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Proc. Fla. State Hort. Soc. 91: 319-322. 1978.

CHLORIDE AND BROMIDE MOVEMENT WITH TRICKLE IRRIGATION OF BELL PEPPERS[1]

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Additional index words. Fertilizer movement, *Capsicum annum.*

Abstract. **The distribution of chloride (Cl) and bromide (Br) with trickle-irrigated bell peppers** (Capsicum annum L.) **was determined as an indicator of fertilizer salt movement. In 1977, peppers were irrigated to maintain the soil at a moisture level of 0.3 bar. At the end of the growing season, KCl was added through the irrigation system and Cl distribution in the bed was monitored over a 93 hr period. Results indicated that Cl, and thus soluble fertilizer salt, were readily moved out of the root zone in 20 hours. In 1978, water was applied at 2 quantities based on pan evaporation, i.e., equal to 0.5 pan evaporation and pan evaporation, and at 3 discharge rates, 0.5, 1.5, and 3.5 gal/hr/plant. Chloride (KCl) was applied weekly as part of the fertilization program. Chloride distribution in the root zone determined two-thirds through the growing season again indicated rapid movement of Cl away from the emitter. No major differences were noted between treatments. At the end of the above study, Br was applied to the treatments receiving water at 0.5 and 3.5 gal/hr/plant at an amount equivalent to pan evaporation. Irrigation was applied twice daily during this period. Bromide moved out of the zone directly below the emitter during the 48 hr sampling period but considerable amounts remained at a radius of 6 inches around the emitter. Greater lateral distribution was indicated at the higher discharge rate suggesting that faster discharge rates may improve distribution of soluble fertilizer salts in the root zone.**

Trickle irrigation has gained wide acceptance in agriculture because it not only conserves water but allows more effective management of water and fertilizer applications, and has resulted in higher yield than other commonly used irrigation techniques (2, 3, 4, 5). However, coarse-textured soils require careful management of nutrients and water applied by trickle irrigation to prevent excessive loss of nutrients through leaching (2, 4, 6). Locascio and Myers (3, 4) have shown that nutrients must be applied with the irrigation water to obtain maximum yields of strawberries and tomatoes. Application of water without nutrients resulted in considerable leaching of nutrients applied at planting and lower yields. With daily trickle irrigation of mulched strawberries, N and K were leached from the top 12 inches of soil (6). Soil nutrient levels were maintained at a higher level where N and K were applied weekly through the irrigation system (2, 4, 5, 6).

Water management with trickle irrigation for shallow-rooted crops is very critical since the vertical component of the wetted zone is dominant compared to the radial component. The net effect is to develop a narrow cone of wetted soil (2). Thus, root growth may be limited which may result in poor utilization of both water and nutrients by the plant. Recently, it has been shown that water distribution in the bed is affected by water discharge rate (gal/hr), i.e., the faster the discharge rate, the greater the horizontal water distribution (1, 2). The overall effect of improved water distribution in the bed should be a larger root system which would result in more efficient use of both water and fertilizer. The objective of this study was to determine the effect of water discharge rate and amount of water applied by trickle irrigation on salt distribution within the root zone of bell peppers.

Experimental Procedure

Three experiments were conducted in 1977 and 1978 to evaluate salt distribution in the root zone of trickle irrigated bell peppers. These experiments were part of studies to evaluate the effect of trickle irrigation management on pepper yield. In 1977, soil moisture levels were maintained at 0.3 or 0.1 bar in the root zone, however, data will be reported only for the 0.3 bar level. Plots (4′ x 50′) were single beds with border beds between each treatment. Fertilizer was applied at the rate of 30-100-30 lb/acre N-P-K[2] and was roto-tilled into the beds. Bi-wall (anjac) trickle tubing with a discharge rate of 0.5 gal/hr was placed near the bed center and black polyethylene mulch was applied. 'Yolo Wonder L' peppers were transplanted at 1-foot intervals on April 1. Additional fertilizer was applied with the trickle irrigation at the rate of 120 lb/acre N (NH_4Cl) and 150 lb/acre K (KCl). Fertilizer was applied at weekly intervals with 20, 30 and 50% applied during April, May and June, respectively.

