MANAGEMENT OF POTATO STORAGES

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The necessity of maintaining high quality, sprout-free potatoes over an extended storage period for the fresh market and the processing industry, has resulted in an increased emphasis on the proper management of potato storage facilities. A potato storage - properly managed - prevents the development of rot, retards growth of sprouts, reduces dehydration and excessive moisture loss, and reduces the amount of bruising which takes place, either as pressure bruises or black spot when handling potatoes into or out of storage.

In years past, a hole dug in the gound covered with straw and soil, usually kept tubers in a marketable condition until spring. Now, with increased emphasis on maintaining high quality and appearance over a longer storage season, improved temperature and humidity control are necessary. Well designed storages with automatic temperature control systems, and automatic air ventilation systems are becoming a necessity, and are replacing older types of storages.

Successful storage begins before the potatoes are actually placed into the storage and much successful storage is dependent upon the harvesting and handling methods and the care used during these operations. Therefore, it can be said that successful storage begins by preventing or eliminating bruised and injured tubers, and an especially important factor is that potatoes should go into storage with the least possible injury. Unbruised tubers will store well with little loss, whereas, injured tubers require special care. In a storage period of 8 months, the moisture loss from sound tubers may be as low as 4 percent. Serious bruises may often result in rot and storage losses of 50 percent or more. In several tests conducted at the University of Idaho Aberdeen Branch Experiment Station, sound tubers did not rot even under unfavorable conditions, but tubers that were badly injured, rotted under the best possible storage conditions. Rot-causing fungi and bacteria can enter bruised and injured tubers easily, but seldom enter through the unbroken skin of uninjured tubers. The more injuries present, the more need for special care to prevent loss during storage.

With the advent of the digger-picker and bulker combines, bruising caused by the human element has become less and the machine element has become all important; therefore, before harvesting and storing tubers, all equipment should be examined and all points where injury might occur should be eliminated or padded. Precautions that all machine operators should follow during the harvesting operation include: (1) rubberize all

chains, (2) reduce the speed of transfer, elevator and piler chains to 70 feet per minute, (3) never drop tubers more than 6 inches, (4) pad the sacking platform, truck bed, and piler hopper, (5) DO NOT THROW tubers into piler hopper -- pour steadily, (6) use small boards in the bottom of bulk trucks, so only a few potatoes can be released at a time, (7) do not walk on piled tubers, and (8) if possible allow the potato temperature to increase to 45°F. before removing from storage.

Whether the potatoes are put into the storage through the ceiling, or whether they are unloaded into a piler on the floor and elevated to the top of the pile makes little difference provided equal care and caution are taken to eliminate injuries and bruises.

A well-supervised harvest and handling program can make more money for a farmer during storage than a complete complement of ventilating equipment. All the storage equipment obtainable cannot make sound tubers from bruised and injured ones. Uninjured tubers store well with little loss. Injured tubers require special care and loss is usually high.

STORAGE MANAGEMENT

Proper management of a potato storage includes control of temperature, humidity, and air circulation, so that stored tubers retain maximum appearance and food value with a minimum loss from rot, shrinkage, and sprouting.

Storage management can be divided into three definite periods: (1) the wound-healing and curing period, (2) the storage or holding period, and (3) the removal or grading and sacking period. Each period has a particular function and should be carefully managed.

The Wound Healing and Curing Period

The wound healing and curing period is that period immediately following harvest. During this period the bruises and other wounds caused during the harvesting operation heal over, i.e., a wound periderm or suberized layer forms - preventing entrance of rot organisms and reducing the danger of rot. Two conditions are usually considered necessary for rapid healing of wounds: (1) A temperature of 45°F. or higher, and (2) a high relative humidity in the air surrounding the tuber. The Russet Burbank variety in Idaho heals about as readily at 45° to 50°F. as it does at warmer temperatures, providing the relative humidity of the storage cellar is 90% or higher. If the relative humidity of the storage is low during this wound healing period, a starch layer may form over a bruise and prevent healing. Maintaining sufficient humidity in the air during the wound healing period is one of the most important steps in the proper management of a potato storage cellar.

During the harvesting period, the doors of the storage cellar are usually left open to allow trucks to go in and out, and the temperature inside the cellar raises to 50° or even 60°F. Therefore, to provide good conditions for rapid tuber healing, proper relative humidity must be maintained inside the storage cellar. First, thoroughly wet down (soak) the cellar during the late summer months so that at the time of storage, the floor of the storage is moist but not muddy. Different methods of maintaining a high humidity are:

1. wetting down the alleyway or vestibule
2. keeping wet burlap sacks in or by an air stream
3. blowing air across a free water surface
4. spraying a fine mist of water into an air stream

If water rot or field frost is present, a great deal of harm can be done by keeping the temperature higher than 50°F. immediately after harvest. A much safer practice is to reduce the temperature of the storage cellar as rapidly as possible to 40°F. Healing is slower at 40°F. but will take place if the humidity is kept high (above 90% r.h.). Practically no water rot infection occurs at 40°F.

The rate of weight loss during the wound healing and curing period is greater than at any other period (Figure 1). This is the time when the respiration rate is high and the amount of water lost through injuries is also high. Careful handling of tubers and proper management of equipment and the storage cellar during harvest and filling the storage will reduce weight loss during the entire storage period.

