DESICCATION OF DORMANT RED RASPBERRY CANES IN RELATION TO HARDINESS

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E. A. H. Banks

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INTRODUCTION

Winter injury to red raspberry canes is a problem throughout most of the raspberry growing sections of North America. The injury is most commonly manifested in spring by a partial or complete failure of growth in the tip section of the cane. Often this is not extensive enough to be of practical importance but in many cases the entire upper half or more of the cane is either completely dead or else the buds in this region make very feeble growth. Less often, death of the entire cane occurs. This may be due either to injury to the base of the cane, to the crown, or to the roots.

In order to present a logical consideration of the causes and possible prevention of winter injury it is necessary to recognize the fact that there are several distinct types of injury.

Occasionally early fall freezing may completely kill the young laterals, or any tender, late-growing shoots. Such injury obviously belongs to the "immaturity" class. It is not of much importance except in the occasional unusual season of severe early freezes.

Later injury may be represented by outright killing of various tissues by very low temperatures. If the plants are partly protected by a blanket of snow or other mulch material the injury usually extends back to the protected part and, upon thawing, the exposed parts will show the characteristic browning of tissues killed by freezing. Where the soil is bare and unprotected direct freezing injury may occur at the crown or roots.

A third type of injury is that which is described as being due to "winter drying". This appears to be the most common and widespread type. It may occur in combination with more or less direct freezing injury of certain tissues, or it may be relatively serious in seasons when winter injury would be quite unexpected, if drastic drops in temperature were the chief cause, and when periodic examinations throughout the winter and early spring have shown no definite symptoms of injury.

Since freezing itself is a desiccating process, it is obvious that moisture conditions play an important part in the over-winter survival of raspberry plants.

Cultural methods, the application of fertilizers, fall cover crops, degree and time of pruning, protective mulches, and protective sprays all affect the water economy of the plant. Therefore, before further considering the possible means of prevention of winter injury it is necessary to make an analysis of the information already available on these methods of treatment and their relationship to winter injury.

REVIEW OF LITERATURE

A review of the literature on the nature of winter killing in general, and the theories regarding frost resistance in plants, would be too voluminous to include here. Adequate discussions of the literature have been written by Gardner, Bradford, and Hooker

(12), Chandler (6) (7), Maximov (20), Martin (19), Crane (9), and others.

It is now generally agreed that the formation of ice crystals in the intercellular spaces results in the withdrawal of water from the cells as freezing progresses, thus producing a dehydrated condition of the plant cell. There are two main views on the causes of death from dehydration. One lays the cause to the chemical influence of increased concentration of salts and acids on the colloids of the protoplasm; the other to the mechanical injury of protoplasm caused by compression or grinding of the cells by ice crystals which accumulate in the intercellular spaces. But, whatever is the ultimate cause, the loss of water from the cells is admitted.

Susceptibility of Varieties   Red raspberries are less subject to winter injury than blackberries and are usually hardier than black raspberries also, although contradictory reports have appeared from different parts of the country. In Nebraska (27) the black raspberry has been reported as hardier than the reds. Card (5) reports that the reds are less hardy than blackcaps in the eastern states, although Stene (22), reporting from Rhode Island, says that red raspberries suffered much less injury than blackberries and blackcaps, especially in 1927-28. Slate and Rankin (21) state that winter injury on red raspberries is more troublesome in the Hudson Valley than elsewhere in New York state, and that "black and purple raspberries are rarely injured except where poor site conditions prevail".

Latham, King, Sunbeam, Ohta, and Chief are classed as hardy in Nebraska. In Michigan, Latham is reported to stand lower temperatures than many other red varieties, while Cuthbert is more subject to freezing injuries than some of the other varieties.

Locklin (17) reports that in western Washington Cuthbert is the variety most severely injured by low winter temperatures and that Antwerp and Marlboro are injured only in the most severe winters. He notes the fact that Cuthbert is very slow to drop its leaves, to stop cane growth, and to harden up the cane tips.

Stene (22) lists Latham, June, Cuthbert, and Herbert as being hardy in that order in Rhode Island.

Slate and Rankin (21) describe Latham, Chief, and Herbert as being generally considered very hardy to severe winter temperatures; June and Ontario as sufficiently hardy for New York conditions; Newburgh not yet sufficiently tested but so far entirely hardy in central and western New York; Lloyd George as generally rather tender in New York but showing no signs of injury at Geneva where cover crops have been used; and Cuthbert as being moderately hardy.

Slate and Rankin emphasize a fact that has been noted by others; namely, that certain varieties of the red raspberry which are more inherently hardy than others may show contradictory behaviour in certain localities. For example, Viking, which is resistant to the very low temperatures common at Ottawa and Montreal, often suffers rather severely from winter injury in the Hudson Valley. This is explained as being due to the fact that dormancy is broken by unseasonably warm weather in late winter and it is stated that this injury has been more prevalent during mild winters.

Effect of Soil Conditions and Cultural Treatments Since the importance of maturity in preparing plants for winter has been emphasized, a resumé of the literature bearing on the maturity of raspberry canes and the effect of soil conditions and cultural treatments in preparing the plants for winter will serve to crystallize some of the information already available.

Craig (8) found that summer-pruned Cuthbert raspberries suffered more injury at Ottawa, Ontario, than unpruned plants.

Gardner, Bradford and Hooker (12) advise against summer pruning, stating that "immature canes, laterals on canes pinched back, and suckers that develop late are sometimes injured by comparatively mild freezing".

Card (5) expresses doubt of the "current belief" that a comparatively dry fall favoring a slow well ripened growth of wood promotes resistance to winter injury, and cites the fact that slender canes produced during the latter part of the season often winter-kill less than older large canes. He also notes that "during one winter in Nebraska the mercury fell below zero but once, and then only five degrees below, yet unprotected canes were entirely killed......The following winter was much colder, but the preceding summer and autumn were favorable, with plenty of rain. The plants, therefore, went into winter quarters with a good supply of moisture in the ground. Both raspberry and blackberry plants came through that winter in good condition without protection".

Card also says that excessive, as well as deficient, moisture may contribute to winter injury.

Lott (18) corroborated Card's findings in reporting that the removal of the first two crops of young shoots from the Cuthbert raspberry caused a significant increase in hardiness.

Hilton (15), in reviewing Card's observations offers the suggestion of Bradford that second growth induced by cool and rainy autumns following a hot dry summer is an important factor in producing injury in raspberries. "This view would assign immaturity as the immediate antecedent of the injury, and, at the same time, recognize that the older canes of the current season would be most liable to second growth and hence actually less mature in the fall."

Locklin (17) states that "most injury can be laid to fall freezes coming before the cane tips have ceased growth and to low winter temperatures occurring in weakened fields. When the canes are properly mature it is seldom that temperatures low enough to cause serious damage have occurred in western Washington". The fact that Cuthbert, which is the variety most subject to injury in western Washington, is slow to drop its leaves in autumn and is most likely to react to growing conditions, supports these conclusions.

Thornber (25) and Taylor (23) state that raspberries are freer from injury if grown on a moderately dry soil.

Teske and Gardner (24), reporting the results of a field survey of a number of Michigan plantations, say that "invariably winter injury was found in the low-lying fields or localized in depression 'pockets' or 'draws' in plantations otherwise free from trouble of this kind".

Harris, East Malling (13), reported more killing on low ground where there was more water.

Brierley (4) states that rapid resumption of growth after heavy rains led to the conclusion that the red raspberry is very sensitive to variations in the moisture supply of the soil.

Bregger (2) reported that deep cultivation, when continued throughout the life of the plantation, was apparently highly favorable.

Slate and Rankin (21), on the other hand, say that "raspberries are shallow rooted and easily injured. Four inches is sufficiently deep (for cultivation) and it is advisable to shorten the cultivator teeth next to the plants". They also advise not continuing cultivation much beyond the picking season as "the growth stimulated by late cultivation will not mature sufficiently to withstand the winter". In addition, Slate and Rankin point out that "cover crops are rarely used in raspberry plantings in this State (N. Y.) but they are useful and deserve the attention of every grower. Not only do they add considerable humus to the soil, but what is more important, they aid very materially in ripening the canes by competing with them for food and moisture during the fall, thus preventing rank growth and consequent winter injury".

Hilton (15) concludes that cultural methods similar to those used with tree fruits, which reduce moisture in the soil in the fall would likewise have the same effect upon hardening raspberries. Although similar advice has frequently been given by other workers but little direct experimental evidence has been brought forward to prove definitely the value of such a general recommendation. Lott (18) found that a cover crop of oats materially increased the hardiness of raspberry canes but this seems to be the result for one season only and he does not state what the moisture conditions in the fall were. The winter in question was characterized by severe freezing near the end of December, at which time most of the injury in the field took place. Freezing injury at this date when the canes had possibly not yet had their rest period broken could quite justifiably be laid to immaturity of the canes, but often raspberries are found injured when no such definite killing freeze has been experienced early in winter and when autumn conditions have been such as to lead one to believe that immaturity was not a factor.

Hilton found that the canes, or parts of the cane, most resistant to artificial freezing in the laboratory had slightly lower moisture content and a slight increase in pentosan content over less resistant samples. Also, Lott found a close degree of correlation between observed hardiness, the percentage of bound water in the tissues, and the percentage of pectin present. In other words, canes attain a "hardened" condition, as evidenced by their chemical or physico-chemical constitution, which is related to their ability to withstand freezing; but whether or not ordinary cultural factors are important in inducing this hardened condition appears to be somewhat open to question. Moreover, in many cases it appears doubtful whether the degree of hardiness is of prime importance in assisting the plants to escape winter injury.

It seems likely that natural weather conditions often play a far more important part than artificial cultural treatments and indeed would, in such cases as extremely dry summers followed by wet autumns, or vice versa, outweigh any effects of applied cultural treatments, except possibly in irrigation districts. Therefore it would appear that broad general recommendations regarding the alleviation of winter injury by cultural practices are of doubtful value and should be preceded by more careful inquiry into specific conditions.

A COMPARISON OF WINTER INJURY IN DIFFERENT SEASONS AT VINELAND STATION, ONTARIO

In order to gain further knowledge of the conditions under which winter injury actually occurs in the Niagara district of Ontario, graphs of the maximum and minimum daily temperatures were compiled, together with a record of the daily precipitation, for several winters for which notes on winter injury were available.

