# Studies of MINERAL BALANCE as related to occurrence of BALDWIN SPOT in Connecticut

Philip Garman and W. T. Mathis

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## Contents



## Acknowledgments

The spectrographic analyses were made in large part by Sunrae Agostini and the nitrogen determinations by Owen L. Nolan in the Department of Analytical Chemistry. The laboratory samples were prepared by Bessie H. Kennedy.

## Methods

All analyses for minerals were by spectrograph, nitrogen by the usual A. O. A. C. procedure. Preparation of samples was made in a Waring Blender, adding an equal weight of water before blending, then frozen and held until analyzed. Comparison of mineral ratios was made in the beginning on a wet-weight basis which was changed to a dry-weight calculation as the work proceeded.

All examination of fruit was made by cutting, after the fruit had been held for a month or more in storage. In 1955, all except a few samples were kept in common storage until they were removed and cut open. Unless otherwise mentioned the varieties considered were either Baldwin or Spy.

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## Introduction

The Baldwin apple has been known in New England for a generation or more as a top-notch dessert apple. It is high in vitamin C and total solids, and has an excellent flavor. Together with the Spy, also a variety susceptible to Baldwin spot, it is highly prized both for eating and cooking. It is apparent, however, from a study of recent marketing trends that both these varieties are being replaced by others less susceptible.

Various scientists have attempted to explain the cause or causes of Baldwin spot (also known as stippin or bitter pit). Until recently the accepted cause appeared to be desiccation (of the spots) from varying osmotic pressures or fluctuating water supplies. Reports (3, 4, 8 and others) indicate that Baldwin spot can be increased by:

1. Ringing the branches.
2. Heavy nitrogen fertilization.
3. Heavy pruning.
4. Irrigation with added magnesium sulfate (Epsom salt).

It can be reduced by:

1. Stripping off the leaves (probably midseason).
2. Care in choosing the correct picking date.
3. Choosing the variety.

All of these facts are useful, but they do not tell us *why* Baldwin spot is worse in some varieties than others (page 10), apparently unknown in some, or why the spots turn brown deep in the flesh where desiccation (after picking) could be expected to be much less than at the surface. The spots themselves have been described in Australia as bitter, but this is not true for Connecticut or the Northwest (Rose et al. 31)

Because of the puzzling nature of the trouble, as well as the high quality of the varieties involved, work reported herein was started to learn as much as possible about it.

## Review of Previous Investigations

The most extensive investigation of the trouble is that of Smock (34) in his bulletin on Studies of Bitter Pit of the Apple published in 1941. In discussing osmotic pressure (theoretical considerations no. 8, p. 42) he says:

> "As has been stated, a question logically arises as to whether these osmotic phenomena which have been described actually have something to do with the causing of bitter pit or merely accompany its appearance. The evidence is more or less circumstantial. The increase in pitting caused by fruit-stem girdling, however, would seem to bear out the thesis that pitting may be increased by any treatment which increases the leaf-fruit competition for water."

As will be shown later, competition for water between leaves and fruit evidently involves differential selection of solutes or chemicals dissolved in the sap. Therefore, while osmotic differential is of greatest importance, mineral nutrition plays a part in influencing the osmotic phenomena observed, as well as a possible role in the toxicology of the spots. Crafts, Currier, and Stocking (13) state that "evaporation follows definite physical laws and is affected by osmotic concentration of the solution—mineral nutrients may affect transpiration through their osmotic effects upon the DPD (diffusion pressure deficit) of the soil solution their tendency to increase the concentration within plant cells" etc.

Authors in two widely separated countries (2, 3) have emphasized the importance of mineral ratios such as potassium, calcium, and magnesium in plant nutrition. Statements of others not concerned with Baldwin spot make it apparent, furthermore, that excesses of either magnesium or calcium in plant tissue might produce lesions. In Japan, (2) the nutrient ratio thought to give best results is 3 parts lime to 1 of magnesium. Leaf spotting and early fruit drop of certain plants occur with a magnesium deficiency and sometimes severe spray burn may be associated with that condition. On the other hand, small overdoses of magnesium have sometimes caused severe leaf injury and one experimenter was able to produce symptoms very similar to Baldwin spot by adding Epsom salts to irrigation water (Rose et al. 31).

In more recent publications workers seem to question the lime/magnesium theory while others stress the importance of potassium/magnesium levels. It is of course well known that magnesium is needed in chlorophyll formation and as such is indispensable. However, Wallace (35) states: "Two groups of cases are distinguishable when MgO is deficient, the first when CaO is also low and the second when it is high." It is assumed here that a balance would be desirable.

In leaves, the deficiency limit for calcium is said to be around 0.7 per cent; for magnesium about 0.3 per cent, which would possibly mean a ratio of about 2 calcium to 1 of magnesium. For fruit apparently not much is known of deficiency limits, though it is probably much lower than for leaves. For shoot wood and bark, deficiency limits for magnesium are said to be (Goodal and Gregory (20) from Wallace) 0.04 to 0.08 per cent, approximately one-eighth that of leaves at the higher level. Boynton and Compton (6) reported that both calcium and magnesium increase in leaves with nitrogen fertilization. Our figures confirm this. However, the comparative rates are perhaps more important than just the increase, and the differential decline in late season should be kept in mind.

