WOUND PERIDERM FORMATION IN THE POTATO AS AFFECTED BY TEMPERATURE AND HUMIDITY[1]

By ERNST ARTSCHWAGER

Associate Pathologist, Office of Sugar Plants,[2] Bureau of Plant Industry, United States Department of Agriculture

INTRODUCTION

Largely because of its practical significance, the formation of wound cork in the potato tuber has been the subject of numerous investigations, and at present the factors governing its development are in general well understood. The present investigation had for its primary object the study of the effect of temperature on the suberization process, since the only data available are those by Priestley and Woffenden,[3] who left cut tubers for 12 days at temperatures of 15° and 25° C. and found that the rate of formation may be doubled when the temperature rises from 15° to 25° C.

MATERIALS AND METHODS

An extensive study of the relation of suberization and wound periderm in cut tubers to infection by Fusarium storage rots[4] afforded an opportunity to obtain quantities of material for a study of the effect of temperature and humidity on the wound-healing process. From the cut surface, after various intervals and exposures, tissue blocks were cut, usually about 5 by 15 by 10 mm., with the longest dimension traversing the vascular ring and extending into both cortex and inner phloem. This depth of block is sufficient to include all wound periderm that may be formed below a smooth cut. The material was fixed in ordinary chromo acetic acid and stained with an ammoniacal gentian violet. In preparing the stain it was found that the following procedure gave satisfactory results:

To 70 c. c. of a 1 per cent gentian-violet solution in 80 per cent alcohol add gradually 30 c. c. of aqua ammonia. Stain for several hours or leave the material in the stain over night. Rinse in water and treat for a few seconds with an 8 per cent HCl solution; transfer to water and examine.

It will be found that the suberized cells and old periderm retain the violet stain; the remaining tissue, including the newly formed periderm, becomes colorless.

SUBERIZATION OF THE CUT SURFACE

The formation of wound periderm, as shown by Appel,[5] and later substantiated by Priestley and Woffenden, is preceded by a process of suberization of the cut surface. The rapidity with which this blocking off by a suberin lamella takes place depends largely on

[1] Received for publication Aug. 8, 1927; issued January, 1928.

[2] This paper reports work carried on while the writer was a member of the Office of Vegetable and Forage Diseases.

[3] PRIESTLEY, J. H., and WOFFENDEN, L. M. THE HEALING OF WOUNDS IN POTATO TUBERS AND THEIR PROPAGATION BY CUT SETS. Ann. Appl. Biol. 10: 96-115, illus. 1923.

[4] WEISS, F., LAURITZEN, J. I., and BRIERLEY, P. FACTORS IN THE INCEPTION AND DEVELOPMENT OF FUSARIUM ROT IN STORED POTATOES. [Unpublished manuscript.]

[5] APPEL, O. ZUR KENNTNIS DES WUNDVERSCHLUSSES BEI DEN KARTOFFELN. Ber. Deut. Bot. Gesell. 24: 118-122, illus. 1906.

environmental conditions, especially humidity and temperature. If kept at low humidity the cut surface of the tuber will dry out and crack while the tuber itself shrinks from loss of water; at high humidity, however, suberization will proceed at a rate determined largely by the storage temperature. If the temperature is very low suberization will be greatly delayed, so that noticeable changes will not be observed in the cut surface even after a period of a week or 10 days. Ultimately, however, the surface will suberize. At high humidity and high temperature suberization becomes noticeable even after the first day. It appears first in the outermost exposed cell layer. The walls in this region, as shown by the ammoniacal gentian-violet stain, retain a faint purple color, while the adjacent tissue is hyaline. As suberization progresses the coloration becomes more intense and at the same time the deeper-lying cells begin to retain the stain. The number of affected cell layers does not exceed two or three, and none of the varieties examined show the extreme depth of suberization reported by Priestley and Woffenden for some of their material. Suberization appears to be quite uniform over the entire surface. Wherever vascular bundles are exposed in the cut, the blocking off may extend farther down than elsewhere; but this may be an illusion, since the vascular tissue has a tendency to retain the violet stain, though less distinctly than the suberized cells, if the after treatment with HCl is less prolonged.

