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# FURTHER OBSERVATIONS ON THE OSMOTIC PRESSURE OF THE JUICES OF THE POTATO PLANT[1]

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## INTRODUCTION

The observations made by the author[2] during the summer of 1918 have been continued during 1919, 1920, and 1922, and greenhouse readings were taken in 1921. The data obtained from juices produced during seasons of varying character and from a number of varieties of potato will extend the knowledge of one internal factor of annual plants, since no previous investigation seems to have covered such a lengthy period of time for one plant. Unfortunately, it was not possible to make any cryoscopic determinations during 1921, owing to other work; this was particularly regrettable, as 1921 was a very good year for the production of physiological tip burn of typical form.

As the literature on this subject was discussed in the report of the earlier work, it is unnecessary to refer to it here. It may be stated, however, that the work in 1918 was an attempt to ascertain whether the internal osmotic pressures of the juices from different parts of the potato plant varied in such a way as to be a possible factor in the production of tip burn. The readings seemed to show that although the juice of the growing leaves has a higher osmotic pressure during the early part of the season, the stems attain a still higher pressure as a result of the accumulation of sugars in the sap during the height of the activity of the plant, when the flowers and young tubers are being produced. It is just at this time that tip burn of the physiological type appears.

The writer is again indebted to Mr. R. L. Gale for the sugar determinations made in 1919 and for assistance in the cryoscopic determinations during that year. The methods used have already been described. The results obtained, while probably not absolutely accurate, as the material was not frozen before grinding and no pressure was used in extracting the juice, will give a fairly correct determination, as the same methods were used throughout and the readings obtained were made for comparison with each other only. These data are shown in Tables I, II, III, IV, and V.

[1] Accepted for publication Mar. 3, 1923.

[2] LUTMAN, B. F. OSMOTIC PRESSURES IN THE POTATO PLANT AT VARIOUS STAGES OF GROWTH. *In* Amer. Jour. Bot., v. 6, p. 181-202. 1919. Literature cited, p. 202.

TABLE I.—*Comparative cryoscopic readings in 1919*

| No. | Date. | Weather. | Material. | Depression. | Depression in atmospheres. | Glucose. | Sucrose. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | | | | *P. ct.* | *P. ct.* | |
| 1 | July 13..... | Hot and dry... | Young leaves.. | 0.915 | 11.02 | 1.31 | 0 | Lower leaves slightly wilted; slight tip burn on some plants. |
| 2 | ..... | ..... | Old leaves..... | .845 | 10.18 | .74 | .31 | |
| 3 | ..... | ..... | Stems..... | 1.089 | 13.18 | 2.15 | 0 | |
| 4 | ..... | ..... | Tubers..... | .697 | 8.396 | .26 | 1.68 | |
| 5 | July 21, 9 a. m... | Hot and muggy | New leaves.... | .694 | 8.34 | .61 | 0 | Tip burn developed in past few days. |
| 6 | ..... | ..... | Old leaves..... | .747 | 7.78 | .74 | 0 | |
| 7 | ..... | ..... | Stems..... | .766 | 9.21 | 1.52 | 0 | |
| 8 | ..... | ..... | Tubers..... | .555 | 6.66 | .36 | 1.21 | |
| 9 | Aug. 7, 10 a. m.. | Dry, but showers on Aug. 8. | Foliage..... | .634 | 7.64 | ..... | ..... | Shaded plants grown in tiles. |
| 10 | ..... | ..... | Stems..... | .707 | 8.52 | ..... | ..... | |
| 11 | ..... | ..... | Tubers..... | .552 | 6.65 | ..... | ..... | |
| 12 | ..... | ..... | Foliage..... | .792 | 9.54 | ..... | ..... | Plants grown in tiles in the open. |
| 13 | ..... | ..... | Stems..... | .754 | 9.09 | ..... | ..... | |
| 14 | ..... | ..... | Tubers..... | .548 | 6.58 | ..... | ..... | |
| 15 | Aug. 13, 2.30 p.m. | Hot and dry... | Leaves..... | 1.047 | 12.60 | .84 | .71 | Leaves slightly wilted and yellow. |
| 16 | ..... | ..... | Stems..... | .735 | 8.85 | .40 | .14 | |
| 17 | ..... | ..... | Tips of tubers. | .672 | 8.10 | .12 | .46 | |
| 18 | ..... | ..... | Butts of tubers | .635 | 7.65 | .35 | .64 | |
| 19 | Aug. 13, 11 a. m.. | ..... | Leaves..... | .928 | 11.17 | .91 | .54 | Same as Aug. 12. |
| 20 | ..... | ..... | Stems..... | .667 | 8.02 | .36 | .28 | |
| 21 | ..... | ..... | Inside of tuber | .663 | 7.99 | .07 | .48 | |
| 22 | ..... | ..... | Outside of tuber. | .666 | 8.01 | .07 | .62 | |
| 23 | Aug. 18..... | Cloudy and warm. | Young leaves.. | .669 | 8.05 | .56 | 0 | Healthy plant. |
| 24 | ..... | ..... | Old leaves..... | .710 | 8.55 | .49 | .20 | |
| 25 | ..... | ..... | Stems..... | .865 | 10.42 | 1.80 | 0 | |
| 26 | ..... | ..... | Tubers..... | .544 | 6.55 | .62 | .32 | |
| 27 | ..... | ..... | Young leaves.. | .750 | 9.03 | .61 | 1.02 | Mosaic plant. |
| 28 | ..... | ..... | Old leaves..... | .791 | 9.52 | .70 | 0 | |
| 29 | ..... | ..... | Stems..... | .788 | 9.48 | 1.21 | 0 | |
| 30 | ..... | ..... | Tubers..... | .580 | 6.99 | .89 | 0 | |
| 31 | Aug. 21, 2 p. m.. | Clear; rain on Aug. 19 and 20. | Young leaves.. | .970 | 11.68 | .19 | 1.45 | Sample No. 1 from heavy clay loam soil, Randolph, Vt. |
| 32 | ..... | ..... | Old leaves..... | .811 | 9.77 | .03 | .80 | |
| 33 | ..... | ..... | Stems..... | .675 | 8.13 | .89 | 19 | |
| 34 | ..... | ..... | Tubers..... | .522 | 6.28 | 0 | .70 | |
| 35 | ..... | ..... | Young leaves.. | .980 | 11.80 | .19 | 1.48 | Sample No. 2, from another part of the same field. |
| 36 | ..... | ..... | Old leaves..... | .807 | 9.70 | .06 | .86 | |
| 37 | ..... | ..... | Stems..... | .676 | 8.15 | 0 | .54 | |
| 38 | ..... | ..... | Tubers..... | .572 | 6.88 | 0 | .60 | |
| 39 | Aug. 28, 3 p. m.. | Clear..... | Young leaves.. | .734 | 8.83 | .08 | .28 | Healthy plant. |
| 40 | ..... | ..... | Old leaves..... | .995 | 11.98 | .52 | 0 | |
| 41 | ..... | ..... | Stems..... | .680 | 8.19 | .38 | .47 | |
| 42 | ..... | ..... | Young leaves.. | .849 | 10.24 | .63 | .07 | Mosaic plant. |
| 43 | ..... | ..... | Old leaves..... | .967 | 11.64 | .69 | .04 | |
| 44 | ..... | ..... | Stems..... | .708 | 8.52 | .63 | 0 | |

