Studies on Some Factors Relating to Hardiness in the Strawberry

I. The Development of Cold Resistance in Strawberry Varieties

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II. Winter Soil Temperatures as a Factor in the Environment of the Strawberry and Some Other Herbaceous Plants

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III. The Respiratory Rate of Dormant Strawberry Plants

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2. During the winter of 1934-35, peat was very effective as a mulch because it remained in a dry, loose condition. In 1935-36 it lost much of its effectiveness when it became wet, packed, and frozen.

3. The data for the season of 1935-36 indicate that, of the organic mulches tested, mixed leaves would be the most consistently effective mulch material because it was the least affected by physical conditions.

4. Ice had little value as a mulch in protecting the soil against low temperatures, and when it was present in organic mulch materials the value of such materials was reduced proportionately.

5. During severe winters, plant injury generally attributed to smothering by a covering of ice might be explained on the basis of low-temperature injury. The investigations of Roberts (47), Steele, Waldo, and Brown (55), and Angelo (Part I) relative to cold resistance of strawberries show that strawberry plants may be injured at relatively high temperatures—about 15° to 20° F. Temperatures considerably lower than this were recorded beneath ice and icy mulches.

III. The Respiratory Rate of Dormant Strawberry Plants[1]

W. G. Brierley and R. H. Landon

It is generally recognized that in the northern part of the United States the strawberry enters its winter rest period about the time of the first frosts. The plants remain dormant beneath the winter mulch, usually in a frozen condition, until the advent of spring temperatures. During this time respiration continues even though all plant activities are at a low ebb. Since information concerning the respiration of the dormant strawberry plant is of interest in connection with certain phases of strawberry culture, this study was undertaken.

In the fall of 1933 an attempt was made to determine the respiratory rate of potted strawberry plants that were in a dormant condition. Because of the nature of the strawberry crown that prevented sealing, neither ice nor paraffin was found to be satisfactory for this purpose. The results also were considered inconclusive because of the small size of the samples and lack of information relative to the movement of gases through frozen soil. Later, material was obtained by digging plants from frozen ground and washing them free from adhering soil. This procedure was unsatisfactory in that it was impossible to avoid injuring the plants.

To eliminate the difficulties previously encountered, a somewhat different method was adopted in the fall of 1936. For the samples used on October 6 and October 23, plants were dug in the field, washed free from

[1] A preliminary report of this study was published in the Proc. Am. Soc. Hort. Sci., 35:480-482.

soil, and used immediately. For all the samples used later, the method of handling was as follows.

On October 28, before the ground was frozen, a sufficient number of well-developed plants of the Dunlap variety were dug and washed free from soil. An attempt was made to select plants that were uniform in size. After washing, the plants were tied in bunches of 25. The bunches were then packed in boxes of moist peat with the leaves of the plants projecting above the surface. After this the boxes were placed in a deep coldframe and mulched with 12 to 15 inches of straw. With the approach of cold weather, the frame was covered with tight doors that excluded snow but allowed access to the plants. Temperatures in the peat in the boxes were recorded daily throughout the winter. From the beginning of cold weather until the middle of January the temperature remained very close to −1° C., with minor fluctuations that tended to follow changes in the air temperatures. During a period of severely cold weather the temperature in the peat fell to −3° C. but soon rose again and remained at slightly below freezing until April 14, 1937, when 0° C. was recorded. These temperatures correspond very closely with those recorded by Iverson (Part II) in his study of soil temperatures beneath mulch in the field. To ascertain the effects of the method of handling, all of the plants used were set in the field in May. Of these plants, 98 per cent made a satisfactory growth. From this it is evident that the

