breeding lines with LMV resistance in their pedigrees and judged to be LMV resistant, were free of seedborne LMV. The definition of what represents 'resistance', is a debatable subject. Resistance can range from infection but not expression of deleterious symptoms that affect quality (tolerance), to complete immunity to infection. Another type of resistance to LMV is resistance to LMV seed transmission that has been demonstrated to exist in *Lactuca serriola* (7). This resistance was present in one of our original sources of LMV resistance, line 419. What effects the various sources of LMV resistance had on seed transmission of LMV in our tests are unknown. However, our data suggest that exploring the use of LMV resistance to control seed transmission of LMV deserves further evaluation.

Although LMV seed indexing is not expensive or difficult, and gives excellent control of LMV by preventing introduction of primary inoculum into commercial lettuce fields, if LMV resistance were incorporated into commercial lettuce cultivars it would still be very useful. If LMV resistance were coupled with seed indexing this would be a double check to keep LMV out of commercial lettuce production fields. However, LMV resistance would be even more useful for lettuce seed production. LMV is difficult to control in seed production fields. Many times breeding lines and commercial cultivars are planted in the same seed increase fields. If a single cultivar carries seedborne LMV it can introduce LMV into the seed production field where subsequent secondary LMV spread by aphids can result in infection of all cultivars. This also can result in a level of seedborne LMV in the seeds that makes the seed unacceptable in states such as Florida, where LMV seed indexing is practiced. Thus, this would result in substantial economic losses to the seed company, which in turn are passed on to growers and consumers. Our data show that seed harvested from LMV-resistant lines are much less likely to harbor seedborne LMV when LMV is present in the seed production fields. Thus to strive for lettuce cultivars that are LMV-resistant is a worthwhile goal both for commercial lettuce production and for seed production.

Acknowledgment

We acknowledge the excellent technical assistance of Ms. G. Echenique and the support of the Florida Lettuce Mosaic Committee and the Florida Lettuce Foundation.

Literature Cited

1. Bannerot, H., L. Boulidard, J. Marrou, and M. Duteil. 1969. Etude de l'heredite de la tolerance au virus de la mosaique de la laitue chez la variete Gallega De Invierno. Ann. Phytopathol. 1:219-226.
2. Falk, B. W. and D. E. Purcifull. 1983. Development and application of an enzyme-linked immunosorbent assay (ELISA) test to index lettuce seeds for lettuce mosaic virus in Florida. Plant Dis. 67:413-416.
3. Falk, B. W. and G. Echenique. 1983. Use of the enzyme-linked immunosorbent assay in Florida's lettuce mosaic virus seed indexing program. Proc. Fla. State Hort. Soc. 96:63-66.
4. Kimble, K. A., R. G. Grogan, A. S. Greatherd, A. O. Paulus, and J. K. House. 1975. Development, application, and comparison of methods for indexing lettuce seed for mosaic virus in California. Plant Dis. Rptr. 59:461-464.
5. Purcifull, D. E., and T. A. Zitter. 1971. Virus diseases affecting lettuce and endive in Florida. Proc. Fla. State Hort. Soc. 84:165-168.
6. Ryder, E. J. 1970. Inheritance of resistance to common lettuce mosaic. J. Amer. Soc. Hort. Sci. 95:378-379.
7. Welch, J. E., and G. M. Kibara. 1978. Lettuce breeding, pp 2-8. In: California Iceberg Lettuce Research Program Annual Rpt, April 1977-Mar 1978.
8. Zitter, T. A. and V. L. Guzman. 1974. Incidence of lettuce mosaic and bidens mottle viruses in lettuce and escarole fields in Florida. Plant Dis. Rptr. 58:1087-1091.

Proc. Fla. State Hort. Soc. 97: 181-187. 1984.

IMPROVED SEEPAGE IRRIGATION EFFICIENCY BY CONTROLLED WATER APPLICATIONS[1,2]

Allen G. Smajstrla
University of Florida, IFAS,
Agr. Eng. Dept.,
Gainesville, FL 32611

D. R. Hensel
University of Florida, IFAS,
Agr. Res. and Ed. Center,
Hastings, FL 32045

D. S. Harrison, F. S. Zazueta
University of Florida, IFAS,
Agr. Eng. Dept.,
Gainesville, FL 32611

Additional index words. water table controls, subsurface irrigation.

Abstract. **A float-actuated control system for regulating the amount and timing of seepage irrigation applications was developed. The system used float switches, an irrigation pump controller and time delays to turn the irrigation pump on and off in response to field water table elevations. Field experiments were conducted in which the float-controlled irrigation management system was compared with the conventional continuous flow management system. The float-controlled irrigation management system saved 3.54 inches of water during the mid-March through May irrigation season. This system used 83.9% of the 21.99 inches of water used by the conventional irrigation management system. Water table depths were greater near the water furrows than at the centers of the production beds for both of the irrigation systems studied. Average water table depths varied from 20 to 22 inches from row 4 to row 8 on the 16-row beds for the conventional irrigation system. Average depths were less variable at 21 inches on row 4 to 22 inches on row 8 for the float-controlled irrigation system.**

Currently, almost 2.5 million acres of cropland are irrigated in Florida. Approximately 1.4 million are irrigated by gravity flow systems, of which 800,000 are estimated to be seepage irrigation systems (7). Thus, seepage systems are a major type of irrigation system in Florida.

