the pre-emergence herbicide used with no-mulch and for the herbicide used with plastic mulch are equal and have no effect on energy requirement differences between the systems.

Results

The plastic mulch system is both more energy intensive and more productive. The total energy requirements for plastic mulch grown staked tomatoes were estimated to be 123,893,000 BTU/acre (332,990 MJ/ha) whereas the no-mulch staked tomato system was estimated to require 78,378,000 BTU/acre (204,332 MJ/ha). The plastic mulch system therefore requires about 58% more energy per unit production area.

Energy productivity is approximately the same with the two systems. The plastic mulch system, assuming 854 marketable units/acre, produces tomatoes at an energy productivity of 206.8 lb./million BTU (0.0889 kg/MJ). The no-mulch system, assuming 500 marketable units/acre, produces tomatoes at 191.4 lb./million BTU (0.0823 kg/MJ), or about 7% less efficiently in terms of the total energy inputs. Within the error limits of this analysis, it could not be said that the energy productivities of the 2 alternative systems are different.

Discussion

The plastic mulch tomato production system, though much more energy intensive per unit land area, is no more energy intensive per unit of production than the no-mulch system. In fact, it may be slightly less energy intensive per unit of production (8% greater energy productivity was indicated). The plastic mulch system does conserve land resources, but not at the expense of increased energy consumption per unit of production.

Two of the most important energy consuming inputs in the plastic mulch tomato production system are the fumigant, which accounts for 52% of the net difference, and the polyethylene, which accounts for 33% of the net difference. Any potential reduction in the energy requirements for either of these inputs, such as a reduction in fumigant application rate or a reduction in polyethylene thickness, would result in decreased total energy consumption and, unless production were concurrently reduced, increased energy productivity. The 2 next most important energy consuming inputs are due to the different rates of fertilizer and irrigation application, accounting for 9 and 5%, respectively, of the net difference. The remaining energy consuming inputs unique to the two systems are essentially inconsequential in comparison.

This analysis of the energy requirements of 2 production systems for tomatoes has demonstrated that the plastic mulch system is more energy intensive per unit area but is likely no more energy intensive per unit of product. Such a situation may hold true for other production systems also.

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PEPPER PRODUCTION EFFICIENCY USING THE GRADIENT-MULCH CONCEPT[1]

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Abstract. **Over a span of more than 50 years, including the 1971-72 season, average pepper production in Florida had ranged from 200 to 400 marketable units per acre (30 lb. bushels).[2] In the last 6 years cultural procedures centering around the use of a full bed mulch was associated with an increasing production. By 1975-76 the average yields reached 550 bu/acre with about 50% of the growers using procedures which include a full bed mulch. A few growers have obtained yields of 2 to 3 times that average. Since 1960 a number of intensively grown crops have been evaluated at the Bradenton Agricultural Research and Education Center in the development of the gradient-mulch concept. More recently a precision combination of selected components have been associated with consistent pepper yields that ranged from above 1000 to 1500 bu/acre. By approaching the maximum potential of a production system (using essentially the same components), unit production costs can be markedly decreased which, in turn, favors a maximum return per dollar invested. This also favors maximum efficiency per unit of energy, fertilizer, water and other contributing components. In this paper the more critical variations of contributory components will be evaluated with relevance to maximum efficiency.**

Over a span of more than 50 years, including the 1971-72 season, average pepper production in Florida has fluctuated

[1]Florida Agricultural Experiment Stations Journal Series No. 848.
[2]For metric conversions see Table near the front of this Volume. Ed.

from 200 to 400 marketable units per acre (30 lb bushel) (7). In the last 6 years cultural procedures that included the use of a full bed mulch were associated with a marked increase in yields. By 1975-76 the average yields reached 550 bushels/acre *with about* 50% of the growers using production systems which included a full bed mulch (1). Using mulch as a soil bed cover necessitates changes in fertilizer and irrigation procedures which can favorably or unfavorably affect production. An approach to establish a minimal stress root environment has markedly improved production efficiency with consistent yields of 1200 to 1500 bu/A. Before mulching, cultural procedures were designed to buffer changes caused by periodic rains which caused varying degrees of root environment stress. Since 1960 a number of intensively grown crops have been evaluated in the development of the gradient-mulch concept (3, 6).

