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Irrigation Methods and In-row Chiseling for Tomato Production[1]

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Abstract. **Field studies were conducted on Plinthic and Typic Paleudult soils in central Alabama to determine the response of tomatoes (*Lycopersicon esculentum* Mill.), to furrow, sprinkle, and trickle irrigation with and without in-row chiseling. Irrigation by all methods and in-row chiseling increased plant heights which ranged from 70 to 120 cm at first harvest. Marketable tomato yields were influenced more by irrigation (37% increase) than by chiseling (8% increase). Yields averaged 36.7 metric tons/ha with no irrigation and 50.1 metric tons/ha with irrigation. No difference was found between irrigation methods. Amounts of irrigation water applied per season averaged 34.5 cm for furrow, 37.4 cm for sprinkle, and 16.0 cm for trickle. In-row chiseling increased yields an average of 3.7 metric tons/ha, but was significant in only 1 of 3 years.**

Even in areas of high rainfall, poor water distribution during critical plant growth periods can reduce yields or cause crop failure. The supply of available water for plant growth can be increased either by supplemental irrigation or by management practices that result in a deeper root system, thus making more of the soil water available for plant use. In soils with plowpans or compacted zones resulting from field traffic, deeper rooting normally occurs after the compacted layer is broken in some manner such as chiseling (4).

Several researchers have reported that supplemental irrigation increased tomato yields (3, 5, 11, 12). Moore et al. (12) reported that maximum returns from supplemental irrigation on tomatoes were obtained by maintaining the available soil moisture above 50% along with close plant spacing. Trickle irrigation has been reported to save water and increase crop yields by as much as 50% compared with furrow and sprinkler irrigation (1, 2, 8, 9). Drip irrigation of staked tomatoes in California resulted in slightly higher yields and appreciable water savings as compared with furrow irrigation (10). Chiseling the compact and infertile subsurface of a Varina sandy loam soil (Typic Paleudult) increased the rooting depth and plant water availability in the soil profile, and resulted in increased yields of millet and sweet corn (6, 7).

The purpose of this experiment was to determine the effects of irrigation methods and in-row chiseling on plant growth and yield of staked tomatoes.

Materials and Methods

'Tropic' tomatoes were grown in Central Alabama with 4 irrigation and 2 tillage treatments on a Dothan (Plinthic Paleudult) loamy sand soil in 1976 and on an Orangeburg (Typic Paleudult) sandy loam soil during 1977 and 1978. A winter cover crop of 'Abruzzi' rye was mowed and land was turned to a depth of 20 to 25 cm 5 weeks prior to land preparation for the experiment. Plots were fertilized with 56 kg N/ha, 50 kg P/ha, and 140 kg K/ha, according to soil test recommendations. Soil test pH was 6.2. Trifluralin at the rate of 0.56 kg/ha was applied for weed control. Fertilizer and herbicide were thoroughly incorporated to a depth of 8 to 10 cm.

Transplants were 6 weeks old when set in mid-April and spaced 38.1 cm apart in 2.03 m rows. Plants were staked and tied 6 times with twine, beginning when 45 cm tall and thereafter every 15 cm as the plants grew taller. Plants were not pruned. Additional sidedress N was applied from NH_4NO_3 at 78 kg/ha when first fruits were 2 to 3 cm in diameter.

