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Frost Protection with Sprinkler Irrigation
Michigan State University Extension Service
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Issued April 1955
12 pages

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EXTENSION BULLETIN 327

264 Feb 64

FROST PROTECTION

WITH

Sprinkler Irrigation



By John R. Davis

MICHIGAN STATE COLLEGE
COOPERATIVE EXTENSION SERVICE
EAST LANSING

Frost Protection with Sprinkler Irrigation

By JOHN R. DAVIS¹

How Well Does It Really Work?

Late spring and early fall frosts on mineral soils, and mid-summer frosts on low muck areas, can cause considerable damage to high-value crops in a single night. Many growers in southwestern Michigan experienced, in 1954, a succession of 10 to 11 killing frosts during the strawberry blossom season. Those that irrigated for frost control during this period reported that irrigation was the difference between a good strawberry crop and a near failure. One strawberry grower put it this way: "Irrigation for frost control was the difference between an 80 percent crop and a 20 percent crop".

In some years only one or two damaging frosts occur; but by irrigating the crop during the frost period, growers have avoided considerable damage and discouraging setbacks. Many strawberry growers have said that they find it difficult to separate the greater usefulness of an irrigation system for either drouth or frost protection.

As an example of the extra dividends that can be expected from frost control by irrigation, consider a crop of strawberries which will yield about 500 crates or more each acre with good management practices. An 80 percent crop of 400 crates an acre, at \$5 per crate, is worth \$2,000; while a 20 percent crop of 100 crates an acre at the same price is worth \$500. This difference of \$1,500 an acre is then the gross profit due to irrigation for frost control — quite outstanding when one considers that killing frosts occur about 3 years out of 4 in many areas.

Irrigation for frost control has worked so well that several growers are now transplanting tomatoes earlier in the spring, so that a portion of the crop reaches maturity sooner than usual. Irrigation can prevent frost damage to these early plantings and the grower can usually expect to sell to an early market at a good price. However, if daily temperatures in the spring are below normal, the plants may not grow or set fruit, and the grower may not be any further ahead than if he had transplanted as usual.

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Extending the picking time in the fall for tomatoes, beans and other vegetable crops can also quite profitably benefit the grower. For example, if tomatoes can be protected against an early fall frost, the extra pickings can be sold on the market for a week or so later than usual, which could be in time for a more profitable late market.

In 1953, late-planted tomatoes, peppers, peas, broccoli, etc., were still uninjured on November 3 on the experimental garden plot on the horticultural farm at Michigan State College. This was made possible by protecting the crops against frost damage by the continuous application of water with the irrigation system. (See cover.) All tender crops not protected were killed by frost during the first week in October. In many seasons, one or two nights of irrigation for frost protection in the fall may prolong the picking time by 10 to 15 days.

How Does It Work?

Heat is applied in one way or another to turn ice into water. Similarly, to turn water into ice, heat is taken away. When an irrigation system is used for frost control, water is almost continuously sprayed on the plants and the soil. Because the air temperature surrounding the plants drops below freezing, the water starts to freeze on the plants. When the water freezes, it gives off heat—some of which goes into the plant leaves and blossoms, while some goes out into the air. The heat absorbed by the plant is enough to keep the plant above its freezing temperature, except when the air temperatures are very low or when the heat is rapidly removed by a cold wind.

Water must be sprayed on the plant continuously, or at frequent repeat intervals as would be applied by a rapidly rotating sprinkler, to provide enough heat to keep the plant from freezing. Irrigation equipment *cannot* be moved during frost protection work — the water must be applied to the plants almost continuously.

Ice usually forms on the plant to a varying thickness of 1/16 inch to 1/2 inch, depending on the duration and intensity of below freezing temperatures. (Fig. 1.) Ice may not form when the frost is very light; temperatures may be 1 or 2 degrees below freezing before ice starts to form. When ice forms, *do not stop*, but continue to apply the irrigation water until the air temperature is above 32 F. and all the ice has melted off the plants.

What Weather Conditions Lead to a Frost?

Still, clear nights with low temperatures forecast usually indicate possible "radiation" frosts. The weather condition is this: a cold mass of air moves into the area behind a "cold front". Then, if the wind dies down toward evening or during the night and the sky becomes clear, heat is radiated from the plant and the soil to the colder outer atmosphere. The temperature near the ground surface may drop very quickly; as much as 4 degrees in an hour.