Choice of components was made to establish gradients that could provide minimal stress during the entire growing season. Gradient limits, which function as non-variables, included a concentration of soluble nutrients on a flat-topped soil bed a given distance above a constant water table (Fig. 1) (6).

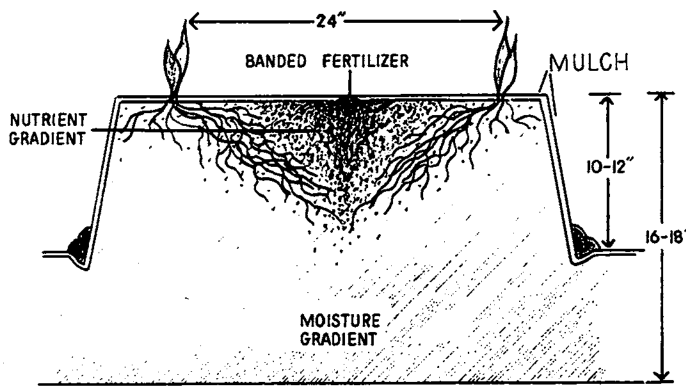

Fig. 1. Control of the root ionic environment.

Methods and Procedure

Methods were designed to evaluate production achievement, which was relevant to establishing and maintaining the desired gradient. A measure of the concn and balance of nutrients at 3 depths and 2 locations in the soil profile supports the concept of a minimal stress root environment.

Certain components (surface placement of fertilizer on a flat bed surface a given distance above a constant water table) were considered as basic structure to provide the desired gradients and were established as non-variable components. Variations in plant populations and varieties in conjunction with fertilizer levels and source materials were evaluated as contributing components.

A minimal requirement of 180 lbs of N and 250 of K_2O to produce 2000 marketable units (30 lb) of tomatoes had been previously established (3). The same minimal rate was used for peppers and higher rates were compared to determine a range for optimal production. Levels should be sufficient to prevent any potential deficiency stress. At the same time the design of the system minimized the potential of excess stress which might occur because all of the required fertilizer was applied before the crop was planted or set.

In order to study the effect of variations in nutrient balance, single salts mixed with the basic fertilizer were provided as a *gradient limit* and evaluated while all other components were maintained as non-variables.

Plant populaions and varieties to a lesser extent were also included in these studies. Broadcast surface placement of fertilizers was evaluated as an alternative gradient which might accommodate increased plant populations.

A Myakka fine sand located at the AREC-Bradenton was used as the soil base. Soils were limed to a pH of 6.5 and seepage irrigation was used to provide the constant water table. Average yields from replicated field trials were reported as 30 lb marketable units; average size was obtained as lbs/fruit by dividing the total marketable weight by total number.

Analyses of total salt and % of specific cations or anions in the soil solution were used to describe the ionic root environment. Correlations between production and ionic composition were established.

Results and Discussion

A series of evaluations of pepper production using the gradient-mulch system are summarized in Tables 1, 2 and 3. The effect of single salts added to a base fertilizer on pepper production are recorded in Table 1. The addition of the more mobile ions such as chloride, nitrate, potassium and sodium altered the root environment composition to a measurable degree. The effect on root environment composition is reported in an earlier paper (4). Yield decreases were associated with the addition of chloride salts and to a lesser degree with certain other salts. Recorded yield increases occurred infrequently. The degree of effect varied with the growing season.

Table 1. The effect of single salts and the base fertilizer on pepper production.