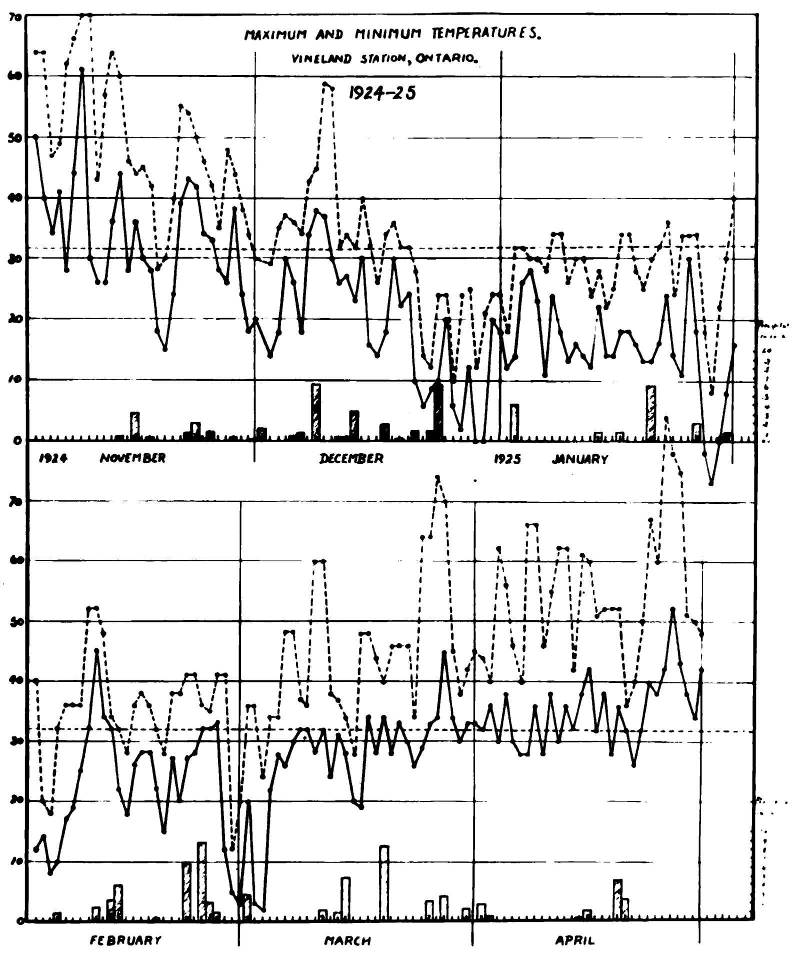
<u>Season of 1924-25</u> Notes on winter injury for this season were obtained from work done by W. H. Upshall (26) on Cuthbert raspberries at Vineland Station, Ontario. He states that "winter injury was rather severe, though no more so than commonly occurs other years". Rating the canes from 1 to 10, with 1 indicating very slight injury and 10 indicating a completely dead cane, the check canes received a mark of 5. It is presumed therefore that the canes were about 50 per cent injured in this season.

The fall of 1924 was exceptionally dry in the Niagara district. Upshall says, "It is possible that there was an actual deficiency of water or at least that the soil water was not easily absorbed. Then again the canes may have absorbed plenty of water but may have lost it too rapidly in respiration or by evaporation; in other words the water-holding power of these canes may have been low."

The winter was generally characterized by steady low temperatures. The temperature dropped to zero on several occasions in the latter part of December and to -2° and -7° on January 27 and 28. The lowest autumn temperature was 15°F on November 18. In spring the lowest temperatures were 3° and 2° on March 2 and 3 and 19° on March 16. There were no severe cold days in the latter part of March or in April.

<u>Season of 1930-31</u> This winter followed an exceedingly dry summer and fall. The total rainfall for November was only .71 inches, as compared with a 1916-1932 average of 2.48 for the same month. Every month from April to November, inclusive,

Figure 1


MAXIMUM AND MINIMUM TEMPERATURES.
VINELAND STATION, ONTARIO.
1924-25
1924 NOVEMBER
DECEMBER
1925 JANUARY
FEBRUARY
MARCH
APRIL

was below normal in rainfall.

Examination of the temperature graph shows extreme temperature fluctuations at the end of November and beginning of December. The temperature dropped steadily for four days to a minimum of 13° on November 28 and 29. This was followed by a rapid rise to well above freezing, accompanied by rain. On December 2 the temperature had again reached a minimum of 9°. After a steady climb the temperature again descended to 6° on December 16.

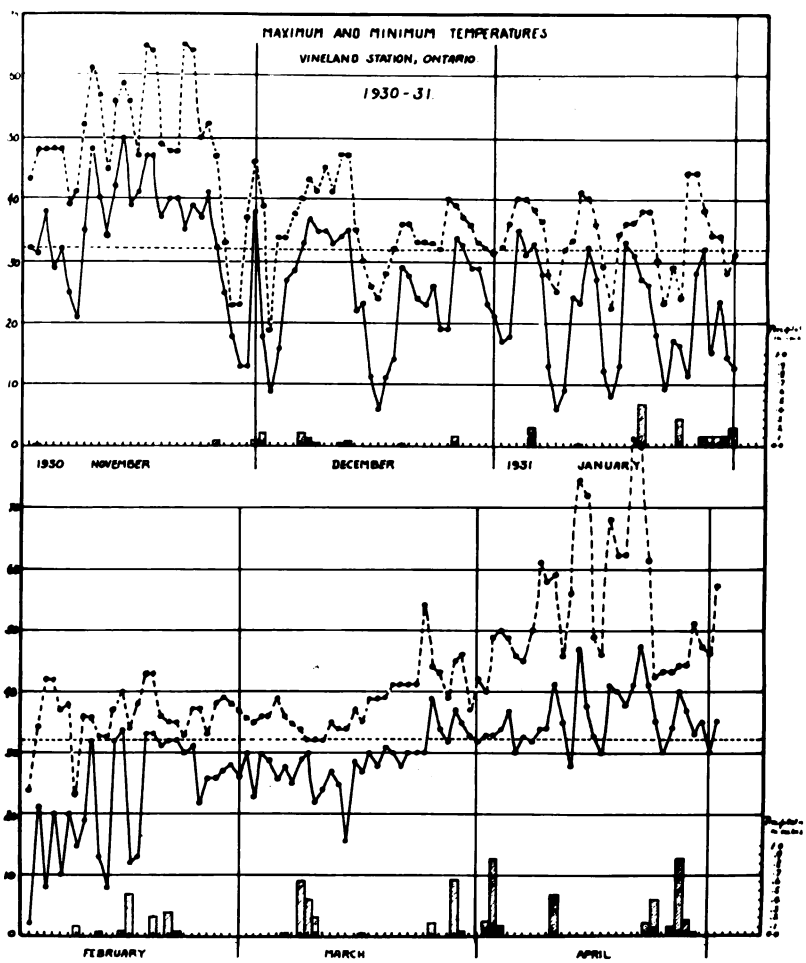
January and February were characterized by fairly steady low temperatures, reaching a minimum of 3° on February 1. From the middle of February the minimum temperatures gradually ascended to above freezing by the end of March and dropped no lower than two or three degrees below freezing from then on.

The winter injury to raspberries was comparatively slight in the Niagara district. Measurements made at Vineland Station showed an average length of cane for 217 canes of Viking of 5.4 feet with an average of 1.0 ft. killed back or injured, or 18.5 per cent injury.

<u>Season of 1931-32</u> Although the winter of 1931-32 was exceptionally mild, many raspberry plantations in the Niagara peninsula suffered rather severe killing back of the canes.

An examination of the weather conditions shows that on March 9 the temperature dropped to 8°. This was a steady drop accompanied by high winds over a period of three days. Immediately before this the minimum temperature had remained at or above freezing for a week, the maximum temperatures for the

Figure 2


MAXIMUM AND MINIMUM TEMPERATURES
VINELAND STATION, ONTARIO
1930-31
1930 NOVEMBER
DECEMBER
1931 JANUARY
FEBRUARY
MARCH
APRIL

same week ranging from 47° to 36°.

Two other brief drops in temperature had occurred on December 31 and February 16, with readings of 11° and 13°, respectively, both occasions being immediately preceded by high temperatures between 50° and 65°.

Except for several other temporary drops to slightly below 20° during December and February, the winter was characterized by warm weather, the temperature in many cases remaining above freezing for several days at a time. There were no sudden drops in temperature after the middle of March.

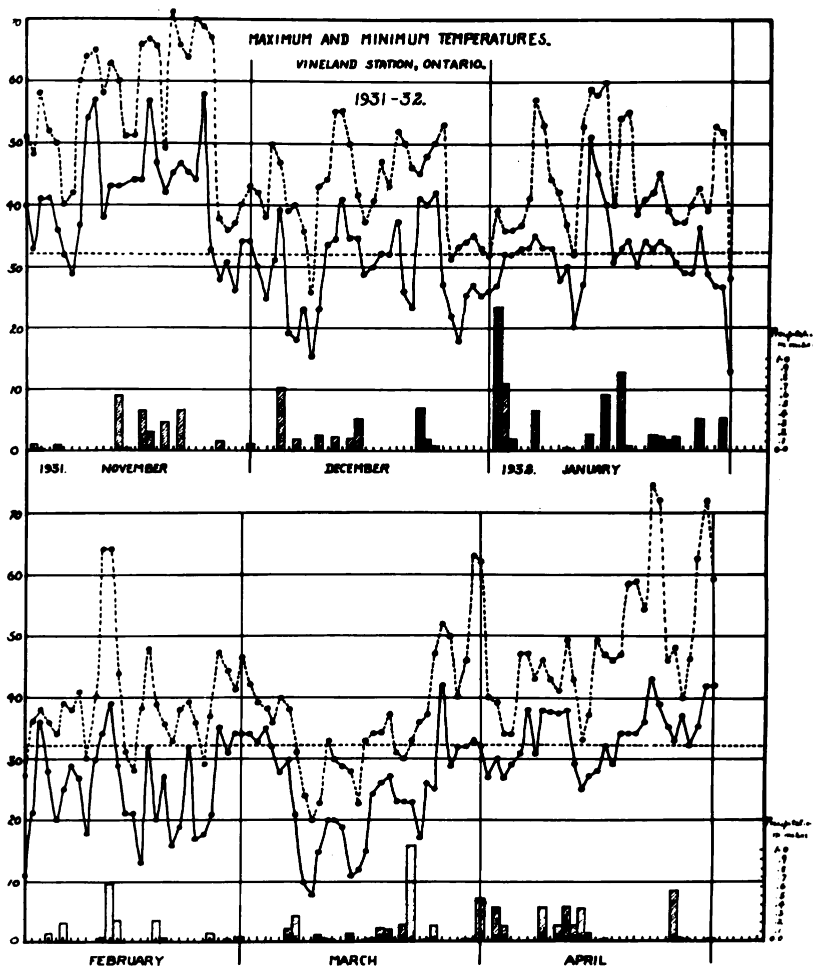
The injury in the Viking block at Vineland Station was more severe than in the same block in the preceding year, but not as severe as in many commercial plantations in the district.

In November, 1931, there were several reports of second crops of raspberries due to the warm moist autumn.

Season of 1932-33 The winter of 1932-33 was comparatively mild, with many days of warm weather occurring in January and no very sudden and severe drops in temperature except in February when the temperature dropped from a maximum of 45° on the 7th to -2.0° and -2.7° on the 9th and 10th. A period of daily precipitation for all of the first week of February was concluded by nearly half an inch of rainfall on the 7th; this preceded by two days a drop to -2°F.

