Frost Protection with Sprinkler Irrigation
Michigan State University Extension Service
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Issued January 1956
12 pages

EXTENSION BULLETIN 327 (REVISED)

Frost Protection

WITH *Sprinkler Irrigation*

MICHIGAN STATE UNIVERSITY

COOPERATIVE EXTENSION SERVICE

EAST LANSING

Frost Protection with Sprinkler Irrigation

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How Well Does It Really Work?

Late spring and early fall frosts on mineral soils, and also midsummer frosts on low muck areas, have caused considerable damage to high-value crops in a single night. Many growers in southwestern Michigan experienced 10 to 11 killing frosts during the strawberry blossom season in May 1954. Those irrigating for frost protection 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 protection was the difference between an 80 percent crop and a 20 percent crop".

As an example of the extra dividends that can be expected from frost protection 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 protection—quite outstanding when one considers that killing frosts occur about 3 years out of 4 in many areas.

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 decide which way an irrigation system is most useful — for drouth or frost protection.

Irrigation for frost protection 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 after planting in the spring stay below normal, the plants may not grow or set fruit earlier 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, lima beans, peppers, 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 to 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 University. 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 protection, 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 and some to the soil. The heat absorbed by the plant is enough to keep the plant above its freezing temperature, except when the air temperature is 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 such as would be applied by a rapidly rotating sprinkler or oscillating pipe, to provide enough heat to keep the plant from freezing. Irrigation equipment *cannot* be moved during frost protection work.

Ice usually forms on the plant to a thickness varying from 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 ½ 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. A "cool" day may precede a night frost.

Muck farmers, and those who face frequent frosts in low mineral soil areas can either establish a relation between local weather bureau minimum temperatures and their field temperatures or observe and 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 from 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 minimum temperature forecasts can be used in some measure as a frost warning. However, their thermometers are placed several feet above the ground, may be located at a different elevation, and may be some distance away, which can mean a different temperature at their station than at the level of the plants in your 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. Expect your lower fields to be several degrees colder than your higher fields.

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. Higher rates of water application will probably be needed for temperatures lower than 20 degrees.

On What Crops Can It be Used Successfully?

Irrigation for frost protection 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 lower temperatures 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 protection, 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 will occur on tall-growing plants and trees. Some growers have reported damage to strawberry plants when they stepped on the ice-covered plant. Others have reported ice breakage on trees when strawberries are grown between tree rows in a new orchard. 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 protection is needed, so it may be necessary to apply an additional amount of nitrogen fertilizer to stimulate plant growth. Growers on heavy soils have more trouble with saturated soil because of low absorption rates.

What Additional Equipment is Necessary?

One piece of equipment, in addition to the irrigation equipment, that is a "sleep saver" is some form of temperature alarm or thermostat. These inexpensive switches can be placed in the field *at plant level* and wired in an electric circuit 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 alarm goes off, the grower can put the irrigation system into operation before frost damage occurs.

Some thermo-switches may not be accurately adjusted. 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 you do not use an alarm switch, place an accurate thermometer at plant level in the field and check frequently during the night. It will mean lost sleep every night a frost is expected, and if you don't hear or fail to reset 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 you can start the irrigation system.