The rate of suberization for the Irish Cobbler and Russet Rural varieties is shown in Figures 1 and 2. In the Irish Cobbler variety the beginning of suberization may be seen after the eighth day at 2½° C. Russet Rural at this time is still unsuberized. At 5° suberization in the Irish Cobbler appears after the fifth day and in Russet Rural only after the eighth. At 10° in both varieties suberization is observed after the third day, at 15° after the second day, and at temperatures between 21° and 35° after only one day. Increase in temperature from 21° to 30° appears to have no effect on the rate of suberization, but in several instances at 35° suberization was found to extend less deeply. At 10° C. and above, the different varieties appear to exhibit no noticeable differences in the rate of suberization.

Olufsen,[6] in his extensive studies on wound periderm formation in the potato, states that moderate moisture is the most essential requirement for periderm formation; an excess of it plays a hindering rôle and causes cell proliferation. At the temperatures here employed no unfavorable effect was observed at the highest humidities, which at the lower temperatures closely approached saturation.

FORMATION OF THE WOUND PERIDERM

Since suberization or an equivalent blocking-off process is prerequisite to wound periderm formation, the factors governing the rate of suberization will also affect the second process. No periderm cells were observed at a temperature lower than 7° C. within the duration of this experiment. At 7° the first periderm cells appeared in the Irish Cobbler variety after the ninth day; in the Russet Rural and other varieties examined no cork cells appeared

[6] OLUFSEN, L. UNTERSUCHUNGEN ÜBER WUNDPERIDERMBILDUNG AN KARTOFFELKNOLLEN. Bot. Centbl., Beihefte 15: [269]-308, illus. 1903.

even on the tenth day. At 10° the first periderm cells appeared in Irish Cobbler after the fourth day, and in the other varieties after the sixth. At 15° periderm cells were seen after the third day, and at 21° and above after the second day, regardless of the variety. Once initiated, periderm formation proceeds rapidly at the higher temperatures, so that after the third or fourth day there are usually present several rows of new cells. (Fig. 3, A.)