The Holding or Storage Period

The second phase of storage management is the holding or storage period. In general the higher the storage temperature above 40°F., the shorter the storage period will be without sprouting and excessive shrinkage. Tubers can be kept for only 12 to 15 weeks at a temperature of 50°F. before they begin to sprout, but they can be kept 40 weeks or more without sprouting at 40°F. even if no chemical sprout inhibitor is used. Thus, if potatoes are to be stored until late May, June, or July without excessive dehydration or sprouting, they must be kept at or slightly below 40°F., and the relative humidity must be maintained at 90% or above. If chemical sprout inhibitors are used, the temperature may be slightly higher. (Sprout inhibitors will be discussed more fully in another section).

The lower the temperature below 40°F. the greater is the conversion of starch to sugar. Sprouting increases as temperature increases above 40°F. Therefore, for long-term storage, the best compromise is to store the tubers at 39° to 40°F., with about 90% relative humidity. This temperature is low enough to prevent sprouting and high enough to allow only a minimum conversion of starch to sugar.

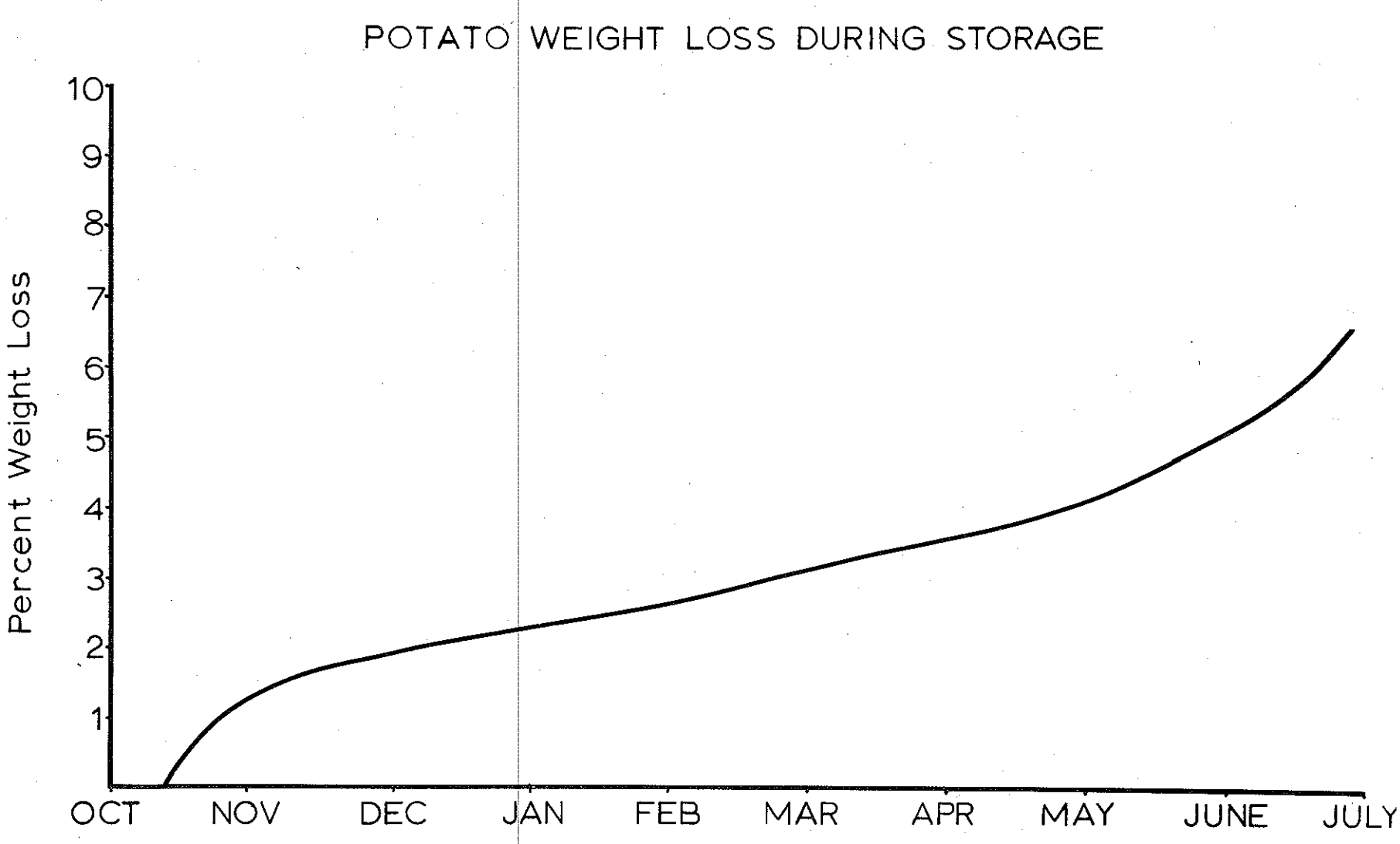

Figure 1. The percent weight lost from potatoes during storage.

The Removal or Grading and Packing Period

Removal of potatoes from the cellar is also a part of the storage operation. Development of new machinery has increased the removal of potatoes from storage by bulk methods.

In most of the larger storages today, tubers are removed by means of a self-propelled mechanical scoop. The scoop is forced into the pile of potatoes, and as the tubers roll down the face of the pile, they are caught on a conveyor belt and carried into the truck.

Some storages are built adjacent to the processing or grading plant, and the tubers are removed by means of water flumes. The water is piped to the back of the bins and flows under the bin of potatoes in the same ducts used for air distribution. Boards cover the air-water duct and are removed to allow the tubers to roll down into the water for transporting to the grader or processing plant.

In a few storages the air tunnels are made large enough to allow insertion of a small conveyor belt. These air tunnels are covered with small removable slats or sections. When the tubers are to be removed from the storage, the conveyor is inserted into the air tunnel, a slat is removed, and the tubers drop the 2 or 3 inches from the floor onto the conveyor belt. The tubers then move by conveyor belts into the truck.