At the end of the growing season (July 7), an additional amount of KCl was applied. Irrigation was continued during the sample period to maintain the soil

[1]Florida Agricultural Experiment Stations Journal Series No. 1548.

[2]For metric conversion see table at front of this volume. Ed.

moisture level at 0.3 bar to a depth of 6 inches. Soil cores were taken at the emitter and 6 and 12 inches perpendicular to either side of the trickle line to determine Cl distribution. Samples were taken 1, 3, 20, 44, and 93 hr after KCl application at 2.5 inch increments to a depth of 12 inches. A different emitter location was used at each sampling time. Samples were extracted with a 1:1 ratio of deionized water:soil (vol/wt) and Cl was determined with a specific ion electrode.

In 1978 (April 4), peppers (cv 'Yolo Wonder L') were planted on a Chipley fine sand as in 1977. A preplant fertilizer application of 30-100-30 lb/A of N-P-K was rototilled into the bed and the bed was covered with black polyethylene plastic. Additional N (NH_4NO_3) and K (KCl) fertilizer was applied through the irrigation system to give a total application rate of 200 lb N and 180 lb K/A. This fertilizer was applied weekly through the irrigation system with 20, 50, and 30% applied in April, May, and June, respectively. Treatments with trickle irrigation were three water discharge rates (0.5, 1.5, and 3.5 gal/hr/plant) and two water quantities (water equivalent to 0.5 pan evaporation and pan evaporation) and were replicated four times. Emitters to provide the appropriate discharge rate were placed at each plant. On June 8, soil samples were taken at depths of 0-3, 3-9, 9-15 inches at 6 locations within the bed to determine Cl distribution. Samples were taken in 2 transects: 1) at the emitter and at 6 and 12 inches perpendicular to the emitter, and 2) mid-way between emitters and 6 and 12 inches perpendicular to the mid-way point. Irrigation and fertilizer were applied 6 days prior to sampling. Chloride distribution at the time of sampling represents the distribution as affected by the water treatments applied throughout the experiment.

A second evaluation of salt distribution was conducted with Br as a tracer on the 1978 experiment at the end of the growing season. Potassium bromide (KBr) was applied through the trickle system to treatments with discharge rates of 0.5 and 3.5 gal/hr with a water rate equivalent to pan evaporation. Water was applied twice daily for 26 and 5 min at the 0.5 and 3.5 gal/hr discharge rates, respectively. Soil was sampled at similar locations to those in the Cl distribution study at depths of 0-3, 3-9, and 9-15 inches at 1, 5, 23, 30, and 48 hr after application. In the 1978 studies, Cl and Br were extracted with a 1:1 soil: water extract. Chloride was determined by coulometric-amperometric titration with Ag ions and Mr was determined using a specific ion electrode (7).

Results and Discussion

The distribution of Cl in the root zone of peppers irrigated to maintain the soil moisture level at 0.3 bar is shown in Table 1. One hour after application, the highest Cl concentration was 0 to 5 inches below the emitter and up to 6 inches from the emitter on the plant side. A chloride peak was also detected at a depth of 7.5 to 10 inches on the plant side 12 inches from the emitter at one hour. The tendency for the higher Cl concentrations to be on the plant side of the emitter at this time indicates low water content in this area prior to irrigation due to uptake of water by the plant. Three hours after Cl application, the highest Cl concentrations were located 5 to 12 inches below the emitter and at 6 inches on both sides of the emitter. Smaller amounts had reached 12 inches from the emitter at that time. Most of the added Cl had moved beyond a depth of 12 inches 20 hr after application. The only indication of above-background Cl levels was at a depth of 7.5 to 12 inches at the edge of the bed.