Fig. 1. Continuous sprinkler irrigation formed ice to the thickness of $\frac{1}{2}$ inch on these pepper plants in an experimental plot during a late-fall frost. Yet after the ice was melted, the plants were found to be healthy, vigorous, and undamaged by the freezing temperatures.

Summer and fall frosts on muck are difficult to forecast. Temperatures near the soil surface may drop below freezing very quickly, even though the soil and air temperatures may be as high as 80°F. during the daytime.

Muck farmers, and those who face more frequent frosts than common on mineral soils in southern Michigan, either can establish a relation between local weather bureau temperatures and their field temperatures, or can observe or record their field temperatures with an accurate thermometer. This would minimize the possibility of crop damage by a frost that may not have been forecast.

Windborne freezes are different than radiation frosts. They are caused by a mass of cold air of below freezing temperature moving into the general area. Windborne freezes are likely to be more severe

and may last all night and all day. Protection from windborne freezes by sprinkler irrigation is usually less successful than at other times, because the wind could rapidly remove from the field most of the heat given off by the freezing water. Also, the water distribution pattern of the sprinklers may be badly distorted, so that many areas of the field are not properly covered.

U. S. Weather Bureau forecasts can be used in some measure as a frost warning. However, their thermometers may be located at a different elevation and at some distance away, which can result in a different temperature at their station than at the level of the plants in the field. There will be times when frosts occur that are not forecast, which points out the need for every grower to observe temperature conditions in his fields. When the Weather Bureau forecasts a minimum temperature of about 40°F., it is time to be prepared. If the wind dies down or the sky clears rapidly or unexpectedly, the temperature may fall below that which was forecast.

What Temperatures Can I Protect Against?

With proper design and operation of the irrigation system, many crops have been protected against temperatures as low as 20°F. Future advances in irrigation equipment and further research studies may make possible the protection of some crops at temperatures below 20 degrees.

On What Crops Can It be Used Successfully?

Irrigation for frost control has been tried on many crops with varying degrees of success. It can be used on low-growing vegetable crops — such as tomatoes, cucumbers, peppers, beans, squash, etc. — and on cranberries and strawberries. However, some growers have found that, during low-temperature frosts, the ice that accumulates on trees can be heavy enough to break down the branches. A similar accumulation of ice could break down corn plants; celery; pole beans; and tall flowers, such as gladiolus and hyacinth.

Several growers have reported protecting gladiolus against frosts as low as 27°F. They reported, however, that at temperatures any lower the ice which formed on the plants damaged the stems and the flowers. Generally, tall, thin plants are not adapted to this method of frost control, because of the ice load that sometimes builds up on the plant during low-temperature frosts.

Is There Any Damage to a Crop or to the Soil?

Ice-load damage, as just mentioned, will occur on tall-growing plants and trees. Some growers have reported damage to strawberry plants when they stepped on the ice-covered plant. Repeated applications of water can saturate the soil and leach fertilizers down below the plant roots, especially nitrogen. Normally, fertilizers are applied to strawberries prior to blossoming, before frost control is necessary; so it may be necessary to apply an additional amount of nitrogen fertilizer after or during irrigation for frost control.

What Additional Equipment is Necessary?

One piece of equipment, in addition to the irrigation equipment, that is desirable is some form of a temperature alarm or thermostat. These inexpensive switches can be placed in the field at plant level and wired to a *loud* bell alarm in the house. The temperature switch should be adjusted to close the electrical circuit at 34°F. Then when the temperature drops to about 34°, the alarm goes off and the grower can put the irrigation system into operation before frost damage occurs.

Some thermo-switches may not be accurate. To check their accuracy, set the dial on the switch to close the circuit at 34°. Then place an accurate thermometer (Fahrenheit) close to the switch and put both outside either during the first frost or during the winter. If the switch does not close when the thermometer reads 34°, it can be adjusted to do so. Then you will know that when the switch is set at 34°, the circuit will be closed at 34°, and not at a lower temperature. To check the accuracy of a Fahrenheit thermometer, immerse the bulb in a container of well-stirred ice water. If the thermometer reads 32°, it is reading correctly. It would be desirable to check the accuracy of a new thermo-switch and to recheck it at the beginning of each season.