Care must be exercised in removing tubers from storage regardless of the method used.

Cold brittle potatoes are easily injured. Research at the University of Idaho Aberdeen Branch Station found that over 2 percent cullage could be prevented by warming the tubers from 35° to 40° before they were handled. Therefore, warm the tubers to a temperature of 40° to 45°F. or more before removing them from the storage. Closing the air vents to prevent cold air from entering the storage is an easy way to raise the temperature. Heat from the respiring tubers will be enough to raise the temperature several degrees in a few days. In large storages, where potatoes are taken out of storage over a period of several months, a warm-up period may have to be omitted to prevent sprouting of those tubers remaining in the storage cellar. In all cases, careful handling must be practiced to reduce injury.

VENTILATION OF STORAGES

The main reason for ventilating potato storage cellars is to maintain the desired temperature and humidity within the pile of potatoes. Ventilation can be done by manually opening and closing the doors, or by using automatically controlled air circulating systems. The oldest method of ventilation and temperature control is manual operation of the doors.

Constant attention and supervision are required so that doors are open enough to provide cooling, but not enough to allow freezing. Various automatic temperature control units are available that will reduce the number of man hours required to keep storages at the proper temperatures.

Amount of Air

Only enough air needs to be supplied to the tubers to provide the desired uniform temperature throughout the pile. Research carried on by the University of Idaho Aberdeen Branch Experiment Station indicates that 10 cubic feet of air per minute per ton (cfm/T) of potatoes supplied on an intermittent basis will maintain a uniform temperature throughout a pile of potatoes 20 feet deep. This air-flow will keep potatoes in a firm, sprout-free condition without the aid of refrigeration (Figure 2) as long as the tuber temperature can be maintained below 40°F. (in Idaho this is into late May and in other areas would be until the mean minimum temperature raises to 39° to 40°F.).

The air distribution ducts should be placed every 10 feet. Some ducts are permanent and are built into the floor - others are portable above ground sections (Figure 3). This method has proved to be very satisfactory in several large commercial potato storages. Other designs are acceptable providing air movement and temperature are maintained at desirable levels. A temperature sensing unit should be placed directly in the pile of potatoes at the warmest spot, usually from 1 to 1-1/2 feet from the top of the pile (Figure 4). The fan needs to run only when the temperature of the potatoes in the pile is higher than the desired storage temperature. This sensor will also turn the fan off when the potatoes are cooled to a given temperature (usually 38° or 39°F.).

Chemical Sprout Inhibitors

In those areas or regions where the temperature is not low enough to maintain the tubers below a 40°F. mark, it becomes necessary to control sprouting by means of refrigeration or chemical sprout inhibitors. I will not go into detail regarding refrigeration except to point out that the temperature must be kept at 40°F. or below to prevent sprouting. At the present time, there are two inhibitors which have been approved by FDA and tolerances established. There are also two additional sprout inhibitors which have received an extended period for the gathering of additional toxicology data. These inhibitors can be classed into 4 general catagories as to the time and method of application: (1) Spray the potato plant when it is still in a green productive and absorptive condition in the field, as with Maleic Hydrazide (MH-30). (2) Apply a material such as TCNB (trade name, Fusarex) onto the tubers as they are being put into the storage cellar. (3) Blow a dust (TCNB) or volatile

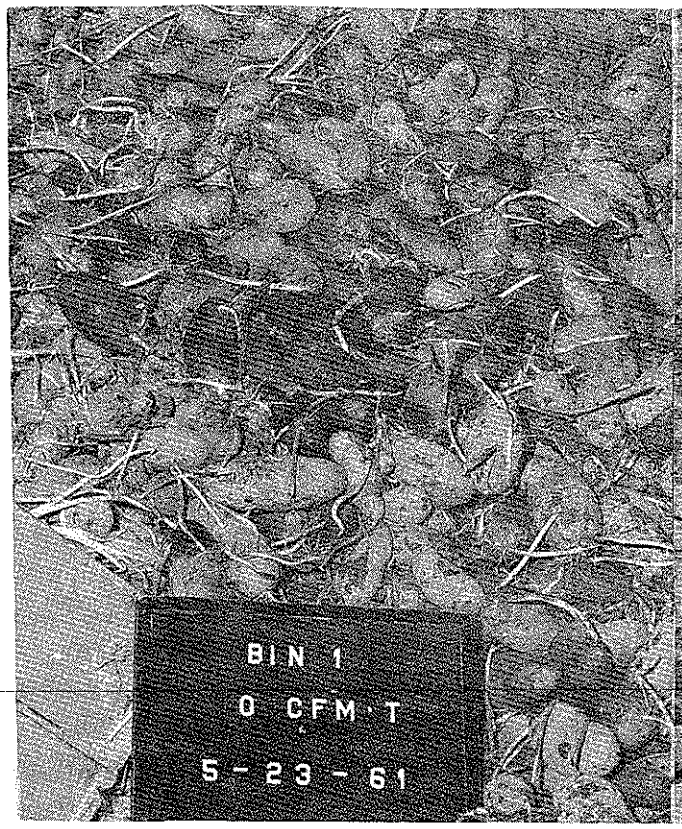

Figure 2. The effect of airflow on the sprouting of tubers. (A) Potatoes receiving no air (0 cfm/T) have many long sprouts.

Figure 2. (B) Potatoes receiving 10 cfm/T have very few sprouts. The fan operation was on an intermittent basis.