Mulder (28) has discussed at length the causes of bitter pit and gives a diagram of the various contributing factors.

He concludes that:

> "Bitter pit in apples cannot be attributed to one single factor of nutrition or to cultural or weather conditions, there are several causes and occasions in different rates contributing to the formation of bitter pit."

He states further:

> "The control of bitter pit is a matter requiring the attention of the grower all the year round, as every measure of culture has some effect on bitter pit. This applies to causes of bitter pit such as: excess of nitrogen, relative shortage of phosphates due to magnesium deficiency, unfavorable ratios of foliage to fruits resulting from a relatively small number of fruits . . ."

He also directs attention to magnesium deficiency as a factor.

More recently, the Dutch authors have attributed stippin (or Baldwin spot or bitter pit) to an unbalanced potassium-magnesium ratio. Thus with a K/Mg ratio of 20-30 to 1 no Baldwin spot occurred, but with a level of 4 or 5 to 1 there was an increase (32). What may possibly be involved here is a low level of calcium accompanying the low potassium level.



Before attempting to analyze or diagnose the trouble as it appears in Connecticut, it might be well to add some observations dealing with apple nutrition alone. Gourley and Howlett observed (21 p. 159) that calcium is a "component part of plant structure, influences translocation of carbohydrates, influences absorption of other ions and *reduces the toxic effect of other elements and organic acids.*" Horsfall states that calcium and magnesium are apparently antagonistic in fungicides and each may counteract the injury produced by the other (21, p. 184).

Some authors have indicated that high potassium may produce an apple of unsatisfactory keeping quality and, of course, the effect of boron deficiency is well known in causing internal cork in Cortland and other varieties. In this connection the observed correlation between high K and low B should be kept in mind (Table 16). The general effects of nitrogen excess are equally well known; i. e. the production of quantities of leaves and frequently a soft apple of poor keeping quality. Hopkins and Gourley observed (23) that calcium in the ash of the apple declined faster than phosphorus or potassium. It is also apparent from the work of Rogers and Batjer (29) that calcium declines faster than magnesium in the Delicious and Winesap. These observations check with ours in Connecticut for Baldwin and McIntosh.

We have mentioned the subject of mineral balances, but the critical question is which element or elements in the ratios may be more important. Various ratios are compared in Table 3 and comparisons offered between Baldwin and McIntosh. Table 2 gives the percentage ratios of Mg, Ca, and P based on K = 100 per cent.

In the article by Rogers and Batjer (29) it is apparent from their Figure 5 that calcium is in excess of magnesium in the Delicious and Winesap apples of the Wenatchee Valley. We can find no reference to Baldwin spot or stippin in the Winesap variety although Delicious in Connecticut, with heavy ground fertilization and an excess of magnesium over calcium at harvest, had a small per cent of Baldwin spot in 1954 (Table 11). Possibly a better balance between calcium and magnesium occurs in the western areas than is found in Connecticut.

## Preliminary Studies of Ratios

Preliminary analyses of Baldwin spot, normal and healthy tissues are shown in Table 1. It was noted here that a considerable excess of magnesium existed in the spots and that the ratio of Mg/Ca in diseased tissues was very high as compared with normal. From Table 3, it will be seen that Baldwin spot could be correlated with (1) the K/Ca ratio, (2) the Mg/Ca ratio, or (3) the K/Mg ratio. If we consider the fact that excess magnesium was found in affected spots and that calcium antidotes magnesium; also, if calcium decreases faster than magnesium or phosphorus (Tables 5, 6) the Mg/Ca ratio would assume considerable importance. Examination of the ratios given in Table 3 indicate that K/Mg and Mg/Ca show the greatest differences between healthy and diseased fruit. However from Table 4, the $K+Mg+P/Ca$ ratio appears fully as important as the Mg/Ca ratio, indicating a needed balance of all these elements.

From this discussion, considered from several angles, taking into account the rapid decline of calcium percentagewise compared with other elements, it appears as though some varieties of Connecticut fruit are not getting enough of that important element (see Varietal Influence, p. 10).

**Table. 1. Results of chemical analyses of apples, 1950, (averages of five analyses in each case, dry weight)**

| Area and time of analysis | | K | Mg | Ca | P | B |
|---|---|---|---|---|---|---|
| | | % | % | % | % | p. p. m. |
| *From spots* | March | 1.16 | .13 | — | .09 | 18.0 |
| | December | 1.32 | .28 | .072 | .12 | 38.0 |
| *From good portions* | March | .55 | .015 | — | .054 | 12.5 |
| | December | .71 | .031 | .070 | .065 | 21.0 |
| *From apples without spot* | March | .62 | .020 | — | .053 | 10.5 |
| | December | .66 | .034 | .083 | .055 | 16.7 |

In McIntosh fruit, calcium declined considerably from June 15 to August 14. At the same time leaf analysis showed an increase in calcium from .844 to 1.03 per cent. Similar figures were obtained from Stark comparing analyses of August 17 and October 1 (Table 8).

It would appear from Table 4 that the ratios Mg/Ca and K+Mg+P/Ca are more important than K/Mg. This together with the comparative ratios of amounts in leaves and fruit (Table 6) seem to point, as mentioned above, to calcium as the critical element. On the other hand, if we calculate the K+Mg/Ca ratio, the results are essentially the same as when phosphorus is included. It should be remarked, however, that the K levels in these analyses are fairly high according to Dutch standards, though not high enough to tell whether the ratio, as such, has any influence on Baldwin spot.