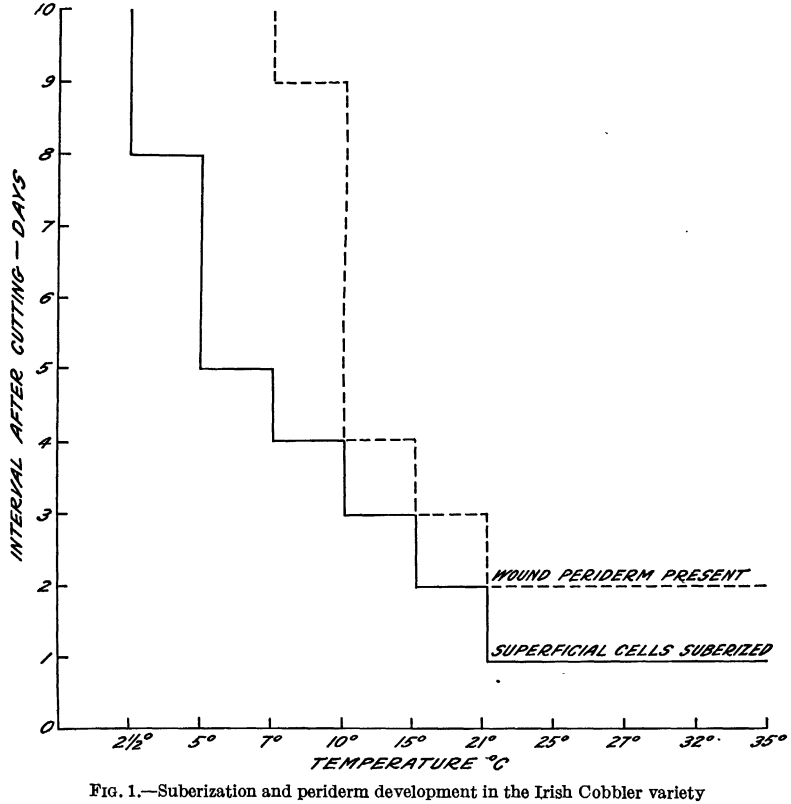

FIG. 1.—Suberization and periderm development in the Irish Cobbler variety

EFFECT OF HUMIDITY ON SUBERIZATION AND WOUND PERIDERM

Although at low temperatures variations in relative humidity produce less effect on the evaporation rate than at higher temperatures, an effect on the rate of suberization and periderm development is, nevertheless, noticeable. In tubers of the varieties Green Mountain, Spaulding Rose, and Russet Rural kept at 12° C. for six days at 64 per cent humidity, only the initial stages of suberization became evident; at 74 per. cent humidity one or one and a half layers were suberized, and at 94 per cent humidity up to two layers were well suberized. Periderm formation, however, became evident only after the ninth day, and only in the third group, which had been kept at a humidity of 94 per cent.

At lower storage temperatures the effects are similar. At 6.5° C. and 70 per cent humidity, suberization was marked after a period of 53 days, but no periderm developed. At 95 per cent humidity, however, a well-developed periderm was noticeable. Different tubers often react differently. For instance, tubers of the Green Mountain variety, kept under identical conditions, showed the presence of a wound periderm in one case and its absence in another. No explanation can yet be offered for such irregularities, but their relation to infection of injuries despite apparently favorable conditions for healing is suggestive.

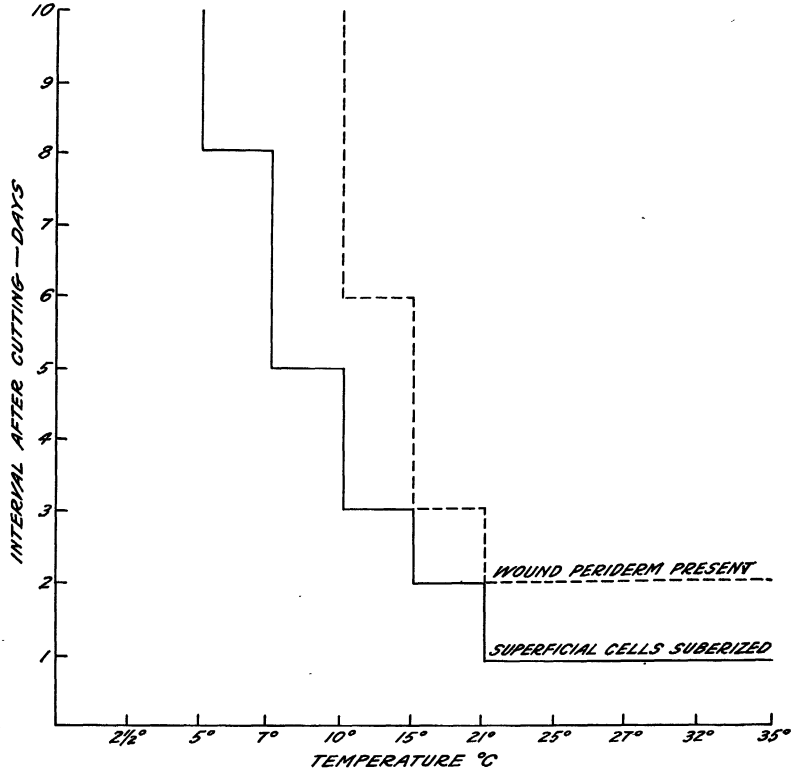

FIG. 2.—Suberization and periderm development in the Russet Rural variety

In a cross section of the tuber the topography of the periderm surface is practically flat; it may extend slightly nearer the wound surface in the vascular ring, but the difference is insignificant. The central region may sometimes show a marked contrast, exhibited in fewer periderm layers which lie farther from the surface, and this is especially true if the central medulla is very large. If the medulla is small, that is, if the phloem groups extend practically to the center of the tuber, no such regional differences will be observed. When the xylem vessels are transected, the wound periderm layer is formed around but not through them. The vessels are, however, subject to blocking by deposits of gum, which extend but a short distance back from the cut.