Because of the rapid movement of Cl out of the root zone with the 0.5 gal/hr emitters, as indicated in the above data, the 1978 experiment was set-up to determine whether lateral water distribution, and thus salt distribution, could be increased by an increase in the water discharge rate. Three discharge rates, 0.5, 1.5 and 3.5 gal/hr/plant were compared at 2 water quantities, 0.5 pan evaporation and pan evaporation. Soil samples were taken on June 8, about two-thirds through the growing season. Chloride distributions at the locations opposite the emitter as affected by the six water treatments are shown in Table 2. Differences between treatments were generally not significant except 6 inches from the emitter at the 3-9 inch depth. Chloride concentrations at the emitter were generally low at all depths indi-

Table 1. Changes in chloride distribution with time at 5 distances and depths from emitter of trickle irrigation for bell pepper.

Distance from emmitter, inches	Hours after Cl added	Soil sample depth, inches 0-2.5	2.5-5.0	5.0-7.5	7.5-10.0	10.0-12.0
		Cl at 10% soil moisture, ppm[z]				
0	1	6,420	2,380	180	100	100
	3	540	540	1,900	2,330	2,070
	20	400	220	160	210	300
6 (plant side)	1	580	1,130	1,200	870	740
	3	1,140	1,530	3,380	1,880	840
	20	320	220	230	320	380
12 (plant side)	1	180	180	290	800	340
	3	720	920	600	480	660
	20	340	350	310	840	850
6 (opposite plant)	1	90	120	160	470	300
	3	1,020	710	1,200	220	620
	20	520	250	220	360	560
12 (opposite plant)	1	530	210	190	210	70
	3	760	700	460	190	140
	20	390	940	540	1,140	960

[z]F values were significant at the 5% (*) and 1% (**) levels or not significant (N.S.) as follows: at 1 hr, significant factors were sample location (L)**, sample depth (SD)**, interactions between water quantity X**, L X SD**, and W X L X SD**; at 3 hr., N.S.; and, at 20 hr. significant factors were W** and W X L*.

Table 2. Chloride distribution at three distances opposite the emitter as affected by 6 water treatments supplied by trickle irrigation to bell pepper.

Sample depth, inches	Water quantity: 0.5 pan evaporation; Discharge rate, gal/hr: 0.5	1.5	3.5	Pan evaporation: 0.5	1.5	3.5
	Cl at 10% soil moisture, ppm					
	At emitter					
0-3	50	50	20	60	140	120
3-9	30	15	40	10	10	20
9-15	20	45	60	25	10	10
	6 inches from emitter					
0-3	60	70	30	60	40	160
3-9	60b[z]	260a	30b	70b	45b	25b
9-15	110	190	80	80	65	50
	12 inches from emitter					
0 3	360	620	550	740	740	400
3-9	135	370	475	430	260	265
9-15	195	145	150	135	155	215

[z]F value was significant and treatment mean separation by Duncan's multiple range test, 5% level.

cating rapid movement of Cl, and thus other soluble fertilizer salts. Chloride concentration was generally greater 6 inches from the emitter than at the emitter, particularly at depths below 3 inches. Highest Cl concentrations were observed at the edge of the bed at the 0-3 inch depth.

Chloride distributions at 3 distances midway between emitters are shown in Table 3. Lowest concentrations occurred directly between the emitters. Concentrations increased with distance away from the trickle tube indicating rapid movement of Cl away from the emitters. As in the samples taken directly perpendicular to the emitter (Table 2), highest concentrations were observed at the 0-3 inch depth at the edge of the bed. The only significant differences in Cl movement due to water treatment occurred 12 inches from the tubing at the 9-15 inch depth. Concentrations of Cl were higher at that location with the 3.5 gal/hr discharge rate than with the lower discharge rates at both water quantities. This indicates that the high discharge rate is moving the Cl a greater radial distance than the lower discharge rates.