At Jordan Station, Ontario, several raspberry plantations showed a scattering of more or less completely dead canes throughout the rows. In one or two instances where careful examination was made the injury was situated chiefly at, or just above, the

Figure 3


MAXIMUM AND MINIMUM TEMPERATURES.
VINELAND STATION, ONTARIO.
1931-32.
70
60
50
40
30
20
10
0
1931. NOVEMBER
DECEMBER
1932. JANUARY
FEBRUARY
MARCH
APRIL

crown and seemed to be due to an excessive amount of surface water lying on the ground just previous to the severe freeze of February 9 and 10. In other instances the origin or location of such injury was not so apparent. Reports were received of numbers of plantations in eastern Ontario and Quebec suffering from extensive injury of a type apparently similar to that of the Jordan area. Where this scattering of completely killed canes did not occur there was only a very slight dying back of the tips. In general, it can be said that the typical tip injury was not predominant this season, i.e., the canes were not killed back but were rather killed up from a point near the base.

The block of Vikings at Vineland Station seemed to have good surface drainage and only very slight tip injury occurred. In this year, weather records and location of the injury suggest severe freezing of wet tissues as the primary factor.

SUMMARY OF THE FOUR SEASONS STUDIED

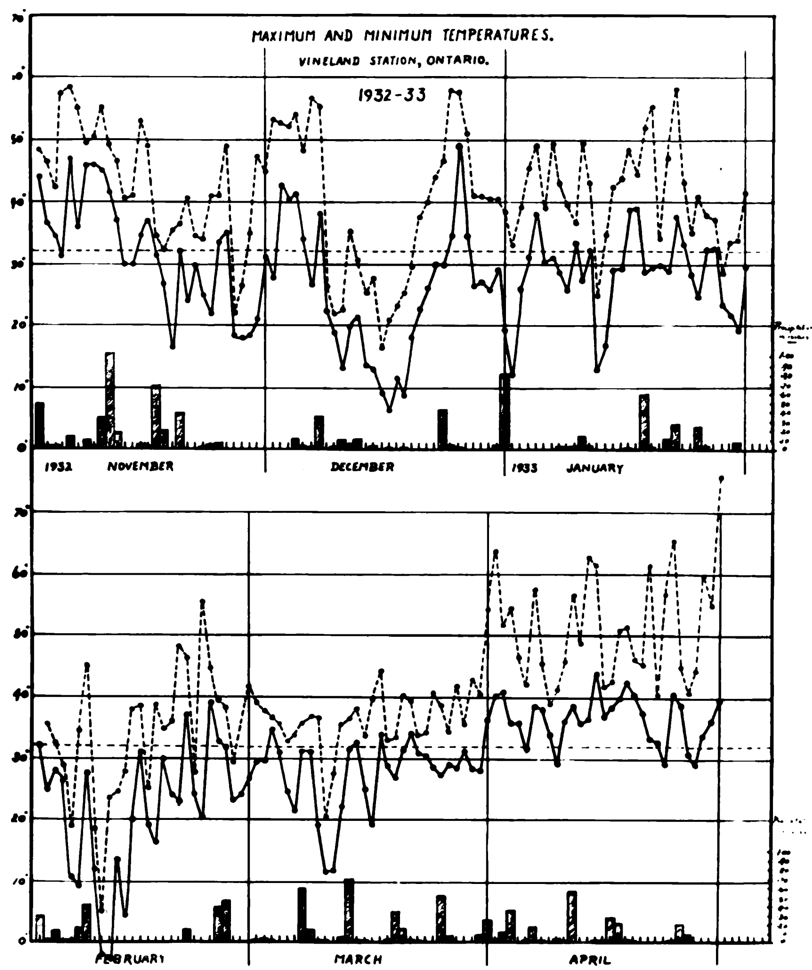
1924-25 A very dry summer followed by long continued moderately severe cold in late December and parts of February with severe cold at the end of February.

Rather heavy injury.

1930-31 A very dry summer and exceptionally dry November followed by a moderately cold winter with fluctuating low temperatures in December, January, and early February.

Comparatively light injury at Vineland Station.

Figure 4


MAXIMUM AND MINIMUM TEMPERATURES.
VINELAND STATION, ONTARIO.
1932-33
1932 NOVEMBER
DECEMBER
1933 JANUARY
FEBRUARY
MARCH
APRIL

<u>1931-32</u> A very warm November followed by a very mild winter. The most severe drops in temperature were to 11° and 13° at the beginning and middle of February, following maximum temperatures of 50° or 60° for two days previously in each case.

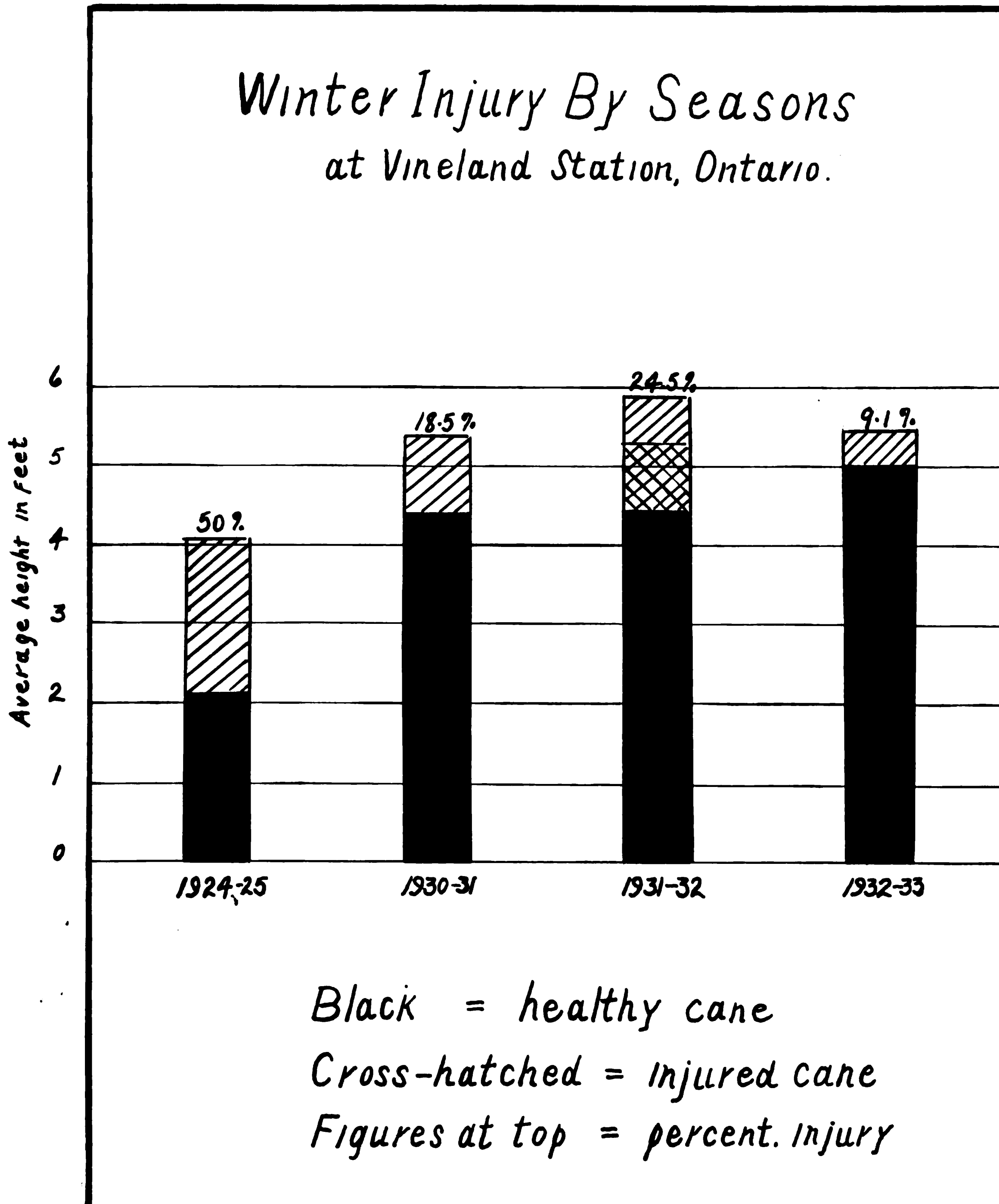
Distinctly heavier injury than in 1930-31, which was a much colder winter.

<u>1932-33</u> Another very mild winter. A drop to 12° on January 1, following warm weather. A drop to -2.7° on February 9 and 10 following a wet day.

Ordinary tip injury less than in any of the other three years at Vineland, but injury occurred to the crowns and bases of canes in other localities.

The conclusion to be reached from this study of injury in different seasons is that the general severity of the winter is often not a clue to the amount of injury to be expected. Long continued cold appears to be conducive to fairly heavy injury. Sudden drops in temperature following warm conditions may or may not cause considerable injury; or injury of varying types may be encountered according to the moisture conditions of the soil. In none of the winters studied could it be said that late fall or very early winter freezes were a definite cause of injury. In 1930-31 when such injury might possibly have been expected at the end of November the injury recorded was rather light. The injury of the winter of 1931-32 may on circumstantial evidence be attributed to immaturity.

Figure 5


Winter Injury By Seasons
at Vineland Station, Ontario.
Average height in feet
0
1
2
3
4
5
6
50%
18.5%
24.5%
9.1%
1924-25
1930-31
1931-32
1932-33
Black = healthy cane
Cross-hatched = injured cane
Figures at top = percent. injury

Although many facts seem to point to the conclusion that the combination, or sequence, of weather conditions during the winter season has more to do with winter injury to raspberries than either the actual severity of the winter or the cultural treatments of the plants, yet, in the four seasons studied, the heaviest killing back of canes did occur in the 1934-35 season, which was a season of long continued cold.

The evidence indicates that this season was probably very conducive to the "winter-drying" of canes so often mentioned in the literature. The canes went into winter with a low supply of water in the soil. The long period of cold without excessive precipitation produced drying atmospheric conditions. The frozen condition of the soil may have prevented the canes from taking up the water necessary to replace that lost.

In view of this fact an experiment was planned to study the effect of the prevention of moisture loss from the canes by means of wax sprays.

GENERAL PLAN OF EXPERIMENTAL WORK

R. A. Emerson (11) had coated raspberry canes with paraffin wax and found little or no injury on the protected canes. In this experiment a paraffin wax emulsion, developed at Michigan State College, which could be sprayed on, was used.

The first work was done at East Lansing in the autumn of 1931. Canes of three varieties, Viking, Cuthbert, and Latham were sprayed with wax emulsion, applied with a small wheelbarrow type of sprayer.

Samples of the sprayed and unsprayed material were taken throughout the winter season. Determinations of the total moisture content were made and the samples were preserved for chemical analysis. Determinations of various carbohydrate fractions, lignocellulose, lignin, and pectins were later made at Vineland Station.

In addition to the spraying experiments started at East Lansing and carried on at Vineland, several other experimental treatments were carried on. These involved thinning out the canes, which were grown in the hill system, to 1, 2, 3, and 6 canes per hill; also summer and fall pruning of the canes, late cultivation of a number of hills with application of nitrate in order to retain the foliage as long as possible. These were used as supplementary experiments chiefly to gain pointers for future work. No conclusive evidence of effect on winter injury was obtained from any of these "side" experiments but a careful analysis of various observations and measurements of winter killing did bring to light some interesting facts.