Seepage irrigation systems are popular because they are cost-effective (1, 7, 17). They are used in regions where water supplies have in the past been abundant and where

[1]Florida Agricultural Experiment Stations Journal Series No. 5965.
[2]A portion of the 1982-83 field research project was funded by the St. John's River Water Management District.

the cost per unit of water pumped is low because of the low pumping heads required. Seepage systems also have another major advantage. The open ditch systems commonly used for irrigation also function as drainage ditches. This is required for crop production because the high water tables and/or restrictive soil layers necessary for a seepage irrigation system to function effectively also lead to drainage problems under typical Florida high rainfall conditions (1, 15, 21).

Seepage systems irrigate crops by raising a water table to just below the crop root zone so that water moves through the soil to the roots by capillarity. Because of the limited capillary movement of water in the coarse-textured soils which comprise most of Florida's irrigated acreage, water table elevations must be accurately controlled to irrigate successfully (2, 8, 10). Other factors such as soil hydraulic conductivities, ditch dimensions, water application rates, depth to restrictive layers, and field slopes are also important (6, 9, 18, 19).

Many irrigators control water table elevations in their seepage-irrigated fields by using a check dam at the point of outflow from the field. The dam establishes the field water elevation and allows excess water to be discarded by discharge over the top of the dam. Other irrigators control water table elevations by providing continuous flows through the water furrows in the fields. This method of control is favored because field slopes are normally too great to allow the check dam method to be effective for water table control at the upslope ends of the fields. With both of these methods, water is applied to the upslope ends of the furrows at rates in excess of the anticipated peak water use rate of the crop, and the excess is continuously discharged from the lower ends of the furrows. For most systems, the irrigation pump is operated continuously. Then water is wasted by discharge from the field during periods of low evapotranspiration demand, such as on cloudy days and during each night.

Many researchers have studied crop response to seepage irrigation in Florida (4, 5, 12, 13, 15). Others have modified the conventional open ditch seepage system used in Florida to improve irrigation or drainage effectiveness (2, 16, 17), or have recovered and recycled tailwater to improve irrigation efficiencies (14). No known study has been conducted of the control of application rates to prevent runoff of seepage irrigation water from the field. This project was conducted to determine whether seepage irrigation systems could be made more efficient with respect to water use efficiencies and energy consumption by automating control of irrigation applications.

Increase in irrigation efficiency would have the effect of reducing water demands from groundwater aquifers and thus reducing problems associated with decreasing potentiometric heads. These problems include failure of centrifugal pumps as a result of cavitation due to the greater pumping depth, and the intrusion of saltwater because of the reduction of potentiometric head and the large volumes of water pumped.

We recognized that a control system that would improve efficiencies of seepage irrigation systems would need to be reliable and cost-effective before it would be generally accepted by the public. This project was initiated with those concerns in mind.

The overall objective of this project was to develop and evaluate an irrigation control system which would allow the efficient use of water and energy for seepage irrigation of vegetables by regulating water inflows to the field. Flow would be regulated by cycling irrigation pumping times in response to water tables in the field and/or at outflow control structures from the field. Specific objectives included:

1) To develop an electric motor control system which would automatically turn a pumping system on and off in response to water table fluctuations.
2) To develop a float switch for controlling the irrigation pump.
3) To develop management practices for the application of the control system to the field conditions studied.
4) To evaluate the energy and water savings obtained by cycling a pumping system for seepage irrigation rather than continuously pumping.

Materials and Methods

Two separate field sites were instrumented in this research. The first year's study (1982-83) was conducted on the 10-acre main laboratory research farm at the Hastings Agricultural Research and Education Center. The second year's study (1983-84) was conducted at the Hastings Research and Education Center Yelvington Farm, about 4 miles from the main laboratory research farm.

1982-83 field experiments. The Hastings Agricultural Research and Education Center main laboratory farm area is shown in Fig. 1. At this site seepage-irrigated vegetables are normally produced on the 16-row bed and open-ditch water furrow system typical of the Hastings production area. With this system, rows are formed on a 40-inch spacing, and with 1 ft change in elevation from the tops of the rows to the bottoms of the alleys. Water furrows, 80 inches in width, are spaced at 60 ft intervals. Irrigation is distributed through an underground pipeline from a 6-inch artesian well and low-head centrifugal pump with sufficient capacity to irrigate the entire field at once. Water is applied to individual water furrows using 1-inch PVC valves.

