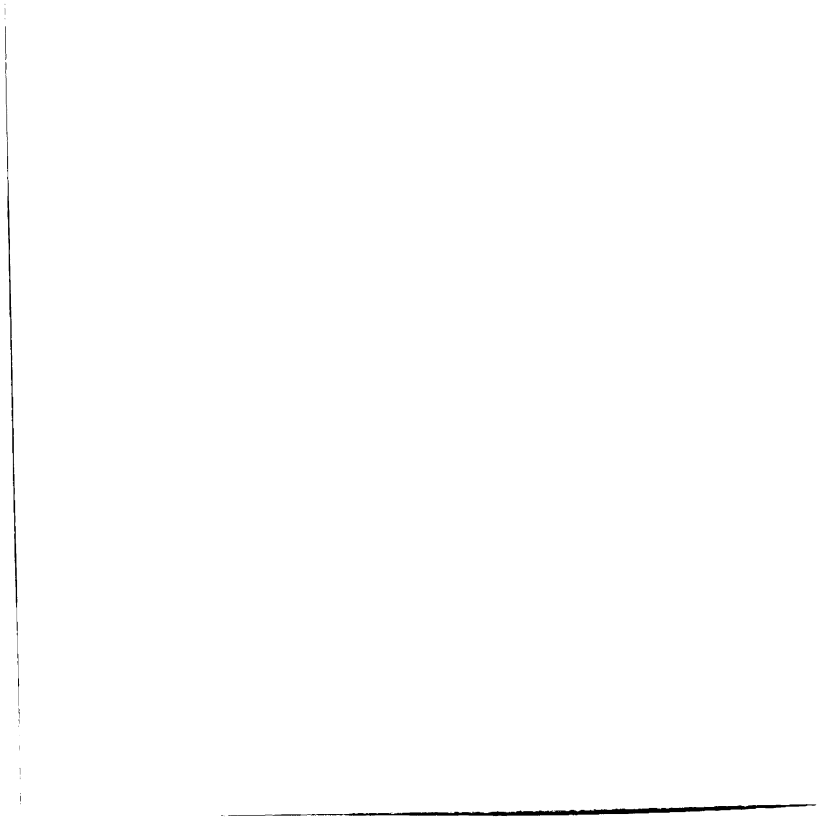
# TRENDS IN NUTRIENT STATUS OF MICHIGAN ORCHARDS AS REFLECTED BY LEAF ANALYSIS

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
HARVEY JAMES BELTER
1970



# TRENDS IN NUTRIENT STATUS OF MICHIGAN ORCHARDS AS REFLECTED BY LEAF ANALYSIS

By

Harvey James Belter

A THESIS

Submitted to
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ABSTRACT

TRENDS IN NUTRIENT STATUS OF MICHIGAN
ORCHARDS AS REFLECTED BY LEAF ANALYSIS

By Harvey James Belter

A study of the analysis of leaf samples submitted by fruit growers in ten Michigan counties for a twelve year period was made to estimate the trends in nutrient status in Michigan orchards. A total of 2,465 leaf samples from the ten selected counties were analyzed between 1956 and 1968 for nine nutrient elements. These results were statistically analyzed to determine the trend (increase or decrease) for each of the elements. Such trends were noted on a state basis, by counties, and by kind of fruit. On a state basis, Michigan orchards have a projected decrease for N, K and Zn and a projected increase for P, Ca, Mg, Mn, Fe, and B. However, K appeared to be the element most likely to become deficient.

The state trends appeared to be generally true for the counties and kind of fruit. However, the trends were less frequently statistically significant.

## ACKNOWLEDGMENTS

The writer wishes to express his sincere thanks and appreciation to Dr. A. L. Kenworthy for his assistance, guidance, and encouragement for suggesting the problem and in preparation of the thesis; to Michael Kilby for assistance in computer programming; to the Cooperative Extension Service for the sabbatical leave which made it possible to carry on this work; and to my family for their patience and sacrifices during my absence.