Table 3. Chloride distribution at 3 distances sampled midway between emitters as affected by 6 water treatments supplied by trickle irrigation to bell peppers.

Sample depth, inches	Water quality: 0.5 pan evaporation			Pan evaporation		
	Discharge rate, gal/hr					
	0.5	1.5	3.5	0.5	1.5	3.5
	Cl at 10% soil moisture, ppm					
	On line midway between emitters					
0-3	80	360	80	90	80	30
3-9	180	285	95	125	65	25
9-15	370	250	190	295	90	65
	6 inches from midway point					
0-3	430	770	410	300	590	200
3-9	575	700	365	520	530	130
9-15	340	440	275	575	400	140
	12 inches from midway point					
0-3	1,130	1,360	920	950	1,500	890
3-9	530	660	700	350	480	640
9-15	180bc[z]	130c	440b	320bc	440b	630a

[z]F value was significant and treatment mean separation by Duncan's multiple range test, 5% level.

Bromide concentrations determined at 1, 5, 23, 30, and 48 hr after application at the emitter and 6 inches from the emitter are shown in Table 4. Irrigation was applied 6, 25, and 31 hr after application. After 1 hr, highest Br concentrations at the emitter were detected at the 6 to 12 inch depth for the 0.5 gal/hr discharge rate and at the 3 to 6 inch depth for the 3.5 gal/hr discharge rate. Little additional movement was detected between the 1 and 5 hr sampling times. At 23 hr and later, Br concentrations decreased at the emitter and increased 6 inches from the emitter for both discharge rates. Bromide distribution midway between emitters is shown in Table 5. Bromide concentrations between emitters increased at 23 hr for the 0.5 gal/hr discharge rate while at the higher discharge rate, some Br was observed at 1 hr and considerable increases were noted at 5 hr. Faster lateral movement at the higher discharge rate was also evident at the 6 inch position. This suggests that the anticipated greater lateral movement at the higher discharge rate was being achieved. Essentially no Br was detected at the outer edge of the bed except at the higher discharge rate where small amounts of Br were detected at 48 hr. An additional soil sample was taken at the 48 hour sampling time at a depth of 15 to 24 inches. A small amount of Br was detected only at the emitter location with both water discharge rates.

Results of these studies indicate that soluble plant nutrients must be applied frequently with trickle irrigation to maintain adequate nutrition in the plant root zone. Soluble nutrients rapidly move away from the irrigation source as indicated by the Cl and Br distribution data. The Br distribution indicated that better nutrient distribution would be obtained by increasing the water discharge rate but, at least in this initial field test, pepper yields were not affected by water discharge rate.

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Table 4. Bromide distribution with time at 5 depths at emitter and 6 inches perpendicular to emitter as affected by 2 discharge rates supplied by trickle irrigation to bell pepper.

Sample depth, inches	Discharge rate gal./hr. 0.5					3.5				
	Time after Br application, hours[z]									
	1	5	23	30	48	1	5	23	30	48
	Br at 10% soil moisture, ppm									
	At emitter									
0-3	80	7	10	20	110	200	70	30	300	20
3-6	530	27	1	1	20	2,000	600	50	300	1
6-9	1,050	1,100	30	1	1	510	2,000	150	500	1
9-12	1,520	650	150	300	250	30	120	510	200	1
12-15	50	20	20	650	500	80	20	100	1	390
	6 inches perpendicular to emitter									
0-3	10	1	440	500	100	60	50	200	200	130
3-6	10	1	550	1,100	120	10	150	20	300	300
6-9	20	1	600	500	350	1	200	1	750	280
9-12	10	1	310	100	400	1	1	1	550	550
12-15	1	1	20	1	70	1	1	1	500	200

[z]Trickle irrigation applied at times 0, 6, 25 and 31 hr after Br application.