EXPERIMENT ON RATE OF WATER LOSS FROM DETACHED CANES

Material supplied through the kindness of Mr. W. J. Strong, of the Experiment Station at Vineland, was so analyzed as to show the loss of water. Canes were cut November 19, 1931, and sealed at the ends and hung in a natural position outside all winter. Ten canes each of eight varieties were used, and each cane was weighed at frequent intervals through the winter.

Figure 6 shows distinct varietal differences in rate of water loss. The varieties used also differed considerably in average size of cane, but apparently size of cane and variety each has an independent effect on rate of water loss. Viking, which was the largest-growing variety, had the slowest rate of water loss while Herbert, which was the smallest, had a rate greater than that of Lloyd George, which was intermediate in size.

To study more closely the effect of size of cane on water loss the individual canes of all varieties were grouped according to their original weights into: (1) large branched canes, (2) small branched canes, (3) large unbranched canes, and (4) small unbranched canes. The data showed that after four days, during which considerable moisture loss took place, the greatest difference between any of these groups was between large branched canes and small unbranched canes, with mean water losses, respectively of 9.84 and 15.78 per cent, a difference of 5.94 per cent. The probable error of the difference was only 1.213; therefore this difference seemed to be significant. The least difference was between small unbranched canes and small branched canes with mean water losses of 15.78 and 14.02 per cent. Since the difference, 0.76, is less than the probable error of the difference, 1.234, this difference is not significant.

After 122 days the greatest difference between any of the groups was between large branched canes and small unbranched canes, with mean water losses of 48.84 and 47.64 per cent, respectively. Since the difference, 1.20, is less than three times

the probable error of the difference, .733, this difference is probably not significant.

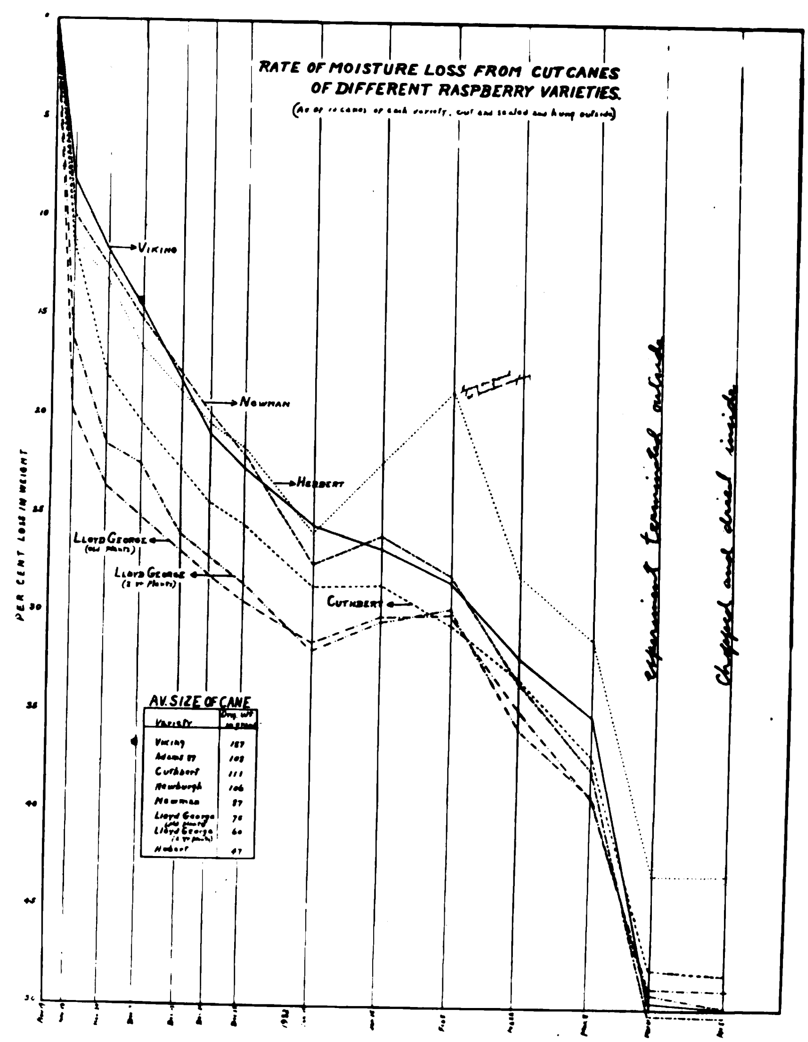
The various groups arranged in order are as follows:

	Per cent water loss after 4 days
Large branched canes	9.84 ± .482
Large unbranched canes	13.20 ± .835
Small branched canes	14.02 ± .533
Small unbranched canes	15.78 ± 1.113

The fact that large branched canes showed less rapid water loss than small branched canes or unbranched canes upsets somewhat the hypothesis that large canes are more subject to the drying out type of winter injury because of their greater height and more exposed surface causing them to become depleted of water more readily. This led to the question, do the larger canes actually suffer a greater percentage of injury? An affirmative answer was given by the study of winter-killing measurements made on a large number of individual canes in two different seasons, as will be shown later.

Hildreth (14) had concluded, from a similar drying experiment on apple twigs done in 1924-25, that cold winter weather may have relatively little evaporating effect on twigs. The measurements made at Vineland on the loss of water from cut and sealed canes of raspberry showed that the rate of water loss was considerably faster, particularly in the initial stages, than with the apple twigs studied by Hildreth. Moreover, the loss with raspberries continued until the canes were completely dry and dead.

Figure 6


RATE OF MOISTURE LOSS FROM CUT CANES
OF DIFFERENT RASPBERRY VARIETIES.
VIKING
NEWMAN
HERBERT
LLOYD GEORGE
LLOYD GEORGE
CUTHBERT
PER CENT LOSS IN WEIGHT
AV. SIZE OF CANE
Variety
Viking
Adams 87
Cuthbert
Newburgh
Newman
Lloyd George
Lloyd George
Herbert
Experiment terminated outside
Chopped and dried inside

Hilton (15) found that by directing a current of air upon raspberry canes in the laboratory he was able to obtain injurious effects similar to those often encountered in the field after more or less severe winters.

The conclusion, therefore, to be reached from a comparison of raspberry with apple is that winter desiccation has far greater possibilities of being a serious factor with the raspberry than with apple.

LENGTH OF CANE IN RELATION TO AMOUNT OF INJURY -- 1931

In the spring of 1931 individual measurements were made on 217 canes of Viking. The total length of each cane was recorded together with the length of the dead portion. The measurements were made in spring after the buds had had ample time to exhibit signs of growth. Table 1 presents a summary of the measurements.

Table 1. Length of Cane in Relation to Amount of Injury --1930-31
(Canes grouped according to length)

	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
Total number of canes	12	18	35	54	58	33	7
Number of canes uninjured	12	17	23	30	28	10	1
Number of canes injured		1	12	24	30	23	6
Per cent of canes injured	0	5.6	34.3	44.4	51.8	69.6	85.7
Average length of dead portion, in feet		1.5	1.4	1.7	2.3	3.1	4.3
Injury expressed as per cent of total cane length			35.0	34.0	38.3	44.3	53.7

Not only was the absolute amount of injury in the tall canes greater than in the medium and small canes but also the actual percentage of injury was greater. This is in agreement with experiments that show that the removal of the first two crops of young canes reduces the amount of winter injury, since most of the canes over 6 feet in height had originated early in the season.

It must be borne in mind that the injury measured in this particular experiment was of the typical tip-killing kind which is variously attributed to immaturity and to drying out. The peculiar significance of this occurrence lies in the fact that it followed a summer and fall of extraordinarily light rainfall, when maturity as usually understood, should have been excellent. As pointed out elsewhere there are frequently seasons when killing originates near the ground level and results in injury more serious than this type.

LENGTH OF CANE IN RELATION TO AMOUNT OF INJURY -- 1932

In the spring of 1932, individual cane measurements again were made, this time on 272 canes of Viking. The measurements were taken after the canes had started into growth so that badly weakened buds showing feeble growth could be clearly distinguished from those of full vigor or those completely dead. For each cane was recorded, in feet, the length of uninjured cane, the length of weakened, or partially injured section, and the length of completely dead cane. Table 2 summarizes the results.

Table 2. Length of Cane in Relation to Amount of Injury --1931-32

(Canes grouped according to length)

	2-3 ft.	3-4 ft.	4-5 ft.	5-6 ft.	6-7 ft.	7-8 ft.	8-9 ft.
Total No. of canes	12	11	46	80	67	44	12
Av. length of injury per cane in feet	0.0	.25	1.01	1.52	2.14	2.85	3.31
Av. per cent total injury	0.0 (± 0)	6.30 (±2.73)	20.16 (±1.73)	25.35 (±1.13)	30.60 (±1.51)	35.68 (±1.27)	36.77 (±2.38)

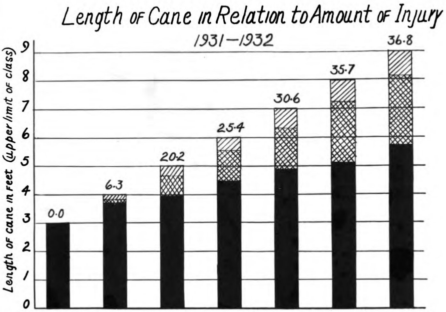
Table 3 summarizes the injury in like manner except that only the completely <u>dead</u> part of the cane is considered instead of weakened plus dead part. Figure 7 combines tables 1 and 2 in graphic form.

Table 3. Length of Cane in Relation to Amount of Completely Dead Cane -- 1931-32

(Canes grouped according to length)

	2-3 ft.	3-4 ft.	4-5 ft.	5-6 ft.	6-7 ft.	7-8 ft.	8-9 ft.
Total No. of canes	16	14	67	141	117	73	23
Av. length of dead part per cane in feet	0	0.19	0.36	0.48	0.69	0.78	0.87
Av. length of dead cane expressed as percentage of the cane length	0	4.7	7.2	8.0	9.9	9.8	9.7

Figure 7



Figures at top of columns = percentage total injury
Single cross-hatched = dead part
Double cross-hatched = weakened or partially injured
Solid black = healthy cane

NUMBER OF CANES PER HILL IN RELATION TO WINTER INJURY -- 1931-32

The average percentage of injury per cane for plants with 4, 5, 6, and 7 canes per plant is shown in table 4.

Table 4. No. of Canes per Hill in Relation to Winter Injury 1931-32

Plants with	Percentage of cane length	
	Injured	Completely dead
4 canes per plant	19.2 ± 1.60	6.0 ± .436
5 canes per plant	21.9 ± 1.68	7.3 ± .653
6 canes per plant	26.2 ± 1.83	10.0 ± .897
7 canes per plant	31.6 ± 2.37	10.7 ± 1.39
8 canes per plant	26.9 ± 2.87	10.1 ± 2.44

Plants with fewer than four canes and over seven canes (up to 11 canes) were not numerous enough to warrant conclusions. Their means did not follow any particular trend.