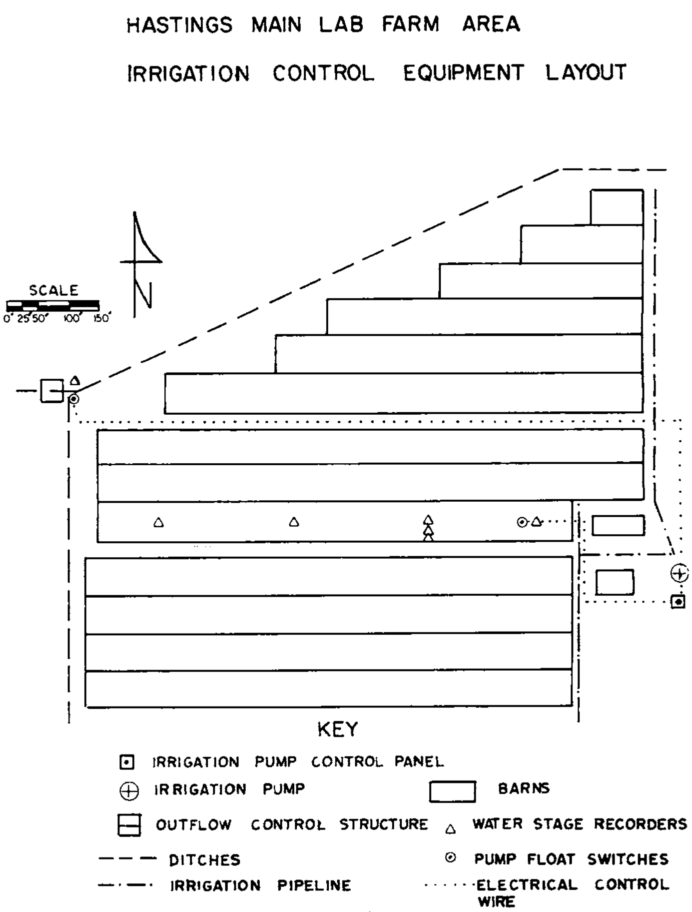

Fig. 1. Float-controlled irrigation system layout at the Hastings Agricultural Research and Education Center main laboratory farm.

Because of the shape of the field, water furrows ranged in length from 100 ft to 900 ft. Average slopes were about 0.35%, but slopes were not uniform. Slopes ranged from near 1% at the upper end of the field to near 0.1% on the lower 1/3 of the field.

Seepage irrigation, typical of the Hastings vegetable production area, is practiced. The irrigation pump is started and the water furrow valves are adjusted to apply the proper amount of water to the individual furrows. The pump is operated continuously at one speed (and flow rate) to raise and maintain the water table in the crop root zone. Flow rates are set sufficiently large so that the water table can be maintained during peak water use periods of the day. Excess water is discharged from the field and lost to the production system.

We modified the above system by constructing a ditch to collect all runoff water at the lower end of the field. (Fig. 1). A culvert and flash-board riser drainage structure was installed to control the elevation of the drainage water. All drainage water was routed through this structure.

The existing irrigation pump and pump controller were replaced because of their mechanical condition. A self-priming centrifugal pump and a controller with manual and automatic (remote) control capabilities were installed. The controller allowed continuous pump operation when set in the manual position, and it allowed pump operation to be interrupted as frequently as desired by opening and closing a remote switch when set in the automatic position.

Float switches (Fig. 2) were installed in the field to control the irrigation pump operation in the automatic mode. Initially, one float switch was installed in a stilling well at the flash-board riser. A 24 VAC control circuit and electrical relay was used with the float switch to interrupt the irrigation pump operation when water began to flow from the field through the drainage structure. It restored pump operation when the water elevation dropped to 1-inch below the top of the drainage structure.

After several weeks of operation, a second float switch was installed in a shallow well in the field. The well was installed near the center of the 16-row bed (on row 8) between water furrows. It was located about 1/4 of the distance from the upper end of the field. At this location, the float switch was used to interrupt pump operation when the field water table rose to a preset level. The float switch was set to control at 20 inches below the tops of the beds. This was the recommended production practice for this soil type and location (9). The float switch was double-acting so that the irrigation pump would be turned on when the water table dropped 1/2 inch to 20.5 inches below the tops of the beds. It would be turned off when the water table rose above 19.5 inches.

To prevent the irrigation pump from cycling excessively and possibly causing mechanical failure, we installed a 15-min time delay relay on the irrigation pump controller. This relay caused the pump operation to be delayed for 15 min whenever the float switch contacts closed. This system prevented the pump from turning on and off frequently in the event of a faulty float switch or if winds, birds or other factors cause the float to fluctuate inadvertently.

Other instrumentation installed included a 3-inch impeller flow meter and a 3-inch solenoid-controlled valve at the irrigation pump. The impeller meter totaled the volumes of water applied, and the solenoid valve shut off artesian flow when the pump was not operating.

A strip chart event recorder and a digital event counter were installed on the irrigation pump controller. These measured the number and timing of irrigations.

Float-type water stage recorders were installed in shallow wells at 6 locations in the field. As shown in Fig. 1, 4 recorders were spaced at about 200 ft intervals on row 8 of the bed where the float switch was located. Two other recorders were located on rows 1 and 4 adjacent to one of the recorders on row 8 on the same bed.