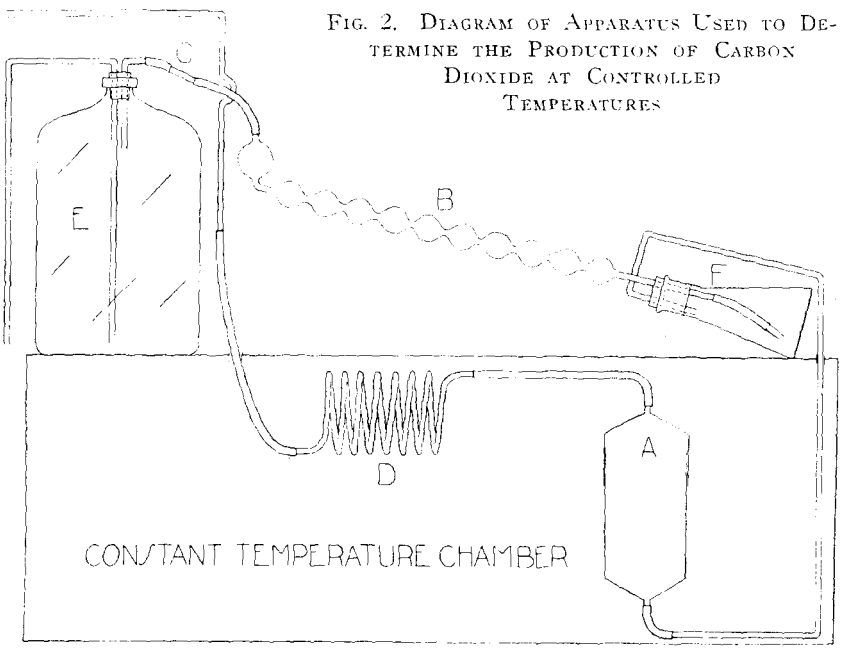

FIG. 2. DIAGRAM OF APPARATUS USED TO DETERMINE THE PRODUCTION OF CARBON DIOXIDE AT CONTROLLED TEMPERATURES

A, respiration chamber; B, absorption tube; C, capillary tube; D, spiral coil to adjust temperature of outside air; E, aspirator; F, flask.

plants remained in good condition during the winter and it can be assumed that the data relating to respiratory activity may be considered representative of the behavior of plants subjected to ordinary field conditions in winter. The high percentage of living plants is of interest in view of the fact that many were used a number of times in making determinations and were usually in a frozen condition when handled.

The apparatus described by Landon and Brierley (34) and shown in Figure 2 was used in ascertaining the amount of carbon dioxide given off by the dormant strawberry plants. The respiration chamber was a tin can of such shape and size that it was well filled by a bunch of 25 strawberry plants. The chamber had a capacity of 1,650 cc. When determinations were made, the chamber was kept in a small freezing box in which a thermoregulator held temperatures within $\pm 0.5^\circ$ F. Normal air brought from outdoors and adjusted to the temperature of the freezing box before passing into the respiration chamber was used. Blank determinations were made at frequent intervals and deducted from the results obtained with plants in the chamber. The rate of air flow through the respiration chamber was such that it was emptied three times in an hour.

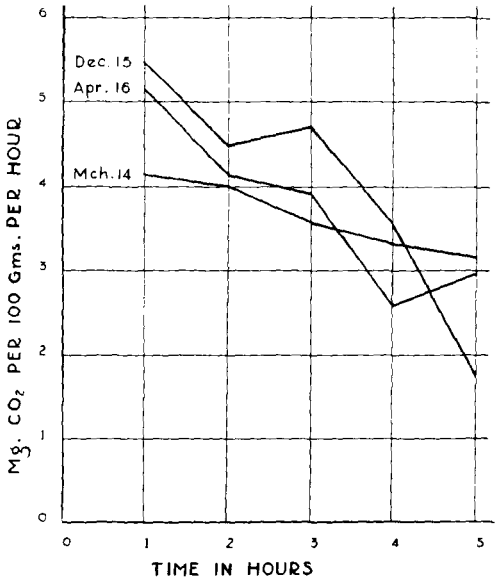

FIG. 3. PRODUCTION OF CARBON DIOXIDE BY THREE SAMPLES OF DORMANT STRAWBERRY PLANTS AT 0° C., SHOWING THE DECLINE IN RESPIRATORY RATE AT SUCCESSIVE HOURLY INTERVALS

When the respiratory rate of a bunch of plants was to be ascertained, the bunch was removed from the coldframe and taken to a cold cellar where adhering particles of peat were brushed off and the bunch weighed. It was then placed in the respiration chamber as quickly as possible and the chamber placed in the freezing box which was already at the desired temperature. Air was passed through the chamber for 30 minutes before the first determination was made. Four or five determinations were made at hourly intervals, after which the plants were returned to the coldframe. The production of carbon dioxide was found to decline at each succeeding hourly interval as shown in Figure 3. Because of this, the initial rates were used in comparing the performance on differ-

ent dates since they were considered to be more representative than an average of the several determinations.

