Our research demonstrated an increase in irrigation efficiency of approximately 8% as compared to the conventional seepage irrigation management system. Considerable improvements in efficiency remain to be made. For these reasons, future research should be directed toward the development of procedures for further reducing runoff losses of irrigation water. Such procedures may include recycling runoff water, reducing bed widths to reduce the time required for lateral movement to the centers of the beds, or direct applications of water to the alleys between rows on the beds using intermittent surge flow techniques. Each of these procedures will have higher initial costs than conventional seepage irrigation systems. However these costs may be balanced by reduced pumping costs and water savings as a result of the increased irrigation efficiencies that these procedures offer.

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COMPATIBILITY EVALUATION OF VARIOUS FOLIAR SPRAY COMBINATIONS ON PEPPER

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Abstract. **A serious disorder resulting in leaf roll, chlorosis and necrosis of leaves, in fruit necrosis and in plant stunt, occurred on pepper (*Capsicum annuum* L.) plantings in the Immokalee area in spring, 1983. Necrotic stages of the leaf symptoms were similar to those of bacterial spot [*Xanthomomas vesicatoria* (Doidge) Dows.)]. Phytotoxicity caused by foliar sprays was suspected. In a controlled field experiment, identical symptoms were produced when plants were sprayed with a paraffin-based petroleum oil (Penetrator 3) alone or in various combinations with pesticides and a foliar nutritional spray. As expressed by phytotoxicity and yield reduction, the petroleum oil was incompatible with oxamyl, methomyl, a foliar nutritional spray and parathion in ascending order of severity. Phytotoxicity increased significantly and yield decreased significantly as the oil rate increased. No phytotoxicity nor yield reduction occurred when the pesticides and the foliar nutritional were combined in the absence of the oil. There were some indications that citric acid tended to reduce phytotoxicity and increase yield.**

Because of the many disease, insect, and nutritional problems confronting Florida vegetable growers, it is common practice for them to apply several pesticides and foliar nutrients simultaneously. In spite of recurring problems of incompatibility, materials are frequently incorporated in tank mixes without adequate testing for compatibility. Although originally diagnosed as bacterial spot [*Xanthomonas vesticatoria* (Doidge) Dows.)], we suspected that a serious disorder culminating in leaf and fruit necrosis on pepper and tomato in spring, 1983 in the Immokalee area was one of incompatibility. Using pepper as the test plant, a field experiment was undertaken to study the effects of certain foliar spray mixes on phytotoxicity and yield.

Materials and Methods

A planting of 'Early Calwonder' pepper on D. J. Farms near Immokalee, Florida was selected for the experiment. The land area had been broadcast with 1200 lb./acre of 6-15-6 fertilizer and bedded on 6-ft centers. Telone C nematicide (a mixture of dichloropropenes and dichloropropanes) was then applied at the rate of 18 gal/acre to the beds and a top band of 19-0-6 fertilizer added at the rate of 1200 lb./acre. The beds were confined with polyethylene plastic. Transplants were set 18 inches apart on 2-row beds. The 2-row test plots were 50 ft long with a 5-ft buffer strip between plots. The test included 15 treatments in a randomized complete block design with 3 blocks.

Common names, trade names, codes and concentrations are listed in Table 1. In addition to these materials, certain of the plots were sprayed on 2 different occasions (December 5 and 20) with methomyl at 1 pt/100 gal added to the mixes.

Table 1. Trade name, code, active ingredient and concentration of chemicals used in the field experiment, Immokalee, Florida, 1983.

Trade name	Code	Active ingredient	Concn/100 gal
Penetrator 3	Pen	Paraffin base petroleum oil	1.0 pt, 4.0 pt
Citric acid	C	Citric acid[z]	1.5 oz
Parathion 8E	Par	O,O, diethyl O-p-nitrophenyl	6.5 oz
Vydate	Vy	Oxamyl	1.0 qt
Vegetable Nutritional Spray	VS	Minor element mix[y]	1.6 pt
Bayfolan Plus	Bay	Foliar nutritional (majors and minors)[x]	1.0 qt

[z]Citric acid was added to specified tank mixes to adjust final pH to 6.2.
[y]Minor element active ingredients (%): Mg 1.5, Mn 1.5, Fe 1.4, Cu 0.25, Zn 0.25, Mo 0.06, combined S 4.0, Bo 0.028.
[x]Active ingredients (%): N 11.0, P 3.5, K 4.2, B 0.02, Co 0.0005, Cu 0.05, Fe 0.1, Mn 0.05, Mo 0.0005, and Zn 0.05.

The plots were sprayed with the test materials 7 times from November 10 through December 20, 1983. The spray was delivered at 200 psi through No. 2½ orifice cones at a ground speed of approximately 4 mph. Depending on plant size, the number of nozzles per bed ranged from 3 to 5. Corresponding volumes ranged from 60 to 200 gal/acre. Spray drift was confined with burlap shields.