If an alarm switch is not used, an accurate thermometer should be placed at plant level in the field and checked frequently during the night. It will mean lost sleep every night a frost is expected, and if you don't hear your alarm clock some night it may mean the end of that crop. Also, the temperature will occasionally drop more rapidly than you expected and frost may damage the plants before the irrigation system can be started.

Using Existing Irrigation Equipment

Your present equipment can be extended to cover more area for frost control than it does for normal irrigation in the summertime.

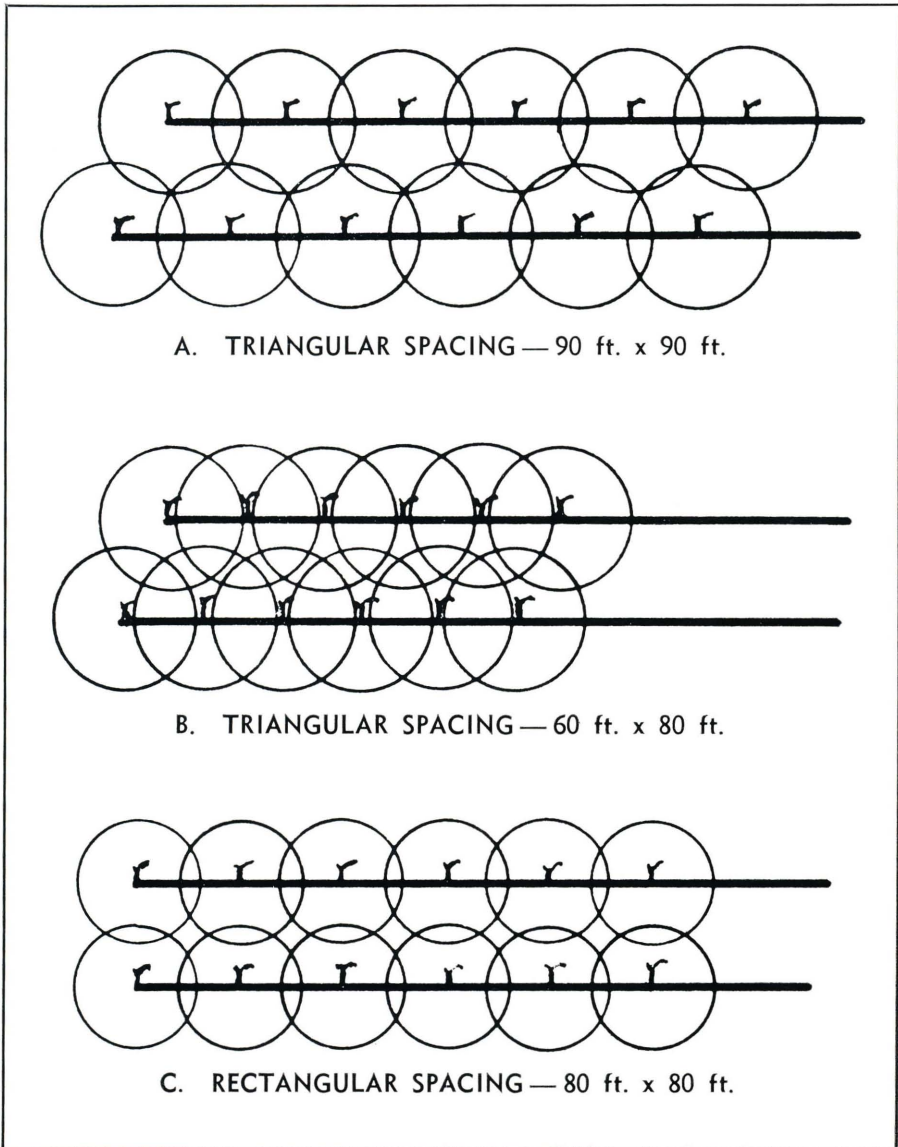


Fig. 2. Effect of sprinkler spacing and arrangement on the application of water for frost protection. Sprinklers in Arrangements A and B represent a 110-foot diameter of coverage. Those in Arrangement C represent a 95-foot diameter of coverage.

Many systems are designed so that the water from one sprinkler would reach the base of the next sprinkler. During the frost control, the spacing of the sprinklers can be increased to cover about twice as much area as the summertime sprinkler spacing.