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# INTRODUCTION

Leaf analysis has been used for many years as a means of determining current nutritional needs of fruit trees. A program designed so that Michigan fruit growers could use leaf analysis routinely as a guide to fertilizer programs was started in 1953 (3). Such programs have been established in many other states.

Leaf analysis has been used in several instances to make a survey of current nutritional status of orchards in a given area (state or region) (1, 2, 5, 6, 7). However, such studies were usually for a one- or two-year period and occasionally for a five-year period. There has been no study in which leaf analysis over a longer period of time was used as a basis for establishing trends in nutrient status and forecasting when applications of specific nutrients may be needed. Results of such a study of Michigan orchards are presented herein.

## METHODS

The analysis of leaf samples which had been submitted by Michigan fruit growers to the Plant Analysis Laboratory, Michigan State University, between 1956 and 1968 were selected for study. Ten counties (see Table 1) were selected and data for leaf samples analyzed for nine elements were used. The data were placed on punched cards and each sample identified as to year, kind of fruit and county. To permit pooling of different kinds of fruit, the data were entered as nutrient balance chart indices (C.I.) (4).

The data were analyzed to determine trends of yearly means on the basis of state, county, and kind of fruit. The significance of linear regression with years was determined by use of MSU, AES, Computer Programs, STAT Series, Program Description No. 13 - one-way analysis of variance with unequal number of duplicates (UNEQ 1).

To estimate when a specific nutrient might become critically low, balance chart indices were used as follows: 80 for N; 70 for K, Ca, Mg; 50 for P, Mn, Fe, B, and Zn (a chart index of 100 would equal standard diagnostic values).

## RESULTS

The distribution of the 2,465 leaf samples by county and kind of fruit is shown in Table 1. The number of samples for each year in the different counties is given in Appendix Table 1, and for different kinds of fruit in Appendix Table 2.

Table 1. Number of leaf samples submitted by Michigan fruit growers for complete analysis.

| County | No. of samples | Kind of fruit | No. of samples |
|---|---|---|---|
| Van Buren | 448 | Apple (all varieties) | 1109 |
| Berrien | 445 | Jonathan | 406 |
| Grand Traverse | 332 | McIntosh | 313 |
| Kent | 265 | Red Delicious | 204 |
| Benzie | 262 | Peach | 90 |
| Oceana | 249 | Sour Cherry | 675 |
| Allegan | 185 | Sweet Cherry | 194 |
| Leelanau | 142 | Pear | 212 |
| Oakland | 71 | Plum | 53 |
| Mason | 65 | Grape | 97 |
| | | Blueberry | 35* |

*Samples submitted through Michigan Blueberry Growers Association not included.

Trends for each nutrient, including all kinds of fruit and for the various counties, are shown in Figure 1. Regression analysis of the leaf analyses showed that N, K, and Zn had a decreasing trend while P, Ca, Mg, Mn, Fe and B had an increasing trend. From the regression equation a general shortage of N by 1994, K by 1990, and Zn by 1998 could be forecast. The rate of increase shown for the other elements does not suggest a reason for concern regarding possible toxicity levels for any element.

Figure 1. Nutritional trends in Michigan orchards. (All crops included.)

A. Nitrogen (Est. N = 102.5 - 0.24 * year*

B. Potassium (Est. K = 145.7 - 0.84 * year

C. Phosphorus (Est. P = 46.3 + 0.71 * year

D. Calcium (Est. Ca = 56.0 + 0.58 * year

E. Magnesium (Est. Mg = 46.4 + 0.64 * year

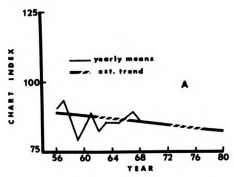
F. Manganese (Est. Mn = 79.1 + 0.23 * year