All plots were sprayed 7 times with a 37% flowable maneb from November 12 through December 23 at the rate of 6 pt/acre. All spray applications and care of the plots were under the supervision of D. J. Farms manager, Ed Tuten.

Beginning on November 18, plots were scored every 2 weeks for phytotoxicity, and on December 28, following the freeze on December 25, yield data were taken by stripping the fruit from 10 representative plants (5 per row) from each plot.

Phytotoxicity and yield data were analyzed statistically, employing the following techniques:

1. Analysis of variance for data from a randomized complete block design.
2. A partitioning of the treatment effects in the analysis of variance into those due to each of the factors of the study adjusted for the effects of all the other factors.
3. A partitioning of petroleum oil effects into linear and quadratic effects, along with an estimation of the interaction effects. These effects were adjusted for all other effects in the model.
4. Correlation of the relationships of all pairs of variables using the 15 treatment means as observations.
5. Analysis of covariance was made to evaluate the methomyl (Methomyl x replication) effects and to see if they could have caused a misinterpretation of the results of this experiment.

Experimental Results and Discussion

Evidence of injury as manifested by slight leaf roll, rugosity and chlorosis appeared by November 18 in most of the plots where petroleum oil was included in the treatment mix. By the next rating date (December 2), necrosis became evident and had progressed significantly by December 16. The necrotic phase exhibited some similarity to bacterial spot. Phytotoxicity and yield data are shown in Table 2.

Analyses of variance showed that the 15 treatments were significantly different (1% level) in various measurements of injury and in both yield measurements. These data also established that the spray materials with or without citric acid in the absence of petroleum oil were non-phytotoxic, and yielded the highest number of fruit (compare Par-VY-VS-C and Par-VY-VS against these same mixes with

Table 2. Treatment means for pepper leaf roll, leaf necrosis, plants stunting and yield,[z] Immokalee, Florida, 1983.

Treatment listed in code	Concn. of petroleum oil/100 gal[y]	Leaf roll		Leaf necrosis		Stunt	Yield[x]	
		Dec 2	Dec 16	Dec 2	Dec 16	Dec 16	Total	Mature (120 count)
Pen-C	Low	0.0	0.0	0.0	0.0	0.0	29.3	20.3
Pen	Low	0.3	0.3	0.0	1.0	0.7	25.0	15.0
Pen-C	High	0.7	1.0	0.0	1.8	2.2	19.0	12.3
Pen	High	2.3	1.0	1.7	2.0	2.3	17.3	9.3
Par-Vy-Vs-C	None	0.0	0.0	0.0	0.0	0.0	31.7	22.3
Par-Vy-Vs	None	0.3	0.0	0.0	0.0	0.0	32.0	20.7
Par-Vy-Vs-C	Low	2.3	2.7	0.3	2.3	2.2	24.3	15.7
Par-Vy-Vs	Low	2.7	3.3	0.0	3.0	2.7	21.0	11.3
Par-Vy-Vs-C	High	4.0	4.7	4.0	4.7	4.7	14.7	11.0
Par-Vy-Vs	High	4.0	4.7	4.0	4.7	4.7	14.7	7.0
Par-C	Low	2.0	1.7	1.3	1.7	1.3	27.0	16.7
Par	Low	2.3	2.3	0.3	1.0	2.3	25.7	16.0
Vy-C	Low	0.7	0.0	0.3	0.7	0.0	25.7	16.0
Vy-C	High	1.0	2.3	1.3	3.0	1.5	19.7	15.0
Bay-Par-Vy	High	4.0	4.3	4.0	4.7	3.8	14.7	11.3
LSD .05[w]		1.0	0.9	0.8	0.8	1.0	5.9	5.4
LSD .01[w]		1.4	1.1	1.0	1.1	1.3	7.9	7.2

[z]Phytotoxicity ratings on a 0-5 scale where 0 = none, 1 = trace, 2 = slight, 3 = moderate, 4 = moderately severe, 5 = severe.
[y]Petroleum oil low rate = 1 pt/100 gal, high rate = 4 pt/100 gal.
[x]Total yield included all fruit at marble size and larger. Mature fruit included 120 count and larger.
[w]LSD values to be used for planned or comparisons suggested logically by treatment structure.

low and high levels of petroleum oil added). Although statistical differences due to citric acid occurred in only a few instances, e.g., stunt on December 16 between Par-C-Pen(low) and Par-Pen(low), there was a consistent pattern of the phytotoxicity means being lower and the yield means being higher when citric acid was added to a mixture.