TABLE II.—*Comparative cryoscopic readings in 1920*

| No. | Date. | Weather. | Variety and portion of plant. | Depression. | Depression in atmospheres. |
|---|---|---|---|---|---|
| | | | White McCormick (mosaic): | | |
| 1 | July 2 | Partly cloudy and warm (4 p. m.) | Young leaves | 0.648 | 7.81 |
| 2 | | | Stems | .626 | 7.54 |
| | | | Pink McCormick (mosaic): | | |
| 3 | | | Young leaves | .588 | 7.08 |
| 4 | | | Stems | .614 | 7.40 |
| 5 | | | Old seed piece | .614 | 7.40 |
| | | | Dibble's Russet: | | |
| 6 | | | Young leaves | .614 | 7.40 |
| 7 | | | Stems | .486 | 5.86 |
| 8 | | | Old seed piece | .492 | 5.93 |
| | | | Early Rose (healthy): | | |
| 9 | | | Young leaves | .573 | 6.90 |
| 10 | | | Stems | .582 | 7.01 |
| 11 | | | Old seed piece | .520 | 6.27 |
| | | | Burbank (healthy); coming into bloom: | | |
| 12 | July 11 | Bright and warm on 10th and 11th. | Young leaves | .664 | 8.00 |
| 13 | | | Stems | .697 | 8.40 |
| | | | Dibble's Russet (healthy): | | |
| 14 | | | young leaves | .782 | 9.44 |
| 15 | | | Stems | .654 | 7.88 |
| 16 | | | Old seed piece | .393 | 4.74 |
| | | | Early Rose (planted June 25, plants just out of ground): | | |
| 17 | July 14 | Hot and clear | Tops (all above ground) | .641 | 7.72 |
| 18 | | | Old seed piece | .639 | 7.68 |
| | | | Dibble's Russet: | | |
| 19 | | | Tops | .632 | 7.61 |
| 20 | | | Seed pieces | .539 | 6.49 |
| | | | Burbank, full grown, in bloom; no tip burn: | | |
| 22 | | | Leaf axis | .663 | 7.99 |
| 22 | | | Inside of leaflets | .723 | 8.71 |
| 23 | | | Outside of leaflets | .764 | 9.20 |
| | | | Lamb's quarter: | | |
| 24 | July 23 | Hazy, clear, warm | Growing tips and small leaves. | 1.083 | 13.04 |
| 25 | | | Old leaves | .898 | 10.82 |
| 26 | | | Stems | .819 | 9.86 |
| | | | Dibble's Russet (some plants in bloom): | | |
| 27 | July 27 | Bright, clear and cool; previous days same. | Young leaves | .832 | 10.02 |
| 28 | | | Old leaves | .805 | 9.69 |
| 29 | | | Leaf stalks | .707 | 8.52 |
| 30 | | | Stems of plants | .838 | 10.09 |
| 31 | | | New tubers (size of hulled walnut). | .637 | 7.67 |
| | | | Early Rose, some in bloom: | | |
| 32 | | | Young leaves | .886 | 10.67 |
| 33 | | | Petioles and old leaves | .768 | 9.25 |
| 34 | | | Stems of plant | .791 | 9.53 |
| 35 | | | New tubers | .613 | 7.38 |
| | | | Lettuce, plants with short stalks: | | |
| 36 | July 28 | Clear and fairly hot | Leaves | .576 | 6.94 |
| 37 | | | stems | .638 | 7.69 |
| | | | Early Rose from garden; old leaves yellowing slightly: | | |
| 38 | Aug. 4 | Clear and warm but not hot | Young leaves | .832 | 10.02 |
| 39 | | | Old leaves | .729 | 8.79 |
| 40 | | | Stems | .693 | 8.35 |
| 41 | | | New tubers | .507 | 6.11 |
| | | | Dibble's Russet: | | |
| 42 | Aug. 5, 3 p. m. | Hot and clear | Young leaves | .948 | 11.42 |
| 43 | | | Old leaves | .727 | 8.76 |
| 44 | | | Stems | .789 | 9.50 |
| 45 | | | New tubers | .617 | 7.43 |
| | | | Dibble's Russet: | | |
| 46 | Aug. 6, 3 p. m. | Hot and dry but no tip burn; atmosphere hazy. | Young leaves | .883 | 10.64 |
| 47 | | | Old leaves | .813 | 9.79 |
| | | | Stems | .884 | 10.65 |
| 48 | | | New tubers | .626 | 7.54 |