G. Iron (Est. Fe = 72.2 + 0.26 * year

H. Boron (Est. B = 17.3 + 1.08 * year

I. Zinc (Est. Zn = 203.9 - 1.57 * year

*Year used in regression as last 2 digits (i.e. as for 70, 71, etc.).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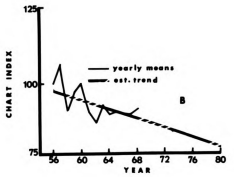
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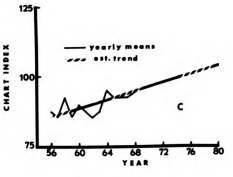
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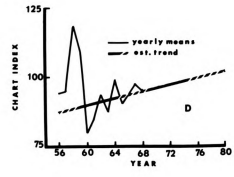
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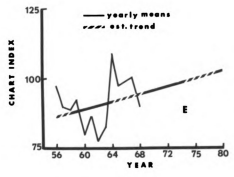
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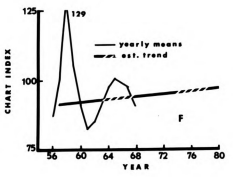
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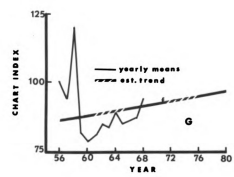
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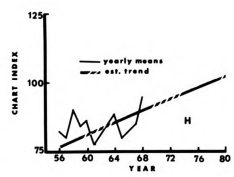
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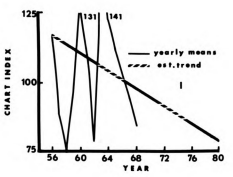
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Estimated nutritional trends for orchards in each of the 10 counties are shown in Table 2. Statistics for the regression equation for each element in each county are presented in Appendix Table 3.

Nitrogen appeared to be decreasing in fruit plantings of all counties except Oceana and Mason while potassium appeared to be increasing in Grand Traverse, Benzie, and Mason. Phosphorus, calcium and magnesium were increasing in all counties. Manganese and iron were increasing in all counties except Kent and Allegan. Oakland was the only county showing a decrease for boron. Zinc appeared to be increasing for Allegan, Leelanau and Oakland counties, and decreasing for Van Buren, Berrien, Grand Traverse, Kent, Benzie, Oceana and Mason counties. Not all of these trends, however, were statistically significant.

The nutritional trends for kinds of fruit from orchards in the 10 counties are given in Table 3. Statistics for the regression equation for each element for each kind of fruit are presented in Appendix Table 4. Statistical significance of the trends was not found in most instances. However, nitrogen appeared to be decreasing for Delicious, Jonathan, sour cherry, peach, sweet cherry, grape, and blueberry, but increasing for McIntosh, Golden Delicious, miscellaneous apple varieties, pear and plum. The increase indicated for McIntosh and Golden Delicious may have association with the fact that the standard value for these two varieties was lowered from 2.3 to 2.0% in 1960.

Table 2. Estimated nutrient trends for orchards in various counties.[1]

| County | N | | K | | P | |
|---|---|---|---|---|---|---|
| | 1956 | 1980 | 1956 | 1980 | 1956 | 1980 |
| Van Buren | 91 | 77(-) | 105 | 74(-) | 87 | 107(+)* |
| Berrien | 88 | 77(-) | 106 | 78(-) | 87 | 114(+)* |
| Grand Traverse | 91 | 85(-)* | 85 | 90(+) | 81 | 94(+)* |
| Kent | 90 | 82(-)* | 102 | 73(-) | 89 | 123(+)* |
| Benzie | 77 | 75(-)* | 77 | 106(+) | 84 | 90(+)* |
| Oceana | 85 | 95(+)* | 91 | 91 | 78 | 98(+) |
| Allegan | 89 | 73(-) | 96 | 81(-) | 87 | 99(+) |
| Leelanau | 96 | 78(-)* | 88 | 78(-) | 77 | 109(+)* |
| Oakland | 93 | 54(-)* | 109 | 74(-) | 97 | 124(+) |
| Mason | 74 | 124(+) | 73 | 121(+) | 80 | 109(+) |