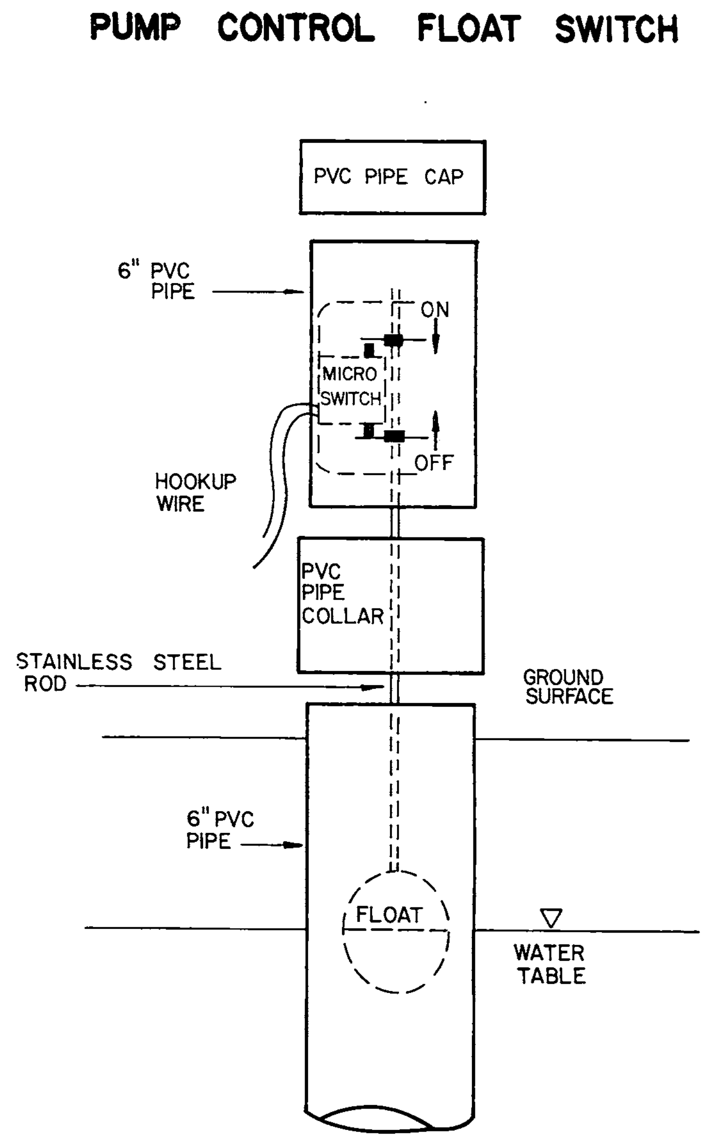

Fig. 2. The pump control float switch we designed to turn the irrigation pumping system on and off in response to water table elevations.

Weather data were measured at the research center weather station. These included rainfall, solar radiation, humidity, and temperature.

Equipment and instrumentation installations were made beginning November, 1982. The system was operated and data collected during the production of potatoes at this field site from March-May 1983.

1983-84 field experiments. Field research during the second year of this project were conducted at the Hastings Agricultural Research and Education Center Yelvington Research Farm. This site was selected because it has soil types and topography more typical of the seepage-irrigated vegetable production lands of this region. Potatoes were produced at this site in Spring, 1984.

Because of limitations of available land, our research was conducted on 2 production beds of about 0.8 acres each. Beds were located adjacent to each other as shown in Fig. 3. One bed was the experimental site on which water tables were controlled. The second bed was the control site

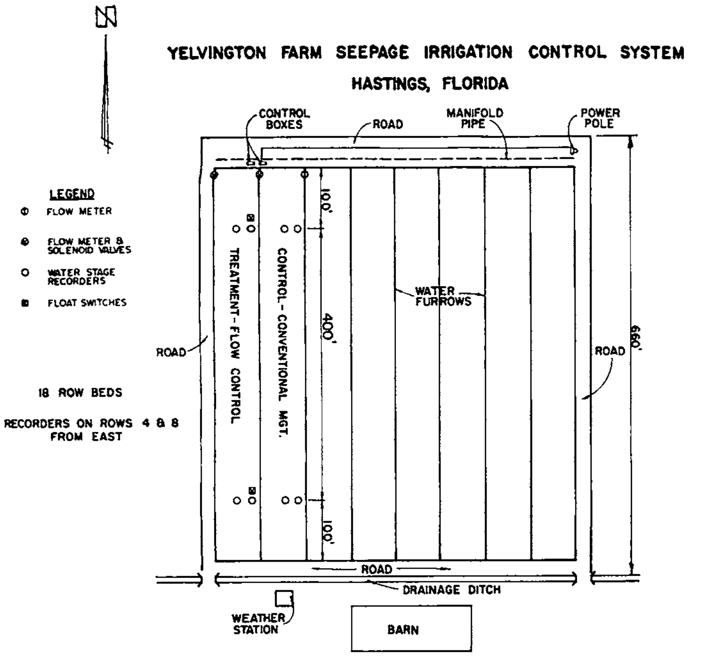

Fig. 3. Seepage irrigation research system layout at the Hastings Agricultural Research and Education Center Yelvington Farm.

on which conventional water applications were made. Each bed was 600 ft long and had the same configuration as those described in the 1982-83 study.