Irrigation and tillage treatments were arranged in a split-plot design, with irrigation as main plots and tillage as subplots with 4 replications. Irrigation treatments were (a) no irrigation, (b) furrow irrigation, (c) sprinkler irrigation, and (d) trickle irrigation. The 2 tillage treatments were in-row chiseling and no chiseling. Irrigation water was applied through a flow meter to all treatments. Furrow irrigation water was applied through a 7.62 cm aluminum irrigation pipe with four 2.5-cm holes spaced 1.02 m apart to deliver water uniformly to each side of the row. Sprinkle irrigation was supplied through 2 sprinkler heads with 3.97-mm nozzles, 1 placed at each end of the plot, and set to rotate 45°. Trickle irrigation was supplied at 0.21 kg/cm^2 pressure through a 4-mil twin-wall hose with trickle holes spaced 30.5 cm in the outer wall. The trickle hose was placed on the soil surface next to the plants. All irrigation methods had water applied to maintain 50% or higher available soil water in the surface 60 cm of soil. Furrow and sprinkler plots were irrigated about 6 to 7 days after rainfall of 2.5 cm or more, and at 6 to 7-day intervals thereafter, until rainfall occurred. Trickle-irrigated plots were irrigated about 4 to 5 days after rainfall and every 2 days thereafter until rainfall occurred. Since water was applied to a limited area by trickle irrigation, it was applied more frequently than to furrow or sprinkler plots. A sufficient amount of water was applied each time to replenish the surface 60 cm of soil to field capacity, which was about 3 cm on furrow and sprinkle plots and 0.6 cm on trickle plots for each irrigation. A dike was constructed around each plot to retain all rainfall and irrigation water. Heavy rainfall sometimes occurred soon after irrigation and resulted in excessive water in the soil profile for short periods. Chiseling was done directly beneath the row to a depth of 30 to 35 cm immediately before plants were set. Main plots were spaced 6.1 m apart to eliminate the possibility of the lateral movement of irrigation water from one treatment to the other and also to prevent overlapping of water from sprinkler-irrigated plots onto the other plots.

Plants were sprayed weekly with insecticides (dimethoate, carbaryl, and/or methomyl) and fungicides (zinc-ion-maneb complex or chlorothalonil) after the sprinkler irrigation treatment was applied. Plant heights were measured at 2-week intervals during the growing season. Fruits were harvested weekly at pink and red ripe maturity beginning in late June and ending in August. Marketable fruit were graded into 3

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size groups: large (5x6 ⩾ 6.8 cm diameter), medium (6x6 = 6.4 to 7.3 cm diameter), and small (6x7 = 5.7 to 6.7 cm diameter). At the end of each growing season, plants were indexed for defoliation, partially attributed to early blight *(Alternaria solani)* and damage from the vegetable leaf miner *(Liriomyza sativae)*. Rooting patterns were observed in each treatment after the last harvest each year by excavating for visual observation. Notes were recorded as to extent of roots in soil; however, no quantitative data were taken.

Results and Discussion

Irrigation requirements were relatively high during 2 of the 3 seasons as a result of low rainfall (Table 1). Rainfall during the period from planting to last harvest was 53 cm in 1976 and 28 cm in 1977 and 1978 (Table 1). Rainfall was low during the first part of the 1977 season, with only 10 cm occurring during the first 82 days after planting. The amount of irrigation water applied per season ranged from 7.3 cm with the trickle method in 1976 to 50.8 cm for the sprinkle method in 1977 (Table 1). The total amount of water applied by the furrow and sprinkle irrigation treatments was about the same each year, with less than half of these amounts applied to the trickle-irrigated treatment.

Table 1. Rainfall recorded and irrigation water applied, central Alabama.

Month	Rainfall (cm)	Irrigation method (cm)		
		Furrow	Sprinkle	Trickle
		1976		
April (16-30)	3.6	--	--	--
May	20.4	--	--	--
June	12.8	11.4	10.7	4.3
July	10.7	11.4	12.2	3.9
August (1-9)	5.9	--	--	--
Total	53.4	22.8	22.9	8.2
		1977		
April (14-30)	2.5	--	--	--
May	2.0	17.2	18.7	8.5
June	5.5	18.4	20.1	9.5
July	17.8	11.4	12.0	6.4
Total	27.8	47.0	50.8	24.4
		1978		
April (20-30)	0.8	--	--	--
May	19.5	3.2	3.8	1.8
June	5.5	15.2	17.9	7.1
July	2.5	15.2	16.8	6.5
Total	28.3	33.6	38.5	15.4