For frost protection, the wetted area from one sprinkler should just meet, or overlap a few feet, the wetted area from the next sprinkler; thus providing adequate coverage to a larger area. To distribute the water satisfactorily to this larger area, the sprinklers should be spaced in a triangular pattern instead of a rectangular or square pattern.

Various sprinkler arrangements and spacings are shown in Fig. 2. Arrangement "A", at the top, approaches ideal conditions: minimum possible application rate, good coverage, and the maximum possible area is covered. An 80 ft. x 80 ft. spacing would be just as good. Arrangement "B" provides possibly better coverage, but note that the application rate for the same sprinklers is higher and the size of the area covered by the 12 sprinklers is smaller than in "A".

Arrangement "C" would not provide adequate coverage and protection, because there are areas between the sprinklers that will not be irrigated. In this case, an 80 ft. x 80 ft. triangular arrangement would be much better because it would provide better coverage than the rectangular arrangement.

The arrangements shown in Fig. 2 are not meant to be general recommendations for frost control, but only illustrations to show the effect of spacing and arrangement on the efficiency of this method. Specific sprinkler spacings can be recommended by the irrigation equipment dealer.

The reader is also cautioned that the spacings shown in the figure are to be used only for frost control — not for regular summertime irrigation. Regular irrigation practice will require a closer spacing to obtain a more uniform application of water.

The water distribution in the field should be checked to make sure that all the plants are sprinkled with enough water. This can be done by measuring the water depth in several tin cans placed midway between two sprinklers, where the water application is likely to be the least. This should be done as a "test run" before the equipment is used for frost protection.

The water application rate for frost control should be just enough to prevent damage to the plant. Putting on more water than is needed is a waste of water and power, and may lead to water-logging the

soil. A minimum water application rate of about 1/10 to 1/8 of an inch per hour, as measured in cans between sprinklers in the field, appears to be adequate.



Fig. 3. Results of frost control with sprinkler irrigation. Frost-killed peppers on the left were given no protection. Peppers on the right were protected by continuous water application—and survived a recorded low temperature of 21° F.

Most of the rotary irrigation sprinklers used in Michigan, especially those with two or more nozzles, usually apply more water than is needed for frost control. Some growers plug one nozzle and use only the nozzle with the “kicker arm”; by use of this procedure, usually less than half the normal amount of water is applied. It may also be necessary to use a smaller-size sprinkler nozzle to further reduce the application rate. In most cases, higher pressure at the sprinkler will increase the wetted area and will create finer water droplets, both of which are desirable. Your irrigation equipment dealer can be of assistance in selecting the proper size nozzle and in adjusting the sprinkler spacing.

The turning speed of the sprinklers can be an important factor in the effectiveness of irrigation for frost protection. Small, one-nozzle sprinklers turning one revolution in 12-20 seconds have given very satisfactory results; whereas somewhat larger sprinklers with one nozzle plugged, turning one revolution in 90 seconds or more, did not adequately protect a tomato crop against a 24-degree frost. Until further research evidence is available, definite recommendations regarding the turning speed of sprinklers cannot be made. The rota-

tional speed of most sprinklers can be increased by increasing the spring tension or by making other adjustments.

It is desirable to "test run" the irrigation system during the day before the night that it is needed for frost control. This is "good insurance" that the engine and pump will run; that the couplers and fittings won't come apart or leak too much; that leaves, trash and small animals are flushed out of the lines; that the sprinklers are operating satisfactorily; and that the proper amount of water is falling on the entire area. Because the engine or motor is probably the part of the irrigation system that is most susceptible to operating failures, it should be thoroughly reconditioned and in top working condition before the frost damage period.

Be sure to have plenty of fuel in the tank to run all night (12-14 hours) and have more on hand to refill the tank, if necessary.

How Much Water Will I Need?

