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Observations on Winter Injury

I—Early and Late Winter Injury

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II—An Aftermath of Winter Injury

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I.—Early and Late Winter Injury

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Destruction of flower buds without attendant damage to other parts of the tree is the most common manifestation of winter injury in the peach and apparently very uncommon in the apple. Conversely, injury to other tissues without attendant damage to flower buds seems relatively more common in the apple than in the peach. In short, blossom buds are ordinarily the susceptible point in the peach and the resistant part of the apple tree. The general recognition of the connection between responsiveness of peach flower buds to high temperatures in winter and the too frequent consequent damage from ordinary winter cold has fostered a rather widespread assumption that injury to flower buds of any kind must be attributed to this combination of weather conditions. For this reason an occurrence of injury confined to blossoms in the apple while peaches in the same orchards were wholly undamaged, constituting a case of injury supposedly due to premature starting from dormacy in a fruit supposedly least subject to this weakness, merits investigation and record.

MANIFESTATIONS

Late in December, 1921, it was noted that a small percentage of fruit buds on Jonathan trees in the University orchard at Columbia had been injured, the floral parts being clearly discolored. In the spring of 1922 these trees blossomed very heavily. Shortly after the blossoms had fallen, the unusual persistence of the bud scales and the peculiar behavior of the axillary buds attracted attention. In many cases the terminal buds were dead and growth was proceeding from axillary buds. Most of the dead buds abscissed, leaving a smooth, flat surface, as shown in Fig. 1. In other cases the terminal growth was very feeble and fruit had set from axial blossom clusters. An instance of this is shown in Fig. 2. Since in Jonathan the formation of axillary flower buds without accompanying flower buds on terminals has not been observed, the association of axillary blossoms with leafy terminals invited attention. Furthermore, the setting of fruit from axillary buds in such numbers as appeared this spring was unusual; ordinarily the terminal buds set fruit and the axillary buds do not.

Many spurs which had not blossomed this year bore fewer leaves than is usual in non-blossoming spurs. Figs. 3 and 4 show views from two angles of a spur of this type found on a Ben Davis tree. Careful examination of either reveals a sharply marked ring just above the lowest leaves. An enlarged view of a similar spur (Fig. 5) shows the significance of this appearance perhaps more clearly. Here the ring, just below the leaf insertions, is plainly visible. This ring, a single continuous line, is quite different from the composite belt of scale scars marking the transition from one year's growth to the next. It occurs only on fruiting wood at the point where the vegetative axis leaves the purse.

At the right of the spur, just below the ring, is a black protuberance; this is the dried remnant of a flower cluster which was killed in the bud. The purse, or cluster base, the swelling which bears the blossoms and fruit, so prominent in the majority of bearing spurs (cf. Fig. 15), is here reduced to extremely small dimensions. The vegetative axis, relatively small in many blossoming or bearing spurs, in these cases constitute nearly all the current season's growth. In some the purse is reduced to even smaller size and can scarcely be distinguished (Fig. 8). In others it is fairly conspicuous.

Fig. 6 is a photomicrograph of a longitudinal section of the bud shown in Fig. 5. Though this section does not pass through the exact center, the dead blossoms within the cluster are discernible. The smallness of the pith cylinder extending to the blossoms is rather better evidence than the possibly shrivelled blossoms could be, of the size of the bud at the time of the killing. Fig. 7, representing a January stage in an uninjured bud of another variety, is used here to illustrate the extent of the injury to the Jonathan bud. That part of the bud represented by the portion above the line **k k'** was killed. Growth continued from the vegetative point just below this (v), resulting in the growth shown to the left of and above the injured portion.

A section of another bud is shown in Fig. 9. In this case the dead tissue had abscissed and the pith cylinder extending to the point of abscission (**a**) is the best evidence of the former presence of blossoms at this point. Injury to the pith is shown at **k** and the growth from the vegetative point was less vigorous. More severe injury is shown in Fig. 10, also some regenerative tissue. Complete killing is shown in Fig. 11 and, in Fig. 12, complete killing followed by abscission.

Dissection of these twigs and spurs showed, in many cases, though not invariably, some discoloration of the pith. Generally when the bud had sloughed off, as shown in Fig. 1, little injury was visible in

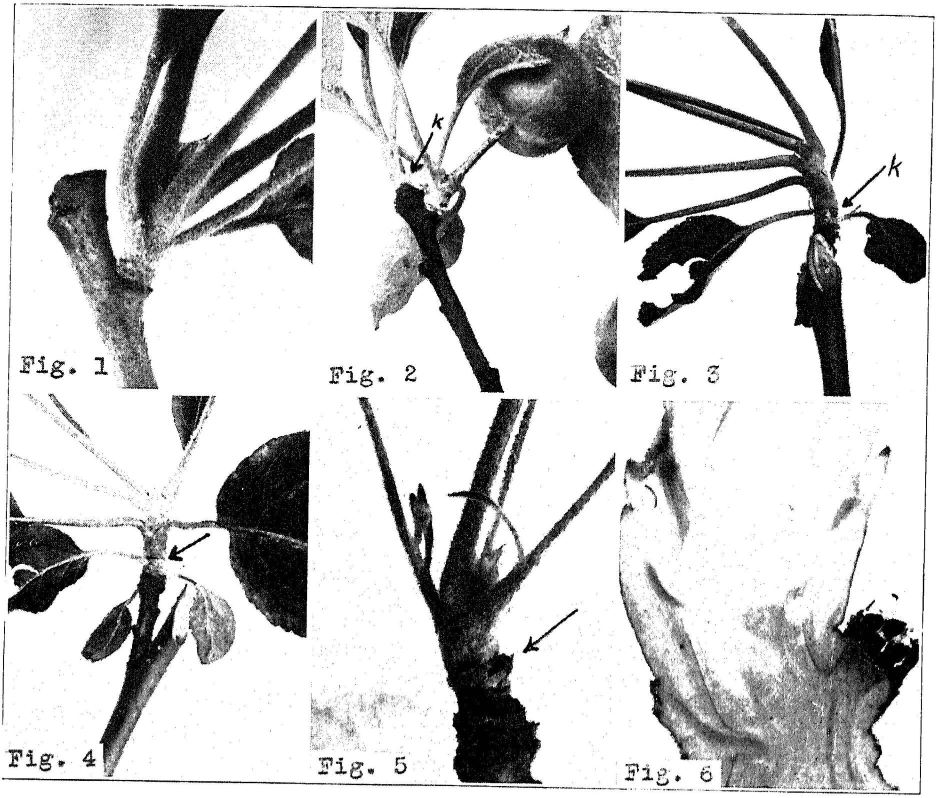

PLATE I.—Fig. 1. Jonathan, showing abscission of winter-killed terminal. Fig. 2. Jonathan, showing setting of fruit from axial blossom clusters. Figs. 3 and 4. Ben Davis spur, showing winter killing of blossoms. Fig. 5. Jonathan spur, showing dead blossoms. Fig. 6 Photomicrograph of section of spur shown in Fig. 5.