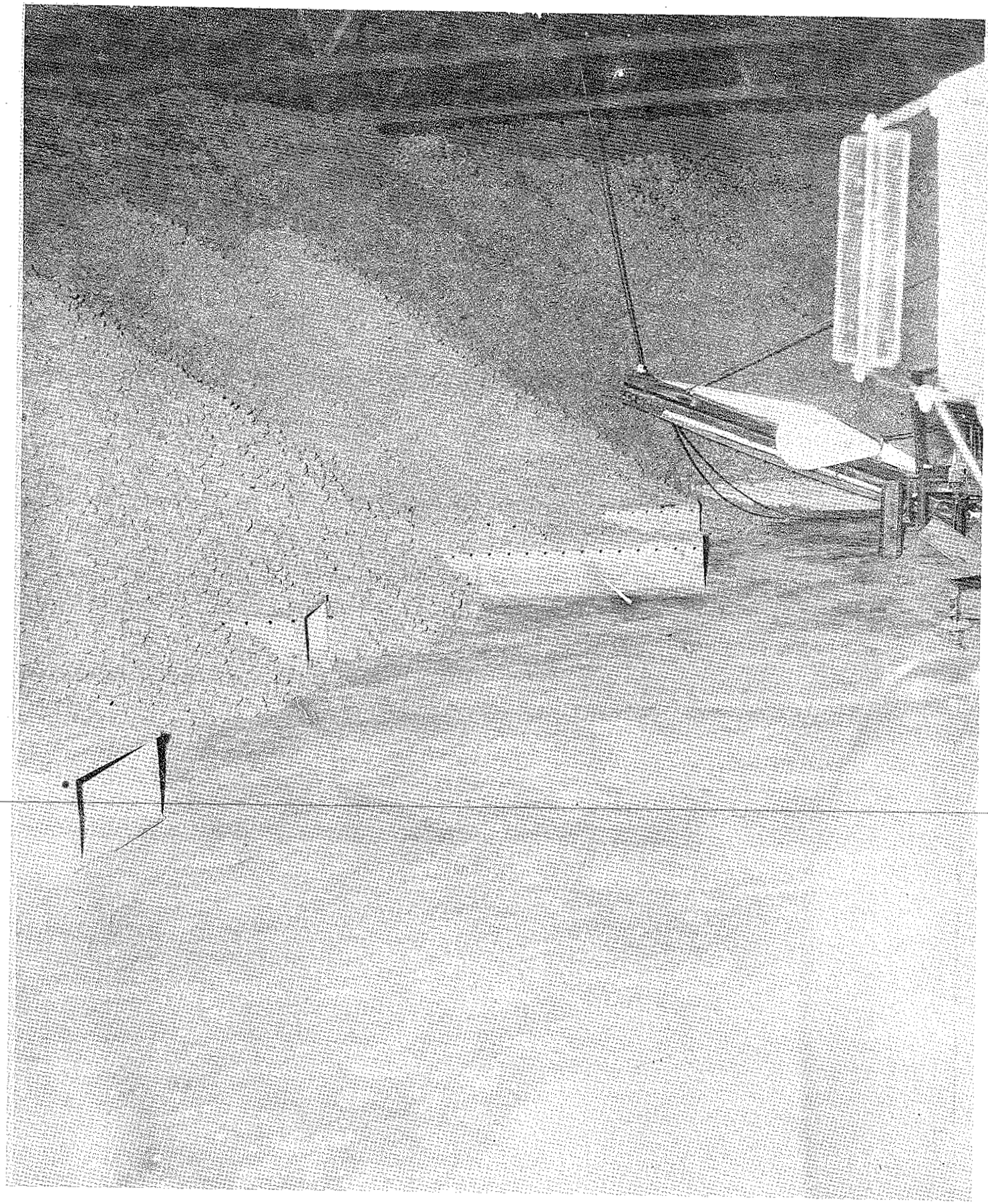

Figure 3. Portable air distribution ducts placed every 10 feet, 1 inch diameter holes every 6 inches, and potatoes piled 20 feet deep.