TABLE II.—*Comparative cryoscopic readings in 1920*—Continued

| No. | Date. | Weather. | Variety and portion of plant. | Depression. | Depression in atmospheres. |
|---|---|---|---|---|---|
| | | | Dibble's Russet: | | |
| 50 | Aug. 8, 3 p. m... | Hot and dry but hazy sunshine; 90° F.; no tip burn. | Young leaves..... | 0.891 | 10.73 |
| 51 | ..... | ..... | Old leaves..... | .840 | 10.12 |
| 52 | ..... | ..... | Stems..... | .843 | 10.16 |
| 53 | ..... | ..... | Tubers..... | .631 | 7.60 |
| | | | Early Rose plants from garden; old leaves are yellow and dying: | | |
| 54 | ..... | ..... | Young leaves..... | .858 | 10.34 |
| 55 | ..... | ..... | Old leaves..... | .721 | 8.68 |
| 56 | ..... | ..... | Stems..... | .737 | 8.88 |
| 57 | ..... | ..... | Tubers..... | .622 | 7.49 |
| | | | Early Rose field plants: | | |
| 58 | ..... | No tip burn..... | Young leaves..... | .912 | 10.97 |
| 59 | ..... | ..... | Old leaves..... | .850 | 10.24 |
| 60 | ..... | ..... | Stems..... | .728 | 8.77 |
| 61 | ..... | ..... | Tubers..... | .633 | 7.63 |
| | | | Green Mountain: | | |
| 62 | Aug. 16..... | Hot, dry, clear; no tip burn as yet on these plants. | Young leaves..... | 1.028 | 12.38 |
| 63 | ..... | ..... | Old leaves..... | 1.088 | 13.10 |
| 64 | ..... | ..... | Stems..... | .940 | 11.32 |
| 65 | ..... | ..... | New tubers..... | .810 | 9.75 |
| | | | Green Mountain plants under shelter: | | |
| 66 | ..... | ..... | Young leaves..... | .926 | 11.15 |
| 67 | ..... | ..... | Old leaves..... | .881 | 10.61 |
| 68 | ..... | ..... | Stems..... | .860 | 10.36 |
| 69 | ..... | ..... | New tubers..... | .691 | 8.32 |
| | | | Tomato (Early Jewel): | | |
| 70 | Aug. 18..... | Hot and dry; brilliant sunshine; plants with large fruit. | Leaves..... | .715 | 8.61 |
| 71 | ..... | ..... | Old leaves (yellowing in most cases). | .613 | 7.38 |
| 72 | ..... | ..... | Stems..... | .581 | 7.00 |
| 73 | ..... | ..... | Green fruit..... | .562 | 6.77 |
| | | | Irish Cobbler, from another field: | | |
| 74 | ..... | Wind from north; cool in shade. | Young leaves..... | 1.117 | 13.44 |
| 75 | ..... | Some tip burn on these plants.. | Old leaves..... | 1.001 | 12.05 |
| 76 | ..... | ..... | Stems..... | .878 | 10.58 |
| 77 | ..... | ..... | New tubers..... | .648 | 7.81 |
| | | | Dahlia: | | |
| 78 | Aug. 19, 3 p. m.. | Hot and dry; potatoes show some tip burn. | Buds and tips of stalks.. | .665 | 8.01 |
| 79 | ..... | ..... | Leaves..... | .650 | 7.83 |
| 80 | ..... | ..... | Stems..... | .670 | 8.07 |
| 81 | ..... | ..... | Tubers..... | .818 | 9.85 |
| | | | Lettuce plants lengthening into stalks: | | |
| 82 | Aug. 19, 3 p. m.. | ..... | Stems..... | .920 | 11.08 |
| 83 | ..... | ..... | Leaves..... | .901 | 10.85 |
| | | | Green Mountain potatoes grown in open in tiles; all blossoms fallen: | | |
| 84 | Aug. 25..... | Fairly warm and bright; a little yellowing and tip burn on older leaves; none on younger leaves. | Young leaves..... | 1.061 | 12.77 |
| 85 | ..... | ..... | Old leaves..... | .964 | 11.61 |
| 86 | ..... | ..... | Stems..... | .947 | 11.40 |
| 87 | ..... | ..... | Tubers..... | .733 | 8.83 |
| | | | Green Mountain potatoes in tiles under shade: | | |
| 88 | ..... | A few old leaves show tip burn.. | Young leaves..... | .965 | 11.62 |
| 89 | ..... | ..... | Old leaves..... | .828 | 9.97 |
| 90 | ..... | ..... | Stems..... | .763 | 9.19 |
| 91 | ..... | ..... | Tubers..... | .681 | 8.20 |
| | | | Early Rose; no blossoms: | | |
| 92 | Aug. 27, 3 p. m.. | Hot and clear; fairly dry; plants of July 30, 6 to 8 inches high. | Foliage..... | .901 | 10.85 |
| 93 | ..... | ..... | Stems..... | .661 | 7.96 |
| 94 | ..... | ..... | Seed piece..... | .676 | 8.11 |
| | | | Green Mountain plants show buds 8 to 9 inches high: | | |
| 95 | ..... | ..... | Foliage..... | .820 | 9.87 |
| 96 | ..... | ..... | Stems..... | .705 | 8.49 |
| 97 | ..... | ..... | Seed piece..... | .421 | 5.07 |

TABLE II.—*Comparative cryoscopic readings in 1920*—Continued

| No. | Date. | Weather. | Variety and portion of plant. | Depression. | Depression in atmospheres. |
|---|---|---|---|---|---|
| | | | Dahlia: | | |
| 98 | | Hot and clear; fairly dry | Foliage | 0.695 | 8.37 |
| 99 | | | Stems | .702 | 8.46 |
| 100 | | | New tubers | .671 | 8.08 |
| | | | Artichokes from garden; growth had ceased: | | |
| 101 | Sept. 5 | Hot in sunshine; some haze | Young leaves and tips of stems. | .861 | 10.37 |
| 102 | | | Older leaves and petioles | 1.024 | 12.33 |
| 103 | | | Stems | .800 | 9.63 |
| 104 | | | Young tubers | .773 | 9.31 |
| | | | Dibble's Russet; no growing leaves. Medium-sized leaves of— | | |
| 105 | Sept. 5 | Hot in sunshine; some haze; some tip burn; tubers over a pound in weight. | Foliage | .803 | 9.67 |
| 106 | | | Stems | .648 | 7.81 |
| 107 | | | Tubers | .589 | 7.10 |
| | | | Burbank: | | |
| 108 | Sept. 14, 3 p. m. | Cool and cloudy; rain for 3 or 4 days; plenty of tip burn and some blight; some yellow leaves. | Foliage | .797 | 9.60 |
| 109 | | | Stems | .555 | 6.69 |
| 110 | | | Tubers | .553 | 6.66 |
| | | | Dibble's Russet: | | |
| 111 | | | Foliage | .856 | 10.31 |
| 112 | | | Stems | .481 | 5.80 |
| 113 | | | Tubers | .546 | 6.58 |