The field site was prepared for this research by land grading in November, 1983. Beds were constructed with a uniform gradient of 0.05% along their length. They were level in the direction perpendicular to the rows.

The conventional method of water application to the field site was identical to that of the 1982-83 experimental site. Water was applied to individual water furrows with adjustable PVC valves. We modified this system by adding totalizing flow meters to the 3 valves on the water furrows we studied. They monitored total water applications during the growing season for both the conventional (continuous application) and for the float-controlled (intermittent application) irrigation methods.

Water applications to the 2 water furrows which irrigated to the experimental bed were controlled using 1-inch 24VAC electric solenoid valves. These were actuated using float switches on shallow wells in the field. Float switches opened solenoid valves when field water tables dropped 1/2-inch below the desired control level. They closed solenoid valves when water tables rose 1/2-inch above the desired control level.

As shown in Fig. 3, float switches were located in the field on the fourth crop row from a water furrow. Two switches were used. One was located 100 ft from the upper end of the bed. The second was located 100 ft from the lower end of the bed, 400 ft from the first.

A strip chart event recorder and a digital event counter were used to measure the number and timing of irrigation events. Also, a record was kept of the hours of operation of the irrigation pump which supplied the entire research farm. The pump was operated continuously except following rainfall which caused field water tables to rise above desired levels.

Water table elevations in both the experimental and control beds were continuously monitored using a network of water level recorders on shallow wells. Eight recorders were installed, 4 on each of the beds monitored. Recorders were installed on crop rows 4 and 8, 100 ft from the upper and lower ends of the beds (Fig. 3).

With the exception of rainfall, weather parameters were monitored at the Hastings Agricultural Research and Education Center main farm area as in 1982-83. Rainfall was monitored at the field site.

Results and Discussion

1982-83 field experiments. The irrigation pump controller functioned reliably during this research, turning the pump on and off in response to water table elevations in the field. The instrumentation we developed has several advantages over the conventional continuously operated pumping systems: 1) It conserves water resources by pumping groundwater only when required to raise the field water table. 2) It conserves energy by operating only intermittently. 3) It turns the system off automatically in the event of rainfall which raises the water table above the desired control level. 4) It automatically restarts the pumping system following power outages.

There are some disadvantages of our control system as compared to conventional methods of pump operation: 1) The system we developed is more costly than a conventional irrigation controller because it requires the conventional controller as well as other components. 2) Because there are more mechanical components, there is a greater probability of mechanical failures than the conventional system. 3) The control system requires field installation and may be an obstacle to some field operations. 4) The life expectancy of the pump and controller may be shortened by more frequent starting and stopping.

We believe that the limitations of the use of the control system are small with respect to its advantages. Limitations will also become smaller still as water supplies become more limiting, due either to competing users or to deteriorating quality because of excessive use of the aquifer. Because this system automatically shuts off the irrigation pump when the water table rises excessively due to rainfall, it allows drainage to begin at that time. This may enable the system operator to avoid a trip to the field site after normal working hours. Also, because this system automatically restarts the pump following power outages, it may save the system operator several trips to the field site during a growing season. It also assures proper irrigation should a grower be unavoidably detained from making manual changes.

Electric motor controllers are designed to drop a pump out of an electric circuit when supply voltage drops below a critical level or when the power supply is lost, even only momentarily. Our controller will enable the pump to be dropped out of the circuit under the previous conditions, thus protecting the electric motor, but it will also restart the system when power is restored. The restart will occur after the delay time set on the time delay relay, thus allowing power to be fully restored before the pump motor attempts to operate. This will protect the motor from damage due to low voltage start-ups.

The time delay relay is a critical part of the irrigation pump controller. An irrigation controller should not be constructed without one because it protects the pump motor against damage from low voltage starts. It also protects the motor from damage due to excessive starting and stopping as previously discussed.

It is also very important for a potential user of the previously-described pump control system to recognize that the automatic starting of pumps can only be used on systems where there is no possibility of the pump operating dry. If the pump requires priming and it is operated dry, it may be seriously damaged or destroyed because most pumps require the flow of water for cooling and/or lubrication.

The pump control system that we developed used a commercially-available pump controller with a "HAND (or MANUAL)–OFF–AUTOMATIC (or REMOTE)" switch. Installing the system with this 3-position switch has the advantage of allowing the system to be operated continuously (as systems are conventionally operated) by switching to the "MANUAL" position in the event of mechanical failures associated with the float switches or their power supply. This will allow the system to operate as a conventional continuous flow system while repairs are being made.

