhode Island Greening'). Treatments were 0, 1.9, 3.8, 7.6 liters per hour (lph) in 1975, and 0, 3.8, 7.6, and 15.2 lph in 1976.

Trickle irrigation increased yield of Redhaven peach and Wayne apple in 1975, and Redhaven peach and Wayne, Rhode Island Greening, and Golden Delicious apples in 1976. Fruit size was increased on Redhaven peach and Rhode Island Greening, but not on other cultivars of apples studied. The increase of yield but not fruit size of most of the apple cultivars indicates that preharvest drop was decreased due to trickle irrigation. Similar observations were made in the field.

Increased levels of some nutrients in the leaves occurred when trees were trickle irrigated. The elements showing increases were P, Cu, and B in peach, P, Na, Fe, Cu, Zn, and Al in plum, and Na, Ca, Mg, Mn, and Al in sour cherry. An increase

in the rate of water to 15.2 lph caused a decrease in nutrient content of peach and plum. Nutrient composition of Wayne and Golden Delicious was decreased for some elements with trickle irrigation. Na, B, and Al was decreased in Wayne, and Ca, Mn, Fe, B, and Al in Golden Delicious. Irrigation had no effect on the nutrient composition of Rhode Island Greening.

The percent soluble solids, % total solids, % alcohol insolubles, and % titratable acidity was not affected in sour cherry. The percent total solids, % soluble solids, and % titratable acidity of plums were the same for all treatments, while variable results were recorded for peach. In apple ascorbic acid, % total solids, and % soluble solids was highest at 0 lph.

In a second experiment, N was injected through the trickle irrigation system at three different rates, and applied to the soil at one rate. The rates were the growers rate of N applied to the soil, and 100, 50, and 25% of that rate injected through the trickle irrigation system. This was applied in factorial combination with irrigation rates of 1.9, 3.8, and 7.6 lph in 1975, and 3.8, 7.6, and 15.2 lph in 1976. The same crops were used as in the trickle irrigation trials.

Injection of N through the trickle irrigation system is more efficient than applying it to the soil. Leaf N of all crops was generally as high for all levels of N injected, as the ground application. Yield was unaffected by N treatment, except at the 25% level. N injection generally did not influence fruit size or quality. Injecting N through the trickle irrigation system allows reduction of N application by 50% to obtain the same tree response.

N distribution within the tree is affected by the rate of water applied. N was evenly distributed within the tree at 7.6 lph. At 3.8 lph, the N was accumulated on the side of the tree with the emitter. Lower leaf N occurred at the 15.2 lph indicating leaching and denitrification was occurring, reducing the efficiency of the application.

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INTRODUCTION

The trickle irrigation concept involves the use of a small quantity of water supplied at daily intervals to prevent plant water stress, and thus aid growth and production. The daily application of water eliminates cycling of soil moisture and provides more efficient use of water by reducing evaporation, deep percolation, and run-off.

The principle of trickle irrigation originated in England in 1948 with the introduction of an automated watering system for greenhouse tomatoes. In the 1960's, it was introduced into the United States where it received rapid acceptance for use in arid areas on fruit and nut trees, ornamentals, vineyards, and vegetables.

In Michigan, the first experimental installations of trickle irrigation were established in 1971 followed closely by commercial installations. It is estimated Michigan now has 15,000-20,000 acres of orchards with trickle irrigation.

Applying fertilizer through the trickle irrigation system is practiced in arid states. In such areas, rainfall is not adequate to dissolve and leach the nitrogen into the root zone, making it necessary to apply it with the water.

Research here involved studies on rate (amount) of water applied and the influence of applying nitrogen fertilizer through the trickle irrigation system. Four fruit crops were used; apple, sour cherry, peach and plum. Tree response was measured by yield, fruit size, fruit quality, and nitrogen content.

LITERATURE REVIEW

Research on trickle irrigation in humid climates has recently been initiated. Its use in arid areas was initiated rapidly because of its more efficient application of water, and the lower costs of installation and use compared to conventional irrigation. To date, this is the second report on tree performance in humid areas, and the first on fruit crops.

Application of fertilizer through the trickle irrigation system has been suggested since its early beginnings, but little research has been reported, and none concerned with reducing the amount of fertilizer required due to more efficient utilization of the fertilizer.

Research in arid areas has shown increases in yield and water use efficiency with trickle irrigation (4,5). In humid areas, increases in growth with a more fibrous root system has been reported for some ornamental trees (19,20). A study by Kesner (10) on the distribution of sour cherry roots with trickle irrigation indicated the amount and distribution of the roots was unchanged by trickle irrigation. Other work has suggest higher levels of soil moisture will increase absorption of some nutrients by the plant (12,13,17,18).

Application of fertilizer through the trickle irrigation system may be better with some nutrients than others. NO_3 moves readily with the irrigation water allowing an equal distribution to the roots, providing there is adequate lateral movement of water. When P is applied from a trickle source, it is rapidly absorbed by the clay particles, resulting in the highest concns at the emitter, and an unequal distribution in the soil (22).

Application of N through the trickle irrigation system has been reported to be more efficient than banding with either trickle of furrow irrigation (14). Application of P through a trickle irrigation system has produced higher P content in tomatoes than banding equal amounts (21).

The two parts of the dissertation are prepared in the style for research papers in the Journal of the American Society for Horticultural Science.

SECTION I

TRICKLE IRRIGATION IN HUMID REGIONS: I. ITS EFFECT ON YIELD, SIZE, NUTRIENT CONTENT AND FRUIT QUALITY OF FRUIT TREES

Abstract. In 1975, trickle irrigation plots were established on cherry (*Prunus cerasus* L. cv. 'Montmorency'), plum (*Prunus domestica* L. cv. 'Stanley'), peach (*Prunus persica* Batsch. cv. 'Redhaven'), and apple (*Malus domestica* Bork. cvs. 'Wayne', 'Golden Delicious', and 'Rhode Island Greening') at 0, 1.9, 3.8, and 7.6 liters per hour (lph). During 1976, irrigation rates were changed to 0, 3.8, 7.6, and 15.2 lph. Yield was increased due to irrigation on Redhaven peach and Wayne apple in 1975. Irrigation during 1976 increased yields of peach and the three cultivars of apples. Fruit size was largest on irrigated trees of peach and Rhode Island Greening. Other cultivars and species tested did not show an increase in fruit size. Leaf content of Ca, Na, Mn, Mg, and Al was generally increased in irrigated treatments of peach, sour cherry, and plum. Decreased levels of Na, B, Al, Ca, Mn, and Fe were found in some apple cultivars due to irrigation. Trickle irrigation did not affect total solids, soluble solids, or titratable acidity of plum or cherry. The alcohol insoluble fraction of cherry was highest at 15.2 lph. Total solids of peach were not effected by treatments while soluble solids and titratable acidity yielded variable results. Generally, titratable acidity of apple was not affected while

ascorbic acid, total solids, and soluble solids were highest at 0 lph.

Trickle irrigation was first used in the arid areas of the world. Research was aimed at an evaluation of it as an alternative to other methods of irrigation. In these studies, increased water use efficiency and increased yields were reported (4,5). Today, trickle irrigation has reached the higher rainfall areas of the world. In these areas, most of the installations have been made on sites not normally irrigated. Installations have been made due to low cost of trickle irrigation compared to other systems, and anticipated increases in production.

Ponder and Kenworthy (15,16) reported increased growth of nursery trees and a more compact and fibrous root system in some ornamental trees in Michigan. Other work has suggested a higher soil moisture level may facilitate uptake of various nutrients by the plants (9,10,13,13).

This study was conducted to determine if supplemental irrigation was beneficial in the more humid regions of the world by increased yields. Other factors such as nutrient absorption and fruit quality were studied.