TABLE III.—*Readings in 1921; plants all grown in the greenhouse*

| No. | Date. | Remarks. | Variety and portion of plant used. | Depression. | Depression in atmospheres. |
|---|---|---|---|---|---|
| | | | Burbank: | | |
| 1 | Mar. 22 | Plants 1 to 2 inches high | Aerial portions | 0.494 | 5.95 |
| 2 | | | Seed piece | .557 | 6.71 |
| 3 | | | Roots | .464 | 5.59 |
| | | | Early Rose: | | |
| 4 | | | Aerial portions | .525 | 6.33 |
| 5 | | | Seed piece | .531 | 6.40 |
| 6 | | | Roots | .495 | 5.96 |
| | | | Burbank: | | |
| 7 | Apr. 8 | | Leaves | .586 | 7.06 |
| 8 | | | Stems | .525 | 6.33 |
| 9 | | | Seed piece | .527 | 6.35 |
| | | | Early Rose: | | |
| 10 | | | Leaves | .593 | 7.14 |
| 11 | | | Stems | .517 | 6.23 |
| 12 | | | Seed piece | .373 | 4.50 |
| | | | Green Mountain: | | |
| 13 | Apr. 8 | Plants 8 to 10 inches high; new tubers size of pea. | Leaves | .516 | 6.22 |
| 14 | | | Stems | .501 | 6.04 |
| 15 | | | Seed piece | .441 | 5.31 |
| 16 | | Plants just coming up | Sprouts | .554 | 6.68 |
| 17 | | | Seed piece | .609 | 7.25 |
| | | | Burbank: | | |
| 18 | May 2 | Large plants past blossoming; some of old leaves yellow; new tubers, size of a hulled walnut. | Young leaves | .656 | 7.90 |
| 19 | | | Old leaves | .506 | 6.10 |
| 20 | | | Stems | .607 | 7.31 |
| 21 | | | Seed piece | .300 | 3.62 |
| 22 | | | New tubers | .545 | 6.65 |
| | | | Early Rose: | | |
| 23 | | | Leaves | .783 | 9.43 |
| 24 | | | Stems | .627 | 7.55 |
| 25 | | | New tubers | .544 | 6.5 |

TABLE III.—*Readings in 1921; plants all grown in the greenhouse*—Continued

| No. | Date. | Remarks. | Variety and portion of plant used. | Depression. | Depression in atmospheres. |
|---|---|---|---|---|---|
| | | | Green Mountain: | | |
| 26 | May 31 | Hot in the greenhouse; the plants mature and yellowing; very hot on May 30. | Young leaves | 0.749 | 9.02 |
| 27 | ..... | ..... | Old leaves | .756 | 9.11 |
| 28 | ..... | ..... | Stems | .546 | 6.58 |
| 29 | ..... | ..... | New tubers | .466 | 5.62 |
| | | | Early Rose: | | |
| 30 | ..... | Tubers large | Leaves | .703 | 8.47 |
| 31 | ..... | ..... | Stems | .644 | 7.76 |
| 32 | ..... | ..... | Tubers | .533 | 6.48 |
| | | | Burbank: | | |
| 33 | June 22 | Hot in the greenhouse; only a tuft of green leaves left on each branch; soil dry. | Leaves | .697 | 8.40 |
| 34 | ..... | ..... | Stems | .388 | 4.68 |
| 35 | ..... | ..... | New tubers | .497 | 5.99 |
| | | | Green Mountain: | | |
| 36 | ..... | ..... | Leaves | .778 | 9.37 |
| 37 | ..... | ..... | Stems | .498 | 6.00 |
| 38 | ..... | ..... | New tubers | .493 | 5.93 |

TABLE IV.—*Readings of plants all grown in the greenhouse in 1922*

| No. | Date. | Weather and remarks. | Variety and portion of the plant. | Depression. | Depression in atmospheres. |
|---|---|---|---|---|---|
| | | | Green Mountain: | | |
| 1 | Apr. 4 | Plants not over 1 to 12 inches high. | Sprouts | 0.651 | 7.84 |
| 2 | ..... | ..... | Seed pieces | .601 | 7.24 |
| | | | Early Rose: | | |
| 3 | ..... | ..... | Sprouts | .633 | 7.63 |
| 4 | ..... | ..... | Seed pieces | .533 | 7.42 |
| | | | Burbank: | | |
| 5 | ..... | ..... | Sprouts | .629 | 7.58 |
| 6 | ..... | ..... | Seed pieces | .563 | 6.78 |
| | | | Dibble's Russet: | | |
| 7 | ..... | ..... | Sprouts | .724 | 8.72 |
| 8 | ..... | ..... | Seed pieces | .583 | 7.02 |
| | | | Early Rose: | | |
| 9 | Apr. 27 | Plants show flower buds and young tubers. | Leaves | .893 | 10.73 |
| 10 | ..... | ..... | Stems | .741 | 8.92 |
| 11 | ..... | ..... | Seed pieces | .509 | 6.13 |
| | | | Dibble's Russet: | | |
| 12 | ..... | ..... | Leaves | .795 | 9.57 |
| 13 | ..... | ..... | Stems | .628 | 7.57 |
| 14 | ..... | ..... | Seed pieces | .491 | 5.92 |
| | | | Burbank: | | |
| 15 | ..... | ..... | Leaves | .778 | 9.37 |
| 16 | ..... | ..... | Stems | .737 | 8.88 |
| 17 | ..... | ..... | Seed pieces | .497 | 5.99 |
| | | | Green Mountain: | | |
| 18 | ..... | ..... | Leaves | .860 | 10.36 |
| 19 | ..... | ..... | Stems | .767 | 9.24 |
| 20 | ..... | ..... | Seed pieces | .630 | 7.59 |
| | | | Burbank: | | |
| 21 | June 27 | Hot and fair; tubers large with skin set; soil dry; old leaves yellow and beginning to die. | Young leaves | .895 | 10.78 |
| 22 | ..... | ..... | Older leaves | .828 | 9.97 |
| 23 | ..... | ..... | Upper stems | .758 | 9.13 |
| 24 | ..... | ..... | Lower stems | .590 | 7.11 |
| 25 | ..... | ..... | Seed pieces | .359 | 4.33 |
| 26 | ..... | ..... | New tubers | .576 | 6.94 |
| | | | Early Rose: | | |
| 27 | ..... | ..... | Young leaves | .822 | 9.90 |
| 28 | ..... | ..... | Old leaves | .771 | 9.29 |
| 29 | ..... | ..... | Upper stems | .769 | 9.26 |
| 30 | ..... | ..... | Lower stems | .666 | 8.02 |
| 31 | ..... | ..... | Seed pieces | .764 | 9.20 |
| 32 | ..... | ..... | New tubers | .529 | 6.37 |