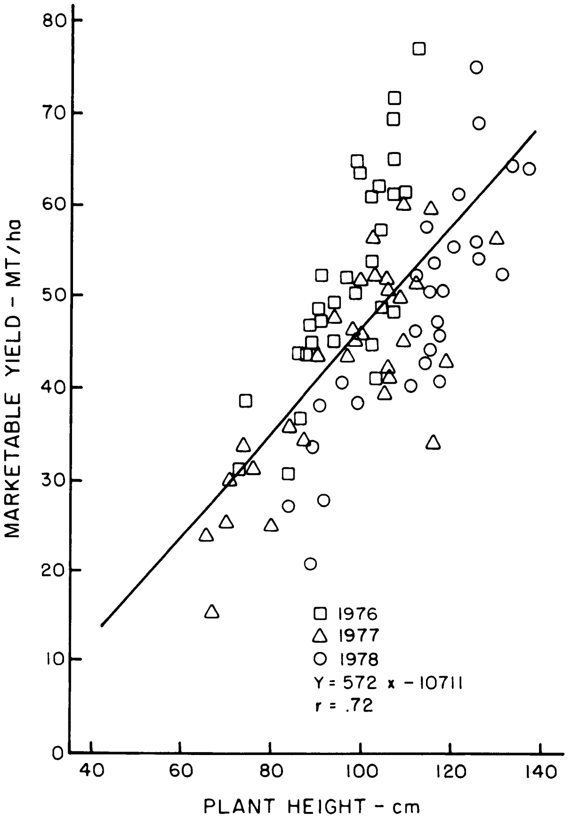

Fig. 1. Relationship of tomato plant heights to marketable yields.

The rate of plant growth in early season and plant height at the time of first harvest were increased by irrigation and in-row chiseling in only 1 of 3 years (Table 2). The average plant height at the beginning of harvest for the various treatments ranged from 70 to 120 cm. The greatest effect from irrigation or chiseling was in 1977, when irrigation increased plant heights at first harvest an average of 36 cm and chiseling increased heights by about 13 cm. Plant height at the beginning of harvest was significantly and linearly correlated (r = .72) with marketable tomato yields during all years (Fig. 1).

Marketable tomato yields as affected by irrigation and tillage are given in Table 3. Yields were increased by irrigation during 1977 and 1978, but were not affected by irrigation in 1976, a year that had high rainfall amounts during the season. Yield response to irrigation was greatest in 1977 when rainfall was lowest during the peak fruiting period. There was little

Table 2. Main effects of irrigation and tillage method on plant height at first harvest.

Treatment	Plant height (cm)		
	1976	1977	1978
Irrigation			
None	98a[z]	70b	109a
Furrow	95a	108a	120a
Sprinkle	96a	108a	114a
Trickle	98a	102a	118a
Tillage			
Not chiseled	94a	91b	114a
Chiseled	100a	104a	117a

[z] Irrigation and tillage mean separation by Duncan's multiple range test, 5% level.

Table 3. Main effects of irrigation and tillage method on marketable tomato yields.

Treatment	Marketable fruit (MT/ha)			Avg
	1976	1977	1978	(1977-78)
Irrigation				
None	50.2a[z]	23.4b	36.4b	30.0b
Furrow	51.8a	46.3a	52.0a	49.1a
Sprinkle	53.5a	46.8a	49.8a	48.4a
Trickle	53.2a	47.8a	49.6a	48.7a
Tillage				
Not chiseled	49.2b	39.7a	45.9a	42.8a
Chiseled	55.2a	42.5a	48.1a	45.3a

[z] Irrigation and tillage mean separation by Duncan's multiple range test, 5% level.

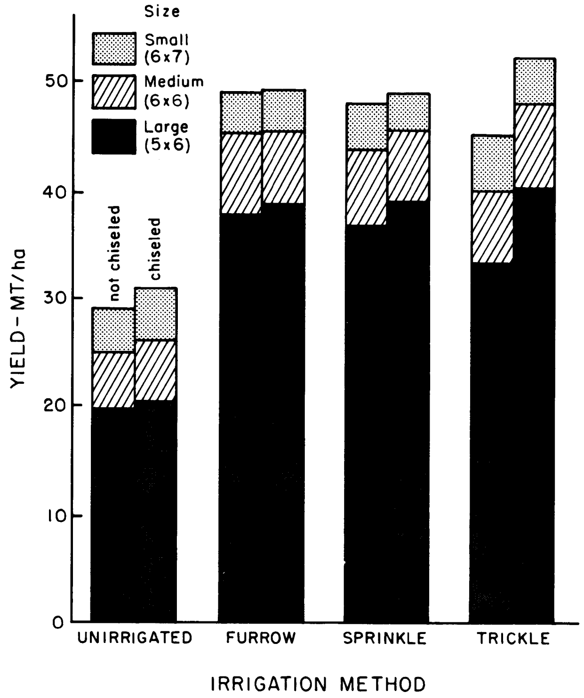

Fig. 2. Marketable tomato yields by fruit size as affected by methods of irrigation and tillage (5x6 = ⩾ 6.8 cm diameter, 6x6 = 6.4 to 7.3 cm diameter, 6x7 = 5.7 to 6.7 cm diameter) (average 1977-1978).

difference between average tomato yields between the 3 irrigation treatments, although the trickle-irrigated treatment had less than half the amount of irrigation water applied that was applied to the furrow or sprinkler treatments. Average tomato yields in 1977 and 1978 showed that irrigation increased yields by 18.7 MT/ha, which was 62% greater than yields on unirrigated plots.