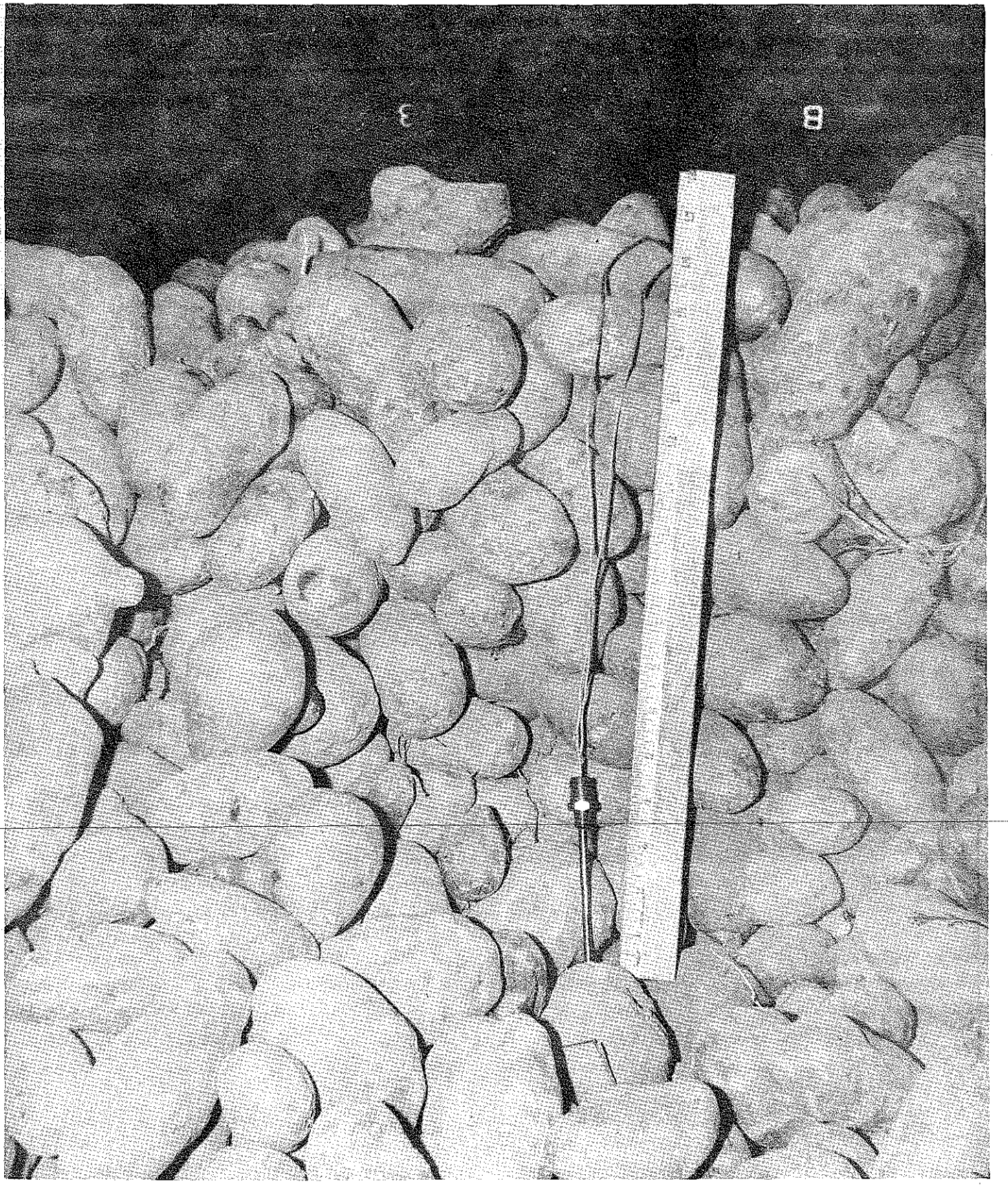

Figure 4. The temperature sensing unit should be placed directly in the pile of tubers, usually 1 to 1-1/2 feet from the top of the pile.

material such as CIPC (trade name, Sprout Nip) through the potatoes while they are in the storage pile. (4) Spray, dip, or wax the tubers with an inhibitor such as CIPC or MENA (trade name, PotatoFix) as they are being handled and moved from the storage cellar into the fresh market channels.

For any given circumstance at least one of the various sprout inhibitors can be found which will do an effective job controlling sprouts. It should be kept in mind that chemical sprout inhibitors cannot take the place of proper storage management and should only be used as a supplement to good storage practices.

The secret to the most successful use of the material which can be sprayed on the foliage of green, actively producing and absorptive plants (with few or no yellow leaves) is to apply the material at the proper stage of growth. In general, the best time to apply MH-30 is from 2 to 3 weeks after full bloom. If the material is applied at full bloom or earlier, yield reductions may result. When the material is applied after the leaves have turned light green and yellow, insufficient material is absorbed and translocated from the leaves to the tubers and poor sprout control results may be obtained. The accompanying graph and photo (Figures 5 and 6) show the effect in Idaho of applying MH-30 at various dates and at various rates on percentage of tubers showing sprouts at the end of 11 months storage. The percentage of tubers sprouting after 11 months storage was less than 2% for treatments applied on or before August 26 (four weeks after full bloom). When MH-30 was applied on September 2, the leaves of the plants were beginning to turn color and become yellowish, and 4 times as many tubers showed sprouts as when sprayed on August 26. Probably only a portion of the material applied to the plants on September 2 was absorbed and translocated.

Proper timing of application has reduced the dosage required to give sprout control. Excellent sprout control has been obtained in Idaho with quantities as low as 2 quarts of MH-30 per acre, when applied by ground rig, and 3 quarts per acre when applied by airplane when applied 2 or 3 weeks after full bloom (approximately August 10 to August 25). No yield reductions have been experienced under Idaho conditions when MH-30 has been applied 2 weeks or later after full bloom.

The chief disadvantage of spraying the foliage of the green growing plant with Maleic Hydrazide (MH-30) is that in many cases the farmer does not know the yield or quality of that particular field of potatoes, nor does he know how long he will store his potatoes. If he sprays his field with MH-30 and then sells his crop early in the storage season (January or February) he will have spent money for a treatment that he is not fully utilizing. But for processors or farmers who are under a delivery date contract, this is not a disadvantage.