**Table 2. Amounts of Mg, Ca, and P per 100 parts of potassium in Baldwin and McIntosh apples**

| Variety | K | Mg | Ca | P |
|---|---|---|---|---|
| | Per cent of potassium | | | |
| Baldwin, no spot | 100 | 4.4 | 9.9 | 9.2 |
| | 100 | 5.2 | 12.6 | 8.3 |
| Baldwin, with Baldwin spot | 100 | 21.2 | 5.4 | 9.1 |
| McIntosh | 100 | 6.8 | 6.2 | 12.9 |

**Table 3. Ratio of minerals in whole Baldwin and McIntosh apples**

| | | Baldwin | McIntosh |
|---|---|---|---|
| | | p. p. m. | p. p. m. |
| K to P | *with* Baldwin spot | 13 to 1 | |
| | no Baldwin spot | 8 to 1<br>12 to 1 | 7.7 to 1 |
| K to Mg | *with* Baldwin spot | 4 to 1 | |
| | no Baldwin spot | 24 to 1<br>55 to 1 | 11 to 1 |
| K to Ca | *with* Baldwin spot | 19 to 1 | |
| | no Baldwin spot | 8 to 1<br>10 to 1 | 15 to 1<br>16 to 1 |
| K to B | *with* Baldwin spot | 545 to 1 | 412 to 1 |
| | no Baldwin spot | 492 to 1 | 352 to 1 |
| Mg to Ca | *with* Baldwin spot | 4 to 1 | |
| | no Baldwin spot | 1 to 1 | 1.1 to 1 |



**Table 4. Various mineral ratios in the whole fruit in connection with Baldwin spot**

| Orchard and variety | (K+Mg+P)/Ca | Mg/Ca | K/Mg | Baldwin spot Shallow | Baldwin spot Deep |
|---|---|---|---|---|---|
| | | | | % | % |
| Burton (Baldwin) | 47.7 | 2.17 | 20.2 | 38.2 | 18.4 |
| Barnes (Stark) | 32.2 | 1.49 | 21.4 | 17.6 | 4.9 |
| Lyman (Baldwin) | 23.7 | 1.25 | 21.7 | 12.5 | 2.4 |

**Table 5. Change of several mineral elements in Baldwin fruit at harvest (October 5) compared with August 15**

| Mineral | Change |
|---|---|
| Boron | 13% increase |
| Potassium | none |
| Phosphorus | 6% decline |
| Copper | 8% decline |
| Magnesium | 19% decline |
| Manganese | 26% decline |
| Calcium | 31% decline |
| Iron | 66% decline |

## Seasonal Changes in Mineral Levels

A bit of additional evidence is presented in Tables 5 and 6. Table 5 gives harvest percentages of several mineral elements as compared with levels found in August. Table 6 gives the ratio of parts per million between leaves and fruit.

From Table 5 it is obvious that not all minerals in the Baldwin apple are behaving the same way. If we calculate typical ratios leaf to fruit (Table 6) it is further evident that there are great differences here also. It is interesting to note at this point the high level of copper in the fruit as compared with leaves.

It is also apparent that calcium is low in the fruit as compared with the leaves and is declining in the fruit at a rapid rate. Iron, in regard to amounts in leaves versus fruit or declines in fruit, indicates a moderate supply as compared to the leaves, but a more rapid decline in the fruit than any other mineral. Boron increases steadily as noted by us (19, fig. 2) and others (29, fig. 6) and is probably associated with formation of sugar. Much more work is needed to understand these changes fully, but any practice that reduces boron should be suspect.

If we calculate the ratios of the different elements in the leaves and fruit on a dry weight basis, we find, as indicated in Table 8, that the one outstanding

**Table 6. Leaves/fruit ratios of certain elements in Baldwins, August 15, 1955, tree F 29**

| | p.p.m. dry weight |
|---|---|
| Calcium | 40.9* |
| Manganese | 25.5 |
| Magnesium | 7.2 |
| Iron | 6.4 |
| Boron | 3.3 |
| Phosphorus | 2.5 |
| Potassium | 2.6 |
| Copper | .2 |

* 40.9 times as much in the leaves as in the fruit.

**Table 7. Comparison of mineral trends in fruit and leaves for the Stark variety, 1954, average of nine trees, dry weight basis**

| | K | Ca | Mg | P | Fe | Mn | B |
|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | p. p. m. |
| Aug. 17 leaves | 1.14 | .88 | .17 | .18 | .045 | .007 | 37 |
| Aug. 17 fruit | .71 | .036 | .039 | .06 | .0039 | .0004 | 19 |
| Oct. 1 leaves | 1.28 | 1.14 | .14 | .17 | .028 | .007 | 38 |
| Oct. 1 fruit | .77 | .016 | .031 | .09 | .0048 | .0024 | 19 |

**Table 8. Leaves/fruit ratios of certain elements in Stark variety, average of nine trees, dry weight basis**

| | August 17 | October 1 |
|---|---|---|
| Ca | 24.4 | 71.3 |
| Mn | 17.5 | 2.9 |
| B | 1.9 | 2.0 |
| K | 1.6 | 1.7 |
| Mg | 4.4 | 4.5 |
| P | 3.0 | 1.9 |
| Fe | 11.5 | 5.8 |

increase from August 17 to October 13 is in calcium. Contrarywise from Table 5, it appears that calcium is declining faster in the fruit than other elements analyzed except iron (as per Hopkins and Gourley, 23).