In-row chiseling significantly increased marketable tomato yields only in 1976 (Table 3). However, in most cases yields tended to be greater on chiseled plots than on unchiseled plots for the other years. There was no significant interaction between irrigation and tillage treatments, but in 1977 unirrigated tomato yields from chiseled plots were 8.5 MT/ha or 44% greater than from unchiseled plots.

Irrigation and chiseling affected the size distribution of marketable fruit (Fig. 2). The percentage of large fruit tended to be higher on irrigated than on unirrigated plots and higher on chiseled than on unchiseled plots. The overall average shows that 73% of marketable tomatoes were large size on unirrigated plots as compared with 79% on irrigated plots. Although chiseling had little effect on fruit size distribution, unchiseled plots averaged 76% large size fruit, and chiseled plots averaged 79%. An overall average for fruit size distribution showed 78% of marketable tomatoes were large size, 14% were medium, and 8% were small.

The yield of cull tomatoes was not affected by tillage methods, but tended to be lower with than without irrigation. Culls averaged 29% of total yield on unirrigated plots and 26% on irrigated plots. Most cull fruit was from catfacing, which apparently was not affected by irrigation or chiseling, and from blossom-end rot, which was greater on unirrigated than on irrigated plots.

The percentage of plants with defoliation ranged from 8 to as high as 48, with more defoliated plants in 1976 than in 1977 or 1978 (Table 4). There was a significant relationship between percent defoliated plants and marketable yields in 1977, but not in 1976 or 1978. The percent of defoliated plants tended to be greater all 3 years with sprinkler irrigation than with other irrigation treatments.

Table 4. Main effects of irrigation and tillage method on percentage defoliated plants at end of harvest season.

	Defoliated plants (%)		
Treatment	1976	1977	1978
Irrigation			
None	34a^z	15b	11a
Furrow	22a	16b	10a
Sprinkle	35a	48a	13a
Trickle	22a	16b	8a
Tillage			
Not chiseled	30a	24a	10a
Chiseled	26a	24a	11a

^{z}Irrigation and tillage mean separation by Duncan's multiple range test, 5% level.

Root observations made at the end of each harvest season indicated that rooting depths and patterns were not greatly affected by irrigation. However, tomatoes grown in trickle-irrigated treatment plots appeared to have more roots in the subsoil both with and without chiseling than did plants on the other irrigation treatment plots. Chiseling appeared to increase the depth and amount of tomato rooting in the subsoil both with and without irrigation. Roots grew down the chiseled slot and branched out into the subsoil. Roots on unchiseled plots grew down to the bottom of the plow layer and stopped, with some roots apparently turning and growing laterally but with few growing into the subsoil.

Conclusions

Marketable tomato yields were increased by irrigation in 2 low rainfall years, but were unaffected by irrigation when rainfall was sufficient. Chiseling had an overall beneficial effect on yields only in 1976 when the experiment was conducted on a Dothan loamy sand soil. However, chiseling did increase plant heights in 1977. Yields with the different irrigation methods were about the same each year, but the trickle plots had less than half the amount of water applied as did the furrow and sprinkler irrigation plots. Tomatoes on irrigated plots outyielded those on unirrigated plots by an average of 37%, and tomatoes on chiseled plots outyielded those on unchiseled plots by an average of 8%. The percentage of defoliated plants at the end of the harvest season was greater in all seasons with sprinkle-irrigation than with either furrow or trickle irrigation.