| | Ca | | Mg | | Mn | |
|---|---|---|---|---|---|---|
| | 1956 | 1980 | 1956 | 1980 | 1956 | 1980 |
| Van Buren | 88 | 96(+)* | 92 | 102(+)* | 97 | 107(+)* |
| Berrien | 85 | 109(+)* | 77 | 117(+)* | 102 | 103(+) |
| Grand Traverse | 83 | 99(+) | 82 | 94(+) | 76 | 116(+) |
| Kent | 92 | 104(+) | 80 | 98(+)* | 96 | 69(-) |
| Benzie | 81 | 93(+)* | 83 | 88(+) | 72 | 131(+) |
| Oceana | 75 | 117(+)* | 72 | 108(+) | 84 | 105(+)* |
| Allegan | 92 | 105(+)* | 83 | 90(+) | 110 | 76(-)* |
| Leelanau | 88 | 115(+)* | 84 | 95(+) | 73 | 95(+) |
| Oakland | 111 | 112(+)* | 93 | 93 | 100 | 198(+)* |
| Mason | 80 | 102(+)* | 78 | 93(+) | 80 | 96(+)* |

| | Fe | | B | | Zn | |
|---|---|---|---|---|---|---|
| | 1956 | 1980 | 1956 | 1980 | 1956 | 1980 |
| Van Buren | 86 | 107(+)* | 82 | 112(+)* | 121 | 92(-) |
| Berrien | 93 | 103(+)* | 81 | 110(+)* | 105 | 105 |
| Grand Traverse | 84 | 116(+)* | 70 | 93(+)* | 105 | 77(-) |
| Kent | 101 | 69(-) | 80 | 111(+)* | 137 | 26(-) |
| Benzie | 69 | 131(+)* | 71 | 95(+) | 109 | 77(-) |
| Oceana | 34 | 105(+) | 70 | 109(+) | 100 | 75(-) |
| Allegan | 81 | 76(-)* | 76 | 126(+) | 130 | 155(+)* |
| Leelanau | 73 | 95(+)* | 65 | 109(+) | 125 | 138(+) |
| Oakland | 116 | 198(+) | 92 | 72(-)* | 106 | 126(+) |
| Mason | 74 | 96(+) | 69 | 104(+) | 100 | 75(-) |

[1] Balance chart indices calculated from regression equation.
* Regression significant. See Appendix Table 3 for statistics.

Table 3. Nutritional trends for orchards of various kinds of fruit.[1]

| Kind of fruit | N | | K | | P | |
|---|---|---|---|---|---|---|
| | 1956 | 1980 | 1956 | 1980 | 1956 | 1980 |
| McIntosh | 88 | 108(+)* | 106 | 59(-)* | 88 | 98(+) |
| Golden Delicious | 82 | 115(+) | 123 | 75(-) | 113 | 70(-) |
| Delicious | 98 | 84(-) | 109 | 71(-)* | 88 | 115(+)* |
| Jonathan | 87 | 84(-) | 101 | 77(-)* | 24 | 33(+) |
| Sour cherry | 91 | 68(-)* | 88 | 78(-)* | 85 | 92(+)* |
| Apples (misc. varieties) | 85 | 96(+) | 45 | 15(-)* | 90 | 108(+) |
| Peach | 85 | 81(-) | 137 | 68(-)* | 87 | 109(+)* |
| Sweet cherry | 86 | 78(-) | 85 | 77(-) | 80 | 77(-) |
| Pear | 84 | 95(+) | 99 | 64(-)* | 81 | 91(+) |
| Plum | 78 | 101(+)* | 152 | 108(-) | 90 | 99(+) |
| Grapes | 98 | 91(-) | 101 | 139(+) | 101 | 157(+) |
| Blueberry | 108 | 56(-) | 169 | 26(-)* | 156 | 249(+)* |