## Connection Between Ratios and Baldwin Spot

From Tables 5 and 6 it would appear as though certain elements, notably calcium and manganese, are increasing in the leaves at the expense of the fruit. If one wishes to combat the more important mineral declines, as indicated in Table 5, it would appear necessary on theoretical grounds to apply calcium, iron, and manganese, in late summer—probably as a foliar spray—or else provide excesses of these chemicals through ground fertilization earlier in the season. However, as pointed out by some workers, K excesses may produce Mg or B deficiency. It is also pertinent to observe that fruit deficiencies may not be apparent from foliar analysis unless a much higher level of calcium in leaves is desired than is commonly indicated. Thus, analysis of leaves from the Burton orchard appeared to be over the deficiency limit for calcium from leaf analysis, although high in Baldwin spot. It, therefore, becomes important to know what ratios we have on trees with high and low spot percentages. Tables 9 and 10 give figures obtained in 1954.

## Varietal Influence

Up to 1954 analyses had shown that calcium was almost always in balance in the McIntosh. Hopkins and Gourley report a similar balance for the Stayman and Winesap, and as mentioned above calcium is higher in the west in Delicious and Winesap. We can find no report of Baldwin Spot in the Winesap variety (see Table 11). Likewise, Romes were analyzed and both calcium and magnesium were nearly equal. In the varieties most seriously affected in the east; namely, Baldwin and Spy, the reverse is true. Magnesium is usually higher than calcium, in some cases two to four times as high.

Analyses of some of the more important varieties grown in Connecticut are given in Table 11. Calculations could have been made here in Mg/Ca or Mg+K+P/Ca and would show similar results, all indicating the influence of calcium.

## The Individual Tree

It is well known that trees within varieties differ in susceptibility to Baldwin spot. This could be due to variations in rate of uptake of various minerals, to location or possibly other factors. For example one tree in the Burton orchard showed a marked difference from branch to branch, without evidence of bark injury which might affect the flow of sap. Since the fruit of different branches varied greatly in appearance, samples from light and heavy branches were analyzed separately. Results of these analyses showed fruit from branches with severe Baldwin spot had a dry-weight ratio (K+Mg/Ca) of 55.8 whereas those low in spot analyzed 10.6.

**Table 9. Ratio of calcium in leaves to that in fruit on trees with high and low Baldwin spot, August 17, 1954**

| | Ratio Leaves to fruit | Per cent Baldwin spot |
|---|---|---|
| Tree E4 (Burton Orchard) | 20 to 1 | 3.6 |
| Tree E18 (Burton Orchard) | 65 to 1 | 61.0 |
| Tree 1 (Lyman Orchard) sprayed | 22 to 1 | 0.0 |
| Tree 5 (Lyman Orchard) unsprayed | 45 to 1 | 39.2 |



## Influence of Crop Size

One of the more outstanding and consistent differences in Baldwin spot percentages is in connection with different amounts of fruit. In order to learn more about what is happening in mineral contents of fruit and foliage comparisons of leaves and fruit from heavy- and light-crop trees were made in 1954

**Table 10. Correlation between calcium in the leaves and fruit with the amount of Baldwin spot, 1955**

| Ca in leaves (p.p.m.) divided by Ca in fruit (p.p.m.) | Per cent Baldwin spot |
|---|---|
| 22.8 | 0.0 |
| 24.2 | 0.4 |
| 29.8 | 17.8 |
| 34.2 | 12.1 |
| 37.2 | 2.8 |
| 40.9 | 17.2 |
| 57.1 | 22.4 |
| 63.5 | 50.0 |
| 74.8 | 75.0 |
| Summary by groups | |
| 20 – 30 | 6.1 |
| 30 – 40 | 12.1 |
| 40 – 50 | 17.2 |
| 50 – 60 | 22.4 |
| 60 – 70 | 50.0 |
| 70 – 80 | 75.0 |

**Table 11. Mineral ratio, K+Mg/Ca, in relation to the variety and its susceptibility to Baldwin spot**

| Variety | Year | K+Mg/Ca | Prevalence (Smock & Neubert) | Prevalence in Connecticut |
|---|---|---|---|---|
| Grimes Golden | 1955 | 11 | Medium | None seen |
| Winesap | 1954 | 11 | None | None |
| Opalescent | 1955 | 12 | — | Rare |
| Gano | 1954 | 12 | Slight | None |
| Golden Delicious | 1954 | 18 | None | None |
| Rome | 1954 | 21 | Slight | None seen |
| McIntosh | 1953 | 28 | Slight | Slight |
| Wagener | 1954 | 31 | Slight | Slight |
| Delicious | 1954 | 32 | Slight | Slight |
| Baldwin | 1954 | 45 | Severe | Severe |
| Spy | 1954 | 49 | Severe | Severe |
| Cortland* | 1955 | 53 | Severe | Severe |

* Cortlands with heavy spot were selected. Probably not typical of the variety.