The determination of October 6 was made at 25° C., corresponding to field temperatures at that time. From October 23 until April 16 the determinations were made at 0° C., as this temperature closely paralleled that of the coldframe and that of the soil surface in the field beneath

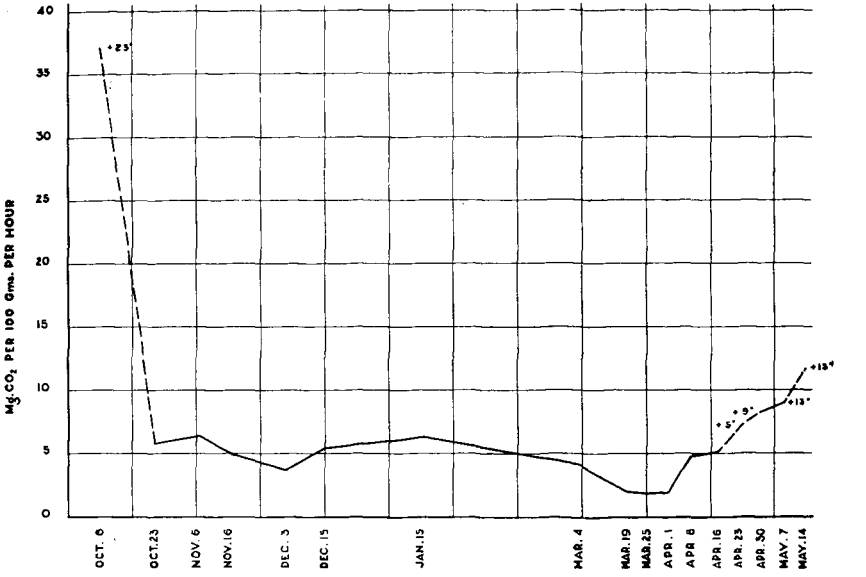

FIG. 4. RESPIRATORY RATE OF STRAWBERRY PLANTS THROUGHOUT THE DORMANT SEASON

Solid line indicates determinations made at 0° C.

mulch and snow found by Iverson (Part II). From April 23 until the end of the study, the temperatures used were those of the coldframe on the several dates.

The data obtained in these studies are shown in Figure 4. The first determination was made on October 6, a few days after the first killing frost, at the field temperature of 25° C. Although growth had ceased, the respiratory rate was found to be relatively high at that temperature. On October 23, after a series of light frosts when a determination was made at 0° C., the rate was found to have declined sharply. From October 23 until April 1, although fluctuations appeared, there was a gradual downward trend in the respiratory rate. It may be that the decline was due to a reduction in the amount of reserve material available for utilization in respiration. Long (37), working with the Aroma variety of strawberry in Missouri, has shown that the total sugars, although fluctuating in amount, tend to remain at the same average level throughout the dormant season. During the same time, however, there was a

decline in starch and hemicellulose which he believed were converted to sugar and used in respiration. On April 8, before any indications of growth were evident, an upward trend in the respiratory rate was noted, which became more pronounced at later dates after the temperature of the coldframe had started to rise. As long as the plants were dormant, the rate was low. At higher temperatures, and the beginning of growth, the respiratory rate increased rapidly.

On October 30 and December 1, the respiratory rate was determined at 5° C. At both times the rate was found to be higher than at 0° C., on somewhat comparable dates. These results were anticipated in view of the known effect of higher temperatures in increasing the production of carbon dioxide by plants. On December 3, January 21, and February 18, the rate at a temperature of −5° C. was found to be consistently lower than at 0° C., as might be expected. In general, the rate at 0° C. was higher than other workers have shown for woody plants. It may be that this is the case when the respiratory rates of dormant herbaceous and woody plants are compared.

When the respiratory rate observed at 0° C. is used as an index of plant activity, it appears safe to conclude that there are no abrupt changes in the activity of dormant strawberry plants from mid-October until the beginning of growth in early April. Plant activity is low in late October. From these data it appears that no undesirable effects are likely to result from early mulching in the field in the north, a practice now recommended in order to avoid injury from severe, early freezes.