| | Ca | | Mg | | Mn | |
|---|---|---|---|---|---|---|
| | 1956 | 1980 | 1956 | 1980 | 1956 | 1980 |
| McIntosh | 97 | 133(+)* | 71 | 96(+)* | 64 | 59(-) |
| Golden Delicious | 92 | 109(+) | 105 | 74(-) | 19 | 78(+) |
| Delicious | 78 | 108(+)* | 83 | 106(+)* | 113 | 86(-) |
| Jonathan | 79 | 115(+)* | 82 | 90(+)* | 108 | 68(-)* |
| Sour cherry | 90 | 108(+)* | 85 | 100(+)* | 41 | 33(-)* |
| Apples (misc. varieties) | 106 | 75(-) | 79 | 77(-) | 115 | 93(-) |
| Peach | 100 | 78(-) | 18 | 7(-) | 65 | 97(+) |
| Sweet cherry | 87 | 86(-) | 88 | 87(-) | 41 | 67(+) |
| Pear | 97 | 114(+) | 80 | 77(-) | 59 | 91(+) |
| Plum | 123 | 70(-)* | 76 | 98(+) | 73 | 109(+) |
| Grapes | 88 | 105(+) | 132 | 122(-) | 110 | 99(-) |
| Blueberry | 45 | 134(+)* | 12 | 29(+) | 73 | 63(-) |

| | Fe | | B | | Zn | |
|---|---|---|---|---|---|---|
| | 1956 | 1980 | 1956 | 1980 | 1956 | 1980 |
| McIntosh | 84 | 79(-) | 84 | 83(-) | 154 | 4(-)* |
| Golden Delicious | 84 | 83(-) | 73 | 70(-) | 206 | 19(-) |
| Delicious | 87 | 72(-)* | 95 | 94(-) | 137 | 33(-)* |
| Jonathan | 90 | 89(-) | 84 | 104(+)* | 137 | 26(-)* |
| Sour cherry | 61 | 57(-) | 71 | 103(+)* | 94 | 93(-) |
| Apples (misc. varieties) | 117 | 35(-)* | 85 | 75(-) | 118 | 71(-) |
| Peach | 101 | 91(-) | 82 | 99(+)* | 80 | 122(+) |
| Sweet cherry | 90 | 86(-) | 78 | 84(+) | 60 | 54(-) |
| Pear | 58 | 87(+)* | 78 | 80(+) | 102 | 149(+)* |
| Plum | 107 | 77(-) | 84 | 101(+) | 119 | 142(+) |
| Grapes | 30 | 5(-) | 100 | 134(+)* | 57 | 225(+)* |
| Blueberry | 35 | 167(+)* | 32 | 194(+)* | 156 | - 11(-) |

[1]Balance chart indices calculated from regression equation.

*Regression significant. See Appendix Table 4 for statistics.

Potassium showed a decrease for all crops except grape. Phosphorus appeared to be on the increase for all crops except Golden Delicious and sweet cherry. Calcium showed an increase for all crops except the miscellaneous apple varieties, peach, sweet cherry, and plum. McIntosh, Delicious, Jonathan, sour cherry, plum and blueberry showed an increase in magnesium, while Golden Delicious, miscellaneous apple varieties, peach, sweet cherry, pear and grape appeared to be decreasing. Manganese showed a decrease for McIntosh, Delicious, Jonathan, sour cherry, miscellaneous apple varieties, for grape and blueberry, and an increase for Golden Delicious, peach, sweet cherry, pear, and plum. Iron appeared to be decreasing for all crops except pear and blueberry. Boron showed an increase for Jonathan, sour cherry, peach, sweet cherry, pear, plum, grape, and blueberry, and a decrease for McIntosh, Golden Delicious, Red Delicious, and miscellaneous apple varieties. Zinc appeared to be decreasing for McIntosh, Golden Delicious, Delicious, Jonathan, sour cherry, miscellaneous apple varieties, sweet cherry, and blueberry, and increasing for peach, pear, plum, and grape.

## DISCUSSION

Throughout the past 10 to 20 years Michigan fruit growers have made intensive applications of mixed fertilizers to their fruit plantings. In recent years the trend has been to reduce fertilizer applications and to apply fertilizers as single elements according to need. Within this same period of time, large amounts of dolomitic lime was applied to adjust pH levels for correcting Mn excess, and to alleviate Ca and Mg shortages; hence, the increased availability of Ca and Mg may be related to the general use of dolomitic lime.