The plants with the greater number of canes were probably the more vigorous. The fact that these suffered the greater injury indicates that weak plants may not necessarily be the most susceptible to injury.

The autumn of 1931 has been mentioned as characterized by a considerable amount of late growth. It is therefore of high interest that the distribution of injury is essentially the same as that following the dry autumn of 1930.

±	±
±	±
±	±
±	±
±	±

EXPERIMENT ON REMOVAL OF OLD (FIRST FORMED) CANES IN SUMMER

All new canes tall enough to protrude above the fruiting canes were cut out of a row of Vikings July 3, 1932. At this date the first berries were just beginning to ripen.

The following spring, none of the canes on the treated row were dead for more than a few inches at the top, while several canes on each of the adjoining rows were killed back from one to two feet and a number were killed back more than six inches.

When examined on June 6, 1933, just when the first flowers were beginning to open the average height of the treated row was practically the same as that of the adjoining rows except that there were no nine- and ten-foot canes scattered through the row. Most of the vigorous canes were about five or six feet tall and appeared to have better growth of fruiting laterals than the large canes of the adjoining rows, although it is possible that the check plants bore more lower laterals which were not so conspicuous.

Table 5 shows that the average length of injury per cane was less in the treated row and also that the percentage of uninjured canes was lower.

Table 5. Winter Injury After Removal of the First Formed Canes in Summer, 1932 - 33.

	Treated Row	Adjoining Rows	
		North side	South side
Total No. of canes in row	170	131	150
Total No. of canes injured	19	17	16
Av. length of injury, in inches	2.68	7.18	5.06

EXPERIMENT ON REST PERIOD OF VIKING RASPBERRY -- 1932 - 33

Observations were made to determine the approximate duration of the rest period.

Samples of canes were cut at intervals from November 23 to January 3 and placed in vessels of water in the greenhouse at a temperature of about 70°F. Each lot was left in the greenhouse until shoot growth had ceased and the canes were dead. Notes were made as follows:

Sample Brought in November 23 Canes were evidently in a complete resting condition at this date since no bud activity occurred in eight weeks or more, except in one cane which was exposed to outside temperatures by poking the tip through a hole in the greenhouse. A 12-bud section of the tip was exposed for 9 days (December 3 to December 12) and breaking of some of the buds (down as far as the 15th bud) occurred by January 6 on this cane.

Sample Brought in December 7 No activity after 30 days (January 6). One bud had burst on one small cane after 33 days. Some canes were still completely inactive after 35 days. Only weak bud development had occurred by end of January (55 days).

Sample Brought in December 15 One cane showed signs of buds swelling after 22 days. Remainder of the canes were still inactive after 27 days. Scattered bud activity occurred after 30-35 days. No buds had made any appreciable growth after bursting, even after 47 days.

Sample Brought in December 23 No activity after 14 days. Buds bursting after 19 days. Had made only weak growth after 35 days.

Sample Brought in January 3 Had made moderately vigorous shoot growth by the end of three weeks. This was about the same rate of growth as was exhibited by later samples taken February 25. Canes brought in April 4 required only two weeks to reach a similar stage of shoot development.

It was noticed in some of the samples brought in in December that egg-laying punctures of the snowy tree cricket caused a marked stimulative effect on the opening of the buds above the injury.

The conclusions from these observations are that the Viking raspberry, under 1932-33 conditions, is in a deep resting condition by late November, that the resting period is partly broken by late December and probably completely broken early in January.

Locklin and Hardy[1], in noting that Cuthbert reacts readily to growing conditions, suggest a causal relationship between profoundness of rest period and susceptibility to freezing injury.

The above experiment shows that it is very unlikely that Viking would suffer from premature starting in late fall or very early winter.

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1. Locklin, H. D. and Hardy, Max B. Artificial freezing of red raspberry canes. Wash. Bul. 260, p. 45. 1932.

A further observation on maturity conditions of the cane was obtained in 1932-33 by comparing a number of Viking canes which had retained their foliage at the tips until comparatively late in fall with a number of canes, of similar size and general appearance, that dropped all their foliage comparatively early. No difference in tip injury was observed.

EXPERIMENT ON ARTIFICIAL FREEZING OF CANES TAKEN FROM THE FIELD DURING WINTER -- 1932-33

On February 25, 1933, Viking canes were taken from the plot at Vineland Station. They were cut at 10:45 A. M., placed in water for two hours on arrival at Guelph at 1:30 P. M. and half of them were then placed in cold storage at 3°F for approximately 40 hours.

When taken out of the cold storage room they were distinctly shrivelled on the surface, particularly at the basal end, though the tip section for 12-20 inches showed scarcely any shrivelling. After the bases had been wrapped in moist burlap for 2½ hours the shrivelling had disappeared and the canes resembled the check canes which had been kept standing in water without freezing.

<u>Examination of Canes on March 2, 1933</u> There was apparently much more bud injury on treated canes than on the check canes. The tips of the buds appeared dried out and dead, although they showed little discoloration. The bases of the buds showed considerable discoloration. The buds on the checks showed some slight discoloration; particularly those from the base of the

canes, this being due, no doubt, to the freeze of February 10. The check canes also show slight signs of browning of the cambium in the top section. It is noteworthy that many of the canes as brought in from the field showed a poor appearance of the cambium in the top half or top third of the cave with healthy appearing buds, while the relative condition of buds and cambium appeared to be reversed in the lower half of the cane. The canes kept in the cold storage showed browning of the cambium throughout and in more severe degree.

On March 13, 1933, only two out of 12 frozen canes showed any signs of life after being kept in water in the greenhouse. A few buds were feebly bursting on these two canes. All unfrozen check canes were bursting fairly uniformly along the cane.

The Effect of -2.7°F in the Field, 1932-33 Examination was made February 15, 1933, five days after the severe freezing weather of the 9th and 10th when the temperature dropped to -2.7F.

The canes in general showed no signs of injury to the buds on the tip section (about 25 bud section). The bottom $1\frac{1}{2}$ foot sections showed a certain amount of browning or discoloration about the "neck" of the buds--apparently mostly in the vascular system. Some rusty brown discoloration of the pith in this region also occurred. The ground at this time was fairly well frozen. Some canes to which wax had been applied in the fall were included in this study.

In the waxed canes (basal section) there was more injury than in unwaxed canes. Five representative waxed canes had an average of four buds out of five examined showing browning as compared with an average of two or three discolored buds on unwaxed canes, with the remaining two or three buds showing no injury or only extremely slight indications of injury. Superficial examination of an additional number of canes bore out these observations.

This behaviour of the canes is possibly attributable to the fact that the base of the cane is more liberally supplied with water than the tip and in the waxed cane this condition is accentuated by partial prevention of evaporation. Hence a larger amount of free water in the vascular system of the region injured might account for freezing injury in these places. Late spring observations showed that the canes apparently made good recovery from most of this injury.

A COMPARISON OF ARTIFICIALLY FROZEN CANES WITH THOSE FROZEN UNDER FIELD CONDITIONS

A comparison of those canes which had undergone a temperature of -2.7^{o} in the field with those artificially frozen at 3^{o}, or over five degrees higher, substantiate the theory that the presence of free water may be an important factor with certain types of freezing injury. The artificially frozen canes had liberal opportunity to take up free water immediately before freezing and showed severe injury as compared with slight injury previously suffered in the field at a lower temperature. However, it is probable that the rapidity of the artificial freezing may have been important in causing injury.

Whether it was rapidity of freezing or increased amount of water that increased the injury, this particular experiment does not indicate desiccation as a factor concerned.

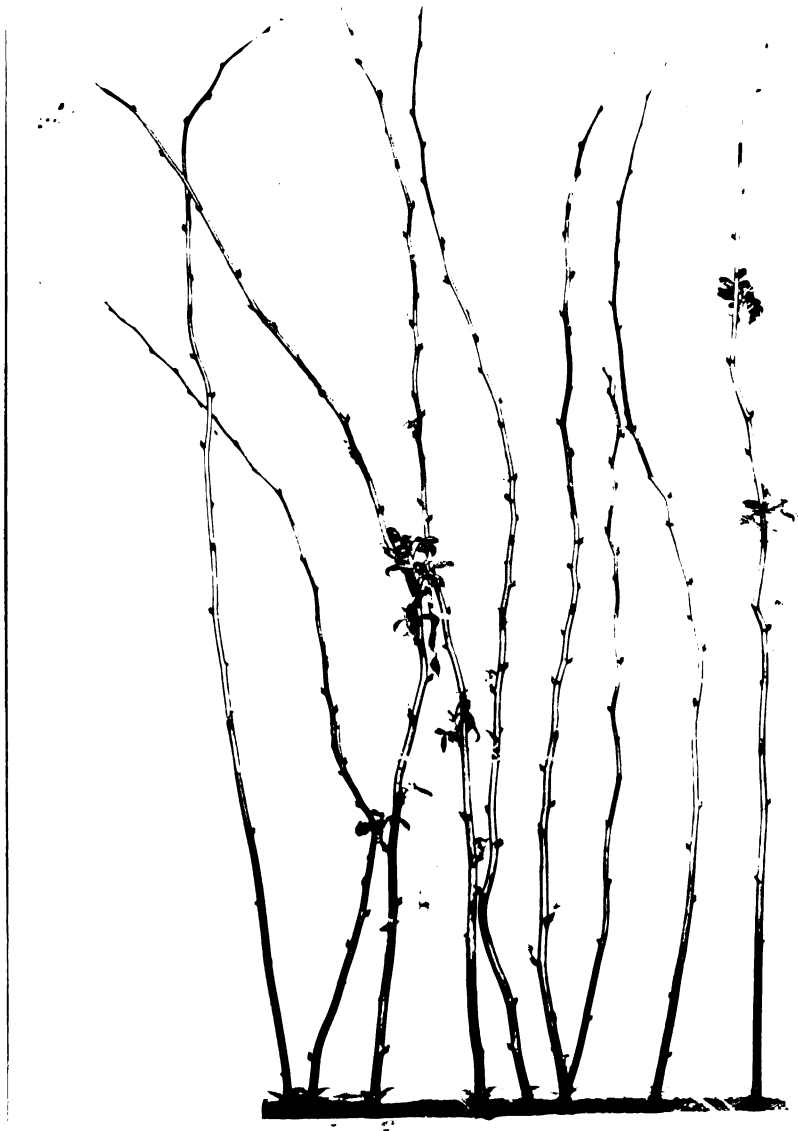
The experience in a raspberry plantation at Jordan Station, Ontario, also points to the effect an excessive supply of free water may have on susceptibility to freezing. In the particular field observed, there was an unusual amount of surface water lying in the field (due to a blocked ditch) immediately before the severe February freeze. In the spring there was a heavy scattering of completely dead canes throughout the plantation. Examination showed marked discoloration and browning, particularly noticeable in the pith, at, or for a few inches above, the crown. The tissue above this area was mostly only dried and dead but not discolored. It is highly probable that the injured part of these canes was in a very water-soaked condition shortly before the freeze. In a great many cases the injury appeared not to extend down into the crown or roots.