TABLE IV.—*Readings of plants all grown in the greenhouse in 1922*—Continued

| No. | Date. | Weather and remarks. | Variety and portion of the plant. | Depression. | Depression in atmospheres. |
|---|---|---|---|---|---|
| | | | Green Mountain: | | |
| 33 | | | Young leaves | 0.991 | 11.93 |
| 34 | | | Old leaves | 1.010 | 12.05 |
| 35 | | | Upper stems | .808 | 9.73 |
| 36 | | | Lower stems | .752 | 9.06 |
| 37 | | | New tubers | .709 | 8.54 |
| | | | Dibble's Russet: | | |
| 38 | | | Young leaves | .950 | 11.44 |
| 39 | | | Old leaves | .953 | 11.48 |
| 40 | | | Upper Stems | .815 | 9.82 |
| 41 | | | Lower stems | .749 | 9.02 |
| 42 | | | New tubers | .631 | 7.60 |

TABLE V.—*Comparative cryoscopic readings in 1922*

| | | | | | |
|---|---|---|---|---|---|
| | | | Burbank: | | |
| 1 | July 12 | Hot and clear; 87° F., no tip burn | Young leaves | 0.706 | 8.504 |
| 2 | | | Old leaves | .725 | 8.732 |
| 3 | | | Stems | .718 | 8.65 |
| 4 | | | Old seed piece | .305 | 3.68 |
| 5 | | | New tubers | .581 | 7.00 |
| | | | Green Mountain: | | |
| 6 | | Slight tip burn | Young leaves | .677 | 8.15 |
| 7 | | | Old leaves | .920 | 11.08 |
| 8 | | | Stems | .802 | 9.66 |
| 9 | | | New tubers | .555 | 6.69 |
| | | | Dibble's Russet: | | |
| 10 | | Leaves all of same size on the plants; no tubers. | Young leaves | .691 | 8.32 |
| 11 | | | Old leaves | .761 | **9.17** |
| 12 | | | Stems | .659 | **7.94** |
| | | | Irish Cobbler: | | |
| 13 | July 26 | Bright and warm in sunshine, but cool in shade and at night. | Young leaves | .646 | 7.78 |
| 14 | | | Old leaves | .728 | 8.77 |
| 15 | | | Stems | .786 | 9.47 |
| 16 | | | New tubers | .565 | 6.81 |
| | | | Green Mountain: | | |
| 17 | | | Young leaves | .407 | 4.91 |
| 18 | | | Old leaves | .788 | 9.49 |
| 19 | | | Stems | .847 | 10.20 |
| 20 | | | New tubers | .481 | 5.60 |
| | | | Dibble's Russet: | | |
| 21 | | | Young leaves | .456 | 5.50 |
| 22 | | | Old leaves | .812 | 9.78 |
| 23 | | | Stems | .763 | 9.19 |
| 24 | | | New tubers | .506 | 9.10 |
| | | | Green Mountain: | | |
| 25 | July 27 | Hazy, bright, cool; plants grown in tiles and watered regularly. | Young leaves | .562 | 6.77 |
| 26 | | | Old leaves | .787 | 9.47 |
| 27 | | | Stems | .738 | 8.79 |
| 28 | | | New tubers | .439 | 5.29 |
| 29 | | | Old seed piece | .257 | 3.10 |
| 30 | | Plants grown under a cloth shelter in tiles and watered regularly. | Young leaves | .357 | 4.30 |
| 31 | | | Old leaves | .613 | 7.37 |
| 32 | | | Stems | .698 | 8.41 |
| 33 | | | Seed pieces | .333 | 4.01 |
| 34 | Aug. 9 | Clear and bright but very cool; almost a frost preceding night. | Young leaves | .706 | 8.50 |
| 35 | | | Old leaves | .774 | 9.32 |
| 36 | | | Stems | .895 | 10.78 |
| 37 | | | New tubers | .540 | 6.51 |
| | | | Dibble's Russet: | | |
| 38 | | | Young leaves | .674 | 8.12 |
| 39 | | | Old leaves | .716 | 8.62 |
| 40 | | | Stems | .720 | 8.67 |
| 41 | | | New tubers | .476 | 5.74 |