**Table 12. Effects of heavy and light crops on magnesium and calcium levels in Baldwin fruits, 1955**

| Trees | Crop | August | October | Difference | Decline as per cent of August reading |
|---|---|---|---|---|---|
| | | Calcium in p.p.m., dry weight | | | |
| G3, G5 | heavy | 457 | 459 | +2 | — |
| G27, G31 | light | 313 | 214 | -99 | 31.6 |
| | | Magnesium in p.p.m., dry weight | | | |
| G3, G5 | heavy | 633 | 514 | -119 | 18.8 |
| G27, G31 | light | 445 | 406 | -39 | 8.8 |

**Table 13. Effects of heavy and light crops on magnesium and calcium in Baldwin leaves, 1954**

| Trees | Crop | September | October | Difference | Increase as per cent of September reading |
|---|---|---|---|---|---|
| | | Per cent calcium, dry weight | | | |
| E4, E28 | heavy | 1.09 | 1.46 | .35 | 32 |
| E18, E20 | light | .88 | 1.05 | .17 | 19 |
| | | Per cent magnesium, dry weight | | | |
| E4, E28 | heavy | .31 | .33 | .03 | 10 |
| E18, E20 | light | .29 | .34 | .05 | 17 |

and 1955. Results are set forth in Tables 12 and 13. The trees selected were from Burton orchard (E and G rows). They were first grouped into "heavy" and "light" crops and the amounts of calcium and magnesium were compared (Table 12). The Mg/Ca ratios were then computed for heavy and light crops

**Table 14. Relation between number of fruits, the Mg/Ca ratio, and the per cent of fruit with Baldwin spot**

| Tree | Year | Number of fruits | Mg/Ca ratio | Per cent Baldwin spot |
|---|---|---|---|---|
| E4 | 1955 | 43 | 1.96 | 55.8 |
| E6 | 1955 | 48 | 2.37 | 75.0 |
| F21 | 1955 | 51 | 3.33 | 45.1 |
| E34 | 1955 | 36 | 1.43 | 22.2 |
| E32 | 1955 | 39 | 1.69 | 17.9 |
| | | 43 | 2.15 | 43.2 |
| E18 | 1954 | 177 | 4.22 | 61.0 |
| E24 | 1955 | 177 | 1.61 | 2.8 |
| E22 | 1955 | 168 | 2.56 | 36.9 |
| G19 | 1955 | 204 | 2.39 | 37.3 |
| F7 | 1955 | 234 | 2.05 | 26.9 |
| | | 192 | 2.56 | 33.0 |
| E18 | 1955 | 446 | 2.42 | 34.9 |
| G9 | 1955 | 476 | 2.02 | 26.8 |
| E16 | 1955 | 464 | 1.81 | 12.1 |
| G17 | 1955 | 471 | 1.40 | 34.4 |
| G33 | 1955 | 446 | 1.91 | 30.2 |
| | | 461 | 1.91 | 27.7 |
| E32 | 1954 | 1243 | 2.77 | 3.2 |
| E20 | 1955 | 1014 | 1.50 | 2.8 |
| G27 | 1955 | 1817 | 2.06 | 5.5 |
| E30 | 1955 | 1155 | 1.51 | 17.6 |
| G7 | 1955 | 1671 | 1.50 | 6.8 |
| | | 1380 | 1.86 | 7.1 |
| E28 | 1954 | 2383 | 2.12 | 5.3 |
| E4 | 1954 | 3518 | 1.03 | 7.3 |
| G3 | 1955 | 4085 | 1.23 | 2.7 |
| G5 | 1955 | 3371 | 1.03 | 3.0 |
| G29 | 1955 | 2322 | 1.20 | 1.6 |
| | | 3136 | 1.12 | 4.0 |



(Table 14), and finally trees were selected for examination in two different years (Table 15).

From Tables 12 and 13 it appears that calcium is declining faster in the fruit of light-crop trees than in heavy and that magnesium is declining faster in the heavy-crop trees. This would tend, therefore, to leave a much more unfavorable balance in light-crop fruit than in heavy.

The leaves, on the other hand, are increasing in calcium at a faster rate than in magnesium but, contrary to expectations, somewhat faster in the heavy-crop trees than in the light. Compared with magnesium, however, the rate of increase as indicated in Tables 12 and 13 is much greater than for magnesium, indicating depletion of reserves in the fruit and creating an unbalanced condition there. This would support the theory that heavy foliage in the case of light-crop trees is drawing calcium from the fruit more than is encountered in heavy-crop trees where foliage is usually smaller.

The figures in Table 14 show a general correlation between low and high ratios and Baldwin spot but the correlation is not perfect. They indicate another factor which as already stated may be due to individual tree variation. Comparisons of the same trees in two successive years seem to support this idea (Table 15) for they show a more nearly perfect correlation between Mg/Ca ratios and the amount of Baldwin spot.