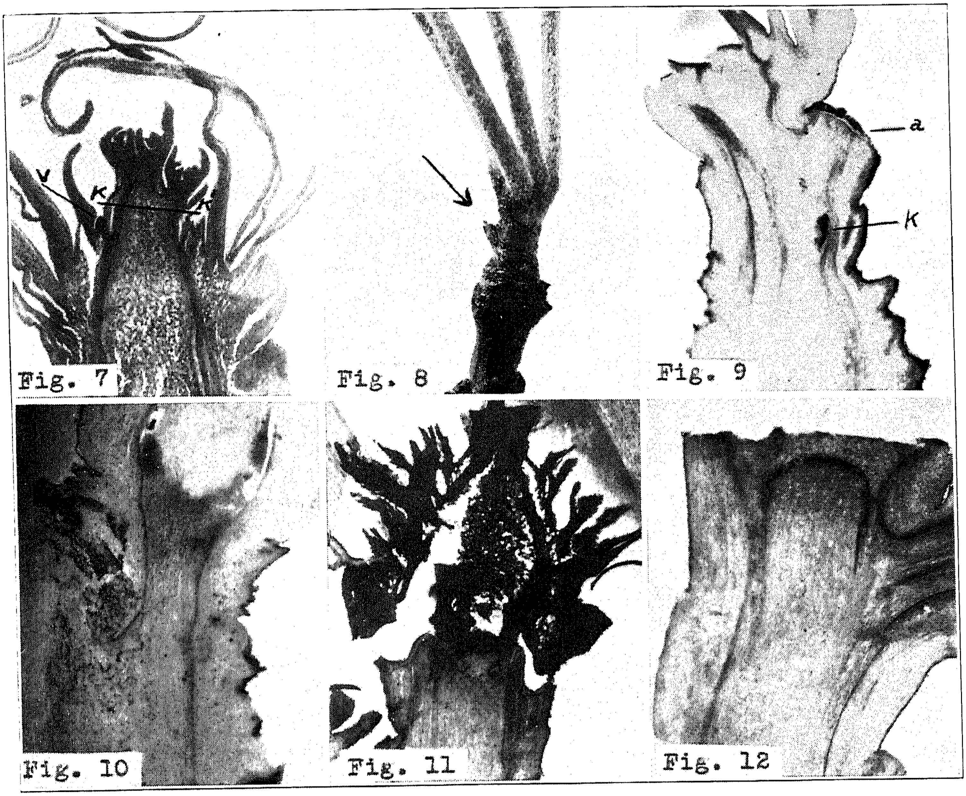

PLATE II.—Fig. 7. Uninjured bud. In injured buds, tissues above *k-k'* killed and growth proceeds from *v*. Fig. 8. Jonathan spur, showing dead blossoms at *k* and extreme reduction of purse. Fig. 9 Jonathan spur, showing abscission of dead blossoms at *a* and injury to pith at *k*. Fig 10. Similar injury involving greater area. Fig. 11. Whole bud killed. Fig. 12, bud killed and abscissed.

PLATE III.—Fig. 13. Kieffer pear, showing replacement of killed spurs from supernumerary buds. Fig. 14. Kieffer pear spur, injured in spring of 1921, bearing in 1922. Injury shown in blackened wood. Fig. 15. Ben Davis spur, July, 1921. Bearing from normal and from second bloom.

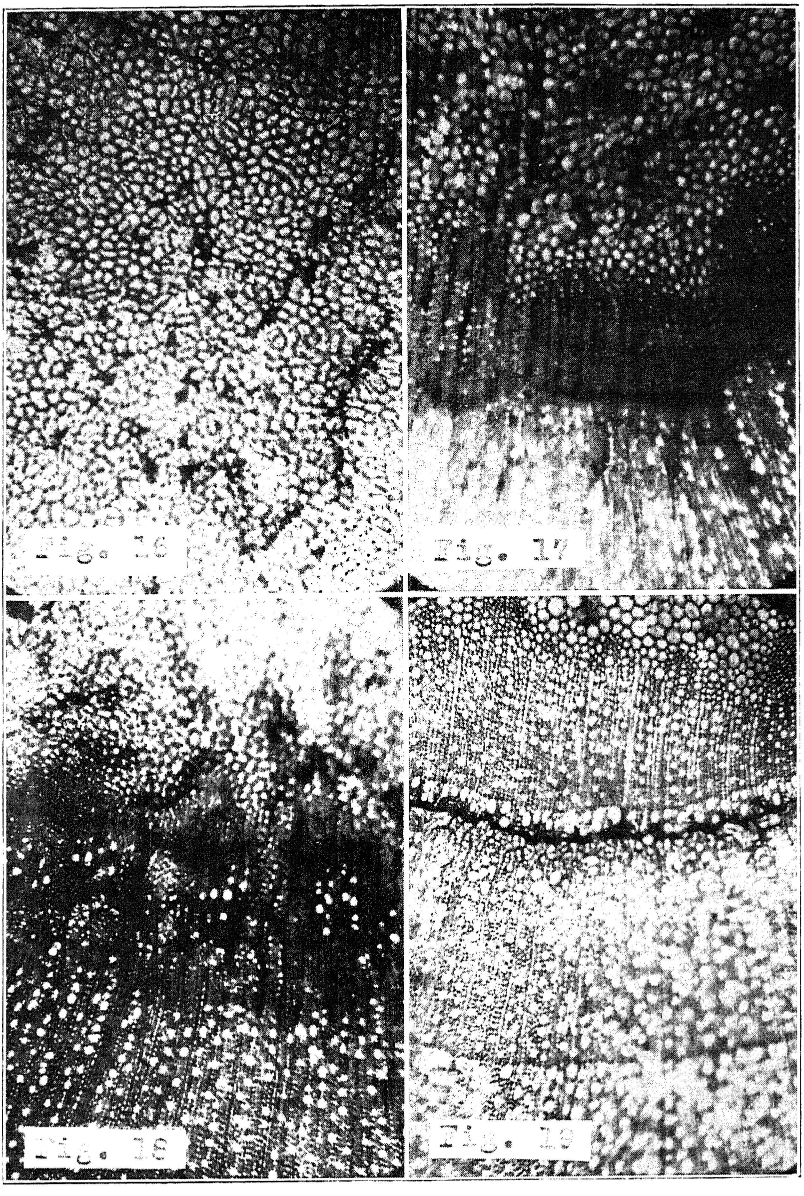

PLATE IV.—Series of sections of Kieffer pear. Fig. 16. Pith injury near tip of 1921 wood. Fig. 17. Injury to pith and wood in 1920 wood. Fig. 18. Section from lower level in 1920 wood; more wood and less pith injury. Fig. 19. Still lower on 1920 wood; injury confined to wood.