Treatment[z]	Sp 72 bu/A	Sp 72 lbs/fruit	Fall 72 bu/A	Sp 73 bu/A	Avg.
1. Base (18-0-25)	935	.305	1500	980	1138
2. + $Ca(NO_3)_2$	970	.328	1360	1090	1140
3. + $CaCl_2$	825	.312	1240	780	948
4. + $MgSO_4$	875	.324	1330	890	1032
5. + NH_4NO_3	905	.345	1340	870	1038
6. + $(NH_4)_2SO_4$	895	.329	1350	830	1058
7. + $(NH_4)_2HPO_4$	870	.312	1360	860	1043
8. + $NaNO_3$	705	.288	1420	1040	1055
9. + K_2SO_4	640	.276	1460	950	1017
10. + KCl	362	.244	1280	870	870
11. + KNO_3	790	.301	1260	950	1000
12. + 18-0-25	1025	.329	1545	930	1167

[z](1) Base fertilizer: 1500 lbs/A 18-0-25 banded on the soil bed surface; (2-12) Supplement: 1000 lbs of the indicated salt mixed with the base fertilizer.

Fertilizer placement in conjunction with plant placement was evaluated utilizing 2 varieties and 2 fertilizer levels (Table 2). Results of another plant-fertilizer placement study is presented in Table 3. It is significant that yields from all treatment variables consistently ranged 2 to 3 times more than the state average for 1975-76 (550 bu/A) (1). Yield increases were most frequently associated with increased plant populations and sometimes more nutrients than the basic 1000 lbs/A 18-0-25-2. Broadcasting the total fertilizer over the soil bed surface compared to the normal banded procedure requires further discussion.

Broadcasting fertilizer over the entire bed surface does provide another type of minimal stress gradient which can accommodate higher plant populations. Two to four rows of Speedling(R)-type plants were wedged through the mulch

Table 2. The effect of fertilizer levels, variety and fertilizer-plant[z] placement on pepper production (Fall 1974).

Placement: Fert.	Placement: Plant	Yield bu/A	Av. size lbs/fruit
A. Banded Bed center	2 rows 20″	1154	0.343
B. 2 bands Between rows	3 rows 12″	1436	.348
C. 2 bands Bed edge	2 rows 15″	1196	.339
Fertilizer rate			
1000 lbs/A		1244	0.334
2000 lbs/A		1276	.347
Variety			
Yolo W		1280	0.335
Cal W		1242	.351

[z]Fertilizer: 18-0-25-2 banded on the soil bed surface as indicated with about 5 to 10% of the total broadcast over the bed surface. Plants spaced 1 foot in the row: 2 rows/bed = 15,000 plants/acre; 3 rows/bed = 22,500 plants/acre.

and the concentration of salts on the surface. In order to avoid downward movement of these salts, plants set in this manner were not pot watered. Results in Table 3 indicate the success in providing a non-stress root environment utilizing this procedure. High concentrations on or near the soil surface do not contribute to seedling loss (poor stands) or retard growth when utilized as described.

Peppers require nutrients in close proximity to the roots to initiate growth. Excess salts have often been considered a problem of pepper growers using full-bed mulch. Thus, placement of nutrients has been a critical consideration. This can be illustrated by considering certain hypothetical calculations which indicate potential concn. An application of 1000 lbs of water soluble fertilizer mixed in the top 6 inches of a soil bed would provide a concn of 10,000 ppm in the soil solution at 10% moisture. Consider the soil bed as half the soil acre or 1 million lbs of soil per 6-inch depth. This salt level is prohibitive for seedling survival and excessive for plant growth. This same quantity of salt, if concentrated on the surface, has been associated with good production as indicated above and in Table 3. Varying quantities of starter fertilizers have been applied in different ways. Consider another hypothetical calculation where a starter fertilizer might add 100 lbs of salt per acre which, if mixed into the center third of the bed (6″ depth), would increase the salt concn in the soil moisture by 3000 ppm.

Table 3. Effect of fertilizer level, fertilizer-plant[z] placement on pepper production.