Table 5. Bromide distribution with time at 5 depths sampled midway between 2 emitters at trickle line and 6 inches from line as affected by 2 discharge rates supplied by trickle irrigation to bell pepper.

Sample depth, inches	Discharge rate gal./hr.									
	0.5					3.5				
	Time after Br application, hours[z]									
	1	5	23	30	48	1	5	23	30	48
	Br at 10% soil moisture, ppm									
	Midway between emitters									
0-3	10	10	650	450	20	110	1,010	10	260	60
3-6	1	1	250	350	20	20	100	550	450	30
6-9	10	1	460	100	400	10	20	140	700	40
9-12	1	1	260	250	500	10	1	200	450	40
12-15	1	1	30	1	320	10	20	100	260	310
	6 inches perpendicular to above position									
0-3	1	1	60	1	50	10	20	10	100	300
3-6	1	1	1	1	20	10	1	1	150	100
6-9	1	1	1	1	60	10	1	1	250	250
9-12	1	1	1	1	30	10	1	1	1	300
12-15	1	1	1	1	10	1	1	1	1	300

[z]Trickle irrigation applied at times 0, 6, 25 and 31 hr after Br application.

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Proc. Fla. State Hort. Soc. 91: 322-324. 1978.

EVALUATION OF SUMMER SQUASH VARIETIES FOR FLORIDA[1]

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Additional index words. Cucurbita pepo.

Abstract. **Due to the proliferation of new varieties and the need for performance information on production under Florida conditions, replicated field trials of yellow and green summer squash varieties were conducted on Apopka sand at Leesburg in 1977 and 1978. In general the yellow straightneck (YSN) varieties had higher marketable yields than the yellow crookneck (YCN) varieties. 'Goldzini,' 'Gold Slice,' 'Golden Girl,' and 'Seneca Butterbar' had the best early and total yields of the YSN varieties while 'Slendergold' and 'Dixie' were the highest yielding YCN varieties. 'Ambassador,' 'Elite,' 'Castle Verde,' and 'Hyzini' were the most productive green varieties. Differences in color intensity and plant type were very apparent among the green summer squash varieties.**

Florida accounts for about 40% of the total U.S. production of summer squash, *Cucurbita pepo* (1). Pronounced changes in value, yield, and production have occurred over the last 16 years in Florida (2, 3). Total crop value increased from 3.7 million to over $11 million between 1961-62 and 1976-77. Yield per acre increased from 56 cwt/acre to 72 cwt/acre[2] during this same period. The increased yield was due not only to the adoption of improved cultural practices and the introduction of new, more productive varieties, but also to a strong market which determines how long a grower will pick in a given field. Value per cwt increased from $6.78 to $14.51 between 1961-62 and 1976-77.

Production in Florida increased from about 54.0 million pounds in 1961-62 to nearly 85.5 million pounds in 1976-77 (2, 3). Statistics on the per capita consumption of squash are not compiled by the USDA but a 50% increase in production in Florida with a concomitant U.S. population increase of only 17% indicated increased per capita consumption (4). A further indication of increased per capita consumption is the tripling of frozen processed squash from 10.7 million to 35.4 million pounds over the last 10 years.

Summer squash is grown commercially in all agricultural areas of the state except the Everglades. It is harvested from September through July with more than 90% marketed from November through May. Of the 12,000 acres harvested in Florida during the 1976-77 season, 3,500 (almost 30%) were planted in Dade County (3). Harvested acreage in Collier County has increased from 420 acres in 1971-72 to 1,900 acres in 1976-77 and now accounts for 15% of the Florida production.

Due to the limited amount of recent performance information available on summer squash varieties grown under Florida conditions, commercially-accepted and re-

[1]Florida Agricultural Experiment Station Journal Series No. 1506.

[2]1 cwt/acre = 100 lb/acre = ca. 112.5 kg/ha. For other metric conversions see table at front of this volume. Ed.