MATERIALS AND METHODS

Trickle irrigation plots were established on sour cherries (*Prunus cerasus* L. cv. 'Montmorency'), plum (*Prunus domestica* L. cv. 'Stanley'), peach (*Prunus persica* Batsch. cv. 'Redhaven'), and apple (Malus domestica Bork. cvs. 'Wayne', 'Golden Delicous', and 'Rhode Island Greening'). In 1975, peach was 6, cherry 7, apple 5, and plum 7-years-old. MM 106 was the rootstock for all apple cultivars. Soil type was a sandy loam with a clay layer at approximately 75 cm. Treatments were 0, 1.9, 3.8, and 7.6 liters per hour (lph) in 1975, and 0, 3.8, 7.6, and 15.2 lph in 1976. A randomized complete block design was used with five blocks for apple, peach and plum, and ten blocks for cherry. Replications were five-tree plots for cherry and plum, and four-tree plots for peach and apple.

Irrigation began June 10 and ended September 15 in 1975. Apples were irrigated 1.5 hr per day, and peach, plum, and cherry 3 hr per day, 7 days a week. In 1976, irrigation started June 8 and ended October 1, with 4 hr per day on cherry and peach, and 2.5 hr per day for plum and apple, 6 days a week. Rainfall was 686 mm from April 1 to September 30, 1975, and 270 mm for the same period in 1976.

Leaf samples were collected for analysis during mid July both years. Samples were analyzed for N by Macro-Kjeldahl procedure (1), K by flame spectrophotometer[1], and the spark emission spectrograph[2] (6) was used for the other elements.

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[1]Beckman model B.

[2]Applied Research Laboratories Quantograph.

Small variations in tree sizes existed in the orchards, and to compensate for this, yield was adjusted to kg/100 cm^2 trunk area for all species, except peach. Fruit size was measured on cherry and plum by weighing 100 fruit. Average diameter of 25 fruit per replication was measured on apple and peach.

Fruit samples were collected at harvest for analysis. Two blocks were used for apple, peach, and plum, and four blocks for cherry. Each replication was divided into two subsamples for analysis. The % total solids was determined by taking an aliquot of the sample and freeze drying it. The % soluble solids and % titratable acidity were determined on an aliquot ground in a blender for two minutes, and filtered through Whatman number 1 filter paper. The % soluble solids were determined on the filtrate with an Abbe refractometer. An aliquot of the filtrate was mixed with distilled water, then titrated to pH 8.0 with 0.1 N NaOH (1). Acidity was expressed as % citric acid for cherry, peach, and plum, and as % malic acid for apple.

Ascorbic acid content was determined on apple by blending 50 gm of slices with 200 ml of oxalic acid, then filtering through Whatman number 1 filter paper. Three 1 ml aliquots were pipetted into colorimeter tubes with 9 ml of distilled water in one for the blank, and 9 ml of sodium-2,6-dichlorobenzenone indolephenol as the indicator in the others. Samples were analyzed using the colorimeter (8).

The % alcohol insolubles of cherry was determined by blending 25 gm of cherry with 150 ml of 80% ethanol. The blended material was transfered quantitatively to a beaker with an additional 150 ml of 80% ethanol, then simmered in a boiling water bath for 30 minutes. The alcohol insolubles were removed from the solution by filtering through teared Whatman #5 filter paper in a Buchner funnel. Filters were dried for 2 hr at 70^{o}C and weight of insolubles determined (1).

Statistical analysis of data was by Fishers F-test with mean separation by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Yield was increased in 1975 for Redhaven peach and Golden Delicious apple (Figure 1). Water above 1.9 lph did not result in further increases in yield on Golden Delicious. Highest yields from peach were at 3.8 and 7.6 lph. No differences were found for other crops tested. In 1976, all three cultivars of apple showed an increase in yield due to trickle irrigation (Figure 2). Golden Delicious and Wayne did not respond to additional water above 7.6 lph. Maximum yield for Rhode Island Greening was at 15.2 lph. Peaches responded to each increment of irrigation applied with 15.2 lph producing the highest yield (Figure 3). Cherry yield did not increase with irrigation in either year. This may be due to their early harvest before moisture stress can become severe.

Figure 1. Yield related to the rate of trickle irrigation in 1975. Letters indicate significance at the 5% level within each fruit. Yield of peaches is in kg/tree, others are in kg/100 cm^2 trunk area.

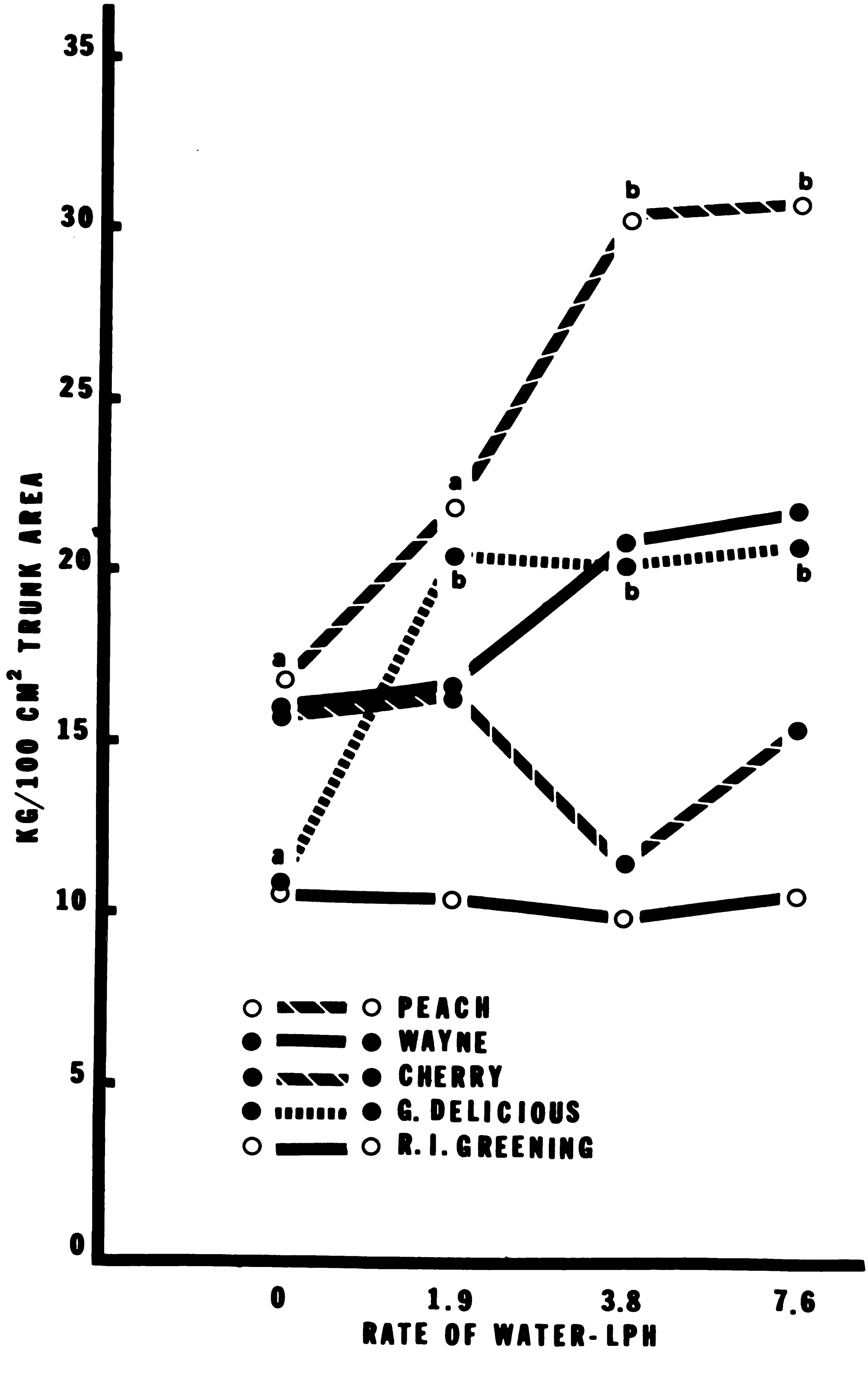
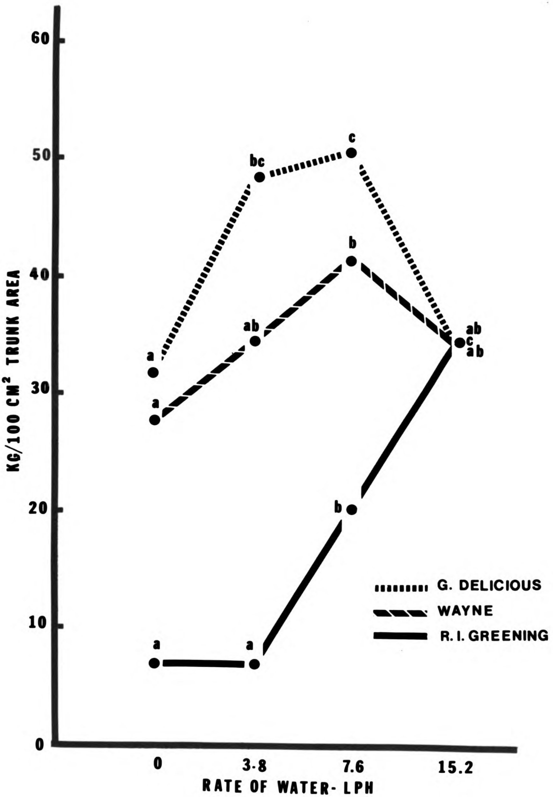