the remaining tissue. Some of the spurs in which the blossoms had been killed showed no further injury. In the majority of these cases, however, there were rather poorly defined small areas in which the pith was in some cases brown, in some cases orange. Other spurs, however, which were bearing normally showed somewhat the same injury. This has been observed in Oregon and in Missouri in other seasons.

Parenthetically it may be recorded that spurs somewhat similar in external appearance at this time to those just described, but with the purse better developed, were shown by dissection to be infected with fire blight. Here the discoloration was black and primarily in the vessels rather than the pith. Its course from the blossom attachments was easily traced. Leaves on infected spurs at this stage are still green and practically the only external evidence of infection is the rather flaccid condition of the purse.

OCCURRENCE

The distribution of this winter injury was rather general among the Jonathan trees in two parts of the University orchard. Other varieties examined, as Ben Davis, Ingram and Wealthy, showed it, but very rarely. Others, as Oldenburg, York and Gano, apparently had none. It was very common in *Malus prunifolia*. In Jonathan it affected certainly 10 per cent of the buds. It was found in young Jonathans in the cultivated orchard at Turner though less abundantly than in the sod orchard in Columbia. Possibly the trees in the better drained positions suffered less, but the differences were not marked. In a row on the northern boundary of the orchard injured buds were distinctly more plentiful on the north side of the trees. This might have been taken as evidence of a cold wind as a factor in the injury, were it not that elsewhere in the orchard injury was distinctly localized on other sides. Almost invariably it was most abundant on that side which faced an open space, regardless of orientation.

Much more consistent was the preponderance of injury in buds on terminal shoots over that on spurs. Though spurs greatly outnumber terminals, probably three-fourths of the cases of injury appeared on terminal shoots. The importance of this observation will appear later.

In the peach no sign of injury could be found, though many axillary leaf buds failed to open in the spring. Poorly developed axillary buds on vigorous shoots of many perennials, whether they are those formed in the first flush of spring growth or those laid down just before growth stops in late autumn, are inclined to remain dormant. Consequently this failure to grow is no indication of winter injury, particularly in view of the absence of any evidence of injured tissue. In the peach the pith was brown in spots, but the cells were not collapsed. In this fruit the pith is short-lived and discoloration often occurs in new growth before midsummer. Fruit buds were, practically without exception, uninjured. Consequently it may be said that the peach came through the winter without injury.

TABLE 1.—PRECIPITATION AND TEMPERATURE AT COLUMBIA, SEPTEMBER TO DECEMBER, 1921, COMPARED TO THAT OF THE SAME MONTHS, 1911 TO 1920 INCLUSIVE.

Precipitation (inches)	Aug	Sept.	Oct.	Nov.	Dec.
1921	5.83	10.04	2.33	1.34	1.41
Average, 1911-1920	4.90	6.06	4.90	1.86	1.63
Maximum	7.83	9.69	7.68	3.24	2.94
Minimum	0.77	2.38	0.72	0.10	0.44
Daily Mean Temperature (°F.)					
1921		71.9	57.4	43.8	35.5
Average, 1911-1920		68.6	57.1	45.1	32.4
Maximum (monthly)		73.0	60.1	48.9	39.8
Minimum (monthly)		61.4	48.5	38.0	25.4
Absolute Minimum Temperature (°F.)					
1921		44	32	17	7
1911-1920		32	20	6	—9

CAUSE

The records of the United States Weather Bureau Station at Columbia, made available by Dr. George Reeder, section director for Missouri, are summarized in Table 1, to December 31, covering the period during which the injury occurred. They show the mean temperatures for September and December to have been rather well above the averages for the previous ten years and that for November somewhat lower, but in no case did they reach the extremes recorded in the previous ten years. The absolute minima for the several months have in each case been exceeded in other recent years. Unusual cold is evidently not the primary factor in this injury.

The precipitation record, however, shows an unusual rainfall in September, higher than any in the previous ten years; indeed it was exceeded but twice in 35 years. This rainfall, coupled with the considerable increase in mean temperature for the same month, undoubtedly tended to delay maturity. Raspberries made considerable new growth and fall blossoming of cherries was rather widespread. Some Japanese plums in the University orchard were partly in blossom in October. Though the subsequent winter was not at all remarkable for cold weather, in either duration or intensity, it resulted in practically complete destruction of red and purple raspberry canes and serious damage to black raspberries.

Injury confined to flower buds during early winter has been recorded but rarely. Maynard[4]* and Bartlett[1] described cases of December killing of peach buds in Massachusetts. In the case cited by Maynard the cold was not intense (10°F.), but it followed warm weather during which the blossoms were observed to develop. Chandler[3] found mild injury to peach blossom buds in New York during the winter of 1914-1915. The previous August had been characterized by heavy precipitation. The coldest temperature of the winter, —9°F., occurred in December. The injury was in the pith of the bud and of the twig and apparently had no effect beyond retarding blossoming. In these cases it is not altogether clear whether the buds had started to develop or had failed to mature.

The only careful report of winter injury to blossom buds in apple unaccompanied by further injury is that of a case observed by Whipple[5] in Montana. This form is apparently identical in its manifestations with that just described for Columbia. Though this form of injury seems rare, it is quite possible, as Whipple points out, that, since the injury escapes casual observation, it may occur from time to time and pass unnoticed. Whipple suggested that the damage in Montana might have been due to thawing in high winds or to freezing after warm weather in January or February.