As a result of the field installation in 1982-83, we demonstrated that the control system that we developed turned the pumping system on and off reliably in response to water table elevations at the float switches. Both the control instrumentation and float switches functioned well, thus satisfying the first 2 objectives of this research. Unfortunately, however, the site we selected for this study was not a good one with respect to the functioning of a seepage irrigation system. It was not possible to establish and maintain the desired water table elevations in the field, even with the irrigation system operating continuously. Only when rainfall occurred did the water tables rise to the desired levels temporarily. Therefore, objectives 3 and 4 of this study were not achieved.

As field data collection began, the float switch at the flash-board drainage structure was the only one used. However, irrigation water flowed through the water furrows to the drainage structure before field water tables were established. For this reason, we installed a second float switch in the field positioned as shown in Fig. 1. The field float switch was installed in parallel with the float switch at the flashboard drainage structure. This allowed the irrigation pump to continue to operate if either the field water table was too low or if the water table at the drainage structure was too low. With this installation, the pump operated continuously except following rainfall because the field water tables never reached desired levels as a function of irrigation alone.

The reasons that we could not establish and control field water tables at this site were not discovered until we began detailed data collection. First, the slopes were steeper than those typically used for seepage irrigation. This caused water to flow rapidly through the field. Second, the soil was very shallow at the upper end of the field. The water furrows were cut down to the underlying clay, and the water in the furrows flowed downslope rapidly. Gradients required for lateral movement of water were insufficient because of the small depths of water in the water furrows. Third, the soil was finer textured (heavier) than that typical of the Hastings vegetable production area so that lateral movement from the water furrows was further restricted. Fourth, land grading operations several years prior to our study required large cuts in some areas. These cuts may have disrupted the underlying spodic layer which normally helps impede deep percolation water losses.

We attempted to establish the desired water tables by increasing flow rates to the water furrows and by decreasing the spacings between water furrows. Higher flow rates to the water furrows did not increase water tables appreciably. Therefore water applications were made to the alley between the eighth and ninth rows on the 16 row beds in addition to the water furrows. This resulted in our being able to establish the desired water table elevation in only the 2 rows adjacent to the water furrows, and led us to conclude that this was not an appropriate research site for this study. For these reasons, the location of our field research was changed for the 1983-84 crop year.

1983-84 field experiments. Solenoid valves were used on individual water furrows rather than the irrigation pump controller developed during our 1982-83 research because a continuous supply of water was required from the irrigation pump for other research projects being conducted at the Yelvington research farm. Field scale application of the float-controlled method of irrigation would be simplified by using the pump controller rather than attempting to control water applications individually from a large number of solenoid valves.

Rainfall and irrigation distributions from March 14 through May 31, 1984 are given in Fig. 4. The upper part of that figure shows daily rainfall in inches. Rainfall was concentrated in the periods of March 21 through April 6 and May 22 through May 29. The period of April 6 through May 21 was relatively free of rainfall amounts which affected irrigation scheduling.

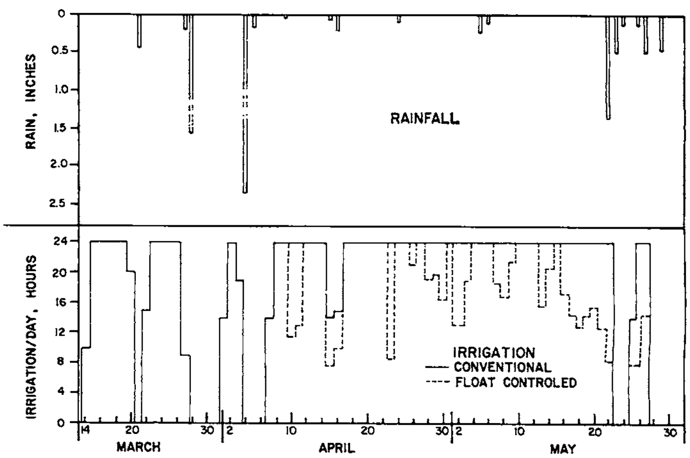

Fig. 4. Rainfall and irrigation hours of operation for the float-controlled and conventionally-managed seepage irrigation systems at the Yelvington Research Farm in 1984.

The lower part of Fig. 4 shows the distributions of irrigation system hours of operation per day. The solid line shows hours of operation of the conventional irrigation system. It was 24 hours per day except when interrupted by rainfall. Interruptions were imposed manually by turning the entire farm irrigation system off when large rainfall amounts occurred. The pumping system remained off until field water tables dropped to acceptable levels as determined by visual inspection. The float-controlled irrigation system was also off at these times because of the design of the farm irrigation system.

The dashed lines in the lower part of Fig. 4 show the hours of operation of the float-controlled irrigation system when they were different than the conventional irrigation hours. The difference between the solid and dashed lines show the hours during which the float-controlled irrigation system was turned off because water tables were sufficiently high while the conventional irrigation system continued to operate. No dashed lines appear before April because the strip chart recorder failed to operate properly before that time. Electric power failed at the field site, and it was not restored until March 21. Before that time the float-controlled system was operated continuously as a conventional system. After power was restored, the strip chart event recorder failed to function properly until repaired April 8. Therefore, the exact time and durations of float-controlled irrigation system operations were not recorded until after April 8.