KG/100 CM² TRUNK AREA
35
30
25
20
15
10
5
0
0
1.9
3.8
7.6
RATE OF WATER-LPH
a
b
PEACH
WAYNE
CHERRY
G. DELICIOUS
R. I. GREENING

Figure 1

Figure 2. Yield of apple related to the rate of trickle irrigation in 1976. Letters indicate significance at the 5% level, within each cultivar.



60
50
40
30
20
10
0
KG/100 CM² TRUNK AREA
0
3.8
7.6
15.2
RATE OF WATER- LPH
G. DELICIOUS
WAYNE
R. I. GREENING
a
bc
c
b
ab
a
ab
c
ab
b
a
a

Figure 2

Figure 3. Yield related to the rate of trickle irrigation in 1976. Letters indicate significance at the 5% level. Yield of peach is kg/tree, others in kg/100 cm^2 trunk area.

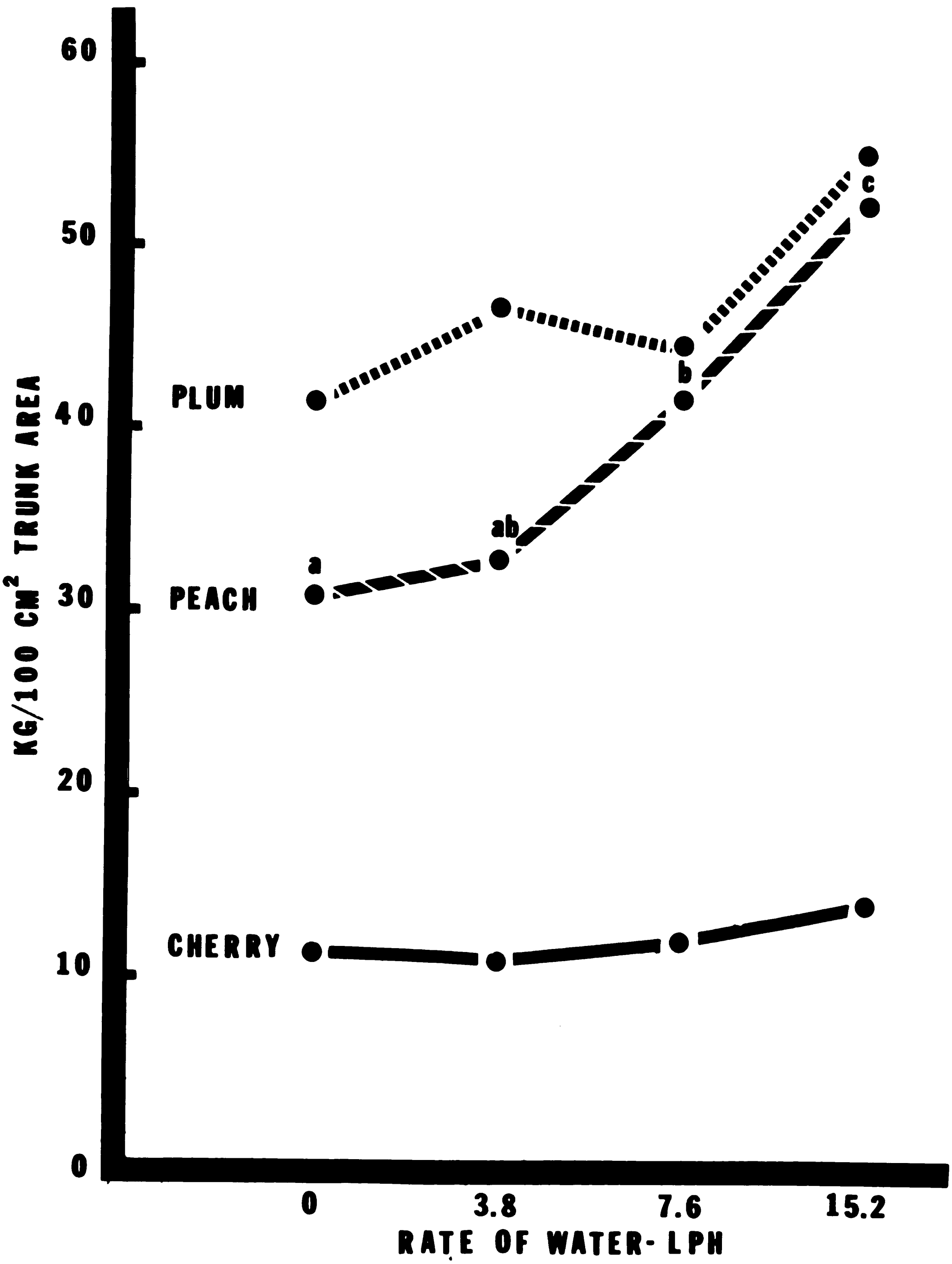

60
50
40
30
20
10
0
KG/100 CM^2 TRUNK AREA
PLUM
PEACH
CHERRY
a
ab
b
c
0
3.8
7.6
15.2
RATE OF WATER- LPH

Figure 3

The peach and Rhode Island Greening increased in fruit size (Figure 4) due to irrigation. In both Golden Delicious and Wayne, size was not effected. June drop and pre-harvest drop was heavy in all three cultivars of apples. Because there was no increase in fruit size, though yield was significantly increased, trickle irrigation may have reduced fruit drop. This agrees with observations made during the season.

