Does Washing Frost from Plants Reduce Cold Damage?

A POSTAL SYMPOSIUM

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In March of 1975, the News & Views newsletter of the American Horticultural Society offered the following anonymous tip under the heading of *Cold Shower Treatment:* "Here is a trick that will reduce the amount of damage caused by morning sunlight on frozen buds. Where plants have been lightly touched with frost, take a hand syringe and spray the vulnerable buds with water before sunlight strikes them." **The following spate of correspondence formed the basis of this "postal symposium."**

Letter of April 30, 1975 from Jules Janick, Editor of HortScience, *to John F. Gerber, University of Florida:*

Enclosed is a news clip from AHS. This bit of advice (to protect plants from the supposedly detrimental rays of the sun) has bothered me for years. Is there any truth to this? I suppose melting ice might withdraw heat from tissue and cause injury – but I don't see why applying water only before the sun comes up will help.

For my first recollection of this type of advice I enclose Chapter XV of Laura Ingalls Wilder's *Farmer Boy*.

I would appreciate a brief article or paragraph on this bit of homespun advice for *HortScience*.

Letter of May 14, 1975 from John F. Gerber to Jules Janick:

I am in the process of putting together a brief article on washing frost from plants. Unfortunately, I don't have any definitive answers because to the best of my knowledge no one has ever done this under carefully controlled conditions. We attempted once but this resulted in a miserable failure. Unfortunately, negative results don't often impress true believers. After you read what I send in a week or ten days, you can decide if it's worthwhile.

Letter of September 8, 1976 (!) from John F. Gerber to HortScience:

Does washing the frost from plants reduce cold damage? Jules Janick asked this question in a letter over a year ago. My first reaction was, of course not! I have examined the question from the physics of freezing. Washing the frost from the plant warms it so it doesn't stay cold as long – a possible advantage. Could the sun's rays melting the frost lower the temperatures? It appears doubtful – however, consider this: Dew point temperatures usually fall as the sun rises because mixing of the lower atmosphere begins. The sublimation of the frost could lower the temperature and in effect refrigerate the plant! How much would it lower it? Maybe a degree at most. This doesn't seem significant but it is colder. My colleagues tell me shading the plant from the sun's rays may protect it. This looks like a physiological phenomenon.

Why should melting the ice with water make a difference? Will those who may know more about this come forward and help us get to the bottom of this?

[The preceding correspondence and the *Farmer Boy* Chapter were subsequently sent to Drs. C. J. Weiser, Oregon State University; J. David Martsolf, Pennsylvania State University; Milon F. George, Virginia Polytechnic Institute and State University; and Michael J. Burke, Colorado State University.]

Response (Oct. 4, 1976) of C. J. Weiser:

It is tempting, and probably accurate, to suggest that washing frost from plant leaves likely has little effect on their subsequent survival. (Refer Gerber letter.) It would be more precise to say that the effects, if any, would be difficult to predict.

Each frost is a unique event. The fickle nature of ice nucleation into cells of supercooled plants, the influence of tissue hydration on the extent and nature of tissue freezing, the divergent genotypic differences in lethal temperatures and response to duration and rates of freezing and thawing, the physiological status of the plant, and the subsequent environmental conditions could affect the outcome.

Based on our scanty knowledge we know that subtle differences in the plant or environment at critical times can affect frost survival. One can visualize situations where water application could induce such differences, and markedly decrease or increase frost damage.

Washing could reduce injury if frosted plants were supercooled but not frozen, if applied water didn't induce damage from rapid thawing, if tissue hydration wasn't increased by the application of water, and if the temperature didn't continue to drop to lethal levels after washing. Research on the interactive biological and physical factors involved would be challenging, but not particularly informative, I expect.

In the same vein – Indian farmers reportedly built smudge fires before dawn in the Andean altiplano after a severe frost to shield frozen potato plants from the direct rays of the sun. What do you think?

Response (Oct. 8, 1976) of J. David Martsolf:

It seems that you are asking me to defend either a yes or no answer to the question, "Does washing the frost from plants reduce cold damage?" Although I am unaware of scientific literature that addresses this question directly, it would seem more appropriate to defend a "yes" answer than to yield to the typical initial reaction that the antidote is an old wives tale.

Two characteristics of frost damage to plant tissue may support an answer

FARMER BOY[1]

Laura Ingalls Wilder[2]
From Chapt. XV: *Cold Snap*

First he helped hoe the cornfield

The air was still and cold that night, and the stars had a wintry look. After supper Father went to the barns again. He shut the doors and the little wooden windows of the horses' stalls, and he put the ewes with lambs into the fold.

When he came in, Mother asked if it was any warmer. Father shook his head.

"I do believe it is going to freeze," he said.

"Pshaw! surely not!" Mother replied. But she looked worried.

Sometimes in the night Almanzo felt cold, but he was too sleepy to do anything about it. Then he heard Mother calling:

"Royal! Almanzo!" He was too sleepy to open his eyes.