Table 1 presents the average water table depths maintained and the range of daily water table fluctuations which occurred by the use of the 2 irrigation systems studied. Data are given at the locations of the water stage recorders shown in Fig. 3; that is, on crop rows 4 and 8

Table 1. Average water table depths and range of daily fluctuations in water table depths for the 1984 Yelvington Farm seepage irrigation studies.

End of water furrow	Rows from water furrow	Average depth (inches)	Range of daily water table fluctuations			
			Average (inches)	SD (inches)	Maximum (inches)	Minimum (inches)
Conventional Continuous-Flow Seepage Irrigation System						
Upper	4	20.1	2.2	0.77	3.1	1.8
Upper	8	21.7	3.7	0.86	4.8	2.4
Lower	4	19.9	1.7	0.95	3.1	0.6
Lower	8	22.3	1.8	0.65	2.5	1.1
Float-Controlled Seepage Irrigation System						
Upper	4	21.5	0.7	0.23	1.2	0.5
Upper	8	22.0	2.0	1.02	3.0	1.7
Lower	4	21.0	2.5	0.49	3.4	1.4
Lower	8	22.4	1.8	1.08	3.0	1.2

from the water furrows and at the upper and lower ends of the beds. Data are presented only for nonrainfall periods of irrigation because of the tremendous effect of rainfall on water tables. For this study those times were April 9-13, April 24-May 3, and May 7-21.

From Table 1, average water table elevations were greater near the water furrows (on row 4) than at the centers of the beds (on row 8). This occurred because of the time lag as water flowed laterally to the centers of the beds from the water furrows. Average water table elevations on row 4 were greater for the conventional seepage irrigation system (20.0 inches) as compared to the float-controlled irrigation system (21.1 inches). On row 8, the differences were less at 22.0 inches and 22.2 inches, respectively. These differences occurred because the float-controlled irrigation system functioned by "clipping off" the tops of the normal daily water table cycles. That is, irrigation was interrupted when the water table rose to the desired level. This prevented the water tables from rising as high with the float-controlled system as with the conventional system. This effect was dampened with distance from the water furrow, as can be seen by comparing the previous row 4 and row 8 data.

In Table 1, data are also presented on the range of daily water table fluctuations measured. Mean values, standard deviations, and maximum and minimum values are presented. Average daily fluctuations tended to be less at the upper ends of the beds when the float-controlled irrigation management system was used. This is probably because of the "clipping off" of the normal daily water table cycles by the float-controlled irrigation applications. This trend is not consistent at the lower ends of the beds. However, the fluctuations are not greatly different at this location. From these comparisons we concluded that daily water table fluctuations would not be expected to greatly differ for the 2 methods of irrigation control. Specifically, we demonstrated that the established water table would not be quickly depressed if applications to the water furrows are cycled as in this research.

Table 2 shows the monthly and total irrigation season depths of water applied by the 2 irrigation methods studied. The total water applied using the conventional continuous-flow seepage irrigation system was 21.99 inches. This was reduced by 3.54 inches to 18.45 inches by using the float-controlled seepage irrigation system. This was a reduction to 83.9% of the conventionally-applied water, a savings of 16.1%. Similar reductions in water applications on a monthly basis occurred for the 3 months of this study.

Table 2 also presents monthly and total rainfall for the duration of this study, and potential evapotranspiration (ETp) for this location. ETp was calculated using the Radiation method as modified for Florida conditions (3). The Radiation method was used because of the limitations on weather data available, and its demonstrated agreement with the Penman method (20). The Penman method is the recommended method for calculation of ETp for Florida conditions (11).

If rainfall is assumed to be only 50% effective because of losses due to runoff from the large rainstorms shown in Fig. 4, the conventionally-managed irrigation system efficiency can be estimated as $(13.66)/(21.99 + 4.22) \cdot 100\% = 52\%$. Likewise, the float-controlled irrigation system efficiency can be estimated as $(13.66)/(18.45 + 4.22) \cdot 100\% = 60\%$.

The water savings documented in this research by the use of the float-controlled rather than conventional continuous water applications for seepage irrigation were not as great as we had anticipated they would be. This occurred because, even with the float controls, a large amount of water was lost from the field by flow through the water furrows and into the drainage ditches. With our control mechanism and with conventional seepage irrigation practices, these losses were unavoidable because a certain depth of water was required in the water furrows to cause water to move laterally to the centers of the beds, and the gradients in the water furrows caused water to flow continuously from the field while soil water tables were being established. Also, the gradients of the water furrows are required for effective drainage following the frequent large rainstorms characteristic of this geographical location.

Table 2. Irrigation, rainfall, and potential evapotranspiration data for the 1984 Yelvington Farm seepage irrigation studies.