All the evidence in the occurrence at Columbia, however, connects immaturity with the injury. It followed weather conditions inviting and in many cases leading directly to immaturity injuries in other fruits. Peaches, far more susceptible to injury from premature development, were entirely uninjured. The greater injury on open sides may have been due to prolonged growth as much as to greater exposure. In the varieties affected, damage was greatest in the terminals on shoots; these are late in differentiating flower buds, late in maturing and late in starting from dormancy. Some late blossoming varieties were affected while some early blossoming varieties escaped. Finally, the injury had occurred before the last of December.

*This and subsequent superscript numerals refer to literature cited in the Bibliography.

IMPLICATIONS

Attention of fruit growers in Missouri has been focused on premature starting of buds during winter rather than on immaturity. In this case peach trees in the same orchard showed no injury, either in wood or in fruit bud. In addition to weather, other conditions were particularly favorable to injury from immaturity in the peach this winter, for, following the Easter freeze in 1921 the trees had been cut back to wood 2 or 3 inches in diameter and had made growths of three to 6 or 7 feet, with secondary and even tertiary branches. Consequently their immunity from injury while Jonathan apples were afflicted indicates that in the peach at Columbia immaturity is less important than premature starting. On the other hand, so far as concerns the apple, evidence is accumulating in a chain, of which the case here recorded is but one link, that even to Central Missouri, as is the case farther north, immaturity is of no mean importance. Crown rot in Grimes and crotch injury in Stayman are presumably due to injury consequent upon immaturity. Cardinell has found serious cases of winter injury—with heart rot as the consequence—in young apples, evidently tracing to immaturity and cold in the fall of 1917. Injuries due to immaturity are not patent. The type described here might well escape observation and the crop failure be attributed to lack of fruit bud formation. Injuries to other tissues are often unnoted until brought to attenion by the wood-destroying fungi which find entrance through such lesions, or until the bark comes away, long after the weather conditions responsible for the injury have passed from recollection. In many cases such injuries are attributed to fungi and referred to under the general term "canker'.

If the conventional notions of the effects of cultivation be accepted, peaches and apples may be bad neighbors in Central Missouri orchards, for the cultural practices which, by inducing late growth, tend to make peaches resist stimulation from warm weather in January and February tend to make some apples more subject to injury in November and December. When peaches are used as fillers in apple orchards, cultural practices designed to protect either fruit against winter injury are likely to make the other more susceptible.

However, it should be recognized that the comparison made here is between peaches in cultivated soil and apples in sod. The generally accepted views of the effects of these two systems of management are, for the most part, founded on investigations in sections with a shorter and uniform growing season. For many crops there are in Missouri two rather distinct growing seasons, separated by a season of dry, hot weather. In some cases, as with potatoes and cabbage, this may be due chiefly to the excessively high temperature of midsummer, but with others dry weather has its undoubted influence. The raspberry, companion of the potato and the cabbage in ability to grow where the summers are too cool to ripen grain, shows the same reaction to the growing season of Central Missouri. Immaturity injury in this fruit occurs every year in varying degree at Columbia before intense cold sets in; it may be produced by temperatures certainly no lower than 12°F. and possibly higher. In late August the canes are often more nearly mature than they are in October, following the moderate temperature and greater rainfall of September. Those which grow through August seem to mature better than those which stop growing at this time. Card[2] found in New York that under some circumstances the first shoots to start in the spring may be more tender in the following winter than those starting somewhat later. Prolonged tillage through the dry season may have the actual effect of inducing final maturity by so prolonging the first flush of growth that the second growth does not start. In short, for this fruit the growing season here is apparently too long; the canes mature and then resume growth.

On the other hand, the peach, adjusted to warmer summers, suffers little or no check from heat during its growing season. The long period of warm weather enables this tree to mature properly despite high cultivation. In fact, prolonged cultivation makes it more hardy.

The apple, with growing season temperature requirements higher than those of the raspberry and lower than those of the peach, undoubtedly suffers more or less here from immaturity. The evidence at hand, however, does not warrant any conjecture as to the effects of tillage on maturity in this fruit. The smaller amount of injury in the cultivated trees at Turner than in the sod orchard at Columbia, eight miles away, is interesting, possibly suggestive, but certainly not indicative. The greater prevalence of injury on terminals than on spurs at Columbia points in the opposite direction. Consequently at present it cannot be stated definitely whether this immaturity injury is due to prolonged growth or to renewed growth.

One thing becomes increasingly evident. Hardiness in Central Missouri is more complicated than it is farther north or farther south. In some regions it is largely a matter of maturity, in others a matter of continuing dormancy. Here it is in some fruits the first, in other fruits the second. This is the first complication. The second complication comes from the fact that immaturity alone, a rather simple matter farther north, is here possibly induced by the very practices that obviate it elsewhere. Finally, since this section shares northern and southern winter weather, extreme measures for guarding against one type of injury may be efficacious in one winter and injurious in the next. Solution of the problems raised will depend on recognition of the types of injury to which each fruit is subject, determination of the probability of the occurrence of weather conditions leading to each type and formulation for each fruit of cultural practices which, over a period of years, will reduce the injuries most likely to occur.

VARIABILITY OF HARDINESS

After the Easter freeze of 1921 the Kieffer pears showed more damage than any other trees in the University orchard. Many spurs were killed, many branches were killed back well into 1920 wood and older wood was discolored. Other pears, such as Garber, Tyson and Surprise, were injured but little. Since the freeze the recuperative ability of Kieffer has been as remarkable as was its susceptibility. The majority of the killed spurs have been replaced by new growths arising from supernumerary buds at the base of the old spurs (Fig. 13), and the spurs whose wood was blackened in 1921 are bearing in 1922 (Fig. 14).

Since this variety had proved so tender in the spring of 1921, it was examined for injury occurring in the late months of the same year. Evidence of injury to pith near the tip of 1921 wood was plentiful (Fig. 16), but there was no indication of injury to fruit buds and little or no indication of injury to wood. Farther back on these same branches showing pith injury in the 1921 wood, appeared injury of another kind. Just below the point where growth was resumed in 1921 both pith and wood were injured (Figs. 17 and 18). Still farther back, but yet in 1920 wood, the injury was confined to the wood. In gross appearance there was a ring of blackened tissue, which is shown by microscopic examination to be very narrow (Fig. 19). Inside the blackened ring is a narrow belt of new wood, one or two cells wide, composed of wood laid down in the spring of 1921 before the freeze. The injury was confined to parenchymatous tissue and the wood just laid down was hardy enough to withstand the freezing.