"Boys, get up! Hurry!" Mother called. "The corn's frozen!"

He tumbled out of bed and pulled on his trousers. He couldn't keep his eyes open, his hands were clumsy, and big yawns almost dislocated his jaw. He staggered downstairs behind Royal.

Mother and Eliza Jane and Alice were putting on their hoods and shawls. The kitchen was cold; the fire had not been lighted. Outdoors everything looked strange. The grass was white with frost, and a cold green streak was in the eastern sky, but the air was dark.

Father hitched Bess and Beauty to the wagon. Royal pumped the watering-trough full. Almanzo helped Mother and the girls bring tubs and pails, and Father set barrels in the wagon. They filled the tubs and barrels full of water, and then they walked behind the wagon to the cornfield.

All the corn was frozen. The little leaves were stiff, and broke if you touched them. Only cold water would save the life of the corn. Every hill must be watered before the sunshine touched it, or the little plants would die. There would be no corn-crop that year.

The wagon stopped at the edge of the field. Father and Mother and Royal and Eliza Jane and Alice and Almanzo filled their pails with water, and they all went to work, as fast as they could.

Almanzo tried to hurry, but the pail was heavy and his legs were short. His wet fingers were cold, the water slopped against his legs, and he was terribly sleepy. He stumbled along the rows, and at every hill of corn he poured a little water over the frozen leaves.

The field seemed enormous. There were thousands and thousands of hills of corn. Almanzo began to be hungry. But he couldn't stop to complain. He must hurry, hurry, hurry, to save the corn.

The green in the east turned pink. Every moment the light brightened. At first the dark had been like a mist over the endless field, now Almanzo could see to the end of the long rows. He tried to work faster.

In an instant the earth turned from black to gray. The sun was coming to kill the corn.

Almanzo ran to fill his pail; he ran back. He ran down the rows, splashing water on the hills of corn. His shoulders ached and his arm ached and there was a pain in his side. The soft earth hung on to his feet. He was terribly hungry. But every splash of water saved a hill of corn.

In the gray light the corn had faint shadows now. All at once pale sunshine came over the field.

"Keep on!" Father shouted. So they all kept on; they didn't stop.

But in a little while Father gave up. "No use!" he called.

Nothing would save the corn after the sunshine touched it.

Almanzo set down his pail and straightened up against the ache in his back. He stood and looked at the cornfield. All the others stood and looked, too, and did not say anything. They had watered almost three acres. A quarter of an acre had not been watered. It was lost.

Almanzo trudged back to the wagon and climbed in. Father said:

"Let's be thankful we saved most of it."

They rode sleepily down to the barns. Almanzo was not quite awake yet, and he was tired and cold and hungry. His hands were clumsy, doing the chores. But most of the corn was saved.

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[1]1933. Harper & Brothers, New York.

[2]Laura Ingalls Wilder (1867-1957) is best known for her "Little House" series of children's books. *Farmer Boy* chronicles the boyhood of her husband in upper New York State. The particular morning in question is July 4, probably 1868.

to the question. One is that a relatively distinct line can be drawn between temperatures that the tissue will tolerate and slightly lower temperatures that cause substantial damage. The second characteristic is that a passage of time at or below the critical temperature is necessary to the development of the irreversible damage. While it is possible for the second characteristic to confound the first, the uniformity of exposure to the environment that is generally achieved through horticultural practices, reduces such confounding.

Many have witnessed the relatively sharp line of demarcation between areas of damaged blossoms in frost pockets and areas of viable blossoms only slightly up slope. It is not unusual to have noted that the blossoms on the lower parts of trees are damaged while those only a few feet above tolerated temperatures that must have been within a degree of those leading to the damage. The atmosphere cannot be expected to permit the existence of a time-average gradient of more than a single degree over such a small distance as a meter or so in elevation (especially when the vertical elements of the tree tend to sweep out such temperature gradients as fast as they tend to develop). There are examples in crops other than orchards of such sharp demarcation between damage and no damage that would add credence to the premise that the difference between damage and no damage is very small in terms of temperature and, therefore, may be quite sharp in terms of space and time – but I will not take up further space to describe these.

The critical point is that only a very small difference in temperature is necessary to result in a spectacular difference in damage. This makes it practically impossible to declare almost any method of frost protection completely ineffective since often a mere

touch of microclimate modification may have made the difference between success and failure.