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Fruit and Leaf Isozymes as Genetic Markers in Avocado[1]

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Abstract. **Leaf samples of over 100 avocado (*Persea americana* Mill.) cultivars and 8 other *Persea* species were analyzed for isozyme variation of peroxidase (PX), malate dehydrogenase (MDH), leucine aminopeptidase (LAP) and phosphoglucose mutase (PGM). MDH, LAP and PGM isozymes of leaf and mesocarp were identical. Isozymes of alcohol dehydrogenase (ADH) and glutamate oxaloacetate transaminase (GOT) were detected in mesocarps but were not available from leaves. Leaf PX isozymes were specified by 3 genes having 11 alleles and MDH isozymes by 1 gene with 3 alleles. To date, 6 enzyme systems specified by 12 genes with 37 codominant alleles are available as genetic markers of possible use in problems of avocado systematics, measurements of outcrossing rates, documentation of parentages and screening of seedlings in breeding programs.**

The methods and the rationale for using variant molecular forms of enzymes, isozymes, as genetic markers in the avocado to overcome the difficulties inherent in its perenniality and breeding system (10) have been described (11, 12, 13). Isozymes are ideal markers because they are colinear with the gene, commonly codominant in effect and relatively unaffected by the environment. An earlier study (13) utilized isozymes from the fleshy mesocarp of the avocado but certain problems are best addressed using leaf tissue because leaves are available sooner than fruit. For example, the breeder may be concerned with screening young seedlings for parentage long before fruiting (5-8 years) so that space and other resources are not needlessly utilized (11); the same problem obtains in citrus (14) and presumably other woody, long-lived, slow-growing perennials. Avocado seeds would provide even earlier analyzable material from controlled crosses but it has not yet been possible to resolve their enzyme systems.

The previous report on avocado isozymes provided the first single-gene analysis for this species (13). It was found that 4 mesocarp enzyme systems were specified by 10 genes with 20 alleles: ADH is dimeric and specified by 2 genes, *Adh-1* and *-2;* LAP and PGM are monomers each coded by 2 genes, *Lap-1* and *-2* and *Pgm-1* and *-2;* the isozymes of *Got-1* and *Got-2* are dimers; *Got-3* is apparently monomorphic as no variation has been found thus far. Isozymes of *Got-4* were studied earlier but they are not included here because of recently observed variations which called into question their assumed subunit structure. The study involved about 30 cultivars including several of major commercial importance in California and Florida. Substantial polymorphism was found and encouraged a search for additional markers.

The present article presents genetic studies of the leaf isozymes of PX and MDH, shows that leaf and mesocarp isozymes of LAP, PGM and MDH are identical and lists the isozyme profiles of over 100 *Persea* taxa.

Methods and Materials

Fruit of Florida cultivars were from the Agricultural Research and Education Center, Homestead; leaves were not available. California materials were from the University of California, Riverside or the South Coast Field Station and each is identified by a UCR field number (Table 1). Samples for leaf PX were prepared by crushing three 8x8 mm pieces of healthy, mature leaves with slip-joint pliers in .07 ml 0.1 M potassium phosphate buffer (pH 7.5) in a plastic weighing boat. The crushing buffer for leaf LAP, PGM and MDH were as above, but included 12% soluble PVP (M.W. 40,000); the addition of 10 mM 2-mercaptoethanol improved resolution. PVP interfered with zymograms of PX. Mesocarp MDH required no crushing buffer. The starch gel electrophoretic conditions for leaf and mesocarp LAP and PGM and for mesocarp ADH and GOT were as described (13). A 17 mM tris-citrate gel buffer pH 7.9 and a 0.4 M sodium borate electrode buffer pH 8.7 were used for PX. The gel buffer for leaf and fruit mesocarp MDH was 16 mM tris-citrate (pH 6.9) and the electrode ubuffer was 48 mM tris-citrate (pH 6.9). MDH gels were run at ca. 1 ma/cm^2 of gel cross section for 6-8 hr. The staining mixture for PX was 40 mg of 3-amino-9-ethylcarbazole, 2 ml dimethyl-formamide, 4 ml 1 M sodium acetate buffer (pH 5.0), 1.6 ml of 0.1 M $CaCl_2$, 93 ml of H_2O and 0.4 ml of 3% H_2O_2. For MDH, the staining mixture included 6 ml of 1 M tris-HCl (pH 8.8), 50 ml H_2O, 8 ml 0.01 M nicotinamide adenine dinucleotide, 0.8 ml 0.01 M phenazine methosulfate, 4 ml 0.01 M nitro blue tetrazolium chloride, and 3 ml 2 M D,L-malic acid neutralized to pH 7.0 with NaOH.

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