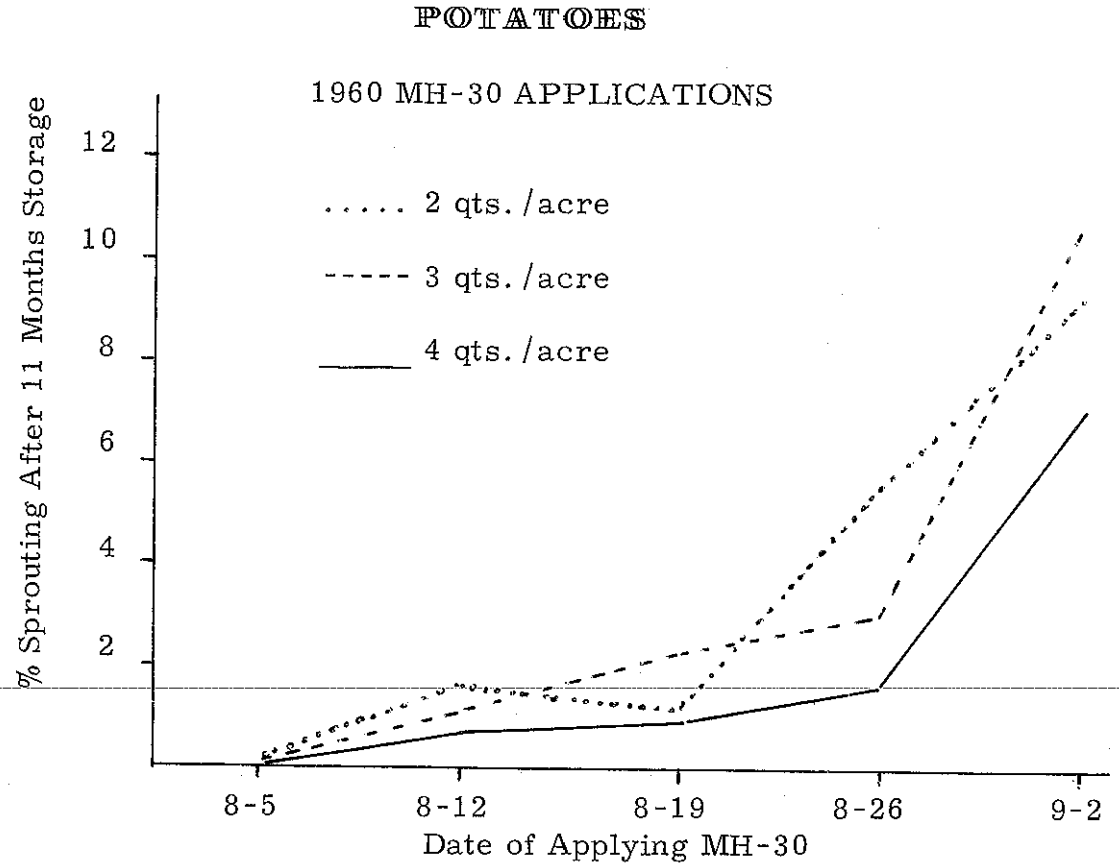

Figure 5. The effect of date and rate of MH-30 application on the percent sprouting of potato tubers after 11 months storage at 40° to 65°F.

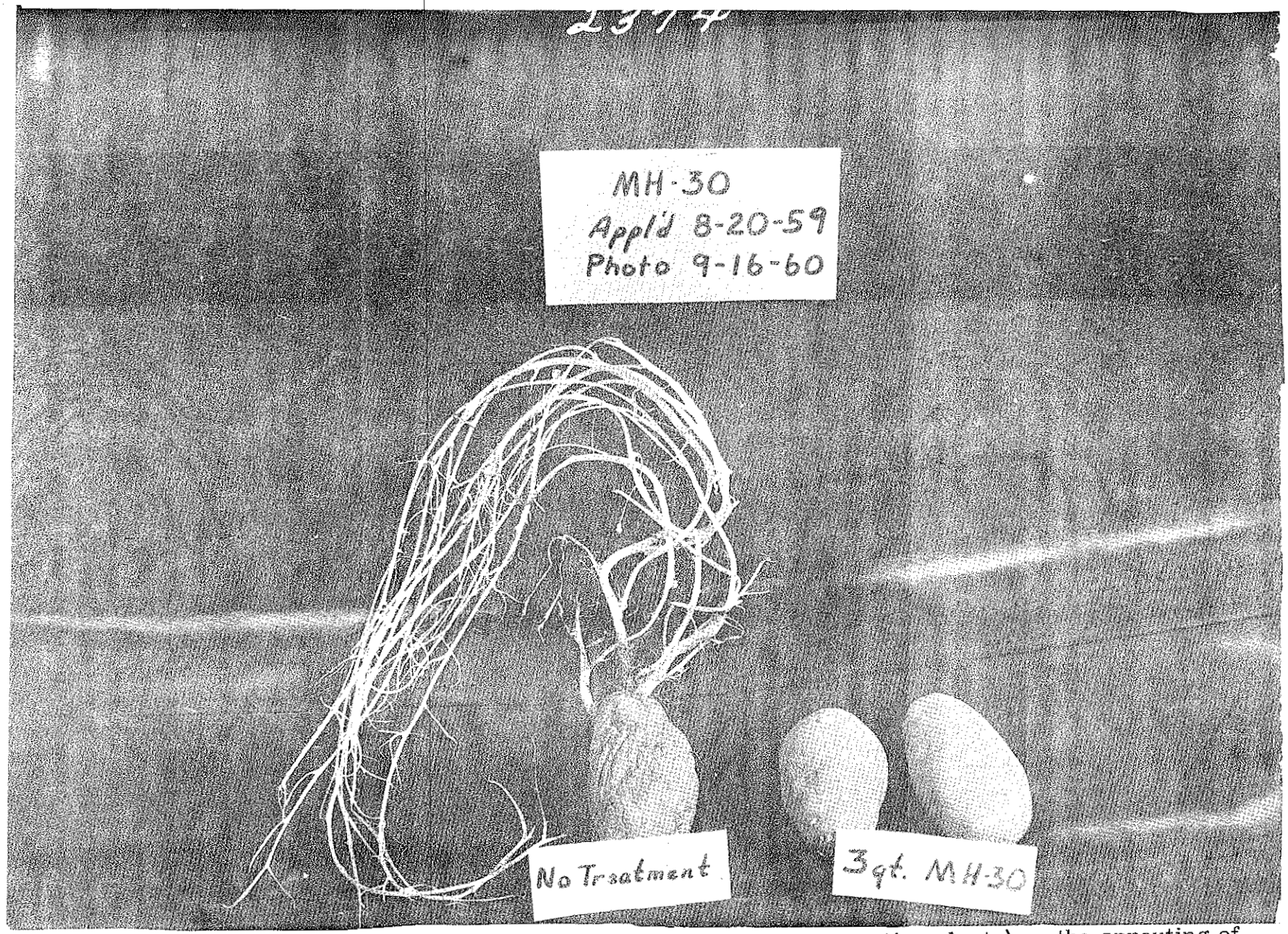

Figure 6. The effect of applying MH-30 (sprayed on the green, receptive plants) on the sprouting of potato tubers.