This observation though primarily indicating the greater susceptibility of water-soaked tissue, indicates just as clearly that the upper portion of the cane may die from dèsiccation under extreme conditions. Since the upper portions were dead before the close of the dormant season, lack of water, rather than of nutrients, seems indicated.

Figure 8

Viking canes cut Febuary 25, 1933.
Photographed March 25. Untreated.

Figure 9



Viking canes cut February 25, 1933.
Photographed March 25. Frozen in cold
storage room at about 3°F for 40 hours.

SPRAYING EXPERIMENT ON RASPBERRIES AT EAST LANSING -- 1931-32

As a study of the possible effects of decreased desiccation, certain canes at East Lansing were sprayed with a wax emulsion. The material used was a compound developed by Dr. E. J. Miller at the Michigan State College and containing:

Water, 100 parts by weight
Paraffin wax, 10 parts
Ammonium linoleate, 3 parts
Bentonite, 3 parts

This was applied from a small wheelbarrow type of sprayer.

The spray was applied on December 3 to two sections of a row of Vikings and to part of three rows of Cuthbert and two rows of Latham. About 40 feet of each row were treated and the remaining parts of the rows acted as checks.

Previous to the date of application only mild freezing weather had been encountered, chiefly at night. The temperature was between 45° and 50° F at the time of application but fell to as low as 5° or 10°F a few days later

Method of Sampling At least 10 canes of uniform size and representative of the row were taken at random from each lot. The bottom 18 inches of each cane were discarded and a one foot section immediately above that was used as a sample. With Latham, only 12 inches of the base of the canes were discarded, because of their shortness. The buds were removed, the wax removed by gentle scraping and the sample cut into one-fourth or three-eighth inch pieces, and weighed. This was done with as little delay as possible. The material was heated at 90°C for 45 minutes, then dried at 70°C to constant weight.

The wax was removed from later samples by holding each portion of cane under a stream of hot water for two or three seconds and then quickly wiping with a dry cloth. It was found by experiment that the quantity of water absorbed was not sufficient to affect the fresh weight when the sample was weighed about ten minutes later.

Samples were taken January 6, February 12, February 29, April 3, and May 3, 1932.

On April 23, it was found that the raspberries in this experiment had been pruned; hence the amount of injury could not be measured. Previous casual observation indicated, however, that it had been rather light in the whole block.

At the time the last samples were taken the Viking buds were just beginning to burst. Cuthbert and Latham were slightly more advanced.

The moisture content at this time was in the same order as the opening of the buds, as follows:

In order of opening --	Cuthbert,	Latham,	Viking
Moisture content --	51.1%	48.1%	43.2%

SPRAYING EXPERIMENT ON VIKING RASPBERRIES AT THE HORTICULTURAL EXPERIMENT STATION, VINELAND STATION, ONTARIO -- 1932-33

Spraying with wax emulsion was done on November 14, 1932, in a manner similar to that followed at East Lansing in the previous season.

The temperature was 53°F at the commencement of spraying but had dropped to 45°F at 4:45 P. M. when spraying was completed. Practically no freezing temperatures had been recorded before the date of spraying, but several days of cold weather followed soon after the first spray was applied. On November 25 the weather had turned warmer and an application of raw linseed oil emulsion (about 10% strength) suggested by Swartwout of Missouri (correspondence) was given to a second lot of canes. On November 30, which was warm and sunny, the first lot of canes was resprayed with wax emulsion as some of the wax had disappeared from the north side of the canes.

On April 4 examination of the canes in the experimental block showed little sign of injury. Most canes showed little or no sign of drying out at the tips, but on the bottom half of the canes the basal part of the buds showed internal discoloration in many cases.

There was no significant difference between waxed and unwaxed canes in the amount of injury in this season, partly because of flaking off of the wax, which may have been due to cold weather immediately after application, and partly because only slight injury was present in the whole block.

More than half of the treated canes had practically no tip injury and the remainder had two or three inches of dead tip with one cane exhibiting 15 inches of dead tip.

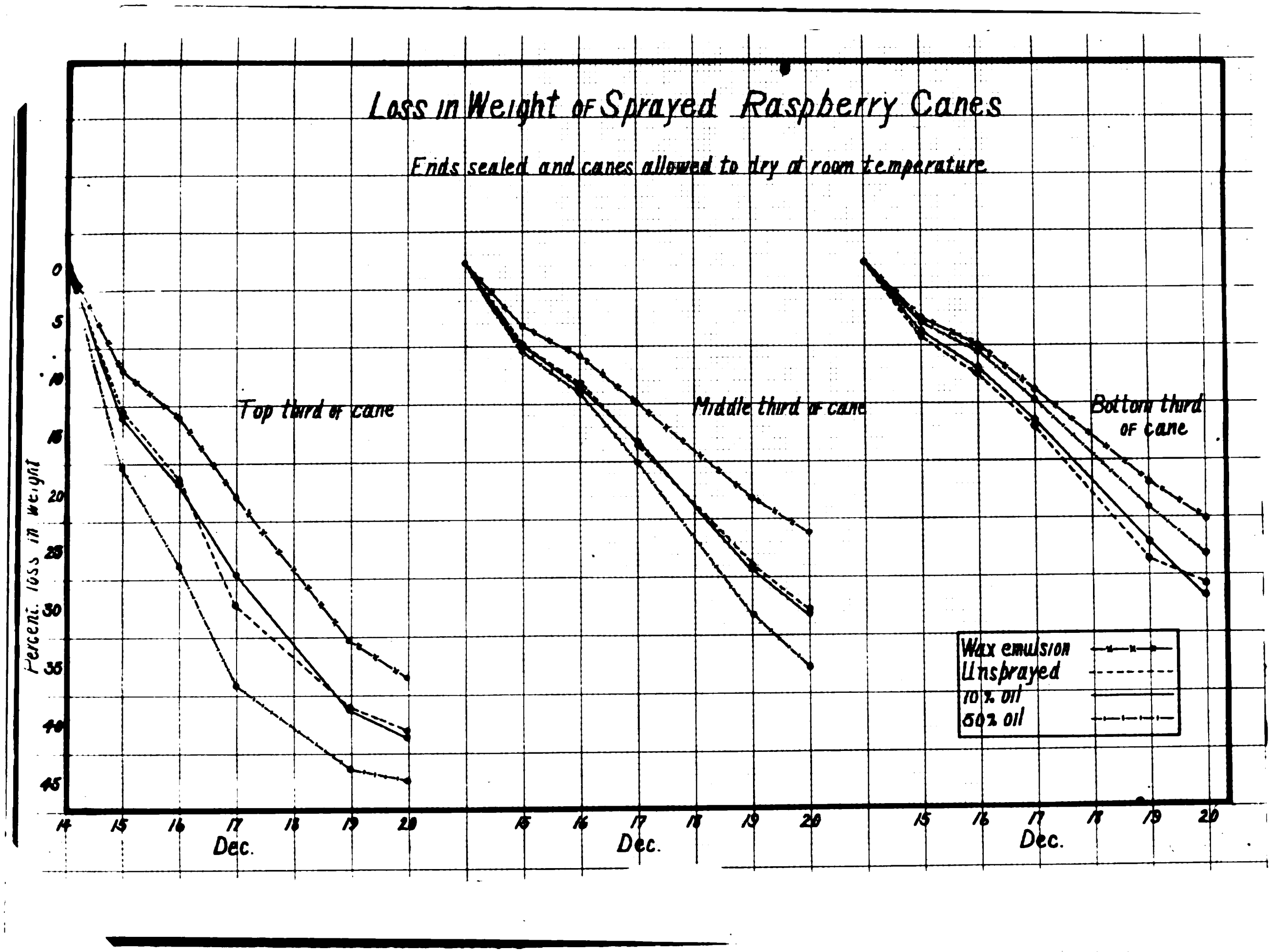
LABORATORY TEST ON SPRAY MATERIALS

Carefully selected single cane samples of (1) unsprayed, (2) wax emulsion-, (3) 10% oil emulsion-, (4) 50% oil emulsion-treated Viking canes were taken from the field on December 14, 1932. Each cane was cut into thirds and each part was sealed at the cut ends with melted paraffin. The rate of moisture loss under room conditions was observed for a period of days, until the canes began to crack from excessive drying.

Table 6. Loss in Weight of Sprayed Raspberry Canes

		Original weight in grams	Per cent loss in weight				
		Dec.14	Dec.15	Dec.16	Dec.17	Dec.19	Dec.20
Tips	Unsprayed	8.2	12.9	18.8	29.6	38.7	40.7
	Wax	10.1	9.3	13.7	20.3	32.8	36.1
	50% oil	7.9	17.7	26.3	36.7	43.8	44.9
	10% oil	10.9	13.5	19.0	27.0	38.7	41.1
Middle	Unsprayed	22.1	7.4	10.7	15.9	26.5	30.5
	Wax	24.7	5.5	8.2	12.3	20.6	23.6
	50% oil	27.8	7.7	11.4	17.5	30.8	35.3
	10% oil	26.0	7.5	10.8	15.8	26.7	30.7
Base	Unsprayed	34.5	6.6	9.8	14.5	26.1	28.3
	Wax	39.5	5.1	7.5	11.3	18.4	22.6
	50% oil	36.9	5.4	8.0	12.1	21.8	25.7
	10% oil	44.2	6.5	9.4	14.0	24.7	29.4

Table 6 and the graphs in Figure 10 show that the wax emulsion up to this time served as a protection against drying. The 10% oil emulsion lot was practically no better than the check, except in the bottom third of the cane. The 50% oil emulsion had caused injury to the canes, particularly in the upper part. This may account for the irregular loss from different sections of these canes.



Loss in Weight of Sprayed Raspberry Canes
Ends sealed and canes allowed to dry at room temperature
Top third of cane
Middle third of cane
Bottom third of cane
Wax emulsion
Unsprayed
10% oil
50% oil
Percent. loss in weight
0
5
10
15
20
25
30
35
40
45
14
15
16
17
18
19
20
Dec.

WATER CONTENT OF RASPBERRY SAMPLES

Tables 7, 8, and 9 show the percentages of total water in the samples taken throughout the season, both at East Lansing and Vineland.

Table 7. Water Content of Samples of Waxed and Unwaxed Canes at East Lansing, 1931-32

	Jan.6	Feb.12*	Feb.29	Mar.12	Apr.3	May 3**
Cuthbert	44.6	41.8	39.9	38.7	40.2	51.1
Cuthbert, waxed	40.9	41.8	40.3	35.3	40.8	
Viking	44.4	41.9	39.1	36.6	40.8	43.2
Viking, waxed	44.0	42.1	37.3	37.7	36.7	
Latham	44.4	43.3	41.9	41.9	43.6	48.1
Latham, waxed	44.6	45.2	42.7	40.5	43.6	
Average of all	43.8	42.7	40.2	38.5	40.9	47.5
Average waxed	43.2	43.0	40.1	37.8	40.4	
Average not waxed	44.5	42.3	40.3	39.1	41.5	

* Heavy showers the previous day. Surface water in low places.