Month	Irrigation (inches)		% of Conventional	Rainfall (inches)	Potential evapotranspiration (inches)
	Conventional	Float-controlled			
March (1/2)	2.89	2.32	80.0	2.16	2.20
April	8.91	7.18	80.5	2.84	5.28
May	10.19	8.96	88.0	3.44	6.18
Total	21.99	18.45	83.9	8.44	13.66

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.

References

1. Bennett, J. M., G. A. Marlowe, Jr., and L. B. Baldwin. 1982. Conservation of irrigation water in vegetable production. Florida Coop. Ext. Serv. Cir. 533.
2. Campbell, K. L., J. S. Rogers, and D. R. Hensel. 1978. Watertable control for potatoes in Florida. Trans. Amer. Soc. Agr. Eng. 21: 701-705.
3. Clark, G. A. and A. G. Smajstrla. 1984. Methods and equations used for predicting potential evapotranspiration. Univ. Florida Agr. Eng. Dept. Mimeo Rpt. 84-13.
4. Csizinsky, A. A. 1979. Calculation of irrigation water for seep irrigated land from riser flow rates. Bradenton Gulf Coast Agr. Res. Educ. Center Res. Rpt. GC1979-12.
5. Csizinsky, A. A. 1980. Yield and water use of vegetable crops with seepage and drip irrigation systems. Agr. Sci. 43:285-292.
6. Fox, R. L., J. T. Phelan, and W. D. Criddle. 1956. Design of subirrigation systems. Agr. Eng. 37(2):103-108.
7. Harrison, D. S., A. G. Smajstrla, R. E. Choate, and G. W. Isaacs. 1983. Irrigation in Florida agriculture in the '80s. Florida Coop. Ext. Serv. Bul. 196.
8. Harrison, D. S., J. M. Myers, and D. W. Jones. 1974. Seepage irrigation for pastures. Florida Coop. Ext. Serv. Cir. 309-C.
9. Hensel, D. R. 1964. Irrigation of potatoes at Hastings, Florida. Proc. Soil & Crop. Sci. Soc., Florida 24:105-110.
10. Hensel, D. R., J. R. Rogers, and K. L. Campbell. 1975. Subsurface drainage and irrigation for potatoes on low flatwoods soils. Hastings Agr. Res. Educ. Center Res. Rpt. PR-1975-9.
11. Jones, J. W., L. H. Allen, S. F. Shih, J. S. Rogers, L. C. Hammond, A. G. Smajstrla, and J. D. Martsolf. 1984. Estimated and measured evapotranspiration for Florida conditions and crops. Univ. Florida Res. Bul. 840 (technical).
12. Marlowe, Jr., G. A. 1977. A rationale for the determination of irrigation needs for vegetable crops grown with seep irrigation. Bradenton Gulf Coast Agr. Res. Educ. Center Res. Rpt. GC1977-8.
13. Persaud, N., S. J. Locascio, and C. M. Geraldson. 1976. Effect of rate and placement of nitrogen and potassium on yield of mulched tomato using different irrigation methods. Proc. Fla. State Hort. Soc. 89:135-138.
14. Prevatt, J. W., C. D. Stanley, and W. E. Waters. 1980. Evaluation of a water conveyance and recovery system for seep irrigation. Proc. Fla. State Hort. Soc. 93:253-256.
15. Rogers, J. S. and D. S. Harrison. 1974. Crop response to drainage in flatwoods. Proc. Fla. State Hort. Soc. 87:193-195.
16. Rogers, J. S., D. R. Hensel and K. L. Campbell. 1975. Subsurface drainage and irrigation for potatoes. Proc. Soil & Crop Sci. Soc., Florida 34:16-17.
17. Rogers, J. S. and C. D. Stanley. 1983. Subsurface irrigation of staked tomatoes in Florida. Proc. Soil and Crop Sci. Soc. Florida 42:65-69.
18. Skaggs, R. W. 1974. The effect of surface drainage on water table response to rainfall. Trans. Amer. Soc. Agr. Eng. 17:406-411.
19. Skaggs, R. W. 1981. Water movement factors important to the design and operation of subirrigation systems. Trans. Amer. Soc. Agr. Eng. 24:1553-1561.
20. Smajstrla, A. G., G. A. Clark, S. F. Shih, F. S. Zazueta, and D. S. Harrison. 1984. Characteristics of potential evapotranspiration in Florida. Proc. Soil & Crop Sci. Soc. Florida 43:40-46.
21. Stanley, C. D., J. S. Rogers, J. W. Prevatt, and W. E. Waters. 1981. Subsurface drainage and irrigation for tomatoes. Proc. Soil & Crop. Sci. Soc., Florida 40:92-95.

Proc. Fla. State Hort. Soc. 97: 187-190. 1984.

COMPATIBILITY EVALUATION OF VARIOUS FOLIAR SPRAY COMBINATIONS ON PEPPER

R. S. Cox
Trop-Ag Consulting Services,
1404 Shirley Court,
Lake Worth, Florida

AND

Larry A. Nelson
Department of Statistics,
North Carolina State University,
Raleigh, North Carolina

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