One advantage of MH-30 is that the tubers from plants which have been sprayed at the proper time, can be stored in almost any type of storage - even those without air distribution systems - without fear of the tubers sprouting, either during the storage season or on the grocers' shelves (Figure 7). MH-30 has been approved for use as a sprout inhibitor on potatoes with a tolerance of 50 ppm on or in the tuber.

The main prerequisite for materials which can be applied to the tuber as a dust or a spray as they are put into the storage cellar, is that they must not inhibit the formation of a wound periderm or prevent suberization and healing to take place. The materials applied at this time can be quite easily applied by attaching a duster or spray machine to the end of the piler when putting the potatoes into the storage bin. As the tubers are elevated into the piler the TCNB material is dusted onto the tubers, with any excess falling onto the pile of stored potatoes.

One disadvantage of this method is that TCNB is a fairly weak inhibitor and will not give prolonged inhibition of sprouts when the temperature rises and the tubers are stored into the late spring and summer months. Since this material is slowly volatilized and affects inhibition by building up a concentration of the gas in the storage pile, it can readily be seen that no more air than absolutely necessary for temperature control should be forced through the pile. With little air movement, TCNB did a fairly good job of sprout control into June, but with warmer temperatures (45^{o} - 50^{o}F.) and a 10 cfm/T airflow rate, the material was blown out of the storage pile, allowing the tubers to sprout (Figure 7). An advantage of this method is that the yield and quality of the harvested crop is already known and the potatoes need not be moved in order to apply the material. TCNB is not a strong inhibitor and for best results, should be used in combination with temperatures below 50^{o}F. It has been applied both as a dust through the air-distribution system and as a dust at the time of putting the tubers into the storage cellar. The fact that it is not a strong inhibitor may be an advantage in some respects as well as a disadvantage in others. Because it is a weak inhibitor and rapidly volatilizes and dissipates in warm atmospheres, it has been successfully used as a sprout retardant or suppressant on seed potatoes. Seed potatoes can be dusted with the material to delay sprouting, and the tubers can still be used for seed because the material is rapidly dissipated in the warm, moist soil air. None of the other inhibitors should be used on potatoes destined for seed. The use period for TCNB has been extended into 1964.

The main prerequisite for materials which can be applied through the air stream while the potatoes are in the storage pile is that each storage cellar to be treated must contain an excellent air distribution system. The material must reach all of the tubers in the pile. In many areas of the country (especially the west) many storages have been constructed without adequate air distribution systems, and in these storages this method of application cannot be satisfactorily used. Where the air

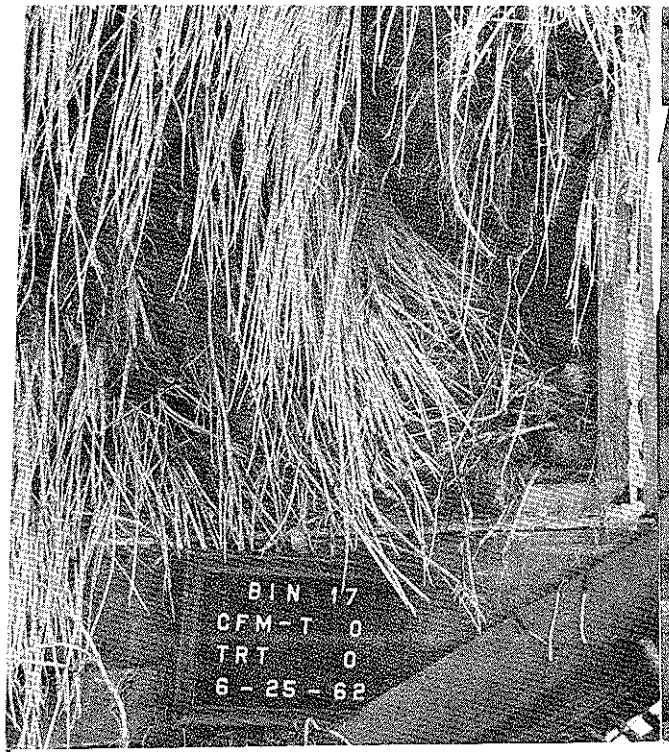

Figure 7. The effect of treating potato tubers with various chemicals on the amount of sprouts on June 25, 26, and 27, 1962. (A) No chemical sprout inhibitor

Figure 7. (B) Tubers from plants treated with 3 quarts per acre of MH-30 on August 20, 1961 (approximately 3 weeks after full bloom)