Discoloration of pith is not invariably a sign of winter injury, but, under the circumstances of its occurrence in the material discussed here, it may be taken as such. The injury to the pith in the 1921 wood was undoubtedly an immaturity injury. The injury to the pith in the 1920 wood may have been due to the weather of the 1920-1921 winter or to the Easter freeze of 1921. In any case, it is clear that the most tender tissue in the fall of 1921 was the pith while in the spring of the same year it was the wood.

Extensive examination of 1920 wood in other pears and several varieties of apple showed no wood injury from the Easter freeze comparable to that in Kieffer. In some cases Ben Davis 1920 wood showed a dark ring (Fig. 3). On microscopic examination this was found to be, not injured tissue, but a false annual ring caused by the check to growth resulting apparently from the killing of the foliage in the same freeze.

The pear trees in the University orchard stand within a few feet of many Jonathan and Ben Davis trees and receive the same cultural treatment. These Jonathans show no wood injury from the Easter freeze, Ben Davis only a check to growth, while Kieffer was severely affected. In the fall of the same year, however, conditions were reversed; Jonathan was injured rather extensively, Ben Davis much less and Kieffer least of all. This condition, coupled with the reversal of the accepted comparative hardiness of the peach and the apple, illustrates anew the fact that hardiness is consitutional only in so far as conditions producing hardiness are constitutional. It is a condition rather than a quality. A given fruit is hardy in a locality as it reacts to the ordinary climatic conditions of that locality and comparative hardiness may be reversed in various localities according as the spring or the fall injuries are likely to prevail.

THE "SECOND BLOOM"

Following a frost causing widespread damage to blossoms and fruit crop there is frequently a flood of reports of crops borne on "second bloom" pushed out as a consequence of the injury to the first crop. The occurrence at times of second bloom in rather considerable quantity is unquestionable. After a destructive frost it is naturally more noticeable than it would be in a frostless season when it would come on about at the end of the first bloom. Its occurrence, however, is not necessarily a consequence of frost injury. It was noted in great abundance in the University orchard at Columbia in the spring of 1921 before any frost had occurred and in the spring of 1922 when there was no damage from frost. Fig. 15, showing a Ben Davis spur taken in the summer of 1920, is significant. Growth for that year started at g. One apple results from the first bloom and one from the second. Clearly in this case the destruction of the first bloom is not concerned with the formation of the second.

SUMMARY

1. Killing of many fruit buds in the apple occurred early in the winter of 1921-1922 in the University orchard at Columbia.

2. The attendant circumstances indicate that this injury was connected with immaturity.

3. Many plants with low optimum growing temperatures have, in Central Missouri, two distinct growing seasons separated by a hot, dry midsummer. The raspberry apparently belongs in this group.

4. Other plants, with higher optima, grow rather uniformily through the season. This group includes the peach.

5. Sod culture may have the effect of accentuating the duality of the growing season for the plants with low optima. Consequently its effect on maturity in these plants may be directly opposite that recognized in regions with short and relatively cool growing seasons.

6. Available evidence is not sufficient to indicate how tillage affects maturity in the apple in Central Missouri.

7. In the Kieffer pear the relative hardiness of the various tissues appears to vary with the season.

8. The Kieffer pear, under the conditions discussed in this paper, is more tender in the wood in the spring than the Jonathan apple, but more hardy in fruit buds in the fall.

9. The so-called second bloom is not necessarily the consequence of the destruction of the "first" or normal bloom.

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II.—An Aftermath of Winter Injury

H. A. CARDINELL

In the course of some continuing demonstration work in 1920 and 1921 in a young orchard at Fortescue, Holt County, Missouri, attention was drawn to the failure of the pruning wounds to heal. Where-ever any wood was removed, large or small, callus formation was very slow or failed altogether (Figure 6). Not only did wounds which should have healed in one season fail to cover over, but the wood in the immediate neighborhood seemed dead. Wounds disinfected and some both disinfected and painted healed no better than those untreated. Cuts made below old wounds revealed much dead wood in the center, surrounded by more or less live wood. Cuts through the trunk still lower on the tree, in many cases down to within three or four inches of the ground, showed the same condition (Fig. 4). For reasons which will appear later in this paper, it was possible to examine 1243 trees this spring. In this group only a few cases were found of discoloration extending below the graft union and fully 50 per cent of the trees were not injured below three or four inches above the ground as shown at **k** in Fig. 4.

Aside from this failure of wounds to heal properly the trees presented no unusual appearance, except in some extreme instances. By the spring of 1922 the trees most affected, though many of these same trees were making 20 to 40 inches of growth each year, as shown in Fig. 5, had one or two dead limbs to the tree. At the base of these limbs the wood on the trunks was practically all dead. In general, however, the trees were making very good growth and on casual observation the orchard would have appeared in excellent condition.

It is no uncommon occurrence to find black-hearted limbs or trunks on trees that have been growing and fruiting in a perfectly satisfactory manner. This condition is known to be caused by winter injury, sometimes from ordinary cold in conjunction with an immature condition of the tree. It occurs when the cold is severe enough to kill the wood but still not severe enough to kill the hardier cambium. Consequently in the following spring the cambium may resume growth and surround the dead area with a layer of new tissue. Sometimes these blackened regions are found surrounded by healthy wood showing 20 or more annual rings, indicating that the injury had occurred as many years previously and apparently had not interfered materially with the tree's life or functions. In itself the condition is not serious, particularly in older trees. In the case here considered, however, there were two disturbing circumstances: (1) the failure of the wounds to heal, already mentioned, and (2) the fact that the discoloration was evidently advancing with the growth, spreading into new wood (Fig. 3, at B and C). This made diagnosis of the cause and prognosis of the ultimate effects somewhat uncertain.

HISTORY OF THE CASE

The trees involved stand in a 60-acre block, on level but well drained Missouri River bottom land. This orchard is one of the properties of George Hitz & Company of Indianapolis and is managed by Mr. C. E. Hitz. In the spring of 1918, yearling trees to the number of 2,997 were planted and in the fall of the same year 567 two-year-olds were set. Jonathans were planted as permanent trees, with fillers of five varieties: Ben Davis, Delicious, Stayman, Grimes and Ingram. All the stock used came from a nursery at St. Joseph, Missouri.