** Last samples taken just as buds were bursting.

Table 8. Water Content of Samples of Waxed and Unwaxed Canes at Vineland Station, 1932-33

	Nov.23	Jan.3	Feb.15	Mar.14	Apr. 18
Viking	45.7	40.6	40.0	39.9	54.1
Viking, waxed		42.2	42.4	42.7	50.2

Table 9. Water Content of Various Parts of Viking Canes, Vineland Station, March 2, 1932

	Top Section	Middle Section	Basal Section
Av. of 45 small canes	38.2	45.5	43.7
Av. of 14 large canes	34.7	35.4	35.4

About half of the large canes showed some signs of shrivelling at the tips.

An examination of Table 7 shows that there was great variation in the water content of both sprayed and untreated varieties. Two other points to be noted are that the average water content of the waxed samples did not deviate significantly from the average of untreated samples and that Latham, even unwaxed, a hardy variety, maintained a somewhat higher and more uniform water content throughout the season than the other varieties. The curves presented in Figure 11 illustrate these points.

The failure of the wax to maintain a higher water content in the canes this season can be attributed partly to the fact that the winter was generally warm, with fluctuating periods of wet weather and wet soil conditions, and also to the fact that during the latter part of the season the wax coating had suffered from partial peeling and flaking.

Figure 12 shows that at Vineland, in 1932-33 the wax was to some degree successful in preventing loss of moisture.

Figure 11.

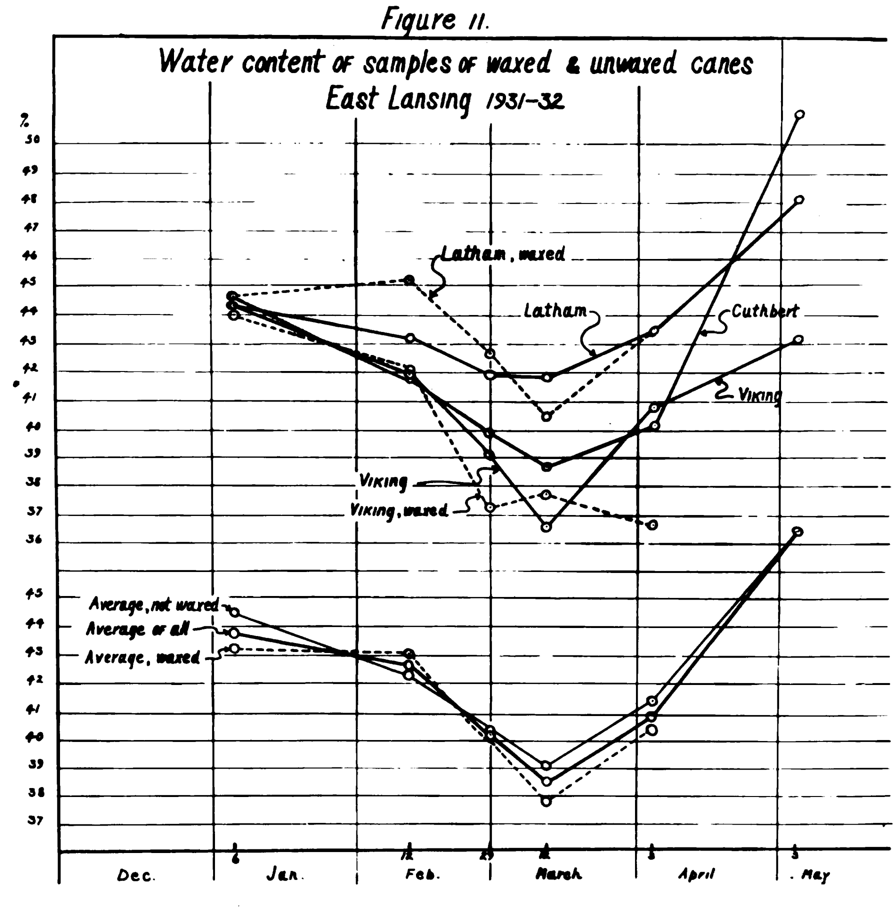
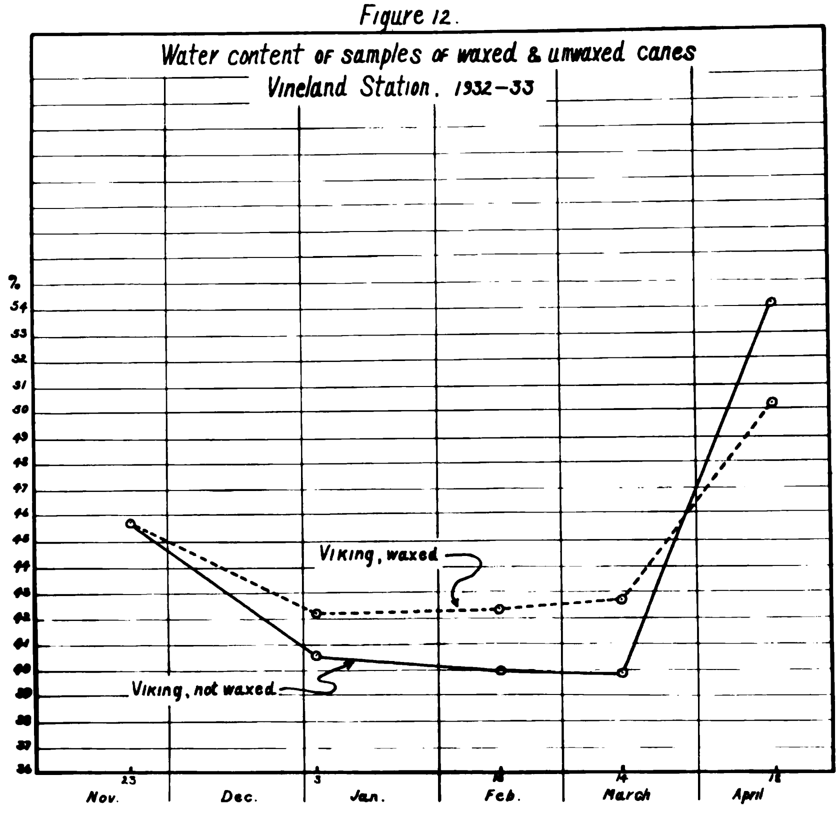


Figure 11.
Water content of samples of waxed & unwaxed canes
East Lansing 1931-32
%
Latham, waxed
Latham
Cuthbert
Viking
Viking
Viking, waxed
Average, not waxed
Average of all
Average, waxed
Dec.
Jan.
Feb.
March
April
May

Figure 12.


Water content of samples of waxed & unwaxed canes
Vineland Station. 1932-33
%
Viking, waxed
Viking, not waxed
Nov.
Dec.
Jan.
Feb.
March
April

CHEMICAL ANALYSIS

In order to obtain some indication as to what chemical changes occur that may affect the desiccation-resisting abilities of raspberries, or their susceptibility to injury, certain chemical analyses were made.

Methods After the canes had been chopped and dried, as described previously, they were ground to pass a 60-mesh screen and stored in tightly corked bottles.

Two-gram samples were subjected to a summative analysis leading to the ultimate determination of lignocellulose and lignin, as described by Crist and Batjer (10).

Three grams of the dry material were used for the determination of total pectic substances and soluble pectin, according to the method used by Appleman and Conrad (1).

Reducing sugars, total sugars, and dextrin and soluble starch were determined by the Shaffer-Hartmann method.

Results of Chemical Analyses The results of the chemical analyses are presented in Table 10 and in Figures 13 and 14.

There was a very slight upward trend in the percentage of pectin during the winter with a slight decline in spring. This agrees fairly well with the results of Lott (18), who found a lack of seasonal development of pectin in some of his samples, although he found a distinct increase in percentages of bound water and pectin in samples from raspberry plots in which the first two crops of young shoots had been removed. The analysis was not sufficiently accurate to indicate whether there was a distinct difference between varieties in their pectin content.

Sugars show a gradual increase and then a rapid falling off with the commencement of respiratory activity in spring. This is in keeping with the observations of many investigators that in woody plants, or in starch-storing plants in general, the starch is transformed to sugar on exposure to cold.

Dextrin and soluble starches show a decrease during winter and then a rise at the time of the sharp decline of sugars in spring, thus indicating a changing back of the sugars to starch.

Lignocellulose and lignin show a marked decline, particularly towards late winter, and then a sharp rise at the time sugars show a sharp falling off. It is probable that the absolute amount of lignocellulose remains somewhat more constant than it appears from the curve constructed on the <u>percentage</u> dry weight basis, but, since the lignocellulose makes up the greater proportion of the dry weight, the relative changes in lignocellulose percentages cannot be accounted for entirely by the fluctuations of the other constituents of the dry matter. It seems that there is a breaking down of lignocellulose; possibly to hemicelluloses and lignin, and from there to pectic substances and eventually to simple sugars following the scheme of biosynthesis mentioned by Crist and Batjer (10).

The similarity of the curve of the water content with the lignocellulose and lignin curves was very marked.

Table 10. Chemical Analyses of Viking Samples from Vineland Station -- 1932-33.

(In percentages of dry weight)