Fert.-plant placement	Rate	Bu/A Sp 75	Bu/A Fall 75	Fert. placement	Bu/A Sp 76 2 row	Bu/A Sp 76 4 row
A. Center band 2 rows	1000	1080	1170	Banded	1365	1690
	2000	1390	1300	Banded	1240	1430
B. Broadcast 4 rows	1000	1320	1280	Broadcast	1490	1710
	2000	1580	1410	Broadcast	1045	1365

[z]Fertilizer: 18-0-25-2 banded or broadcast on the soil bed surface. Plants spaced 1 foot in the row: 2 rows/bed = 15,000 plants/A; 4 rows/bed = 30,000 plants/A.

Salts from well waters and that contained in the soil as a residual add to that mixed in as starter fertilizer. Salt in the bed tends to move upward with seepage irrigation and concentrates toward the seedling root zone. Salt content in irrigation water as well as residual soil salts are a major consideration in choice of site and starter fertilizer in the bed placed on the surface does not contribute to root zone salt concn.

The measured concn and balance of nutrients in portions of the soil profile from 2 different fields are given in Table 4. Field A contains a comparatively higher salt level at the 2-8 inch depth compared to Field B. There was no indication of visible or measurable plant stress in Field B where quality was very good and yields averaged 1350 bu/A. Blossom-end rot was prevalent in Field A with yields about half those in Field B. The higher salts and lower calcium ratios indicate a measurable level of stress in Field A. The association of blossom-end rot with decreasing calcium ratios and increasing salt concn has been documented in previous research results (2).

Table 4. Comparison of salt concn and balance of nutrients in portions of the soil profile from 2 pepper fields[z].

		Salt (ppm)	pH	N(%)	K(%)	Ca(%)
Field A						
Center	0-2″	78,960	5.7	11.0	30.0	2.2
	2-4″	29,080	5.9	5.5	18.6	3.4
	4-8″	5,950	6.4	3.5	9.8	4.0
Edge	0-2″	7,350	6.0	5.2	9.7	7.1
	2-4″	5,670	6.0	2.9	7.7	6.4
	4-8″	4,620	6.3	0.5	6.0	5.0
Field B						
Center	0-2″	62,720	4.9	14.4	30.7	3.2
	2-4″	4,550	7.3	7.4	5.4	9.0
	4-8″	1,480	7.5	5.9	7.3	9.0
Edge	0-2″	6,230	6.6	5.6	3.0	10.4
	2-4″	1,960	6.9	4.4	2.2	9.1
	4-8″	1,120	7.2	1.6	2.4	10.4

[z]Spring crop 1977. Field A—Commercial. Blossom-end rot prevalent. Yield about 50% of Field B. Field B—Experimental plot of AREC. No stress symptoms. Yield average—1350 marketable units/acre.

Other components, such as varieties and planting variations, contribute to the success but do not alter the functioning of the system. In these studies the choice of variety has resulted in equivalent production (Table 2). Two planting procedures, plug mix and containerized transplants have been used successfully. Both contribute to the success of the system, but neither significantly alter the functioning of the gradient-mulch system except that longer duration in the seedling stage provides more potential exposure time to the stress that can occur.

Any given production system is most efficient when maximum yields are obtained. Production costs listed for a 550 bu/A yield average $2.83 per unit (1). With the gradient-mulch system yields which have consistently ranged from 2 to 3 times this average, unit costs could be markedly reduced and approach $1.00/unit as the potential optimum. Average tomato yields in Florida increased about 60% with the use of the full bed mulch (5). The associated decrease in unit production costs placed Florida in a favorable competitive position with Mexico; from a 30% cost deficit (1972) to a 11% cost advantage (1975). The improving pepper production efficiency could be even more spectacular than that for tomatoes.