While these trees were being cut back subsequent to planting, Mr. Hitz noticed that there was a slight discoloration in the wood. During the summer of the same year a pathologist from the United States Department of Agriculture, visiting the orchard on another errand, examined these trees and diagnosed the trouble as winter injury.

DIAGNOSIS

The complication already alluded to and the resemblance of some of the wounds to cankers of fire blight, so common on Jonathan in Northwest Missouri, rather obscured the case. Specimens of injured wood were submitted to pathologists in various sections of the country and the possibility of several other disorders eliminated. In February, 1922, a shipment of injured trees was sent to M. B. Waite, Pathologist in Charge, Fruit Disease Investigations, U. S. Department of Agriculture.

Under date of February 25, Waite states: "I have given these samples careful study. The main trouble is winter injury. It is complicated by secondary trouble due to wood-rot fungi. These wood-rot fungi have produced a heart rot by entering the frozen injured centers of the trunks and main branches, and the wood-rot fungi have extended the injury somewhat, and perhaps complicated and confused the primary injury. * * * There are indications on these samples that they may have been frozen a second time. I have often noticed that trees once injured by freezing appear slightly more susceptible. Part of the two-year wood and most of the one-year wood is sound."

Of the discoloration in the one-year-old wood Waite says: "This appears to be partly due to the growth of the wood-rot fungus from the diseased part up into the healthy tissue. One of the samples shows the tip of a small trunk which has been killed completely and shows the fungus fruiting.* Mr. W. H. Diehl of this bureau has identified this fungus as *Irpex tulipifera Schw*".

Weather records indicate several possibilities of winter injury in the time since these trees stood in the nursery, in the summer of 1917. However, inasmuch as injury to these trees is known to have occurred prior to planting in 1918 and the secondary injury is less certain, interest centers in the weather from October, 1917, to March, 1918. The mean temperature for the state as a whole was below normal during most of 1917 and particularly in October and December. The October mean temperature was the lowest on record. Killing frosts occurred on October 6, ten days earlier than the average. That fall will be remembered by many people in this section for the great amount of soft corn.

TABLE 1.—PRECIPITATION AT ST. JOSEPH, MISSOURI.
(In Inches)

	Aug.	Sept.	Oct.	Nov.	Dec.
1917	5.80	1.60	0.80	0.04	0.16
Average, 1888-1917	4.37	3.34	2.62	1.71	0.96

The Weather Bureau records for St. Joseph, where the trees discussed in this paper were grown, indicate that the preceding autumn was rather dryer than the average. August, however, had a rainfall 1.4 inches above the average. Whether this could have had any material effect in prolonging growth and deferring maturity is problematical.

TABLE 2.—MINIMUM TEMPERATURES AT ST. JOSEPH, MISSOURI.
(In degrees F.)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1917-18	20	17	—13	—19	—13	17
1909-1917	22	5	—10	—24	—16	—4

*After the manuscript was prepared many ungrafted trees had died and one type of fruiting body was noticed on all. This was identified Sept. 8, 1922, by Diehl as *Polystictus versicolor*, Fr.

Minimum temperatures lower than any since 1909, when the St. Joseph record begins, occurred in October and December. Just when the injury to these trees occurred, cannot be stated definitey. Selby records extensive damage in Ohio, involving even complete killing in some cases, by a temperature of 18° in October. Twenty degrees in October would seem more dangerous, particularly to nursery stock, than —13° in December, the other month of record-making temperature.

The date of digging these trees is not known. If they were, according to the prevailing practice, dug in the fall, the period of injury is fixed without question. Without this evidence, however, the probability of the October minimum being the chief factor in the damage is strong.

TABLE 3.—MINIMUM TEMPERATURES AT GENEVA, N. Y.
(In degrees F.)

	Oct.	Nov.	Dec.	Jan.	Feb.
1917-18	26.0	9.0	—18.0	—10.0	—11.0
1909-17	26.0	16.0	— 6.0	—12.0	—14.0
1883-1909	20.5	8.0	—15.5	—18.7	—21.0

Table 3, compiled from reports of the New York Agricultural Experiment Station at Geneva, which is a considerable nursery center and located in a section where immaturity is generally known to be the chief factor in hardiness, is used here for comparison. The October, 1917, minimum for St. Joseph is lower than at Geneva for the same year; it is in fact a trifle lower than any in the long series of records for this place.

Whether or not this particular injury was received in October, if immaturity is likely to be a factor in winter injury at Geneva, N. Y., it is likely to be a factor at St. Joseph, Mo. Table 4, giving in detail the data summarized in Tables 2 and 3, shows this clearly. In the nine years for which data are available, the October minimum for St. Joseph has been lower than that for Geneva in five, identical in three and higher in one. The November minimum has been lower in five years, higher in three and identical in one. If absolute cold at any time be considered the chief cause of injury, the Geneva absolute minimum of —18°F. is offset by one of —24°F. for St. Joseph.

It is true that the higher maximum and mean temperatures of the fall months at St. Joseph may under certain conditions have some influence in hastening maturity. It is also true, however, that they may