Now permit me to focus on the case of splashing water on the young corn plants as described by Laura Wilder (1933). It would appear that the practice was begun well before dawn when the approaching sunlight was but "a cold green streak" in the eastern sky and the "air was dark." Although the corn was covered with frost and the "little leaves were stiff, and broke if you touched them," they were apparently not below the critical temperature long enough to have irreversible damage. Pouring the liquid water on the young corn plants would have to add energy to the system since the poured water was liquid and its temperature must have been above freezing. Water has a relatively high heat capacity, i.e., for each degree decrease in temperature one calorie must be removed from a gram of water, and if the water is to fuse to ice 80 additional calories must be transferred from each gram of water. The washing of the frost from the corn leaves must have increased the temperature of the corn leaves to at least 0°C and possibly somewhat above that temperature for if the liquid water cooled to the freezing point and heat continued to be lost to the environment it would eventually freeze to ice on the corn leaves. Since this is not mentioned by the author who observed other aspects of the phenomenon in wondrous detail, I am of the opinion that the increase in the corn temperature may have been sufficient to carry it through the remainder of the night without damage while much of the untreated corn was below its critical temperature for a period of time sufficient to be damaged by the cold. Perhaps the energy added from the liquid water was sufficient to protect the "splashed" corn leaves from damage. But an interesting aspect remains outstanding.

Why were the participants in the story so concerned about getting the plants sprinkled before the sun arose? The author states that "Nothing would have saved the corn after the sunshine touched it." She further indicates that "A quarter of an acre had not been watered. It was lost." The sun adds energy to the system whereas damage is caused by removing energy from the system. It is difficult to develop a procedure through which an energy adding transfer results in net loss of energy to the system. However, it may be that the presence of the frost interrupts the absorption of the sun's energy enough when it first comes up to prolong the period that the frosted leaves are below their critical temperature to make a difference in the amount of damage sustained. Frost is much more reflective to sunlight than is liquid water and we may imagine that the washed leaves would absorb sunlight at a faster rate than the frosted leaves and consequently move out of the critical temperature realm at a faster rate than the leaves still covered with frost.

It now seems quite possible to me that farmers may have washed the frost from plants in an attempt to avoid frost injury that they associated with the presence of frost and observed that it worked to the extent that they completed the task before the sun's rays struck the plants. It is not beyond possibility that the sun's role was misunderstood in the process since its presence at the time the problem culminated was the most prominent feature in the environment, i.e., anyone who recalls the spectacular appearance of the sun on a frosty morning will find it difficult to ignore its part in the microclimatology of the situation. It may not be unlike the part that farmers felt the full moon played in frosts since its presence during a clear radiation frost night is so memorable.

Response (Oct. 11, 1976) of Milon F. George:

I am replying to the question received in a letter from John Gerber, "does washing the frost from plants reduce cold damage?" Although experimental evidence is lacking, some physiological justification for the practice can be made.

Levitt notes in his treatise *Responses of Plants to Environmental Stresses* that tender plants are generally injured at or near the advent of tissue freezing. Frost on leaf surfaces can act as an inoculating agent for tissue freezing (extracellular) and therefore promote injury. In the absence of a frozen soil, washing the frost away would prevent inoculation. Also, under conditions of a mild night frost or radiation frost, pouring water over the frost covered plant will likely elevate tissue temperature to at least 0°C. If tissue temperature is raised to 0°C, heats of fusion and melting of the ice-water mixture would hold the tissue at 0°C for a short time. If the temperature was raised above 0°C, heat capacity of water on leaf surfaces could possibly buffer the tissue against the surrounding sub-freezing air until daybreak.

Injury from the warming rays of early morning sunlight striking the frozen leaves, as related in the *Farmer Boy,* seems less likely. Thawing of stiff frozen tissues may produce a wilted appearance which suggests injury where little has actually occurred. It is true that under certain conditions rapid thawing can produce injury and possibly pouring cold water (near 0°C) over frozen plants produces a slower thawing than results under direct sunlight. If there has been partial injury from freezing, shading the plant from direct sunlight may be beneficial during the recovery process to limit high tissue temperature.

Since I cannot give a definitive yes or no as to the value of washing frost from plants, I might say that the intuition of the Farmer Boy *may be more reliable than the collective knowledge and speculation of the physiologist (at least this physiologist).*

Response (Dec. 9, 1976) of Michael J. Burke:

John Gerber's explanation of the *Farmer Boy* frost phenomenon is better than anything I could propose. I can't think of a physiological phenomenon that will explain this so well. My first reaction was "by God he's got it!" My last reaction was like Dr. Gerber's first, "of course not!"

Follow the story with me, "All the corn was frozen. The little leaves were stiff, and broke if you touched them. . . Every hill must be watered before the sunshine touched it, or the little plants would die . . . . The sun was coming to kill the corn. . . . But every splash of water saved a hill of corn . . . . 'keep on!' Father shouted . . . Nothing would save the (frozen) corn after the sunshine touched it. . . . They had watered almost three acres. (and presumably saved them). A quarter of an acre had not been watered. It was lost." Well Bah Humbug!

Can you imagine such an occurrence in one of your field experiments? Where would this leave the Duncan multiple range test? Two treatments differing by 1° temperature and leaf wetness and all the plants in one treatment survive and in the other they die before your eyes. My friends who do field experiments never get such clear cut results with such little treatment differences. More usually they are asking me which plants are dead. I believe John Gerber. I don't believe Laura Ingalls Wilder or Almanzo; it's a snow job!