TABLE V.—*Comparative cryoscopic readings in 1922*—Continued

| No. | Date. | Weather and remarks. | Variety and portion of the plant. | Depression. | Depression in atmospheres. |
|---|---|---|---|---|---|
| | | | Green Mountain: | | |
| 42 | Aug. 15 | Very hot and sultry but hazy; very little tip burn. | Young leaves | 0.663 | 7.99 |
| 43 | ..... | ..... | Old leaves | .789 | 9.50 |
| 44 | ..... | ..... | Stems | .789 | 9.50 |
| 45 | ..... | ..... | New tubers | .485 | 5.84 |
| | | | Dibble's Russet: | | |
| 46 | ..... | ..... | Young leaves | .752 | 9.06 |
| 47 | ..... | ..... | Old leaves | .700 | 8.43 |
| 48 | ..... | ..... | Stems | .708 | 8.53 |
| 49 | ..... | ..... | New tubers | .480 | 5.78 |
| | | | Green Mountain: | | |
| 50 | Sept. 1 | Bright and fairly warm with the ground full of moisture; plants watered regularly. | Young leaves | .856 | 10.31 |
| 51 | ..... | ..... | Old leaves | .794 | 9.60 |
| 52 | ..... | ..... | Stems | .746 | 8.99 |
| 53 | ..... | ..... | New tubers | .530 | 6.39 |
| 54 | ..... | Plants grown in tiles under a cloth shelter. | Young leaves | .672 | 8.09 |
| 55 | ..... | ..... | Old leaves | .796 | 9.59 |
| 56 | ..... | ..... | Stems | .791 | 9.53 |
| 57 | ..... | ..... | New tubers | .568 | 6.84 |

## SUMMER OF 1919

The cryoscopic readings taken in the summer of 1919 were not as numerous as those made in 1918 and were all on one variety, Green Mountain. Unfortunately, no readings were made in early July, and by the time the first juices were frozen the plants were already coming into blossom. It will be noted that on July 13, and again on July 21, the juice content of the stem was higher than that of any other part of the plant. Moreover, on August 13, which was a hot dry day, giving the leaf juice a greater depression, the leaves were in a state of incipient wilt.

The juices from various portions of the tuber tip, as compared with those of the butt, or those of the inside compared with those of the outside, do not seem to vary much in their cryoscopic readings, as can be seen from the reading on August 13.

The greater depression of the juice from the aerial portions of plants grown in shade, is to be noted on August 7, while mosaic plants gave greater depressions from the foliage portions on August 18 and on August 28. The mosaic stems, however, showed a reverse condition.

One of the most interesting sets of observations is that made on potatoes from Randolph, Vt. The field from which these plants were obtained is in one of the best potato regions in the northern United States, and the plants themselves were in splendid condition, without a trace of tip burn and still actively growing. It will be noticed that the juice from the young leaves has a markedly large depression, a fact that in the 1918 observations was associated with continued or renewed growth.

SUMMER OF 1920

The difference in the date of the death of the plants in early and late varieties must lie in some factor internal to the plant itself. Differences of osmotic pressure in the various parts of the plant at various stages of growth might give some clue to the early loss of foliage and ripening of the so-called early types. Very early and very late varieties of potatoes were planted, therefore, and tests were made on them at various stages during the growing season. The McCormick Pink and White variety (reputed to be very resistant to hot weather and tip burn), from which some differences in osmotic pressure might have been expected as compared to early varieties that succumb prematurely to tip burn, was a disappointment. The plants very early showed pronounced symptoms of mosaic and only one cryoscopic reading was taken of the juices.

The season was a favorable one, as it presented a contrast to the two preceding years in the weather and in the time of the appearance and the amount of tip burn. The official charts do not show any great contrast in temperature, sunshine, and rainfall, but the effect on the plants was not the same, owing to the fact that much haze and humidity nearly always tempered extreme periods of heat and sunshine. The rainfall during June and July was almost 2 inches above normal, while that of August was 1.64 inches below normal. The rain was well distributed throughout the month, however. The plants grew large and succulent and tubers developed rapidly. The foliage was so extreme and covered the ground between 3-foot rows so densely that it was impossible to avoid stepping on the vines. Tip burn was practically absent until late in the season, after which it advanced fairly rapidly, owing to the rank growth. The tip burn was first noted about August 19, almost a month later than it usually appears here.

The results from the cryoscopic readings of the juices of the potato and other plants in general confirm in the following particulars those taken during 1918:

1. The young growing portions of the plant contained juice with a somewhat higher osmotic pressure than the stems and a very much greater pressure than the old seed piece.

2. The pressure in all parts of the plant is comparatively low during the early growth of the plants, rising to a maximum during August and dropping away during September.

3. The marked differences shown in the freezing points of the juice from various parts of the potato plant do not seem to be shown by the dahlia or artichoke.

The results in 1920, however, do not agree with those of 1918, since in 1918 the stems developed much higher osmotic pressures than the leaves just at the time that foliage growth had ceased and tuber formation begun. The foliage juice at all times in 1920 showed a greater pressure than the juice from the stems, although there were times when it was almost the same.

A few comments on the readings and tables, to bring the facts together, will make the relations a little clearer.

Dibble's Russet (a late variety) and Early Rose are the only varieties of which a fairly complete record was obtained during the critical portions of the growing season. Tables VI and VII summarize the readings.

TABLE VI.—*Comparison of juices from Dibble's Russet during the summer*

| Dibble's Russet. | July 2. | July 12. | July 27. | Aug. 6. | Aug. 8 | Sept. 5. | Sept. 14. |
|---|---|---|---|---|---|---|---|
| Leaves | 0. 614 | 0. 782 | 0. 832 | 0. 883 | 0. 891 | 0. 803 | 0. 856 |
| | ..... | ..... | . 805 | . 813 | . 840 | ..... | ..... |
| Stems | . 486 | . 654 | . 838 | . 884 | . 843 | . 648 | . 481 |
| Old seed piece | . 492 | . 393 | ..... | ..... | ..... | ..... | ..... |
| New tubers | ..... | ..... | . 637 | . 626 | . 631 | . 589 | . 546 |

TABLE VII.—*Comparison of juices of Early Rose under various conditions*

| Early Rose. | Planted June 25. | | | Garden sandy soil, Aug. 4. | Garden sandy soil, Aug. 8. | Field clay soil, Aug. 8. | Plants of July 3, Aug. 27. |
|---|---|---|---|---|---|---|---|
| | July 2. | July 14. | July 27. | | | | |
| Leaves | 0. 573 | 0. 641 | 0. 886 | 0. 832 | 0. 858 | 0. 912 | 0. 901 |
| | ..... | ..... | . 768 | . 729 | . 721 | . 850 | ..... |
| Stems | . 533 | ..... | . 791 | . 693 | . 737 | . 728 | . 661 |
| Old seed piece | . 520 | . 639 | ..... | ..... | ..... | ..... | . 676 |
| New tubers | ..... | ..... | . 613 | . 507 | . 622 | . 633 | ..... |