Using Existing Irrigation Equipment

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

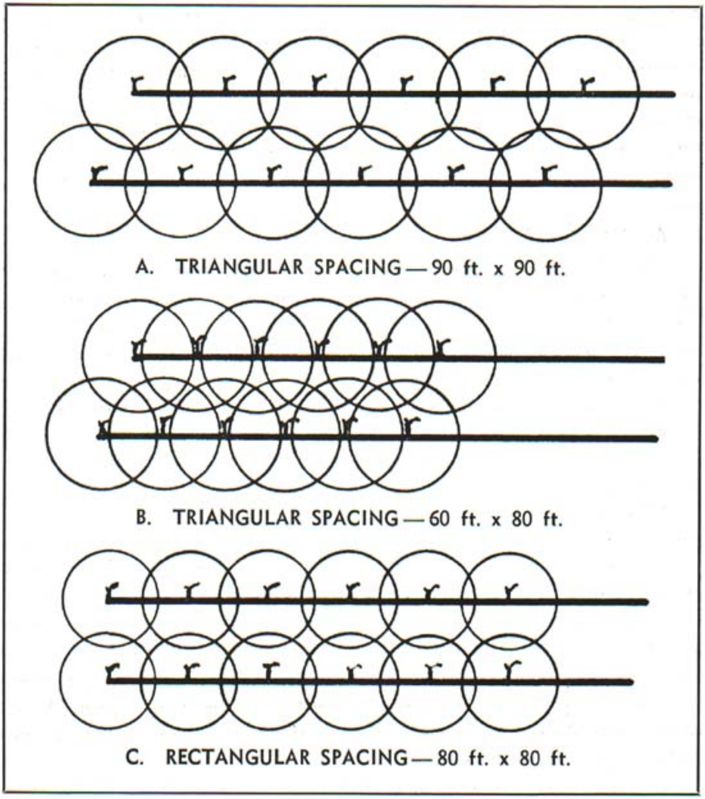

Fig. 2. Effect of sprinkler spacing and arrangement on the application of water for frost protection. Sprinklers in Arrangements A and B represent a 110-foot diameter of coverage. Those in Arrangement C represent a 95-foot diameter of coverage.

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

For frost protection, the wetted area from one sprinkler should overlap, for a few feet, the wetted area from the next sprinkler. To distribute the water satisfactorily to this larger area, space the sprinklers 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, fairly good coverage, and maximum possible area covered. An 80 ft. x 80 ft. spacing would give better coverage. Arrangement "B" provides 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 complete 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.

The arrangements shown in Fig. 2 are not meant to be general recommendations for frost protection, but only to show the effect of spacing and arrangement of sprinklers on the efficiency of this method. Specific sprinkler spacing and nozzle sizes can be recommended by the irrigation equipment dealer. Additional lateral lines and sprinklers may be needed to "blanket" an entire field.

The reader is also cautioned that the spacings shown in Fig. 2 are to be used only for frost protection. Regular summertime 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 oil cans—with the tops cut out—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 protection 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 waterlogging 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 for a minimum temperature of 20°F.

Most of the rotary irrigation sprinklers used in Michigan, espe-

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.

cially those with two or more nozzles, usually apply more water than is needed for frost protection. Some growers plug one nozzle and use only the nozzle with the "kicker arm"; by use of this procedure, usually about 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. Increasing the pressure at the sprinkler will increase the wetted area and may create finer water droplets, both of which are desirable. Your irrigation equipment dealer can help you select the proper size nozzle and adjust 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 rotational speed of some sprinklers can be increased by increasing the spring tension or by making other adjustments.

A "test run" of the irrigation system before the night that it is needed for frost protection is desirable. 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 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 to 15 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 1 acre requires about 60 gallons per minute. Irrigating 6 acres for frost protection 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 protection, pumping 360 gallons per minute for 12 hours would take out all the water in a rectangular pond 8 feet deep, 45 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 using small turbine pumps on 4- to 6-inch wells operating up to 24 hours per day to refill their excavated ponds. These small pumps might be powered by single-phase electric motors or engines.

The temperature of the water that is applied seems to have little effect on keeping the air around 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. During a test in 1953, the minimum air temperature in the protected area was 25 degrees as compared to 21 degrees in an adjoining unprotected area.

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

Usually only one person is needed for a night's frost protection 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 protection. 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 protection, 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 therefore has the advantage of being valuable for both frost and drouth protection.

How Do I Operate My Equipment for Frost Protection?

First, set up the equipment in the field, preferably several days before it is needed for frost control, and give it a thorough "test run" before it is needed for frost protection. Check the amount of water applied by measuring the water depth in cans between the sprinklers.

Second, place 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° to 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, don't expect ice to 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 only when the ice has melted and the air temperature is above 32°F. Some wait only until the air temperature is 32°F. to shut off; but to be safe, wait until the ice is gone. 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, don't expect 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.

SIXTH, listen to the *latest* radio or TV local weather forecasts or call the local weather bureau for minimum temperature forecasts.

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

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

Cooperative extension work in agriculture and home economics. Michigan State University and the U.S. Department of Agriculture, cooperating. Paul A. Miller, Director, Cooperative Extension Service, Michigan State University, East Lansing. Printed and distributed under Acts of Congress, May 8 and June 30, 1914.

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