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THE INFLUENCE OF SPECIFIC IONS ON THE TOTAL SOLUBLE SALT AND pH LEVELS OF COMMERCIAL TOMATO FIELDS IN SOUTHWEST FLORIDA[1]

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Abstract. **Soil test data generated from a 2 year soluble salt survey of commercial tomato fields in southwest Florida were subjected to correlation analysis to assess the relationship of 7 specific ions on the total salt level and pH of the soil solution. Readings from samples taken at 3 depths from 4 portions of full bed mulched tomatoes from 23 farms indicate that K, NH_4, Ca, and Mg were highly correlated with salt levels, and that K, Ca, NO_3, and Mg possessed the highest negative correlations with pH. Total salts and pH were negatively correlated. Soluble salt values decreased and pH values increased with depth of sampling. Salt levels increased with consecutive cropping indicating the danger of salt damage to successive crops.**

Results of a soluble salt survey of commercial tomato fields in southwest Florida in 1976 indicated that salt levels have accumulated in fields cropped for 2 or more consecutive years (1, 2). This survey was continued and expanded during 1977, resulting in a total of 276 individual analyses from which to characterize the total soluble salt level, pH, and concentration of 7 specific ions in the soil solution of 23 fields surveyed in this 4-county area.

This survey, using 2484 discrete analytical inputs, provided a unique opportunity to assess the influence of specific ions on soil pH and total soluble salt level. In both years all sampling was done at the request and assistance of the County Extension Agents in Collier (D. W. Lander), Hillsborough (M. T. Pospichal), Lee (V. W. Yingst) and Manatee (R. T. Montgomery).

Methods

Soil samples were taken from 23 commercial tomato fields in Collier, Hillsborough, Lee, and Manatee counties during 1976 and 1977 to assess the soluble salt status of land used for tomatoes for 2 or more consecutive years. Random soil samples were taken at 3 depths (0-2, 2-4, and 4-8 inches) at each of 4 positions in or near the mulched bed (between bed, fertilizer band, near plant row, and plant row).

In all 4 counties the 'Walter' cultivar, full bed mulch, seep irrigation, and staked culture was used. Fertilizer application, including starter and band, averaged 322 lbs of N, 219 lbs of P_2O_5, and 525 lbs of K_2O per acre.[2] Plant spacing averaged 25 inches between plants with rows spaced 8.6 feet apart with an average population of 2407 plants per acre. A per plant average yield of 13.0 lbs of marketable fruit resulted in an average yield of 1043 cartons (30 lb) per acre.

All samples were submitted to IFAS Soils Laboratories for routine determination of total soluble salts, pH, K, Ca, NO_3 and NH_4 nitrogen, Mg, Cl, and Na from a saturated paste extract which is standard for the Intensity and Balance soil analysis procedure (4). For each field a case history was taken which included previous crops, fertilizer program, plant population, irrigation and drainage information, and pest management program.

The soil samples collected at the 4 positions at 4 depths for 23 fields during the 2-year survey generated 2484 observations which were subjected to correlation analyses by the IFAS Department of Statistics Laboratory. It may be noted that this high population level provided small differences that were significant at the 0.001 level of significance.

Results

In the first year it was noted that the salt level of virgin fields in the 4 counties averaged 476, 382, and 379 at the 0-2, 2-4, and 4-8 inch depth (3). The average level of total soluble salts (TSS) in the soil soln of between-bed areas of fields used for 2 or more consecutive years is presented in Table 1. Current levels in between-bed areas were found to be 2 to 3 times greater than soils in non-cropped fields.

Table 1. Between row mean values, intensity and balance survey, 276 commercial tomato soil tests[z], southwest Florida, 1976-77.

Depth, inches	pH value	Soil solution, ppm							
		TSS	K	Ca	Na	NO_3	NH_4	Mg	Cl
0-2	6.9	2287	164	146	148	95	12	102	264
2-4	6.7	1015	60	84	54	98	10	31	109
4-8	6.5	848	59	62	51	127	13	25	82

[z]Determinations made by IFAS Soils Laboratory, standard I & B procedures.

[1]Florida Agricultural Experiment Stations Journal Series No. 785.

[2]For metric equivalents see Table near the front of this Volume. Ed.