LITERATURE CITED

1. AUGUR, P. M., and others. 1885. The best method of preventing frost. Am. Pom. Soc. Proc. 20:54.
2. BOUYOUCOS, G. J. 1913. An investigation of soil temperature and some of the most influential factors influencing it. Mich. Agri. Exp. Sta. Tech. Bul. 17.
3. ———. 1915. Effect of temperature on some of the most important physical processes in soils. Mich. Agri. Exp. Sta. Bul. 22.
4. ———. 1916. Soil temperatures. Mich. Agri. Exp. Sta. Tech. Bul. 26.
5. BRIERLEY, W. G., and HILDRETH, A. C. 1928. Some studies on the hardiness of certain species of *Vaccinium*. Plant Phys. 3:303-308.
6. CHANDLER, WILLIAM HENRY. 1925. Fruit growing, 619-620. Houghton-Mifflin Company, New York.
7. ———, 539-542.
8. ———, 551.
9. ———, 536.
10. ———, 509.
11. ———. 1913. The killing of plant tissue by low temperature. Mo. Agri. Exp. Sta. Res. Bul. 8.
12. CRAIG, J. 1900. Observations and suggestions on the root-killing of fruit trees. Iowa Agri. Exp. Sta. Bul. 44.

13. CRANE, H. L. 1924. Experiments in fertilizing peach trees. W. Va. Agri. Exp. Sta. Bul. 183.
14. DAVIS, M. B., and HILL, H. 1928. Nutritional studies with *Fragaria*. Sci. Agri. **8**(11) :681-692.
15. DEXTER, S. T. 1932. Studies of the hardiness of plants; a modification of the Newton pressure method for small samples. Plant Phys. **4**:721-726.
16. ————. 1933. Effect of several environmental factors on the hardening of plants. Plant Phys. **8**:123-139.
17. ————. Growth, organic nitrogen fractions, and buffer capacity in relation to the hardiness of plants. (Unpublished.)
18. DORSEY, M. J., and BUSHNELL, J. W. 1920. The hardiness problem. Proc. Am. Soc. Hort. Sci. 17:210-224.
19. DUHAMEL, DU MONCEAU, H. L., and BUFFON, G. L. L. 1737. Observations des different effects que produisent sur les végétaux les grandés gelées d'hiver et les petites gelées du printemps. Mem. Math. et Phys. Acad. Roy. Soc. Paris 233-298. Cited by Göppert.
20. EMERY, S. M. 1898. Mont. Agri. Exp. Sta. Ann. Rept. Bul. 16, pp. 69-82.
21. GARDNER, V. R., BRADFORD, C. F., and HOOKER, H. D., JR. 1922. The fundamentals of fruit production, p. 260. McGraw, Hill Book Co., New York.
22. GÖPPERT, H. R. 1830. Ueber die Wärme-entwickelung in den Pflanzen; deren Gefrieren und die Schutzmittel gegen dasselbe, 1-273. Breslau.
23. ————. 1883. Pflanzen Gefrieren und Erfrieren.
24. GORKE, H. 1907. Ueber chemische Vorgänge beim Erfrieren der Pflanzen. Landw. Versuch. Sta. **65**:149-160.
25. HARRINGTON, E. L. 1928. Soil temperatures in Saskatchewan. Soil Sci. **25**:183.
26. HARVEY, R. B. 1918. Hardening processes in plants and developments from frost injury. Jour. Agri. Res. **15**:83-112.
27. ————. 1930. Time and temperature factors in hardening plants. Am. Jour. Bot. 17:187-196.
28. ————. 1930. Length of the period of exposure to low temperature as a factor in the hardening process of tree seedlings. Am. Jour. For. **28**:50-53.
29. ————. 1935. An annotated bibliography of the low temperature relations of plants. Burgess Publ. Co., Mpls.
30. HILDRETH, A. C. 1926. Determination of hardiness in apple varieties and the relation of some factors to cold resistance. Minn. Agri. Exp. Sta. Tech. Bul. 42.
31. HOOKER, H. D. 1920. Pentosan content in relation to winter hardiness. Proc. Am. Soc. Hort. Sci. 17:204-207.
32. KEEN, B. A., and RUSSELL, E. J. 1921. The factors determining soil temperature. Jour. Agri. Sci. 11:211-240.
33. KIMBALL, D. A., RUHNKE, G. H., and GLOVER, M. P. 1934. A comparison of temperatures in air and at various depths in a light sandy soil in southern Ontario. Sci. Agri. 14:353-359.
34. LANDON, R. H., and BRIERLEY, W. G. 1934. An apparatus for the measurement of respiratory rate. Sci. **80**:75.
35. LI, TSI TUNG. 1926. Soil temperature as influenced by forest cover. Yale Univ. Bul. 18.