A decrease in N may be attributed to growers not making repeat applications often enough or reducing amounts applied to obtain higher quality fruit. K deficiency which has been found in all fruit crops except apple could be attributed to fertilizer applications of N only or inadequate K contained in complete fertilizers. The increase in P availability may be the result of the large amounts of mixed fertilizers applied 10 to 20 years ago. The increase in B availability is somewhat difficult to explain. However, B has been recommended by various agencies to individual growers. Over the years orchard soils have shown a slight increase in pH which may have an effect on the downward trend for Zn.

It should be pointed out that the leaf samples for this study did not always come from the better growers or from the well fertilized orchards.

Growers, in general, do not send in leaf samples to establish a fertilizer program, but from orchards, vineyards, or plantings that were not performing well or where a problem existed. Also, a given grower may not have leaf samples analyzed each year. Therefore, the results were usually from different growers each year, and represent many soil types and age of plantings. The data indicate that the recurrence of below normal values should become less for all elements except N, K, and Zn. However, the frequency of below normal values for N, K, and Zn should increase unless there is a general change in current fertilizer programs.

# SUMMARY

The leaf analysis program was initiated in the state of Michigan in 1953. An analysis of the existing program had never been conducted. There were no existing reports in the literature covering more than five or more years.

A study covering twelve-years data for ten selected Michigan counties was undertaken. This was to determine whether any nutrient element might become deficient or in excess by the year 1980. A total of 2,465 leaf samples were analyzed.

A review of the charts and figures shows some nutrients increasing and some decreasing. Fruit crops reveal nutrient increases and similarly estimated deficiencies or shortages. Likewise, on a state basis, fruits show a projected decrease for N, K and Zn, and a projected increase for P, Ca, Mg, Mn, Fe, and B.

Zn appeared to be the element most likely to show the most prevalent deficiency in fruit crops by 1980. It would appear that most apple cultivars and blueberries are most likely to exhibit Zn shortage. Of the counties, fruit crops in Kent county are estimated to be the first to experience Zn deficiency. The literature reviewed reported Zn deficiency in the Eastern United States, and it could possibly become limiting in Michigan by 1980.

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# APPENDIX TABLES

APPENDIX TABLE 1. Number of leaf samples analyzed for nine elements in ten counties, 1956-1968. (1966 data missing)

| Year | Van Buren | Berrien | Grand Traverse | Kent | Allegan | Benzie | Oceana | Mason | Leelanau | Oakland | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1956 | 54 | 10 | 13 | 6 | 6 | 0 | 2 | 3 | 6 | 9 | 109 |
| 1957 | 29 | 32 | 10 | 4 | 13 | 15 | 1 | 0 | 3 | 0 | 107 |
| 1958 | 9 | 3 | 1 | 3 | 4 | 0 | 0 | 0 | 3 | 5 | 28 |
| 1959 | 7 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 3 | 17 |
| 1960 | 52 | 38 | 5 | 32 | 17 | 4 | 11 | 6 | 8 | 3 | 176 |
| 1961 | 35 | 87 | 60 | 38 | 16 | 18 | 25 | 6 | 33 | 4 | 322 |
| 1962 | 24 | 51 | 25 | 21 | 27 | 8 | 35 | 13 | 3 | 2 | 209 |
| 1963 | 23 | 24 | 14 | 14 | 17 | 24 | 23 | 4 | 7 | 2 | 152 |
| 1964 | 65 | 21 | 26 | 26 | 23 | 28 | 16 | 8 | 17 | 12 | 242 |
| 1965 | 65 | 75 | 70 | 27 | 14 | 75 | 40 | 9 | 14 | 29 | 418 |
| 1967 | 13 | 17 | 41 | 14 | 3 | 33 | 8 | 8 | 17 | 0 | 154 |
| 1968 | 72 | 83 | 66 | 80 | 44 | 57 | 88 | 8 | 30 | 2 | 530 |
| Total | 448 | 445 | 332 | 265 | 185 | 262 | 249 | 65 | 142 | 71 | 2465 |