Two different regression analyses were made (Tables 3 and 5). The first one included only main effects. F-tests were made for each factor (petroleum oil, parathion, etc.) adjusted for the effects of all of the other factors. In comparing the F-values of the main effects, the strongly negative relationship between petroleum oil level and the plant measures is readily apparent. For example, the F-value for the oxamyl effect on leaf roll on December 16 was 5.3, whereas the F-value for petroleum oil was 142.4. The second most important factor was parathion (F-value 61.3). The effects of oxamyl and the vegetable nutritional spray, although important, were less significant. It is stressed that the impact of all materials employed in the test was due to incompatibility with the petroleum oil. Phytotoxicity did not occur with any mixture combination in the absence of petroleum oil.

The adjusted means for the main effects of each of the factors are shown in Table 4. With these means, the impact of any given main effect can be calculated without having to consider other factors included in the study because statistical adjustment for all other factors had already been made. The strong positive relationship (1% level) between the concentration of petroleum oil and the phytotoxicity ratings, and the strong negative relationship (1% level) between yield level and the concentration of petroleum oil are prominently evident from the analyses. Parathion was the second most important factor (significant at 1% for all injury ratings). Oxamyl also had an effect, showing significance at the 5% level on leaf roll, December 16. Citric acid generally appeared to lessen phytotoxicity ratings but was significant only for the leaf roll rating on December 16.

Table 5 shows the results of tests of significance of the linear and quadratic effects of petroleum oil and certain estimable interactions. This was accomplished by conducting a second type of regression which included terms for the linear and quadratic effects of petroleum oil and certain interactions of other added chemicals with rate of petroleum oil. The results clearly show the curvilinear deleterious effect of Penetrator 3 for both yield and all phytotoxicity ratings. There are also some evidences of real interactions: Pen x Vy for leaf roll, December 16; Pen x Vy x Par for *leaf roll*, December 2; and both of these interactions for necrosis, De-

Table 3. Results of tests of significance for the main effect terms in the analysis of variance (F-tests conducted on mean square for each factor adjusted for all of the other factors). Immokalee, Florida, 1983.

Factor	F-ratios[z y]						
	Leaf roll		Necrosis		Stunt	Yield	
	Dec 2	Dec 16	Dec 2	Dec 16	Dec 16	Total	Mature (120 count)
Citric acid	2.7 NS	5.5*	0.6 NS	2.5 NS	2.2 NS	1.3 NS	5.0*
Oxamyl	0.0 NS	5.3*	3.4 NS	6.5*	3.3 NS	0 NS	0.6 NS
Vegetable spray	1.3 NS	2.2 NS	0.4 NS	5.2*	8.9**	2.2 NS	3.2 NS
Parathion	33.9**	61.3**	37.0**	15.1**	22.5**	0 NS	0.0 NS
Bayfolan Plus	0.9 NS	0.13 NS	2.8 NS	3.0 NS	0.8 NS	1.0 NS	0.1 NS
Petroleum oil	63.3**	142.4**	121.0**	160.0**	109.4**	46.2**	27.0**

[z]NS = not significant; * = significant at the 5% level; ** = significant at 1% level.
[y]See the adjusted means in Table 4 to determine the direction of the effects.

Table 4. Adjusted main effect means for each of the factors.[z] Immokalee, Florida, 1983.

Factor level		Leaf roll		Necrosis		Stunt	Yield	
		Dec 2	Dec 16	Dec 2	Dec 16	Dec 16	Total	Mature (120 count)
Citric acid		1.1	0.8*[y]	1.0	1.5	1.3	24.0	16.9*
None		1.4	1.2	0.9	1.7	1.6	22.8	14.6
Oxamyl		1.3	1.3*	1.1	1.9	1.2	23.4	16.4
None		1.3	0.7	0.7	1.3	1.8	23.4	15.1
Vegetable nutritional spray		1.5	1.3	0.8	2.0	2.1	21.5	13.6
None		1.0	0.7	1.0	1.2	0.8	25.3	17.8
Parathion		2.2**	2.1**	1.6**	2.1**	2.2**	23.3	15.8
None		0.3	0.0	0.2	1.1	0.7	23.5	15.8
Bayfolan		1.6	1.1	1.3	2.0	1.7	21.8	15.3
None		1.0	0.9	0.6	1.2	1.2	25.1	16.2
Petroleum oil	0	−0.8[x]	−1.5	−0.5	−0.8	−0.9	32.2	22.6
	Lo	1.7**	1.6**	0.6**	1.9**	1.7**	22.9**	14.5**
	Hi	2.9**	3.0**	2.7**	3.7**	3.6**	15.1**	10.2**

[z]Obtained from analysis of covariance. Each factor is adjusted for the effects of all of the other factors.
[y] (*)significantly different from the control at the 5% level; (**)significantly different from the control at the 1% level.
[x]Negative mean values may be attributed to uncertainty which is inherent in statistical estimates. They may be interpreted as "0" readings.