Concomitant with periderm formation is the disappearance of starch from the cell layers next to the cut surface. It is of interest to note, however, that the protein crystals, found abundantly in the outer cortical cells, are not used up during this process.

EFFECT OF TYPE OF INJURY ON WOUND PERIDERM

While suberization and wound cork formation in cut and stab wounds follow the method given above, tubers from which the skin

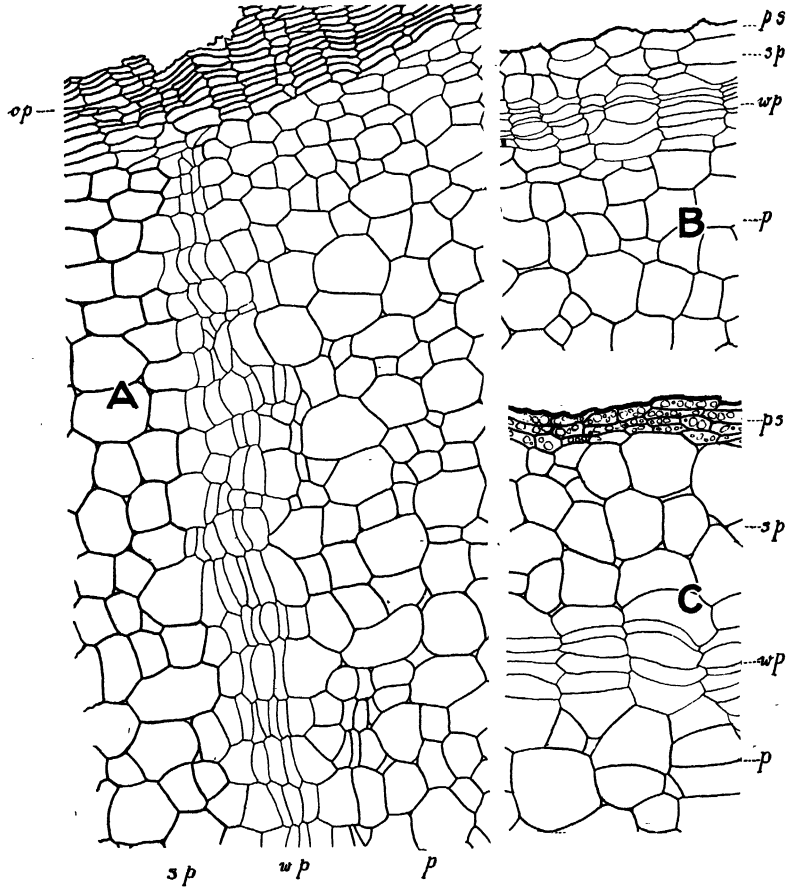

FIG. 3.—A, Wound cork formation in the Early Rose variety: *op*, old periderm; *sp*, suberized parenchyma at surface of cut; *wp*, wound cork; *p*, storage parenchyma. × 85. B, Wound cork formation in the Early Rose variety; tuber was injured by peeling off skin; peel removed smoothly: *ps*, peeled surface; *sp*, suberized parenchyma; *wp*, wound periderm; *p*, storage parenchyma. × 85. C, Same as B, except that in peeling the surface was much abraded. Note that wound periderm is formed farther away from injured surface. × 85

is peeled or which are injured by contusion show a different behavior. When young tubers are injured by blows, the young periderm cells are commonly crushed, while the older periderm shows little effect. (Fig. 4, C.) Typically there is an irregular development of periderm below the margin of the injury or wherever there is an actual break in the original periderm, but there is only slight or no development of periderm beneath the tissues which are merely crushed. (Fig. 4,

A.) It may happen that the wound periderm is formed in several tiers with crushed necrotic parenchyma cells intervening.