APPENDIX TABLE 2. Number of leaf samples analyzed for nine elements in ten counties. Kinds of fruit.

| Kind of fruit | Van Buren | Berrien | Grand Traverse | Kent | Allegan | Benzie | Oceana | Mason | Leelanau | Oakland | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Apple | 208 | 215 | 55 | 213 | 99 | 128 | 96 | 34 | 7 | 52 | 1109 |
| Peach | 22 | 29 | 1 | 3 | 7 | 20 | 19 | 5 | 1 | 5 | 90 |
| Sour Cherry | 98 | 86 | 175 | 24 | 21 | 75 | 81 | 16 | 97 | 2 | 675 |
| Sweet Cherry | 11 | 12 | 67 | 8 | 2 | 37 | 20 | 4 | 32 | 1 | 194 |
| Pear | 41 | 37 | 26 | 15 | 41 | 15 | 20 | 6 | 1 | 10 | 212 |
| Plum | 7 | 10 | 8 | 2 | 1 | 7 | 11 | 2 | 4 | 1 | 53 |
| Grape | 44 | 46 | 0 | 1 | 4 | 0 | 2 | 0 | 0 | 0 | 97 |
| Blue berry | 17 | 10 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 35 |
| Total | 448 | 445 | 332 | 265 | 185 | 262 | 249 | 65 | 142 | 71 | 2465 |

APPENDIX TABLE 3. Mean chart index (C.I.), significance of correlation coefficient, and regression equation values for estimating nutrient trends in each of ten counties in Michigan.

| County | Element | Mean C.I. | R[1] | Constant | Coefficient |
|---|---|---|---|---|---|
| Van Buren | N | 88.8 | NS | 87.40 | 0.23 |
| | K | 96.5 | NS | 93.19 | 0.55 |
| | P | 92.8 | *** | 83.89 | 1.47 |
| | Ca | 90.6 | ** | 85.28 | 0.88 |
| | Mg | 90.8 | *** | 77.72 | 2.15 |
| | Mn | 99.8 | ** | 88.59 | 1.85 |
| | Fe | 94.6 | *** | 68.03 | 4.37 |
| | B | 90.1 | * | 86.82 | 0.53 |
| | Zn | 113.6 | NS | 120.74 | -1.17 |
| Berrien | N | 84.6 | NS | 83.95 | 0.11 |
| | K | 97.7 | NS | 101.78 | -0.69 |
| | P | 95.0 | *** | 87.97 | 1.20 |
| | Ca | 92.8 | *** | 84.30 | 1.45 |
| | Mg | 88.9 | *** | 70.83 | 3.07 |
| | Mn | 93.7 | NS | 88.53 | 0.87 |
| | Fe | 94.9 | *** | 72.99 | 3.73 |
| | B | 90.4 | *** | 82.26 | 1.38 |
| | Zn | 105.5 | NS | 103.31 | 0.37 |
| Grand Traverse | N | 88.6 | *** | 101.77 | -1.94 |
| | K | 87.1 | NS | 79.47 | 1.12 |
| | P | 85.8 | ** | 92.80 | -1.02 |
| | Ca | 95.3 | NS | 91.12 | 0.63 |
| | Mg | 85.9 | NS | 87.14 | -0.17 |
| | Mn | 89.1 | NS | 95.68 | -0.98 |
| | Fe | 85.2 | ** | 77.05 | 1.21 |
| | B | 78.9 | * | 84.53 | -0.83 |
| | Zn | 95.7 | NS | 84.96 | 1.59 |
| Kent | N | 87.4 | ** | 93.21 | -1.53 |
| | K | 92.4 | NS | 94.31 | -0.49 |
| | P | 100.1 | * | 104.10 | -1.04 |
| | Ca | 97.4 | NS | 89.07 | 2.19 |
| | Mg | 85.9 | ** | 81.26 | 1.23 |
| | Mn | 87.1 | NS | 86.81 | 0.08 |
| | Fe | 85.4 | NS | 79.50 | 1.55 |
| | B | 90.3 | * | 93.59 | -0.86 |
| | Zn | 100.4 | NS | 99.50 | 0.23 |