36. LIDFORSS, B. 1896. Die wintergrüne Flora. Eine biologische Untersuchung. Abs. Bot. Centralb. **68**:33-44.
37. LONG, J. H. 1935. Seasonal changes in nitrogen and carbohydrate content of the strawberry plant. Proc. Am. Soc. Hort. Sci. **33**:386-388.
38. MACOUN, W. T. 1918. Winter injury in Canada. Proc. Am. Soc. Hort. Sci. **15**:13-17.
39. MAIL, G. ALLEN. 1930. Winter soil temperatures and their relation to subterranean insect survival. Jour. Agri. Res. **41** (8):571-600.
40. MCCLATCHIE, A. J., and COIT, J. E. 1909. Relation of weather to crops and varieties adapted to Arizona conditions. Ariz. Agri. Exp. Sta. Bul. 61.
41. MCCOLLOCH, J. W., and HAYES, W. P. 1923. Soil temperature and its influence on white grub activities. Ecology **4**:29.
42. MOLISCH, H. 1897. Untersuchungen über das Erfrieren der Pflanzen. 1-73.
43. MÜLLER-THURGAU, H. 1880. Ueber das Gefrieren und Erfrieren der Pflanzen. Landw. Jahrb. **9**:133-189.
44. NEWTON, R. .1924. The nature and practical measurement of frost resistance in winter wheat. Univ. Alberta Res. Bul. 1.
45. POTTER, G. F. 1924. Experiments on the resistance of apple roots to low temperatures. New Hampshire Agri. Exp. Sta. Tech. Bul. 27.
46. ————————. 1922. Winter injury of apple roots. New Hampshire Agri. Exp. Sta. Bul. 203, 14-16.
47. ROBERTS, R. H. 1933. Strawberry "black root" injury. Proc. Am. Soc. Hort. Sci. **30**:295.
48. ROBINSON, W. 1927. The thermocouple method of determining temperatures. Ann. Soc. Ent. Am. **20**:513-521.
49. ROSA, J. R., JR. 1920. Pentosan content in relation to hardiness of vegetable plants. Proc. Am. Soc. Hort. Sci. **17**:207-210.
50. RUSSELL, E. J. 1937. Soil conditions and plant growth. 7th edition. Longmans, Green and Co., New York and London.
51. SACHS, J. 1860. Krystallbildungen bei dem Gefrieren und Veränderung der Zellhäute bei dem Aufthauen saftiger Pflanzentheile. Math. Phys. Cl. **12**:1-50. Bericht. Konig, Sachs, Gesell. Wiss. Leipzig.
52. SCHUSTER, C. E. 1920. Ore. Agri. Exp. Sta. Bien. Crop Pest and Hort. Rept. **3**:44.
53. SHOEMAKER, J. S. 1934. Small fruit culture **159**:19. P. Blakiston's Sons and Co., Philadelphia.
54. SMITH, ALFRED. 1926. A contribution to the study of interrelations between the temperature of the soil and of the atmosphere and a new type of thermometer for such study. Soil Sci. **22**:447.
55. STEELE, T. A., WALDO, G. F., and BROWN, W. S. 1934. Conditions affecting cold resistance in strawberries. Proc. Am. Soc. Hort. Sci. **32**:434-439.
56. THOMSON, W. A. 1934. Soil temperatures at Winnipeg, Manitoba. Sci. Agri. **15**:209-217.
57. WIEGAND, K. M. 1906. Some studies regarding the finding of bugs in twigs in winter. Bot. Gaz. **41**:373.
58. WILCOX, E. V. 1899. The resistance of strawberries to frost and 12 other subjects. Mont. Agri. Exp. Sta. Bul. 22.
59. WINKLER, ALBERT. 1913. Ueber den Einfluss der Aussenbedingungen auf die Kälteresistenz ausdauernder Gewächse. Jahrb. für Wissenschaft. Bot. **52**:467-506.