The Dibble's Russet does not show such a marked falling off in osmotic pressure in the foliage juices after the heavy rains of September as might be expected, but the juice of the stems, especially according to the reading of September 14, did not produce much depression. The maximum readings were obtained on the juice of the younger leaves on August 6 and 8. It will be noticed that the depression from the juice of the stems on July 27 and August 6 and 8 almost equaled that of the young leaves and exceeded that of the older leaves; on July 2, when the plants were younger, the depression from the stem juice was much less than that from the juice of the leaves.

The Early Rose followed in general the same general course of increase in the atmospheric pressure of the sap until a maximum was reached during late July and early August. Unfortunately, no reading was made in late August after the plants had started to decline. The juice of the stems of this variety never approximated that of the foliage in producing freezing point depressions. The nearly similar depressions observed for the juices obtained from the various parts of the plants grown on sandy soil and on heavy clay soil are to be noted. The potatoes on the sandy soil were somewhat more advanced and the older leaves had begun to turn yellow, which will explain the comparatively small depression produced by the juice of these leaves on August 4 and 8; the old leaves had already begun to decline and the material to be withdrawn into the stem. The plants used on August 27 were planted on July 3, and are not comparable. On that date, they showed about the same atmospheric depressions in the juice from the various parts as the plants used on August 8.

The difference in osmotic pressure in the juices of plants raised under shade as compared with those grown in the open is shown in Table VIII.

TABLE VIII.—*Effect of shade on osmotic pressures in the juices*

(Green Mountain, Aug. 25, 3 p. m.)

| Portion of plant used. | Plants in open. | Plants under shade. |
|---|---|---|
| Young leaves | 1.061 | 0.965 |
| Old leaves | .964 | .828 |
| Stems | .947 | .763 |
| Tubers | .733 | .681 |

The Green Mountain plants used for the above experiment were grown in large tiles, half of them shaded with a heavy cotton cloth which cut off at least 50 per cent of the light. A comparison of the readings will show that while the plants grown in the open exhibited a greater depression in the young leaves and tubers, the greatest difference was shown in the readings obtained from the old leaves and stems, especially the latter. The older leaves on the open-air plants were beginning to suffer from tip burn at the time of this experiment in spite of the very great osmotic pressure, while those in the shade were practically untouched. The high pressure in the juice of the open-air stems is probably the result of the very much superior starch assimilation which the leaves of these plants were carrying on.

A few observations were made on plants other than potatoes, for purposes of comparison. Lamb's quarter, on July 23, showed about the same relations as to osmotic pressure as did the potato plant. The pressure at this time, however, was above that obtained on July 14 and 27 for potatoes. Lettuce, examined on July 28, gave comparatively low pressures; the plants were still succulent and tender, with only a very short stalk. Sap from tomato plants examined on August 18 showed much less osmotic pressure than sap obtained from the various parts of the potato plants used on the same day. However, these particular potato plants were beginning to show tip burn. These readings are comparable to those obtained in 1918 from tomato, but the plants in that year were taken very much later and after cold rains, and were consequently much lower. Lettuce, examined August 19, was tried again after the plants had begun to lengthen into flower stalks, but no marked difference is to be noted in the stem and leaf juice atmospheric pressure, although it is much higher than it was at the time of the earlier reading on July 28.

Dahlias and artichokes should show some of the same internal physiological conditions as the potato plant, but it must be remembered that the tubers from them are swollen roots, and not enlarged underground stems. The pressures in the dahlia plant, examined August 27, are practically at an equilibrium, but the new tubers show the least pressure. The pressure in this plant seems to be much less than it was in the Early Rose and Green Mountain potato plants taken from adjoining rows. The readings on the artichoke plants on September 5, taken on a hot day and after the plant growth had ceased, showed very much higher pressures than those of the dahlia plant—in fact, they are comparable to those from the potato plant. This apparent anomaly shows that the juice of the older leaves has higher pressure than that of the younger leaves and tips of the stems. The juices of tubers have a comparatively high pressure, but the lowest of any of the juices in the plant.

All the juices of the tubers produced during the year 1920 seem to show a much higher osmotic pressure than those of 1918. No cause for this difference is apparent. It is consistent throughout the season, however, and so must be due to the particular weather conditions of that summer.

## SUMMER OF 1922

The year 1922 was marked by the wettest June on record, so that it is interesting to see the effect such a period would have on the juice of the plants. On July 12 the juice of the old leaves had the greatest depression, an observation that had not been made before. The leaves at this date were all of one size, but, as the plants were in bud, the formation of new leaves and branches had ceased, and whatever growth was going on was in the form of an increase in the size of the older leaves. It is probable that all material was actually being removed from the tip (smaller) leaves as it was synthesized, and was utilized in other parts of the plant. On July 26, two weeks later, however, the juice of the stems of the Irish Cobbler and Green Mountain varieties had a very much greater depression, but the Dibble's Russet still showed more in the old leaves. The old leaves were of almost the same sizes as the tip leaves in their variety.

The plants grown under a shade showed on July 17 a lower osmotic pressure in all parts except the tubers than did those grown outside and watered regularly, so that the ground was almost moist. On September 1, however, there was not very much difference between the plants grown in the open and those in the shade.

The observations made on August 9 are of interest on account of the coolness of the preceding night, when the temperature sank below 40° F. The highest pressure seemed to be in the stems, especially in the Green Mountain variety. Not much change can be seen in the readings for August 15, although the weather then was hot and sultry.

## GENERAL RESULTS FOR 4 YEARS

A considerable diversity has been shown in the character of the seasons, especially with regard to the amount of rainfall during the 4 years in which these cryoscopic readings have been made on the potato plants. The wet years were 1918 and 1922, while 1919 and 1920 were inclined to be dry, especially the early part of the growing season of 1919. Tables IX and X show all the data obtained from various varieties of potatoes.