Trickle irrigation increased the leaf composition of Na, Ca, Mg, and Al in sour cherry (Table 1). The dominate mechanism for movement of Na, Ca, and Mg to the root is mass flow (2,3,12,13). Of the elements studied, B and N are the only other two which move to the root by mass flow. Boron absorption showed a tendency to be increased by higher rates of water, but it was not significant. Although N moves to the root by mass flow, its uptake would not be expected to be decreased unless transpiration was reduced by high soil moisture tension. This is because the amount of NO_3 in the soil solution is controlled by biological activity and not a solid phase equilibrium or an equilibrium with the exchangeable ions. Therefore, when there is a smaller amount of water in the soil, it results in a higher concn of NO_3 in the soil solution instead of driving it into the solid phase or clay particles absorbing more ions, making it less available for the plant. Due to this, as long as transpiration is not reduced, the same amount of N is available to the plant.

Mn is moved to the plant root by diffusion (12), and some reports have indicated increases in movement of

Figure 4. The effect of trickle irrigation on fruit size. Letters indicate significance at the 5% level within each species.

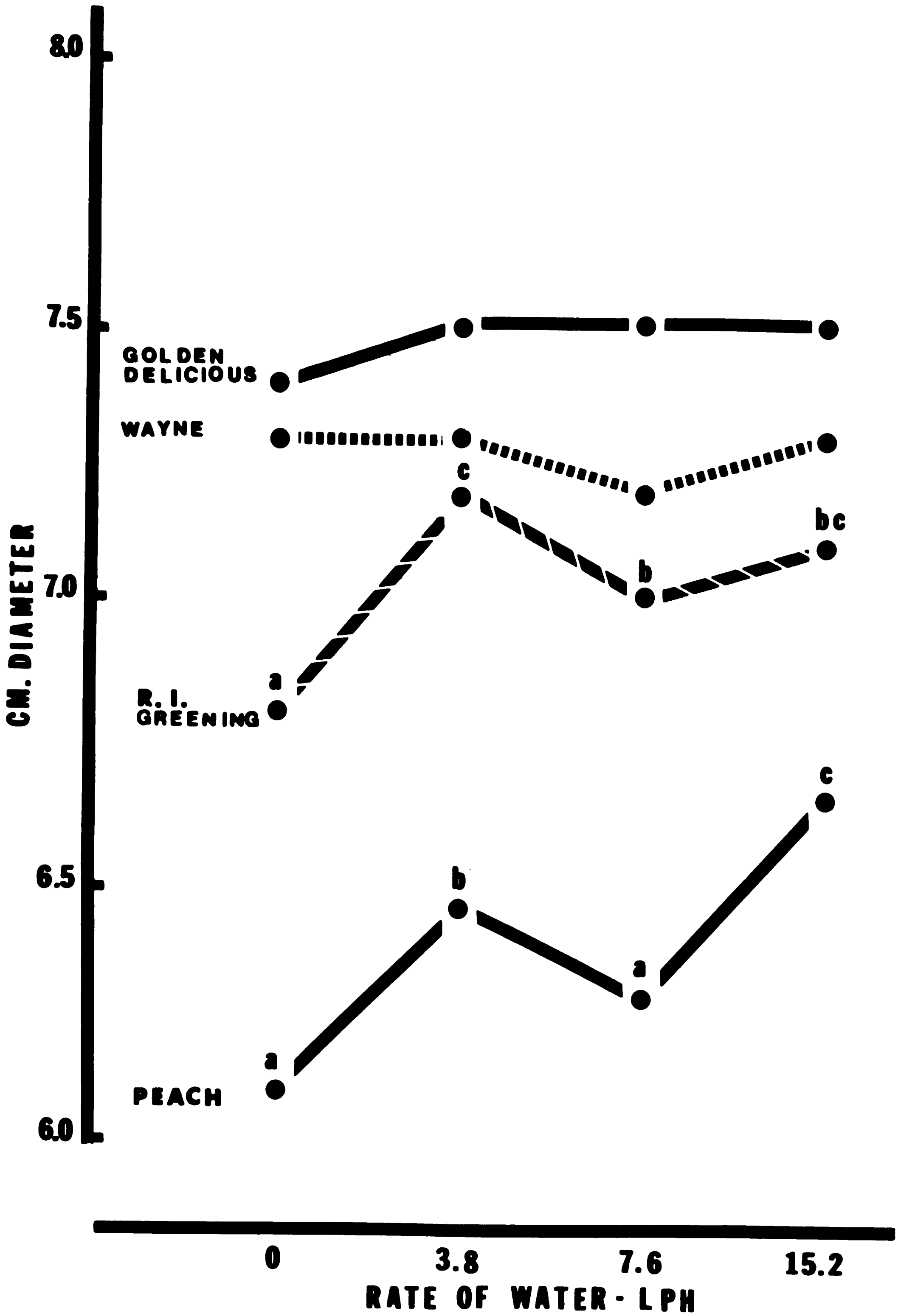

8.0
7.5
7.0
6.5
6.0
CM. DIAMETER
GOLDEN DELICIOUS
WAYNE
R. I. GREENING
PEACH
a
c
b
bc
a
b
a
c
0
3.8
7.6
15.2
RATE OF WATER - LPH

Figure 4

diffusable ions due to higher soil moisture (9,10). This appears to be due to a higher amount of the ion in the solution to maintain the same concn. This allows more time for the ions to move to the roots before they are limiting absorption.

Peach and plum leaves that received trickle irrigation contained more P, Cu, and Al (Table 1). Both Cu and Al concn in the leaves was maximum at 3.8 and 7.6 lph, and dropped off at 0 and 15.2 lph for both crops. This gives indirect evidence for restricted root growth at both 0 and 15.2 lph. At 0 lph, soil conditions may have been too dry for maximum root growth, while excess water at 15.2 lph limited root growth. Additional elements that were increased with trickle irrigation were B in peach, and Na, Mn, Fe, and Zn in plum.

Increasing rates of trickle irrigation on Wayne and Golden Delicious generally reduced the concn of nutrients in the leaves (Table 2). On Wayne, Na, B, and Al decreased while P and Ca content increased. No differences were found for the other elements. Trickle irrigation decreased concn of Ca, Mn, Fe, B, and Al in Golden Delicous with no effect on the other elements. This may be a dilution effect due to greater leaf area and growth in trickle irrigated plots rather than decreased absorption of these ions. The soil in this orchard is more loamy than the other sites and would therefore allow greater ion movement than in the sandier texture soils at the same tension. Therefore, growth may

Table 1. The effect of trickle irrigation on the nutrient composition in leaves of stone fruits.[z]

LPH	N (%)	P (%)	K (%)	NA (ppm)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Zn (ppm)	Al (ppm)
						Sour Cherry						
0	2.82	0.13	1.37	4.5a	1.49a	0.28a	54.9a	93.8	9.45	14.9	11.8	111.7a
3.8	2.86	0.16	1.23	8.1ab	1.80b	0.33b	65.5ab	97.3	6.78	14.9	17.2	126.3ab
7.6	2.84	0.15	1.31	12.4ab	1.75ab	0.31ab	76.2b	102.3	11.39	14.5	17.9	142.0ab
15.2	2.80	0.15	1.33	14.6b	1.68ab	0.30ab	70.3ab	101.1	11.11	17.0	18.4	154.6b
						Peach						
0	3.70	0.13a	1.99	13.7	1.79	0.35b	161.0	116.8	6.79a	20.0a	19.4	218.4ab
3.8	3.74	0.16b	2.28	18.0	1.75	0.32a	177.0	129.7	11.76b	23.1b	25.5	246.2b
7.6	3.74	0.15b	2.05	14.5	1.81	0.33ab	204.6	115.0	12.05b	23.1b	23.4	226.0b
15.2	3.64	0.15b	2.07	7.1	1.76	0.31a	176.5	106.7	11.03b	22.8b	25.0	186.9a
						Plum						
0	2.88	0.13a	3.45	22.9ab	2.00	0.26	150.0b	343.2a	5.69a	31.3	16.9a	253.8a
3.8	2.99	0.18c	3.24	21.7a	1.96	0.26	102.1a	384.4b	16.68a	29.7	29.8a	359.9c
7.6	2.97	0.18c	3.41	37.0b	2.36	0.32	169.8b	331.4a	37.23b	31.9	34.1b	324.5b
15.2	2.94	0.16b	3.76	18.1a	2.10	0.28	84.7a	365.0ab	4.80a	32.8	19.9a	299.3b