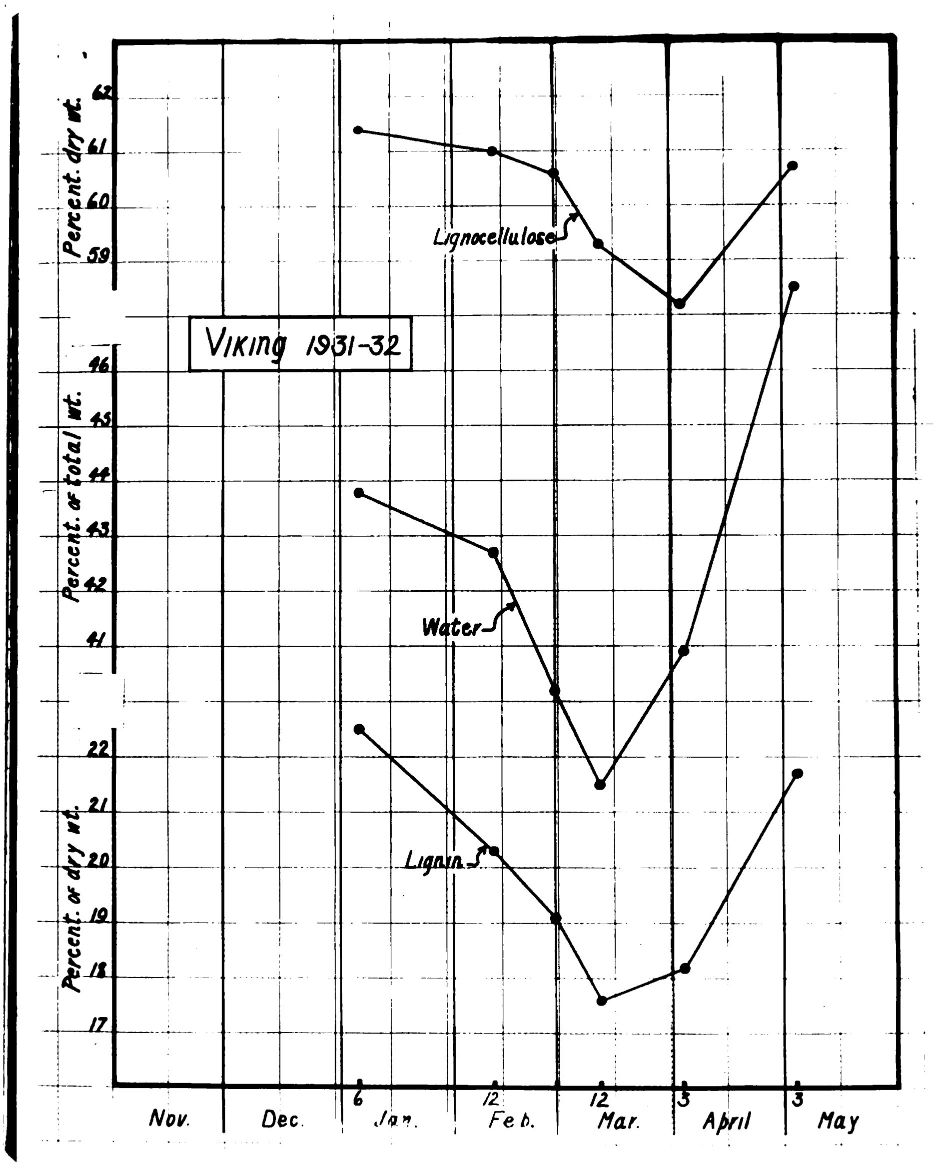
	Total Sugars	Reducing Substances		Dextrin and Soluble Starch	Total Pectic* Substances		Soluble Pectin*	
	not waxed	not waxed	waxed	not waxed	not waxed	waxed	not waxed	waxed
Nov. 23 1932	13.73	6.13		4.55	1.35		.15	
Jan. 3 1933	14.72	6.78	6.95	4.10	1.58	1.42	.16	.25
Feb. 15 1933	14.94	6.24	6.47	3.92	1.65	2.15	.20	.32
Mar. 14 1933	12.96	5.38	5.78	2.13	1.80	1.70	.23	.35
Apr. 18 1933	3.5	2.42	3.06	2.58	1.70	1.42	.26	.15

* Average of three varieties.

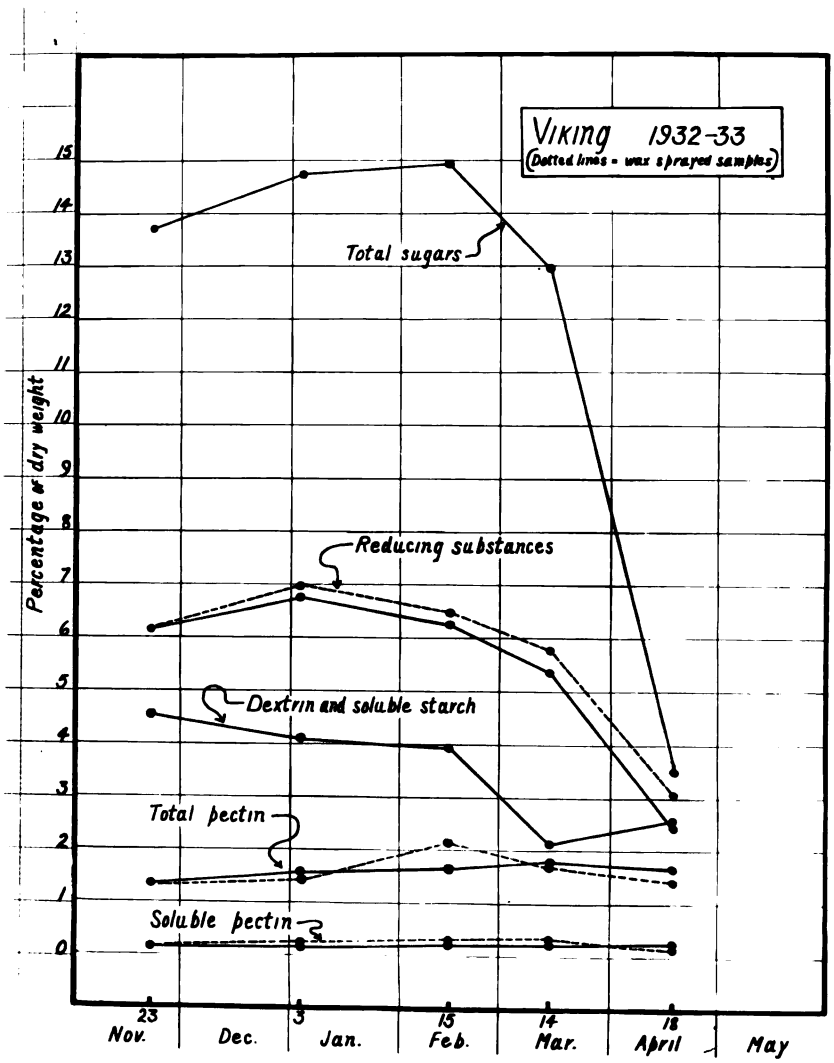
Table 11. Results of Chemical Analysis of Viking Samples, East Lansing -- 1931-32

	Total Water Content	Lignocellulose* Per Cent Dry Weight	Lignin* Per Cent Dry Weight
Jan. 6	43.8	61.4	22.5
Feb. 12	42.7	61.0	20.3
Feb. 29	40.2	60.6	19.1
Mar. 12	38.5	59.3	17.6
Apr. 3	40.9	58.2	18.2
May 3	47.5	60.7	21.7

* Average of four determinations.



Viking 1931-32
Percent. dry wt.
62
61
60
59
Lignocellulose
Percent. of total wt.
46
45
44
43
42
41
Water
Percent. of dry wt.
22
21
20
19
18
17
Lignin
6
12
12
3
3
Nov.
Dec.
Feb.
Mar.
April
May



Viking 1932-33
(Dotted lines - wax sprayed samples)
Total sugars
Reducing substances
Dextrin and soluble starch
Total pectin
Soluble pectin
Percentage of dry weight
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
23
Nov.
Dec.
3
Jan.
15
Feb.
14
Mar.
18
April
May

DISCUSSION

It has been shown that the red raspberry, particularly the Viking, is more susceptible to desiccating conditions than certain other woody plant tissue such as apple twigs.

Under experimental conditions desiccation takes place less rapidly in large canes although, in the field, large canes suffered more injury than small canes, thus seeming to indicate that desiccation was not a factor in the increase of injury with increase in length of canes. However, it should be borne in mind that the cut canes were unable to renew their supply of moisture. Since raspberry canes dry easily, it is highly probable (and field observations seem to bear it out) that they also take up moisture readily. Hence, under field conditions, the smaller canes may be better able than large canes to maintain their moisture content, particularly if a limited supply of water and unfavorable absorption conditions (because of frozen soil or frozen conducting tissue) make it difficult for the longer canes to supply their upper parts with water. In other words, desiccation may be a factor, but is has not been proved whether increased injury in larger canes is due to desiccation or to other factors such as immaturity. Further knowledge of the desiccation of large and small canes should be obtained from a detailed study of moisture fluctuations in undetached canes.

No conclusions could be reached on the effect of prevention of desiccation on hardiness because (1) adequate protection from desiccation was not attained, and (2) there was absence of sufficient injury in the material studied to permit comparison.

Besides desiccation as a possible cause of injury three other plausible causes of injury may be considered: (1) immaturity from prolonged growth, (2) immaturity from renewed growth in the fall, (3) premature development in spring. Of these, the last may be eliminated since bud injury, which is characteristic of premature development, is rare in the raspberry. The second type, immaturity from renewed growth in the fall, is improbable, provided the canes have satisfactorily reached the beginning of their rest period at the time conditions favoring renewed growth occur, but otherwise may be a factor. The fact that the canes which held their leaves longest were no more susceptible than those which dropped them early, in a season when drought defoliation was unlikely, is evidence against immaturity from prolonged growth in the fall. On the other hand, the greater injury to the taller canes and to canes which formed early in the season may be evidence that immaturity is a factor. The greater susceptibility of canes in hills with the greater numbers of canes is also an indication of prolonged fall growth since such canes are ordinarily more vigorous.

In brief, it has not yet been proven whether desiccation or immaturity from prolonged or renewed fall growth is the primary antecedent of winter injury in the raspberry. Much of the evidence can be construed as supporting either hypothesis since many conditions characteristic of maturity are also characteristic of an ability to resist desiccation.

Possibilities for further investigation lie (1) in a more detailed study of moisture conditions in the growing, or undetached cane and (2) in a close study of the growth cycle of individual canes followed by observations of winter injury in the same canes.

SUMMARY

1. An experiment on the desiccation of cut and sealed raspberry canes showed that raspberry canes dry more rapidly than other woody plant tissue such as apple twigs.

2. Large branched canes dried less rapidly than small unbranched canes which raised a doubt that large canes may be more subject to injury from desiccation, but field results showed that large canes do suffer a greater percentage of injury of the so-called "drying" type than small canes.

3. Under ordinary field conditions plants with six and seven canes per hill suffered progressively more injury than plants with only four or five canes per hill. Since the plants with the smaller number of canes were probably weaker plants, this indicated that the greater susceptibility to injury attributed to such plants may be in reality lower recuperative power.

4. The results of an experiment on the effects of removing the first formed canes in summer appeared, in a slight measure, to corroborate Lott's findings that the removal of the first two crops of young canes increased the hardiness of the later canes.

5. Viking was found, in 1932-33, to be in a complete resting condition by late November. The rest period seemed to

be partly broken by late December and probably completely broken early in January.

6. No difference in tip injury was observed in 1932-33 between Viking canes that dropped their foliage early and canes that retained their tip foliage much later.

7. Artificial freezing at 3°F of canes which had been allowed to take up water produced more severe injury than had been suffered by canes under ordinary moisture conditions in the field at nearly -3°F. This, however, may have been due to rapidity of freezing. Canes in fields where there was excess surface water suffered injury at or, mostly, just above the crown. This may be of a similar nature to Johnston's (16) report of greater susceptibility in buds frozen while wet.

8. Because of failure to maintain a good coating of wax throughout the season, wax sprays were rather unsuccessful in preventing desiccation during winter. Some protective effect was obtained in 1932-33 but the amount of injury was very small both on treated and untreated canes.

9. Results of chemical analysis showed a marked decline towards late winter of lignocellulose and lignin, followed by a sharp rise at the time total sugars and reducing substances showed a sharp falling off. The total water content followed closely the lignocellulose and lignin curves. Pectins showed a slight upward trend during winter with a decline at the beginning of spring.

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