TABLE IX.—*Comparison of juices from Green Mountain plants during four years*

| Portion of potato used. | July 20, 1918. | July 21, 1919. | July 27, 1920. | July 26, 1922. |
|---|---|---|---|---|
| Young leaves | 8. 07 | 8. 34 | 10. 02 | 4. 91 |
| Old leaves | 7. 84 | 7. 78 | 9. 69 | 9. 49 |
| Stems | 8. 07 | 9. 21 | 10. 09 | 10. 20 |
| New tubers | 6. 10 | 6. 66 | 7. 67 | 5. 60 |
| **Portion of potato used.** | **Sept. 1, 1918.** | **Aug. 31, 1919.** | **Sept. 5, 1920.** | **Aug. 15, 1922.** |
| Young leaves | ..... | 9. 80 | ..... | 7. 99 |
| Old leaves | 9. 75 | 8. 07 | 9. 67 | 9. 50 |
| Stems | 8. 98 | 8. 15 | 7. 81 | 9. 50 |
| New tubers | 6. 16 | 6. 88 | 7. 10 | 5. 84 |

TABLE X.—*General average on juices of Green Mountain variety during four years*

| Portion of potato used. | 1918 | 1919 | 1920 | 1922 |
|---|---|---|---|---|
| Young leaves | 7.54 | 9.90 | 10.41 | 7.04 |
| Old leaves | 6.59 | 10.03 | 10.20 | 9.19 |
| Stems | 8.74 | 9.14 | 8.97 | 8.56 |
| New tubers | 6.30 | 7.08 | 7.52 | 6.18 |

It will be noticed that the readings for 1918 and 1922 are lower than those of 1919 and 1920, and that this difference is even reflected in the atmospheric pressure in the new tubers themselves. The high pressure in the stems (as compared to that from other portions of the plant) during 1918, and that in the old leaves during 1922, are other peculiar features.

## POTATO PLANTS GROWN IN THE GREENHOUSE, 1921 AND 1922

The almost complete freedom of greenhouse grown plants from physiological tip burn and the fact that such plants will continue to remain green and to continue growth ought to make the osmotic pressures of interest as compared with those from the field.

The osmotic pressure in the young sprouts that come from the seed piece is generally higher than that of the seed piece itself, but an exception was to be noted in the Burbank and Early Rose on March 22, 1921, and in the Green Mountain on April 18. The osmotic pressure in the seed piece drops away rapidly as the stored starch is used by the plant, but an exception again occurs in the Green Mountain seed pieces on April 27, and the Early Rose on June 27, where the pressure continued high. The dry condition of the soil may explain this high pressure, as the water may have passed out of the seed piece, gradually leaving a more concentrated solution behind, or the plant may have been unable to supply water to the seed piece to remove the sugars which went into solution. The soil was very dry and probably drier in some beds than in others.

The roots examined March 22, 1921, had the lowest osmotic pressure of any portion of the growing plants, as was to be expected.

It may be noted generally for both years that the foliage maintained at all times a greater osmotic pressure than any other organ of the plant. In general, the pressures in younger tip leaves were greater than in the older leaves, but there were exceptions. The juice of the stems, however, at no time approached that of the foliage, and in this relation we have something radically different from the conditions in plants grown in the field where, at some time during the growing season, the stems always developed a higher pressure than the leaves. The high stem pressures came usually at the periods of tip burn, and the author is inclined to associate the two phenomena. While the plant is very active photosynthetically the sugars that are so rapidly formed are stored temporarily in the stem to the detriment of the leaves of the plant. Shaded plants, greenhouse plants, and the plants from Randolph, Vt., did not show this abnormally high stem pressure and did not show any amount of tip burn. The two sets of facts may be unrelated, but the common occurrence is at any rate highly suggestive that they are connected.

The pressure developed in the young tubers in the greenhouse is like that in tubers grown out of doors. The average for the young tubers for both years is 6.60 atmospheres in the greenhouse plants of all sorts, compared with 6.30, 7.08, 7.52, and 6.18 atmospheres in new tubers from the field in the four years during which the work was carried on. The very dry condition of the soil in the benches undoubtedly helped to raise the pressure in the tubers grown in such soil.

## SUMMARY

(1) The general results confirm those obtained in 1918; the growing portions, usually the young leaves and branches, have a higher osmotic pressure in their cell sap than in the sap of the old leaves, stems, or new tubers.

(2) The growth of the top leaves may be checked, however, and the lower (older) leaves may show a very much greater pressure.

(3) The stems usually show the highest pressure during the height of the activity of the plant (July 15 to August 20), apparently because of the presence of a high percentage of reducing sugars.

(4) Potato plants taken from fields in one of the best potato regions in the northern States (Randolph, Vt.), even at the height of the plant activity, showed superior pressure in the young leaves and shoots and the plants were apparently still growing at that time, without any signs of tip burn.

(5) Plants grown in tiles under a cloth shade have less osmotic pressure in the juices of the foliage parts as compared with plants grown in tiles in the open; the pressure in the stems and tubers is about the same, however.

(6) No differences could be detected in the juices from the early and late varieties. Weather seemed to have more effect than variety.

(7) Mosaic plants have a higher osmotic pressure in the leaves than healthy ones, but this does not seem to be true of the stems.

(8) The osmotic pressure is greater in some years than in others, depending on the weather; a wet year lowers the pressure while a dry one raises it, especially in the new tubers.

(9) The pressure varies much more between different parts of the potato plant than it does between those of the artichoke or dahlia; the potato seems to be in a state of unstable equilibrium. The older leaves of the artichoke may have a very high pressure, but the dahlia seems to be quite constant throughout, even in very warm, clear sunshine.

(10) Potato plants grown in the greenhouse never developed a superior osmotic pressure in the stems; the pressure in the leaves was always much higher. The osmotic pressure in the new tubers was about the same as that of field-grown plants, probably because of the rather dry condition of the soil.