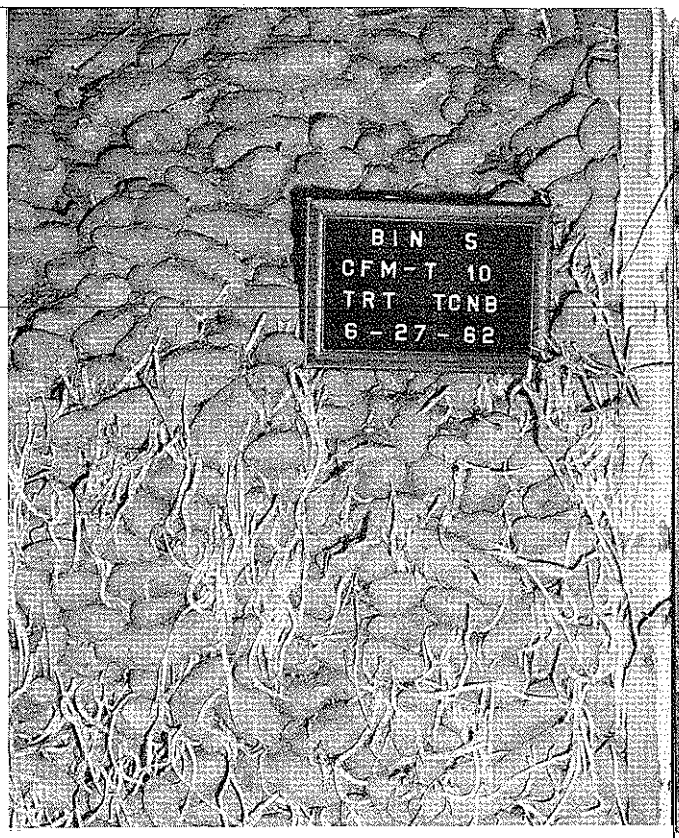

Figure 7 (C) Tubers treated with TCNB (Fusarex) as potatoes were put into storage, and receiving 10 cfm/T airflow during storage.

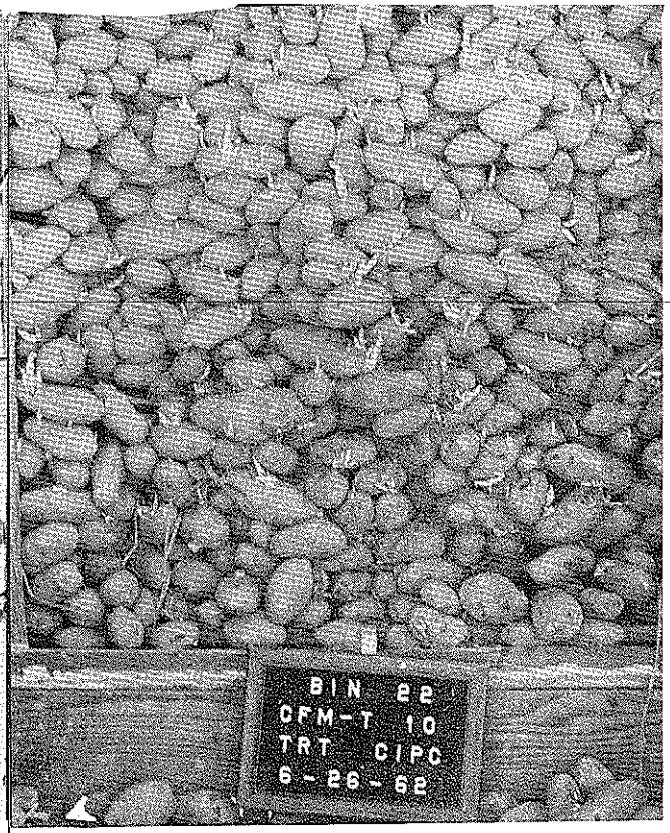

Figure 7. (D) Tubers treated with CIPC (Chloro IPC) through the air ventilation system with an airflow of 10 cfm/T.

distribution systems are adequate, fairly good results have been obtained by using CIPC (Sprout Nip) (Figure 7). In fact, C IPC is probably the strongest chemical inhibitor available at the present time. It not only controls sprouting, but it affects wound periderm formation as well. Consequently, this is a disadvantage in that it should not be applied before harvest bruises and cuts have completely healed. The main drawback with this material is that sometimes, because of dirt, vines, trash, or poor air circulation, inadequate distribution is obtained throughout the pile of potatoes and poor results are obtained. The approved tolerance for CIPC is 50 ppm in or on the tubers.

The practice of spraying, dipping or waxing the tubers with an inhibitor as they are moved from the storage is effective so far as the fresh market channels are concerned, but does not extend the period that the tubers can be maintained in a sprout-free condition in the storage structure, therefore, will not be taken up in detail at this time.

In summary, it might be well to point out a few pertinent points for the proper storage of potatoes. It must be remembered that a well supervised harvest and handling program can make more money for a farmer than a complete complement of ventilating equipment. All the storage equipment obtainable cannot make sound tubers from bruised and injured ones. Uninjured tubers store well with little loss. Injured tubers require special care and loss is usually high.

Maintaining sufficient humidity in the air during the wound healing period is probably one of the most important steps in the proper management of a potato storage structure. Only enough air needs to be supplied to the tubers to provide the desired uniform temperature throughout the pile. Research carried on by the University of Idaho Aberdeen Branch Experiment Station indicates that 10 cubic feet of air per minute per ton of potatoes supplied on an intermittent basis will maintain a uniform temperature throughout a pile of potatoes 20 feet deep. For best results, air distribution ducts should be spaced not farther than 10 feet apart.

In those areas where outside temperatures are not low enough to maintain a tuber temperature of 40°F. and refrigeration is not used, sprout inhibitors must be employed. The particular inhibitor to be used depends upon the final destination of the potatoes, the type of cellar, whether or not the air distribution ducts are present and whether or not the potatoes will be shipped to the terminal market.

Further information regarding Idaho Potato Storages can be obtained from Bulletin No. 410, from the University of Idaho, College of Agriculture, Moscow, Idaho.