[z]Means within each column of the same species followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

Table 2. The effect of trickle irrigation on the nutrient composition in leaves of apple.[z]

LPH	N (%)	P (%)	K (%)	Na (ppm)	Ca (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)	Zn (ppm)	Al (ppm)
						Golden Delicious						
0	2.59	0.13	1.17	22.0	1.51b	0.23	125.4b	115.6b	8.72	23.7b	22.2	320.7c
3.8	2.46	0.12	1.31	26.3	1.47ab	0.22	80.1a	106.1ab	11.03	20.6a	24.0	267.7b
7.6	2.57	0.12	1.32	17.5	1.44ab	0.23	90.4a	106.1ab	8.86	19.9a	19.9	260.1b
15.2	2.55	0.12	1.37	15.5	1.35a	0.21	74.4a	99.6a	8.27	21.1a	19.1a	232.3a
						Rhode Island Greening						
0	2.48b	0.12	1.11	17.0	0.99	0.20	71.5	103.8	6.97	22.8	18.6	238.7ab
3.8	2.49b	0.12	1.16	17.0	1.20	0.22	78.4	100.2	8.42	22.7	23.2	224.8a
7.6	2.34a	0.12	1.18	17.2	1.09	0.19	77.2	103.2	7.12	22.0	18.9	263.9bc
15.2	2.49b	0.12	1.13	11.6	1.09	0.20	66.9	106.7	7.41	20.5	20.1	300.9c
						Wayne						
0	2.30	0.12ab	1.19	28.3b	1.18ab	0.20ab	73.8	94.3	10.01	20.2bc	18.6	281.6b
3.8	2.24	0.11a	1.23	18.4ab	1.13a	0.19a	81.8	89.6	7.41	22.2c	18.9	219.7a
7.6	2.47	0.13b	1.11	9.0a	1.27bc	0.22b	79.6	89.0	8.42	19.2ab	11.4	229.8a
15.2	2.40	0.13b	1.04	18.4ab	1.33c	0.23b	67.0	90.8	7.70	17.7a	10.8	245.0a

[z]Means within each column in the same cultivar followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

have been restricted in plots with less water, while nutrient movement was not, resulting in increased concn in the leaves. Growth measurements did not show any differences between treatments, but data was highly variable, and a representative estimate of growth was questionable. Al was increased in Rhode Island Greening with trickle irrigation while a variable effect was found for N, and no response for the other elements tested.

The rate of trickle irrigation did not effect total solids, soluble solids, titratable acidity, or the alcohol insoluble fraction of sour cherry (Table 3).

Total solids in peaches were not effected (Table 3). Both soluble solids and titratable acidity were highest in 0 and 7.6 lph treatments. This follows fruit size data with 0 and 7.6 lph yielding the smallest fruit. Fruit size being the smallest in these two treatments, there is a concn effect on soluble solids and titratable acidity. Other factors such as crop load are suggested for a variable response to trickle irrigation in this data. Irrigation had no effect on soluble solids, or titratable acidity in plum (Table 3).

The total solids was decreased with increasing rates of trickle irrigation on Rhode Island Greening and Wayne (Table 4). Soluble solids of Wayne and Golden Delicious were also decreased with higher rates of water. This may be attributed to larger amounts of water in these resulting in a lower ratio of dry weight to fresh weight. No differences in treatments were found for the titratable acidity for any

Table 3. The effect of trickle irrigation on fruit quality of stone fruit.[z]

LPH	Soluble Solids %	Total[Y] Solids %	Titratable Acidity %	Alcohol Insolubles %
		Sour Cherry		
0	14.2	15.2	1.24	1.18
3.8	14.0	14.8	1.23	1.14
7.6	14.3	15.2	1.16	1.18
15.2	14.3	15.7	1.16	1.14
		Peach		
0	13.3b	15.4	0.90b	
3.8	11.0a	12.2	0.80a	
7.6	13.2b	13.6	0.85b	
15.2	11.1a	11.8	0.70a	
		Plum		
0	13.1	14.3	0.93	
3.8	13.2	15.6	0.85	
7.6	13.3	14.2	1.00	
15.2	14.2	15.1	0.91	

[z]Means within each column of the same species followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

[Y]The % total solids is equivalent to the % dry weight.

Table 4. The effect of trickle irrigation on fruit quality of apple.[z]

Cultivar	Rate of Water (LPH) 0	3.8	7.6	15.2
	Soluble Solids (%)			
Gol. Delicious	15.6c	15.6c	15.0b	14.3a
R. I. Greening	15.9	16.0	15.1	14.5
Wayne	16.8c	15.6b	14.4a	14.9a
	Total Solids (%)[y]			
Gol. Delicious	17.0	17.1	16.4	15.6
R. I. Greening	18.3b	18.5b	17.5ab	16.5a
Wayne	18.1c	16.8b	15.7a	16.4b
	Titratable Acidity (%)			
Gol. Delicious	0.63	0.58	0.57	0.65
R. I. Greening	0.86	0.95	0.90	0.92
Wayne	0.75	0.60	0.61	0.58
	Ascorbic Acid (mg/100 gm)			
Gol. Delicious	9.80b	8.65b	8.65b	6.20a
R. I. Greening	5.32a	8.98b	8.65b	7.55b
Wayne	11.28b	8.18a	8.78a	8.67a

[z]Means within each row followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

[y]The % total solids is equivalent to the % dry weight.

cultivar. Ascorbic acid content of Golden Delicious and Wayne was highest at 0 lph and decreased with an increase of trickle irrigation. Again, this may be a dilution effect and not necessarily decreased ascorbic acid synthesis. Rhode Island Greening responded in a different manner. The lowest ascorbic acid being found at 0 lph with all rates of trickle irrigation significantly.

SUMMARY

Trickle irrigation increased yield of Redhaven peach and Golden Delicious apple in 1975. Highest yield of peach was at 3.8 lph with 7.6 lph not resulting in further increases. Yield of Golden Delicious was increased with trickle irrigation over no irrigation, however, there was no difference in irrigated treatments. Yield in 1976 was increased by irrigation of peach and the three cultivars of apple. The yield of Redhaven peach and Rhode Island Greening was highest at 15.2 lph, and Golden Delicious and Wayne at 7.6 lph. Treatments did not effect yield on Montmorency cherry and Stanley plum. Fruit size was highest on peach at 15.2 and on Rhode Island Greening at 3.8 and 15.2 lph. No differences in fruit size occurred on the other crops as a result of trickle irrigation.

Nutrient content of leaves for many of the elements was increased in peach, plum and cherry. The elements showing the most consistent increases with irrigation were Ca, Na, Mn, Mg, and Al. Others responding in some cases were P, B, Zn,

and Cu. N and K were the elements least affected by trickle irrigation. There were decreased levels of some elements at 15.2 lph in peach and plum. This may have been due to excess water. Apple showed a general decrease in concn of some elements with trickle irrigation. These were Na, B, Al, Ca, Mn, and Fe. Because most of these were increased in the other crops with irrigation, a dilution due to increased growth may be the result of lower concn rather than decreased absorption.

Trickle irrigation had no effect on total solids, soluble solids, or titratable acidity of cherry or plum. The alcohol insoluble fraction of cherry was not significantly different for any treatment. Total solids of peach were not effected although irrigation produced variable results on soluble solids and titratable acidity. Titratable acidity of all apple cultivars tested was not effected. Total solids, soluble solids, and ascorbic acid was generally highest at 0 lph for apple. This appears to be more of a dilution effect because of increased water, rather than decreased synthesis.