## Influence of Nitrogen and Other Elements

In the McIntosh it has been shown (18) that there is a positive correlation between:

**Table 15. Comparison of calcium ratios in successive years**

| Tree | Year | Number of fruits | $\frac{Mg}{Ca}$ | $\frac{K+Mg}{Ca}$ | Per cent Baldwin spot |
|---|---|---|---|---|---|
| E4 | 1954 | 3496 | 1.03 | 14 | 8.3 |
| | 1955 | 43 | 1.96 | 49 | 55.8 |
| E6 | 1954 | 960 | 2.05 | 15 | 54.8 |
| | 1955 | 48 | 2.37 | 17 | 75.0 |
| E8 | 1954 | 386 | 2.72 | 56 | 55.1 |
| | 1955 | 667 | 2.24 | 36 | 20.7 |
| E22 | 1954 | 2385 | 1.94 | 44 | 51.8 |
| | 1955 | 168 | 2.56 | 42 | 36.3 |
| E28 | 1954 | 2322 | 2.12 | 33 | 25.3 |
| | 1955 | 599 | 1.59 | 43 | 27.0 |
| F7 | 1954 | 464 | 3.75 | 79 | 69.3 |
| | 1955 | 234 | 2.05 | 28 | 26.9 |
| F19 | 1954 | 425 | 3.40 | 71 | 62.5 |
| | 1955 | 264 | 2.17 | 47 | 21.2 |
| G23 | 1954 | 632 | 2.62 | 52 | 45.0 |
| | 1955 | 1665 | 1.91 | 41 | 14.4 |
| G29 | 1954 | 307 | 2.27 | 52 | 42.9 |
| | 1955 | 2322 | 1.20 | 20 | 1.6 |
| G33 | 1954 | 1515 | 2.91 | 65 | 22.8 |
| | 1955 | 446 | 2.18 | 48 | 20.8 |

Significance of ratios P. between .01 and .02

1. The amount of phosphorus and the amount of boron.
2. The amount of magnesium and the amount of phosphorus.
3. The amount of magnesium and the amount of boron.

And a negative correlation between:

1. The amount of calcium and magnesium.
2. The amount of calcium and boron.

In the Baldwin the same positive correlations are apparent, but not the negative, except for the differential levels of calcium and magnesium.

In regard to nitrogen, our data indicate a depression of phosphorus from high levels of nitrogen and a tendency also to depress calcium. High levels of potassium seem to depress boron (see 31), while high or low levels of phosphorus have no effect. There is consequently a somewhat different picture between the mineral nutrition of McIntosh and Baldwins. Study of high and low levels of Ca, Mg, and B seem to show they have little or no effect on other minerals in Baldwin fruit. If, then, high nitrogen depresses phosphorus and calcium with boron remaining static—to correct this condition it would be desirable to add P, Ca, and B. If at the same time we have high levels of potassium it will become advisable to add boron again. The logical solution here would be to fortify the fertilizer with calcium phosphate and boron. Calcium nitrate would not be quite as good as calcium phosphate because of the action of nitrogen and the depression of phosphates. Calcium nitrate would furthermore tend to increase potassium and magnesium in addition to raising the calcium level so an unfavorable ratio, if it existed before, might still remain. If there were an only slightly unbalanced ratio, however, the calcium level would probably be raised enough to bring it in balance. This has apparently occurred in several orchard tests in Connecticut. Results of 1955 analyses are given in Table 16.

**Table 16. Effect of high levels of single nutrient elements on the levels of other elements in the Baldwin fruit**

| High levels of | N | P | K | Ca | Mg | Mn | Fe | B |
|---|---|---|---|---|---|---|---|---|
| N | — | *D* | I | *D* | I | I | I | U |
| P | *D* | — | I | I | I | U | U | U |
| K | I | I | — | I | I | U | U | *D* |
| Ca | I | I | I | — | I | I | I | I |
| Mg | I | I | I | I | — | I | I | I |
| B | *D* | I | I | I | I | I | I | — |

I=Increase *D*=Decrease U=Unchanged

From the above, in summary, to correct for changes following high nitrogen levels it would apparently be advisable to add phosphorus, calcium, and boron to keep a desirable balance (for Baldwin fruit in this orchard). To correct for high potassium it would be desirable to add boron.

Cain and Boynton (10) indicate that there may be the following relation between heavy nitrogen fertilization and levels of other nutrients in leaves: (1) a decrease in potash and phosphorus, and (2) increases in calcium, magnesium and total bases (Ca+Mg+K). Our figures show a depression for P, K, and Fe and increases in Ca, Mg, B, and Mn. High levels of other elements produced somewhat confusing results though if we take one at a time including N, P, K, Ca, Mg, and B we find (1) a decrease in B from excess P and vice versa, a static condition for Fe with most high levels except N where there is a decrease, and a static condition for Mn except for high Mg and N, where increases occurred. Cain and Boynton further point out that there are increases in this direction from a heavy crop, thus putting the heavy-crop trees in the same category with high nitrogen fertilization. Increases in calcium and magnesium in the leaves of heavy-crop trees would not affect the ratio, though it is evident from analyses previously presented (Table 12), that calcium leaves the fruit faster (presumably being taken by leaves) in the light-crop trees than in the heavy. Figures in Table 12 show that calcium declines faster in the fruit in light-crop years, but magnesium shows a reverse trend.



## Experiments to Produce and Control Baldwin Spot

### Injection experiments

Theoretically, if Baldwin spot is associated in any way with unbalanced minerals, it should be possible by injection of fertilizers directly into the apples to reproduce the disease in some measure. This was attempted early in the study, but failure resulted because of injection through the sides of the fruit instead of the calyx. By injection through the calyx (on the tree) and holding the fruit one month after harvest, we obtained some interesting data (Tables 17, 18). They show again a trend for increased symptoms (resembling Baldwin spot) from injections of potassium nitrate, magnesium sulfate, or a combination of the two. This appears to be in agreement with ground applications of fertilizers (Table 19) and dipping experiments.