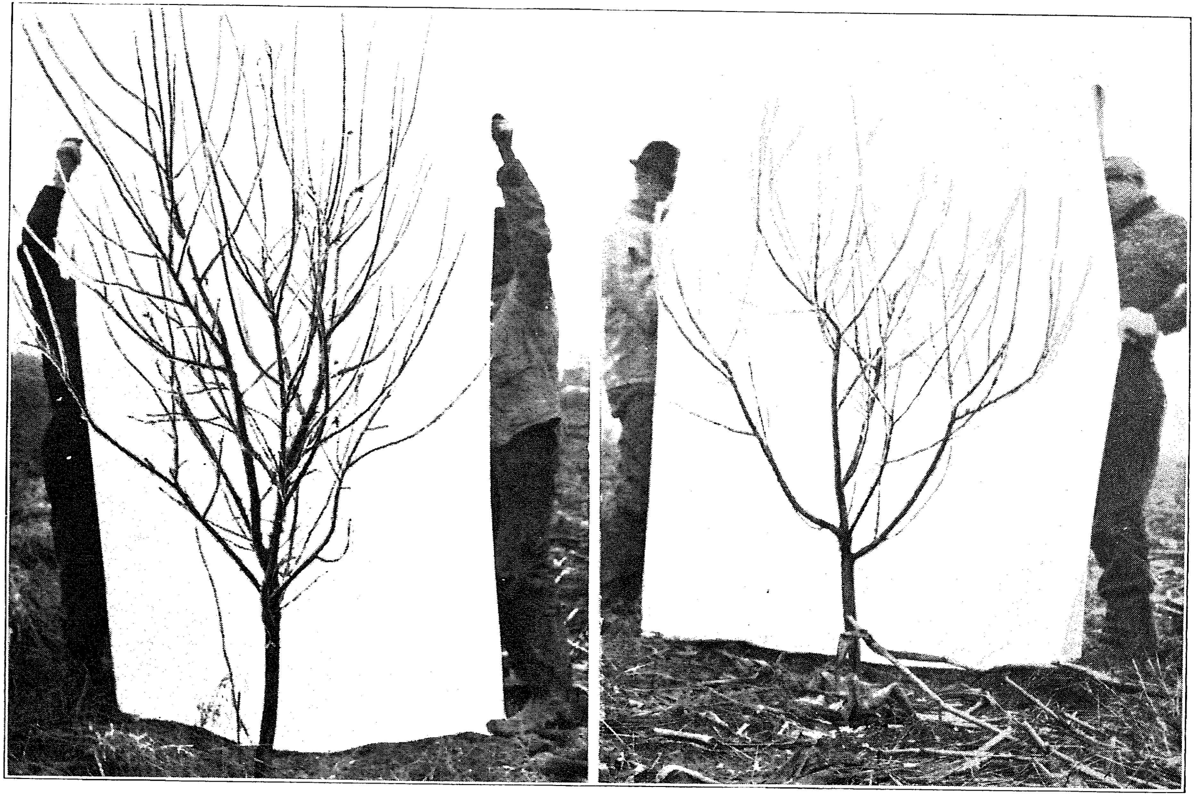

Plate V.—Fig. 1 (Left) Jonathan, 4 years after planting in the orchard, showing growth condition and lack of external evidence that would indicate the condition shown in Fig. 7, a cross section of the same trunk. Fig. 2. (Right) Jonathan, four years after planting. Compare this view with the cross sections of the same tree shown in Fig. 3. Photographed Mar. 28, 1922.

PLATE VI.—Fig 3. Jonathan, four years from time of planting, showing injured areas and heart rot rapidly advancing in later annual rings of apparently sound wood.

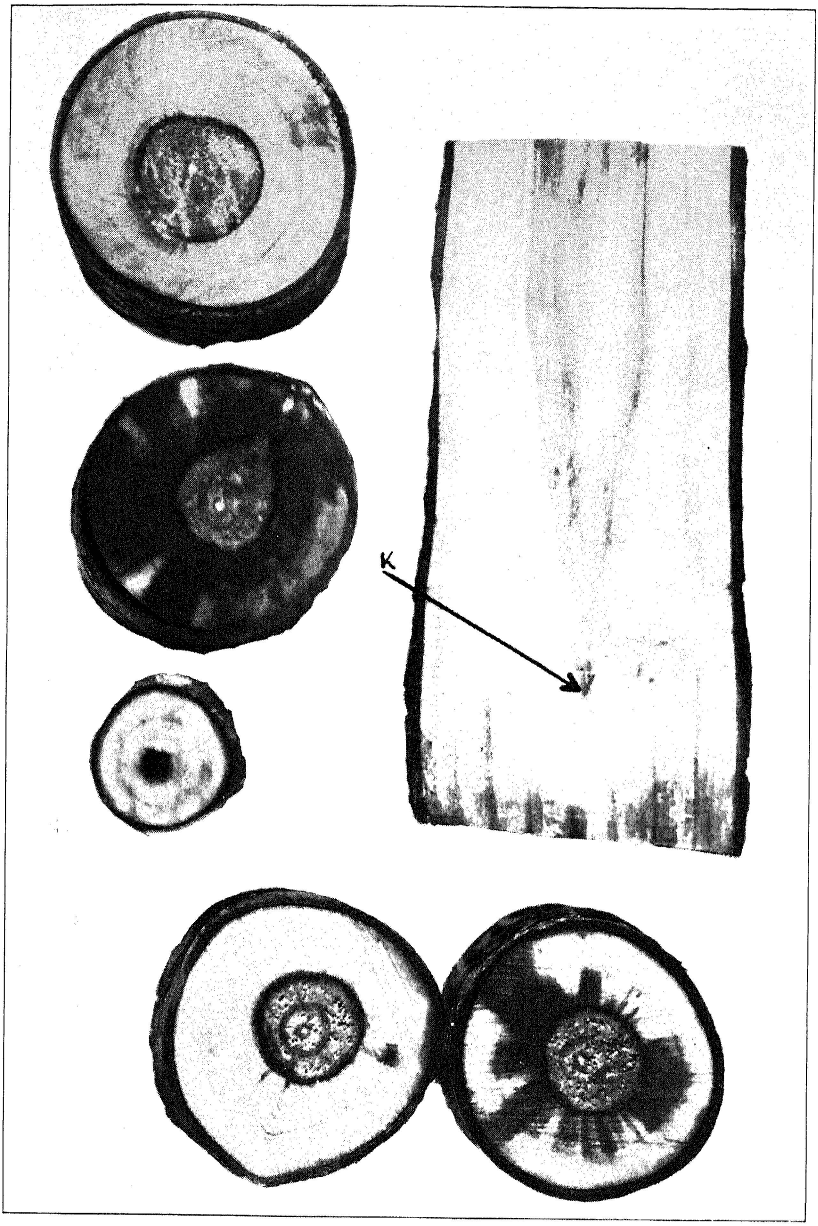

PLATE VII.—Fig. 4. Jonathan, four years after planting showing longitudinal and cross section views of one tree through trunk and scaffold limbs. In a large percentage of the trees cut off, the injury terminated in a point a few inches above the ground.