Tubers injured by peeling off the skin respond readily with the development of an extensive periderm. When the peel is removed

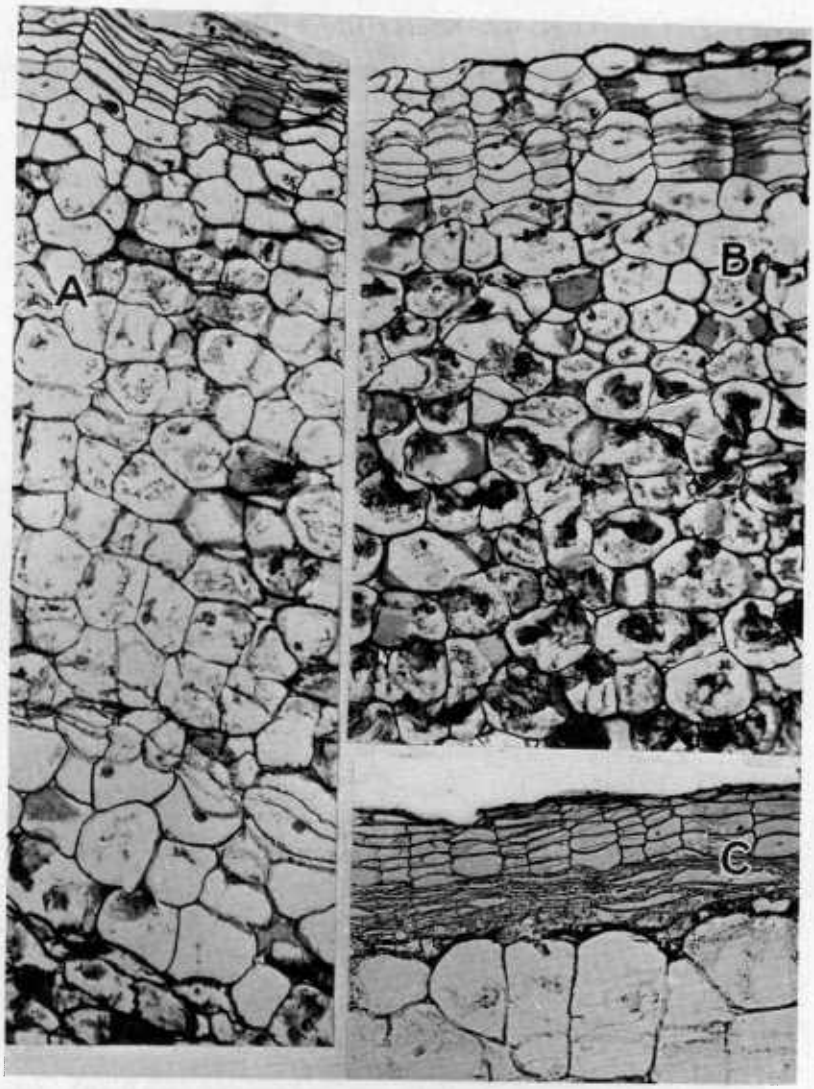

FIG. 4.—A, Deep-seated wound periderm formation in tuber injured by blows. × 85. B, Superficial wound cork formation in tuber injured by peeling off the skin smoothly. × 85. C, Young tuber injured by blows; the young periderm cells are crushed, whereas the old periderm cells are not harmed. × 85

smoothly, the new periderm cells develop within one cell layer of the surface (fig. 3, B, and fig. 4, B), whereas if the surface is much abraded, a deeper-seated periderm results (fig. 3, C).