### Dipping experiments

Whole branches of fruit and leaves were dipped in concentrated solutions with similar results to hypodermic injection. Thus 41 per cent of the fruit treated in this manner with magnesium sulfate plus potassium nitrate was spotted, only 2 per cent when treated with magnesium sulfate and calcium nitrate.

### Field Experiments, 1953 and 1954

Injection and dipping experiments mentioned above were made with fairly concentrated mixtures, (5 and 10 per cent) but the difference between the two types of mixtures indicated that even where the ratio between potassium and magnesium reached 32 to 1 in the solutions, the Baldwin spot condition occurred.

**Table 17. Effect of injecting various fertilizers directly into fruit on the tree**

| Chemical | Number of injections* | Baldwin spot symptoms produced Number | Per Cent |
|---|---|---|---|
| Calcium salts | 26 | 0 | 0 |
| Ammonium salts | 8 | 0 | 0 |
| Potassium salts | 53 | 5 | 9 |
| Magnesium salts | 25 | 5 | 20 |

* Injections with hypodermic needles into core by way of the calyx.

It was decided, therefore, to carry on field experiments along the lines (1) to produce the spot, if possible, by sprays and soil injection and (2) to provide the antidote by use of calcium nitrate. In 1953, plots of Baldwins consisting of five trees each were sprayed with the mixtures given in Table 19. Again in this series, the treatment showing a decrease of Baldwin spot in 2 out of 3 years, was the one containing calcium nitrate.

Another experiment in the Burton orchard consisted of spraying one entire row of Baldwins with calcium nitrate, another with boric acid, and leaving a third as control with no treatment. In this experiment only the control and the row treated with boric acid offered a fair comparison because of differences

**Table 18. Effect of injecting various fertilizers directly into fruit on the tree***

| Fertilizers | Per cent Baldwin spot symptoms |
|---|---|
| $KNO_3$ | 27 |
| $MgSO_4$ | 20 |
| $K_2SO_4$ | 12 |
| KCl | 9 |
| $K_2HPO_4$ | 0 |
| $(NH_4)_2SO_4$ | 0 |
| $CaNO_3$ | 0 |
| $CaH_2PO_4$ | 0 |
| $KNO_3+MgSO_4$ | 20 |
| $KNO_3+MgSO_4+$Boron (Borax) | 10 |
| $KNO_3+MgSo_4+CaHPO_4+$Boron | 0 |
| $KNO_3+(NH_4)_2SO_4$ | 0 |
| $CaNO_3+CaHPO_4$ | 0 |

* Apples held on the trees until harvest and then put in cold storage for one month. Injections were through the calyx end, into the core.

**Table 19. Results of fertilizer treatments* on the amount of Baldwin spot**

| Plot no. | Fertilizer applied | Per cent Baldwin spot 1953 | 1954 | 1955 |
|---|---|---|---|---|
| 1 | Magnesium nitrate plus ammonium sulfate | 38.4 | 7.1 | 46.3 |
| 2 | Magnesium nitrate plus calcium nitrate | 23.6 | 13.2 | 29.9 |
| 3 | Potassium nitrate only | 41.8 | 6.2 | 54.3 |
| 4 | Potassium nitrate plus magnesium sulfate | 38.5 | 24.3 | 55.8 |

* Sprayed on in 1953 and 1954, injected into the soil in 1955.

in pruning. However, the trees sprayed with boric acid had an average of 51.2 per cent spot, no spray 60.6 per cent, and calcium nitrate 37.9 per cent, thus further confirming the effect of calcium salt.

**Table 20. Examination of Stark apples in the field (Barnes orchard) sprayed with calcium nitrate and boric acid**

| | Average number of spotted apples per tree* |
|---|---|
| *Examined on October 3* | |
| Sprayed twice with calcium nitrate (1 lb. to 100 gallons) | .8 |
| Boric acid (1 lb. to 100 gallons) | 3.0 |
| No spray | 4.6 |
| *Examined on October 15* | |
| Sprayed with calcium nitrate | .9 |
| Sprayed with boric acid | 2.4 |
| No spray | 6.6 |

* Figures obtained by counting affected apples seen by passing once completely around each tree.

A fourth experiment consisted of spraying large mature Baldwin trees, half of which were treated with potassium nitrate plus magnesium sulfate, and half with calcium nitrate plus magnesium sulfate. Results were inconclusive though in some trees there was a marked difference in favor of calcium nitrate.

In addition, two fruit growers applied calcium nitrate in 1954 for us, one to Starks, a susceptible variety, and the other to mature Baldwins. The sprays were applied in the Barnes orchard in Wallingford (Table 20) and in the Lyman orchard in Middlefield. Both of these plots were in locations where Baldwin spot has been regularly severe. Crops were light to medium.

At the Lyman orchard a plot of several acres was sprayed twice with calcium nitrate and Baldwin spot estimated in the same manner as in the Barnes orchard. Here 18 spotted apples were seen in 18 trees examined among those sprayed with calcium nitrate (1 per tree), whereas in 18 unsprayed trees a total of 81 spotted apples were counted, or 4.5 per tree. These experiments take into account only the surface spots, but they are indications of the effect of calcium nitrate, nevertheless.