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SECTION II

TRICKLE IRRIGATION IN HUMID REGIONS. II. THE EFFICIENCY OF NITROGEN INJECTION ON FRUIT TREES

Abstract. N was applied at the recommended rate as a ground application, and 25, 50, and 100% of that rate injected through the trickle irrigation system in factorial combination with trickle irrigation rates of 1.9, 3.8, and 7.6 liters per hour (lph) in 1975, and 3.8, 7.6, and 15.2 lph in 1976. Treatments were established on cherry (*Prunus cerasus* L. cv. 'Montmorency'), plum (*Prunus domestica* L. cv. 'Stanley'), peach (*Prunus persica* Batsch cv. 'Redhaven'), and apple (*Malus domestica* Bork. cvs. 'Rhode Island Greening', 'Golden Delicious', and 'Wayne'). Injection treatments had the same % leaf N as the ground application in almost every case. Yield of the ground application, 100%, and 50% injection treatments were equal, but 25% injection had varied results. Injection treatments had no marked effect on fruit size or fruit quality. N distribution within the tree was uniform at 7.6 lph. N levels in the leaves were lower at 15.2 lph.

Conservation of N has become a major goal for agriculture in recent years. More efficient use of N is important to reduce energy required for synthesis, expense for growers, and N pollution in surface and underground water.

N application through trickle irrigation has been reported to be more efficient than banding with trickle irrigation or furrow irrigation (5). Phosphorus content of tomatoes was higher when P was applied through a trickle irrigation system than when equal amounts were banded (6). A study of the movement of NO_3 and P from a trickle source indicates N may be more suitable for injection because of its mobility in the soil (7). NO_3 readily moves with the water in the soil, allowing a more uniform distribution to the plant.

This experiment was set up to test the hypothesis that a localized application of N to the root system could decrease the amount of N required for the same plant response. N application could also be made over the growing season by injection to provide the N when needed by the plant.

MATERIALS AND METHODS

Trickle irrigation rates were 1.9, 3.8, and 7.6 liters per hour (lph) in 1975, and 3.8, 7.6, and 15.2 lph in 1976. N treatments were used at the following rates in both years in factorial combination with trickle irrigation rates.

1. The grower rate of N applied to the ground.
2. The grower rate of N injected through the trickle irrigation system.

3. 50% of the grower rate of N injected through the trickle irrigation system.
4. 25% of the grower rate of N injected through the trickle irrigation system.

Type of Fruit Crop	Age in 1975	Kgms of N/Tree for ground application	
		1975	1976
Sour Cherry	7	0.56	0.56
Peach	6	0.56	0.56
Plum	7	0.66	0.77
Apple	5	0.25	0.39

No additional N was applied to the injection treatments. Ground applications were applied late in the fall both years. Injection treatments of NH_4NO_3 were applied in four equal amounts at weekly intervals starting June 12 in 1975, and June 9 in 1976. Treatments were arranged in split-pot design on cherry (*Prunus cerasus* L. cv. 'Montmorency'), plum (*Prunus domestica* L. cv. 'Stanley'), peach (*Prunus persica* Batsch, cv. 'Redhaven'), and apple (*Malus domestica* Bork. cvs. 'Wayne', 'Golden Delicious', and 'Rhode Island Greening'). Apple, plum, and peach had five replications per treatment, with four trees per block in apple and peach, and five in plum. Cherry had ten blocks per treatment, with five trees per block.

Accumulation of N in the leaves was monitored in cherry at 7.6 lph for each of the N treatments. Samples were collected from three replications prior to the first N injection and continued at weekly intervals until all N had been applied. In all cases, N analysis was by the macro-Kjeldahl method (1).

To determine the effect of emitter placement on the distribution of N within the tree, the three rates of irrigation were sampled all with 100% of the grower's rate of N injected. Sampling time was late July. Five replications were sampled in the cherry, taking one sample from the side of the tree with the emitter, and another from the side without the emitter.

Leaf samples were collected in mid-July over all crops and replications for N analysis. Fruit samples were collected at harvest to determine the various quality factors, and were handled as described in the previous paper.

Yield data was adjusted to kg/100 cm^2 of trunk area for all crops except peach. Fruit size was estimated by the number of gms per 100 fruit for plum and cherry, and the average diameter of 25 fruits per replication in apple and peach.

RESULTS AND DISCUSSION

Nitrogen content of leaves sampled in 1975 was the same for all N treatments of plum, peach, and Golden Delicious apple. Sour cherry had a lower N content at 50% injection, however, both 25% and 100% injection was as high as the ground application (Table 1). Rhode Island Greening had higher leaf N in the ground application than injecting 50% of the ground application, while Wayne had the highest % N in the 50% injection. Samples taken in 1976 had the same % N content for all treatments in plum, peach, and apple cultivars Golden Delicious and Rhode Island Greening (Table 2). In sour cherry, N content was the same for the ground application 100, and 50% injection, but injecting 25% of the ground application had a lower % N. N content of Wayne was highest at 50% injection.

Surface application of N is a less efficient method of applying N than by injecting it. Loss of N through volatilization of NH_3 has been reported to be from 14 to 35% from surface applied N (3,4), but incorporation of 1.5 inches reduced loss to 4% (3). N applied through the trickle irrigation system is moved into the soil and thus reduces this loss. Surface run-off and leaching loss would be reduced by spreading the application period over time, while surface run-off is reduced to almost none by moving the N into the soil. Immobilization of N should also be reduced by applying the N when the plants need it, making the plant more competitive with the microorganisms for the N. Another factor which could aid in increased efficiency of N utilization is reduced NH_4 fixation. By applying the N with the water, it would be in the area of soil which is prevented from excessive drying. This should aid in the prevention of absorption of NH_4 by the clay particles.

Table 1. Leaf nitrogen related to rate and method of application of nitrogen (1975).[z]

Crop	Ground Application	Percent Injected 100	50	25
	Percent of dry weight			
Sour Cherry	2.83b	2.80ab	2.56a	2.75ab
Plum	2.47	2.42	2.46	2.45
Peach	3.85	3.80	3.90	3.77
Apple				
G. Delicious	2.43		2.41	
R. I. Greening	2.22b		1.98a	
Wayne	2.24a		2.30b	

[z]Means within each row followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

Table 2. Leaf nitrogen related to rate and method of application of nitrogen (1976).[z]

Crop	Ground Application	Percent Injected 100	50	25
	Percent of dry weight			
Sour Cherry	2.83b	2.81b	2.82b	2.60a
Plum	2.98	2.99	2.94	2.85
Peach	3.71	3.84	3.81	3.69
Apple				
G. Delicious	2.52		2.51	
R. I. Greening	2.44		2.40	
Wayne	2.36a		2.48b	

[z]Means within each row followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

Because N injection is a more efficient method of application, one would expect injecting 100% of the ground application to result in higher N values. This was not realized in the data, and some reasons may be suggested. NO_3 uptake appears to be an active process, transported across the cell membrane by a carrier. This is similar to an enzymatic reaction in that the carrier becomes saturated, and additional N will not result in increased uptake (2). At 100% injection, the carrier may be saturated while at 50% injection the optimum concn for maximum uptake without too much time required in the soil before the N is used may have been reached. By minimizing the time in the soil before absorption losses such as leaching, denitrification, immobilization, and volatilization are minimized. These losses probably account for the lower efficiency of N usage at 100% injection.