The water requirements will depend on how many hours and nights in a row the system runs. Applying 1/8 inch per hour to one acre requires about 60 gallons per minute. Irrigating six acres for frost control would then require about 6 x 60, or 360 gallons per minute. This quantity of water must be supplied continuously from the time the temperature drops to about 34°F. at plant level, until all the ice is melted off the plants in the morning. When a pond or a dammed-up stream is used for a water supply, make sure there is enough water for the entire night *and that it will be replenished for the next night and succeeding nights.*

As an example of the size of a storage pond needed for frost control, pumping 360 gallons per minute for 12 hours would take out all the water in a rectangular pond 8 feet deep, 44 feet wide and 100 feet long. For the next night's operation, the pond would have to be refilled, either by pumping from another water source or by seepage into the pond. Some growers are making effective use of small turbine pumps operating up to 24 hours per day to refill their excavated ponds. These small pumps can be powered by 5 to 10 horsepower electric motors or engines to pump from relatively shallow 4 to 6 inch wells.

The temperature of the water that is applied seems to have little effect on keeping the plant above freezing temperature. By the time the water reaches the plant, after falling through the cold air, its temperature is close to 32°F.

What Will it Cost and How Much Time Will it Take?

Usually only one person is needed for a night's frost control work to check on the continued satisfactory operation of the system. The length of the operation period is determined by 1) how quickly the temperature falls to the freezing level, and 2) how long the system must run to give continued protection.

Running time varies from 3 to 15 hours, with the average time about 8 to 10 hours each night.

What is the Difference Between this Method and Others?

Remember that not all crops or areas are adapted to this method of irrigation for frost control. For the crops that are adapted, irrigation is often less expensive, less labor is required, crops can be protected against lower temperatures, and generally more satisfactory results are obtained.

In the spring, hot tents may be an effective means of frost protection for small plants, such as tomatoes. For larger plants, row plantings such as strawberries, or for fall frost control, irrigation is more suitable. In deciding whether to use hot tents or irrigation, one must consider the type and size of crop, and how often and how late in the season frost would occur in the particular field. If more than two or three damaging frosts can be expected in the spring after the plants have been set out, hot tents might be more economical. If temperatures after plants have been set out are normal or lower than normal, irrigation will not encourage growth — it will only prevent frost damage to the plants. Hot tents will, however, tend to promote growth and will afford some degree of frost protection.

Several strawberry growers who have tried both heaters and irrigation stated that irrigation gave more satisfactory results. Irrigation serves a dual purpose, and therefore has the advantage of being valuable for both frost control and drouth protection.

Operating the Equipment for Frost Control

FIRST, set up the equipment in the field and give a thorough "test run" before it is needed for frost control. The amount of water applied can be checked by measuring the water depth in cans between the sprinklers.

SECOND, have a reliable thermometer or temperature-alarm switch at plant level in the field, and check its accuracy at the start of each

season. Start the irrigation system when the falling temperature reaches 33°-34°F. An accurately adjusted temperature alarm is a sure way of telling you when to start the system and it can save you a great deal of sleep.

THIRD, check on the system occasionally when it is running, to make sure it is operating satisfactorily. For those who would like to sleep through the night, after the system has been started, an engine failure alarm might be suggested. It could be wired to the electrical system, so that if the motor or engine stopped the alarm would ring and wake up the operator.

FOURTH, keep applying water until you are sure the air temperature is above 32°F. and all the ice is melted off. Ice usually does not form immediately after the system is started — *but when it does, don't be alarmed* and above all, *don't stop irrigating*. Keep going and shut down when the ice has melted and the air temperature is above 32°F. Don't be surprised if a faint breeze or cloudiness during the night causes the temperature to go above freezing and the ice to melt off the plants; *but* it may again drop below freezing before morning, should the breeze die down or the clouds move away, necessitating starting the irrigation system again.

FIFTH, wait until the ice is melted before you shut off the irrigation water. Some wait only until the air temperature is 32°F. to shut off; but to be safe, wait until the ice is gone.

SIXTH, don't plan that one night's work may be all. Be wary of frosts on following nights until the danger is passed. It is discouraging to work hard for many nights protecting crops from frost damage, only to lose the crop on a following night because of oversleeping or running out of water. Listen to the *latest* local weather reports or call the local weather bureau for information.

Ask your county agricultural agent, irrigation equipment dealer, or the Soil Conservation Service for assistance in planning and designing your irrigation system for frost control.

(Field experiments referred to in this bulletin were conducted by the Agricultural Engineering Department in cooperation with the Department of Horticulture, Michigan State College. Several Michigan dealers in irrigation equipment also furnished valuable field assistance and cooperation.)