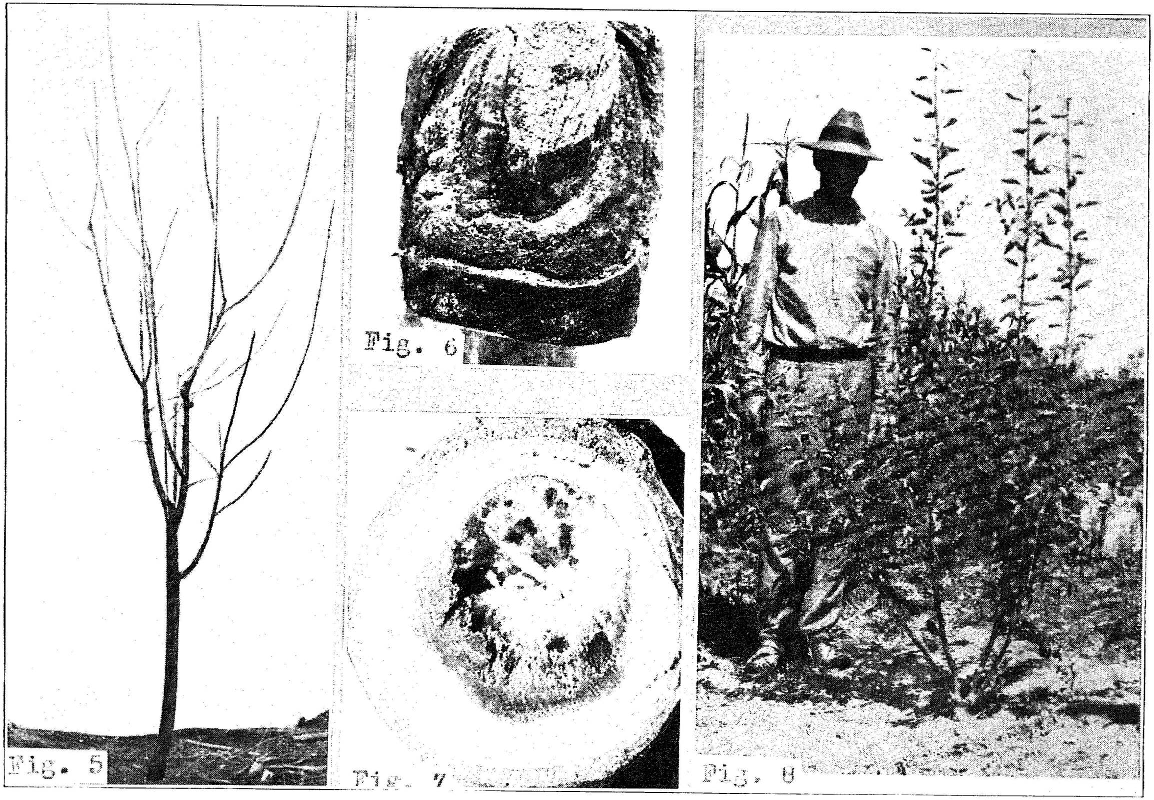

PLATE VIII.—Fig 5. Ingram, four years old, showing remarkable growth in spite of the gradual loss of limbs which died each year as an indirect result of the injury. Fig. 6. Jonathan, a small limb removed during early training of the tree. All such wounds had been treated with disinfectant paint at the time of pruning. Wounds started to heal and the entrance of heart rot stopped all callus formation at that point. Fig. 7 Jonathan, cross section through the trunk of a four-year-old tree, showing action of heart rot. Fig. 8. Jonathan graft, showing one of the 1243 trees grafted during the week of March 26, 1922. Photographed August 14, 1922.

have some influence in the opposite direction. The average rainfall at St. Joseph in August, September and October is greater than that at Geneva; for these three months the figures are, respectively: at St. Joseph, 4.37, 3.34 and 2.62 inches; at Geneva, 3.30, 2.42 and 2.50 inches. When high rainfall is combined with high temperature, growth is prolonged and the first low temperatures are more likely to be damaging.

TABLE 4.—MINIMUM TEMPERATURES AT ST. JOSEPH, MO., AND AT GENEVA, N. Y., 1909-1918 INCLUSIVE.

Year	October		November		December		January		February	
	St. Joseph	Geneva	St. Joseph	Geneva	St. Joseph	Geneva	St. Joseph	Geneva	St. Joseph	Geneva
1909-10	27	27	19	21	—10	1	—13	—8	—5	—3
1910-11	28	26	20	21	8	—2.5	—11	—1	9	4
1911-12	32	33	5	18	— 4	13	—24	—12	—6	—10
1912-13	31	31	20	20	8	12	— 4	8	—2	—10
1913-14	22	29	26	22	11	6	8	—9	—7	—14
1914-15	25	26	7	16	— 8	—6	—12	—3	13	—10
1915-16	29	29	23	21	4	4	—19	—3	—4	—8
1916-17	24	29	12	16	9	4	— 8	1	—16	—8
1917-18	20	26	17	9	—13	—18	—19	10	—13	—11

IMPORTANCE

In a large number of cases occurring in this section winter injury of apples does not command attention at the time of its occurrence. It may induce minor injuries, the consequences of which are not revealed until the original cause is obscured. When a crop of peach buds is killed the loss is plain, but when a small area of bark is killed it receives little attention until decay ensues and by this time possible winter injury is forgotten. This very subtlety of winter injury makes difficult any appraisal of its extent. In the case discussed here the injury was slight. It was noticed at the time of setting the trees, but was thought of no importance. It did not affect the growth of the trees and would have been forgotten but for the work of the wood-destroying fungi. Many cases undoubtedly occur without untoward consequence; in many others the trees will grow for some years and when they begin to go to pieces the evidence to connect the condition with a slight winter injury several years back will be scant indeed.

TREATMENT

Detailed account of the treatment given this orchard following diagnosis of the condition will be published elsewhere. Briefly summarized, it consisted in cutting back to sound wood, frequently to within a few inches of the ground and grafting the stubs (Fig. 8). A few trees cut back without grafting, after growth had started and when the carbohydrate reserve was low, died. Those treated earlier, with grafts inserted in the crowns, have made a practically perfect stand and are growing vigorously. This procedure has involved the sacrifice of the wood grown in the four years these trees have stood in the orchard; but, with proper attention to the grafts, it will ensure perfectly sound trees, with every promise of long life and productiveness.

CONCLUSIONS

Though winter conditions rarely kill apple trees outright in this section, they may have hardly less serious consequences. Evidence of winter injury should, therefore, put the grower on his guard. If new evidence appears every few years it may signify the need of revision of his cultural practices. Injury to wood at any time justifies great care in pruning. If the cuts can be made far enough back to remove all injured wood, there is little danger of infection. If the removal of all injured wood is not practicable there are two courses remaining: (1) careful disinfection and painting of all wounds, (2) omission of pruning altogether till the cuts can be made in sound tissue growing subsequent to the freeze. The practicability of these methods will be discussed elsewhere. However, one guiding principle may be stated: injured wood should not be exposed. Sealed within living wood, it is harmless; exposed it is a source of constant danger.