Yield of the crops tested generally were unaffected by N treatments (Table 3,4). Sour cherry, Rhode Island Greening and Wayne showed no difference in yield for all N treatments in 1975, and Golden Delicious and Rhode Island Greening had showed no difference in 1976. For other crops tested in 1975 and 1976, yield was usually different for only one N treatment, generally the 25% injection. Apple cultivars and peach yields varied between the two years of the study. In apple, the difference is largely due to increased age and size of the tree. Peaches yield less in 1975 due to over thinning using a trunk shaker.

Table 3. The effect of rate and method of application of nitrogen on yield (1975).[z]

Crop	Ground Application	Percent Injected 100	50	25
	kg/100 cm^2 Trunk Area			
Sour Cherry	16.5	16.7	16.0	15.4
Peach[y]	23.7b	18.4a	20.9ab	22.4b
Apple				
G. Delicious	20.8b		14.8a	
R. I. Greening	11.0		10.3	
Wayne	21.2		19.6	

[y]Yield in kg/tree.

[z]Means within each row followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

Table 4. The effect of rate and method of application of nitrogen on yield (1976).[z]

Crop	Ground Application	Percent Injected 100	50	25
		kg/100 cm^2 Trunk Area		
Sour Cherry	12.7b	10.9b	10.1b	9.1a
Plum	48.3b	39.0a	40.6a	48.4b
Peach[y]	46.2a	33.5b	43.7a	42.2a
Apple				
G. Delicious	44.5		43.3	
R. I. Greening	21.3		16.4	
Wayne	36.9b		26.0a	

[y]Yield in kg/tree.

[z]Means within each row followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

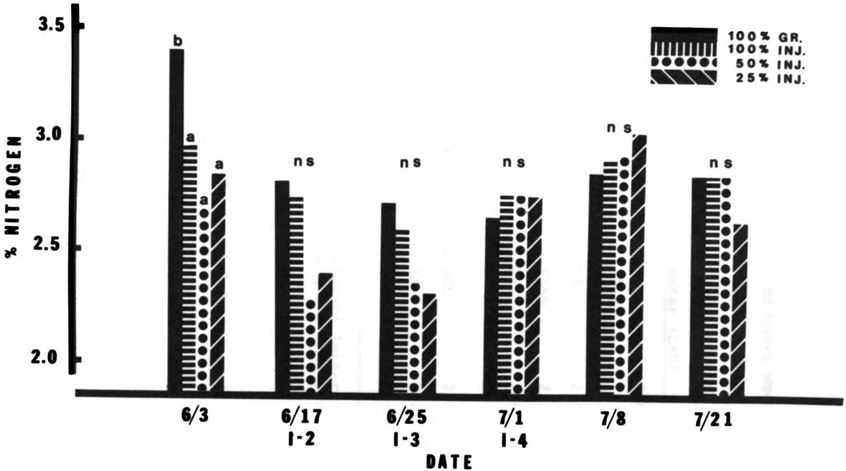
Results of the % N content of leaves and yield indicate that the amount of N can be reduced to 50% of normal recommended rates by injecting it, and still maintain the recommended % leaf N and yield. Injection of 25% N generally did not result in significantly reduced leaf N, but numerically it was less. This accounts for the variable yields obtained at this rate of injection. Injection of 50% of the grower rate maintained yield as high as the ground application in all but three cases over the two years, and as high or higher leaf N.

Accumulation of leaf N is rapid from N injection. Prior to injection, the fall applied ground application had the highest leaf N (Figure 1). One week after first injection, no significant differences between N treatments were found. This pattern continued throughout the rest of the season.

Tables 5 and 6 indicate that the rate of water did not have very much effect on the N content of the trees. The distribution of N within the tree was affected by the rate of water (Figure 2). At 3.8 lph, the N was concentrated on the side of the tree with the emitter, while N was evenly distributed in the tree at 7.6 lph. N content at 15.2 lph was the lowest of the three rates of water indicating there was some denitrification and leaching of NO_3 out of the root zone.

Fruit size was unaffected by N treatment on sour cherry and plum (Table 7). Peach size was largest at 50 and 100% injection (Table 8). Variable results occurred in the three

Figure 1. Accumulation of leaf nitrogen (%) related to time and rate of application on sour cherry. I under dates represents injections of nitrogen.


100% GR.
100% INJ.
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6/3
6/17
I-2
6/25
I-3
7/1
I-4
7/8
7/21
DATE

Figure 1

Table 5. Leaf nitrogen related to rate of water when nitrogen is injected (1975).[z]

Crop	Rate of Water (LPH) 1.9	3.8	7.6
	Percent of dry weight		
Sour Cherry	2.64a	2.69a	2.88b
Plum	2.50b	2.45ab	2.39a
Peach	3.68a	3.85b	3.97b
Apple			
G. Delicious	2.37a	2.50b	2.39a
R. I. Greening	2.05	2.14	2.11
Wayne	2.24	2.27	2.31

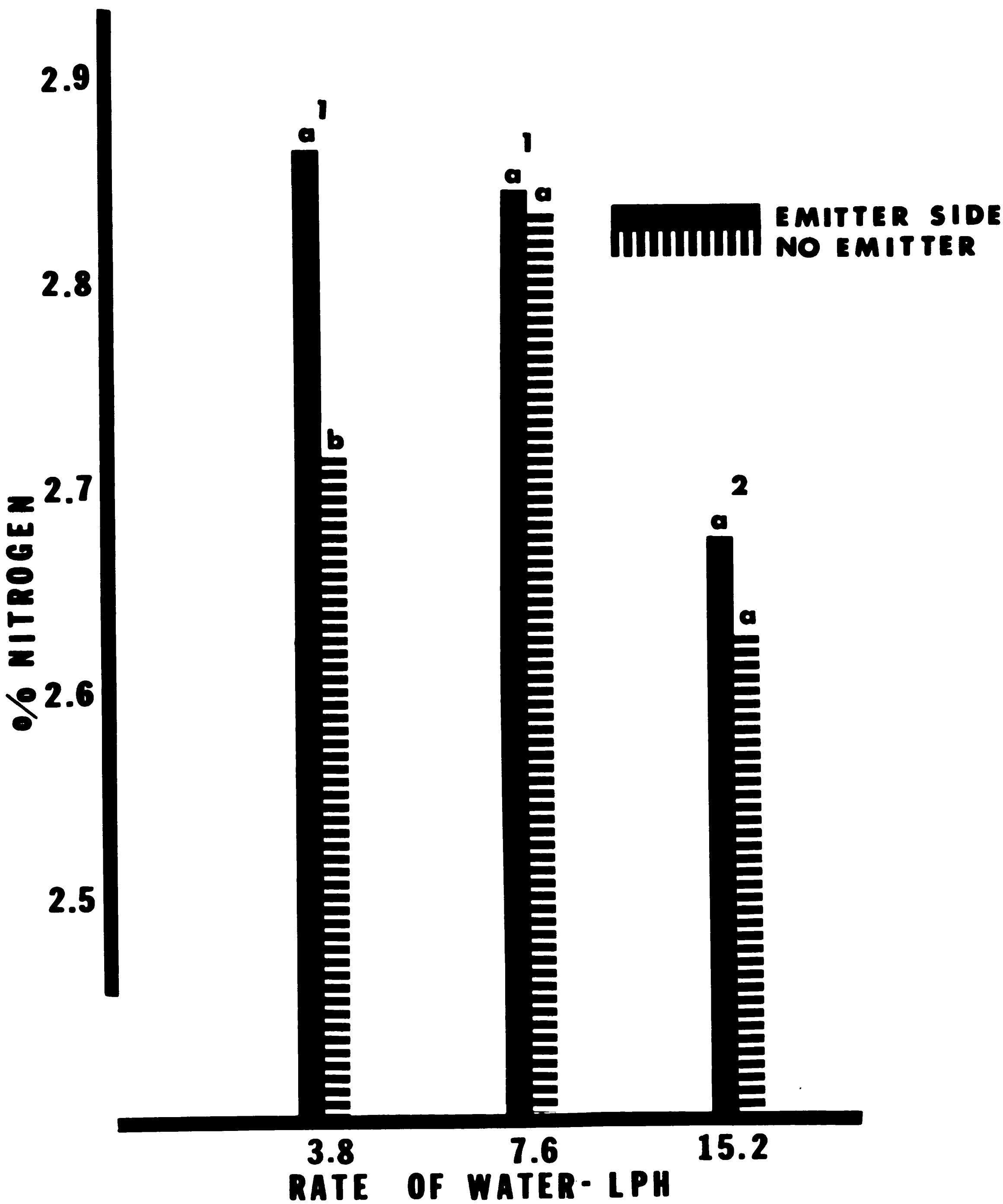
[z]Means within each row followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