There thus appeared to be at the end of 1954 a very strong indication that applications of calcium nitrate sprayed on the tree will reduce Baldwin spot.

**Table 21. Effect of calcium salt* treatments on the amount of Baldwin spot, 1955**

| Number of apples per tree | Treated with calcium salts Per cent spot | Untreated Per cent spot | Difference |
|---|---|---|---|
| 50 or less | 19.3 | 29.6 | +10.3 |
| 100—200 | 2.8 | 36.9 | +34.1 |
| 400—600 | 16.2 | 27.2 | +11.0 |
| 650—850 | 10.1 | 46.9 | +36.8 |
| 1000—1700 | 10.4 | 44.6 | +34.2 |

* Calcium nitrate and calcium phosphate.



**Table 22. Ratios of Mg/Ca in apples treated with calcium salts compared with untreated, 1955**

| Orchard | Salts applied | Ratio (Mg/Ca) |
|---|---|---|
| Burton, Row E | Calcium nitrate | 1.51 |
| Burton, Row E | None | 1.88 |
| Burton, Row F | Calcium nitrate, calcium phosphate | 1.58 |
| Burton, Row F | None | 1.82 |
| Burton, Row G | Calcium phosphate | 1.29 |
| Burton, Row G | None | 1.64 |
| Dwarf orchard | Calcium nitrate, calcium phosphate | 1.76 |
| Dwarf orchard | None | 3.08 |
| Lyman orchard | Calcium nitrate, calcium phosphate | 1.32 |
| Lyman orchard | None | 1.57 |

NOTE: Treatment in all the above was by injection gun which places the solution 12 to 18 inches below the surface of the soil. Trees compared had 10-10-10 fertilizer at 40 lbs. per tree. Injected trees received two applications of calcium nitrate, 5 and 10 lbs. in 100 gals. Fifty gallons per tree, or 5 and 10 lbs. calcium nitrate, on row E. Calcium nitrate 5 lbs., calcium monophosphate 10 lbs. and the reverse 10 and 5 lbs. 50 gals. per tree on row F: 5 and 10/100 calcium phosphate 50 gals. per tree on row G.

### Experiments in 1955

In 1955 our methods were altered. Instead of sprays, an injection gun was used to place fertilizer 12 to 18 inches below the sod level. A similar experiment was started in the Lyman Spy orchard at Middlefield. In both experiments results were much the same although the amount of Baldwin spot was low in the Lyman orchard because of 1954 treatments. The reduction in the Burton orchard was correlated definitely with the number of fruits and individual tree variation as already explained. Results given in Tables 21 and 22 seem to confirm previous experiments on the favorable effect of calcium in reducing the amount of Baldwin spot.

## Discussion

By way of summary a short discussion of the observed factors that increase Baldwin spot and the connection with mineral deficiencies may be in order.

1. Ringing the branches apparently promotes larger leaves and the leaves appear to require quantities of calcium, keeping it from the fruit or taking it from the fruit and leaving a deficiency which affects Baldwin spot.

2. Heavy nitrogen fertilization produces an excess of foliage over fruit with the resultant depletion of calcium in the fruit because of excessive foliage demands. High nitrogen results in increased potassium and magnesium in Baldwin fruit but does not alter calcium; hence the unbalanced ratio.

3. Heavy pruning produces the same result as in 2, above, namely an excess of leaves in proportion to fruit with the same depletion of calcium in the fruit.

4. Irrigation with added magnesium salts evidently increased magnesium to a point where there was no longer protective action from calcium.

5. Stripping off the leaves reduces the depletion of calcium because there is less foliage in proportion to fruit to demand calcium.

6. By choosing the correct picking date it is assumed that a date when calcium is high would be selected. Apparently this differs in different parts of the United States. Thinned fruit kept in storage was low in Baldwin spot in 1954 presumably because of a favorable ratio which occurred at that time.

7. The varieties differ widely in the amounts of calcium contained in the fruit. From our work those having low Baldwin spot generally have a high ratio of calcium to other elements and vice versa.

## Conclusions

From studies so far it is believed that unbalanced mineral ratios have a profound effect on stippin or Baldwin spot in Connecticut. It would appear that the critical element is calcium and the unbalanced condition lies between calcium and magnesium; or calcium and magnesium plus potassium. There is also a definite connection between the amount of spot and the leaf/fruit calcium ratio.

Efforts to cure the trouble have been partly successful through application of calcium salts both as sprays, and injected into the soil. Much more needs to be done especially with trees of unusual susceptibility. The influence of excess nitrogen can easily prevent a favorable balance through promotion of increased potassium and magnesium in the fruit.

Observations in general confirm those made earlier by others, namely: low spot with heavy yields, high spot with heavy nitrogen fertilization and heavy pruning.

So far we have not been able to connect boron with Baldwin spot through experiment, though grower experience indicates that there may still be some relation. Boron is increased in the leaves by heavy nitrogen fertilization, which may mean that it is prevented from reaching the fruit in needed quantities during the ripening process. It is evident, too, from Table 16 that high potassium decreases boron in the fruit and high phosphorus and nitrogen leave it unchanged. Also, the fact that boron increases steadily in the fruit in late season in contrast with other elements point to it as very important in apple nutrition. Further study of this phase is needed.

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