Table 5. Results of tests of significance of the linear and quadratic effects of petroleum oil and certain estimable interactions. (F-tests conducted on mean square for each factor adjusted for all terms above it). Immokalee, Florida, 1983.

Treatments	Leaf roll		Necrosis		Stunt	Yield	
	Dec 2	Dec 16	Dec 2	Dec 16	Dec 16	Total	Mature (120 count)
Pen[z]	91.3**[y]	203.9**	240.4**	263.4**	187.5**	81.7**	41.4**
Pen x Pen	35.2**	80.8**	1.7 NS	57.3**	31.3**	10.6**	12.6**
Pen x Vy	.5 NS	6.2*	39.6**	2.9 NS	0.0 NS	0.7 NS	3.2 NS
Pen x Vy x Par	6.7*	.5 NS	37.0**	0.07 NS	3.3 NS	1.0 NS	3.9 NS

[z]All of these terms have been adjusted for all of the main effects C, Vy, Vs, Par and Bay, which were placed before the 4 terms listed above in the model.
[y](*)significant at the 5% level; (**)significant at the 1% level.

Table 6. Correlation coefficients for relationships of all pairs of variables using treatment means.[z] Immokalee, Florida, 1983.

Symptom and date	Leaf roll		Necrosis		Stunt	Yield	
	Dec 2	Dec 16	Dec 2	Dec 16	Dec 16	Total	Mature (120 count)
Leaf roll Dec 2		0.94	0.83	0.89	0.94	–0.78	–0.77
Leaf roll Dec 16			0.79	0.94	0.94	–0.78	–0.72
Necrosis Dec 2				0.86	0.82	–0.78	– .66
Necrosis Dec 16					0.93	–0.91	–0.83
Stunt Dec 16						–0.88	–0.85
Total yield							0.94

[z]An r of 0.51 is required for significance at the 5% level, and an r of 0.64 is required for significance at the 1% level. The null hypothesis being tested is that the population correlation coefficient is 0. Rejection of this relationship would imply that there is a relationship (subject to usual uncertainties of tests of this type).

cember 2. A test of significance of lack of fit showed that it would be unlikely that there were additional large effects which would be significant other than those included in the model for most variables.

A matrix of correlation coefficients showing the relationships of all pairs of variables using the 15 treatment means as observations is shown in Table 6. The data reveal strong and significant positive correlations between pairs of injury variables (leaf roll, necrosis, stunt) and strong negative correlations between these injury variables and the individual yield variables, and of course, the two yield variables are highly positively correlated. Practically all of the correlation coefficients for pairs of variables are significant at the 1% risk level or lower.

To determine the effect of the methomyl treatment, an analysis of covariance was made in which the effects of methomyl (methomyl x replication) were estimated. This estimation was effected by creating a new variable to which was assigned the value of 1 if the plot had methomyl applied to it, and 0 otherwise. This variable was interacted with replications to obtain the methomyl x replication variable. Neither of the methomyl effects was significant. There was a necrotic spotting on some fruit in the plots receiving the high rate of petroleum oil and parathion, vegetable nutritional spray, and oxamyl in the presence of methomyl. No fruit injury occurred in these treatments or in any others where petroleum oil was omitted.

Conclusions

1. No observable phytotoxicity or yield reduction was associated with oxamyl, parathion, vegetable nutritional spray, and methomyl used in spray mixtures on pepper.
2. Only slight injury was associated with petroleum oil used alone at 1 pt/100.
3. Petroleum oil alone at 4 pt/100 gal was associated with significant leaf roll, leaf necrosis and stunt, and significant yield reduction.
4. Petroleum oil added to the spray mixes was associated with severe plant injury in the form of leaf roll, necrosis and stunt, and with severe yield reductions when compared with equivalent treatments having no petroleum oil.
5. The effect of petroleum oil on phytotoxicity and yield appeared to be curvilinear; the loss in yield or increase in phytotoxicity from concentrations of 0 to 1 to 4 pt/100 gal were usually significant.
6. Phytotoxicity increased with time and with increased petroleum oil concentration.
7. Adding methomyl to spray mixes containing no petroleum oil was associated with no noticeable injury or yield reduction.
8. Adding methomyl to spray mixes containing petroleum oil (high rate), parathion, oxamyl and vegetable nutritional spray caused some fruit necrosis but did not affect yield as reflected in fruit numbers.
9. Leaf roll, leaf necrosis and stunt appear to be accurate measures of phytotoxicity associated with the petroleum oil effect and with petroleum oil interactions with pesticides.
10. Citric acid tended to have a beneficial effect in reducing phytotoxicity and in increasing yield.