Table 6. Leaf nitrogen related to rate of water when nitrogen is injected (1976).[z]

	Rate of Water (LPH)		
Crop	3.8	7.6	15.2
	Percent of dry weight		
Sour Cherry	2.74	2.80	2.76
Plum	2.88a	3.01b	2.93ab
Peach	3.71	3.81	3.76
Apple			
G. Delicious	2.37a	2.61b	2.58b
R. I. Greening	2.38	2.34	2.55
Wayne	2.36	2.49	2.43

[z]Means within each row followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

Figure 2. The interaction between the rate of water and emitter location on the distribution of nitrogen in the tree. Letters indicate significance between emitter placement, and numbers between rates of water at the 5% level.


2.9
2.8
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NO EMITTER
3.8
7.6
15.2
RATE OF WATER- LPH

Figure 2

Table 7. The effect of rate and method of application of nitrogen on fruit size (1976).[z]

Crop	Application	Percent Injected 100	50	25
	gm/100 fruits			
Sour Cherry	468	473	473	469
Plum	2740	2753	2835	2856

[z]Treatments were not significant at the 5% level by Fisher's F-test.

Table 8. The effect of rate and method of application of nitrogen on fruit size (1976).[z]

Crop	Ground Application	Percent Injected 100	50	25
		cm. Diameter		
Peach	6.40a	6.73c	6.64bc	6.55ab
Apple				
G. Delicious	7.56b		7.40a	
R. I. Greening	7.10a		7.37b	
Wayne	7.32		7.41	

[z]Means within each row followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

apple cultivars.

Total solids, soluble solids, and titratable acidity of peach and plum were unaffected by N treatment (Table 9). Titratable acidity and alcohol insolubles of cherry were the same for all N treatments, but soluble solids and total solids were increased at 25% injection. Results were variable on the three apple cultivars (Table 10). Soluble solids were increased on Wayne, decreased on Golden Delicious, and no effect on Rhode Island Greening. Total solids were identical to soluble solids in response. Titratable acidity was increased in Wayne and Rhode Island Greening, and decreased in Golden Delicious. Ascorbic acid content was the same in Golden Delicious and Rhode Island Greening, but higher for Wayne at 50% injection.

SUMMARY

Injection of N at 50% of the ground application resulted in equal leaf N, yield, fruit size, and fruit quality to the ground application in most instances. At 25% injection, leaf N was generally not significantly different, but was numerically lower, and had a varied effect on yield compared to the other N treatments. Injection of 25% of the ground application does not appear sufficient to maintain yield over the years of production.

The rate of water influences both the distribution of N and the amount accumulated within the tree. At 3.8 lph,

Table 9. Fruit quality of stone fruits related to rate and method of application of nitrogen.[z]

Treatment	Soluble Solids %	Total[y] Solids %	Titratable Acidity %	Alcohol Insolubles %
		Sour Cherry		
Ground Application	14.2	15.2a	1.18	1.17
100% - Injected	13.8	15.2a	1.18	1.15
50% - Injected	14.1	15.1a	1.18	1.12
25% - Injected	14.9	15.8b	1.18	1.18
		Plum		
Ground Application	10.0	13.6	0.91	
100% - Injected	9.9	13.0	0.93	
50% - Injected	9.8	13.4	0.96	
25% - Injected	9.7	13.0	0.94	
		Peach		
Ground Application	11.8	12.5	0.78	
100% - Injected	11.6	12.3	0.85	
50% - Injected	11.4	12.3	0.80	
25% - Injected	10.6	11.4	0.79	

[z]Means within each column of the same species followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

[y]The % total solids is equivalent to the % dry weight.

Table 10. The effect of rate and method of application of nitrogen on fruit quality of apples.[z]

Treatment	Soluble Solids %	Total[y] Solids %	Titratable Acidity %	Ascorbic Acid mg/100 gm
		Rhode Island Greening		
Ground Application	15.2	17.5	0.92	8.39
50% - Injected	15.2	17.8	0.95	9.56
		Wayne		
Ground Application	15.0 a	16.3a	0.60a	8.54a
50% - Injected	15.9b	17.6b	0.76b	12.85b
		Golden Delicious		
Ground Application	14.9b	16.4b	0.60b	8.00
50% - Injected	14.4a	15.8a	0.54a	6.83

[z]Means within each column of the same cultivar followed by different letters are significant at the 5% level by Duncan's Multiple Range test.

[y]The % total solids is equivalent to the % dry weight.

the spread of water was not adequate to move NO_3 to the opposite side of the tree from its point of injection. N was equal on both sides of the tree at 7.6 lph. Data from the interaction between emitter placement and rate of water indicates less accumulation of N at 15.2 lph.

Accumulation of N after injection is quite rapid. Within one week after the first injection of N, there was no significant differences between treatments. Additional injections increased N levels in the leaves, but not higher than the ground application.

Results of this experiment indicate N application can be reduced to 50% of the amount normally applied, and maintain the same tree responses. The rate of trickle irrigation effects its performance when applied, with 7.6 lph being the optimum rate in this sandy loam soil.

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SUMMARY

Trickle irrigation plots were established on sour cherry, plum, peach and apple, with treatments of 0, 1.9, 3.8, 7.6 lph in 1975, and 0, 3.8, 7.6, and 15.2 lph in 1976. Yields of peach and Wayne were increased in 1975 and 1976 with trickle irrigation. Rhode Island Greening and Golden Delicious yields were higher in 1976 with trickle irrigation. No differences were found between irrigated and nonirrigated plots of cherry and plum.

Fruit size was increased on peach and Rhode Island Greening with trickle irrigation. Golden Delicious, Wayne and the sour cherry and plum did not respond to irrigation.

Absorption of some elements was increased in peach, plum and sour cherry. Elements generally showing increases were P, Na, Ca, Mg, Mn, and Al. Elements with the least response to irrigation were N and K. At 15.2 lph, many of the composition values of the elements were lower. Nutrient composition of apples were reduced for some elements. These were Na, Fe, B, and Al.

Some of the quality factors measured for the fruits were changed with trickle irrigation. Alcohol insolubles were not changed in cherry. Ascorbic acid content was decreased in apple with irrigation. Other factors measured

for their respective crops either were not changed, or had variable results.

In the second experiment, N was injected through the trickle irrigation system with different rates of water. By injecting 50% of the amount applied to the ground leaf N and yield was as high as the ground application for the crops tested. Injection of 25% of the ground application produced variable results on yield. Fruit size and fruit quality was generally not affected by N treatment.

Optimum rate of water for N injection in the sandy loam soil was 7.6 lph. At this rate, N distribution was equal in the tree. At 15.2 lph, the amount of N in the tree was reduced, while at 3.8 lph, distribution in the tree was unequal.

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