APPENDIX TABLE 3. (Continued)

| County | Element | Mean C.I. | R[1] | Constant | Coefficient |
|---|---|---|---|---|---|
| Benzie | N | 90.7 | *** | 100.93 | -1.87 |
| | K | 87.8 | NS | 92.30 | -0.83 |
| | P | 86.9 | *** | 92.61 | -1.03 |
| | Ca | 86.1 | ** | 78.61 | 1.37 |
| | Mg | 84.8 | NS | 82.28 | 0.46 |
| | Mn | 92.8 | NS | 94.44 | -0.30 |
| | Fe | 77.4 | * | 73.47 | 0.73 |
| | B | 80.6 | NS | 79.45 | 0.21 |
| | Zn | 97.8 | NS | 90.47 | 1.34 |
| Oceana | N | 90.3 | ** | 97.56 | -1.26 |
| | K | 91.5 | NS | 88.26 | -0.56 |
| | P | 86.2 | NS | 84.09 | 0.37 |
| | Ca | 90.2 | ** | 82.00 | 1.42 |
| | Mg | 85.5 | NS | 85.86 | -0.06 |
| | Mn | 91.6 | *** | 104.57 | -2.25 |
| | Fe | 94.0 | NS | 96.29 | -0.39 |
| | B | 85.0 | NS | 83.11 | 0.33 |
| | Zn | 91.3 | NS | 85.37 | 1.02 |
| Allegan | N | 84.2 | NS | 86.92 | -0.49 |
| | K | 91.8 | NS | 95.52 | -0.67 |
| | P | 90.1 | NS | 90.94 | -0.16 |
| | Ca | 96.3 | ** | 86.92 | 1.69 |
| | Mg | 85.8 | NS | 82.36 | 0.62 |
| | Mn | 99.5 | ** | 112.67 | -2.39 |
| | Fe | 87.9 | ** | 79.79 | 1.48 |
| | B | 91.1 | NS | 90.13 | 0.17 |
| | Zn | 137.9 | ** | 179.68 | -7.57 |
| Leelanau | N | 83.8 | *** | 116.15 | -4.49 |
| | K | 84.2 | NS | 59.23 | 3.47 |
| | P | 87.1 | *** | 128.68 | -5.77 |
| | Ca | 97.1 | * | 132.74 | -4.95 |
| | Mg | 87.2 | NS | 95.07 | -1.08 |
| | Mn | 80.8 | NS | 75.09 | 0.79 |
| | Fe | 79.5 | ** | 48.99 | 4.23 |
| | B | 79.8 | NS | 89.29 | -1.32 |
| | Zn | 91.0 | NS | 104.92 | -1.93 |

APPENDIX TABLE 3. (Continued)

| County | Element | Mean C.I. | R[1] | Constant | Coefficient |
|---|---|---|---|---|---|
| Oakland | N | 82.7 | * | 88.37 | -1.29 |
| | K | 98.8 | NS | 96.84 | 0.45 |
| | P | 103.8 | NS | 107.75 | -0.88 |
| | Ca | 105.3 | *** | 90.54 | 3.40 |
| | Mg | 93.0 | NS | 90.87 | 0.49 |
| | Mn | 126.4 | * | 106.08 | 4.66 |
| | Fe | 96.9 | NS | 106.79 | -2.27 |
| | B | 86.2 | * | 90.26 | -0.93 |
| | Zn | 111.8 | NS | 99.58 | 2.82 |
| Mason | N | 89.6 | NS | 95.26 | -1.17 |
| | K | 88.5 | NS | 92.51 | -0.83 |
| | P | 89.7 | NS | 89.66 | 0.01 |
| | Ca | 87.2 | *** | 73.93 | 2.76 |
| | Mg | 83.0 | NS | 88.11 | 0.39 |
| | Mn | 90.9 | * | 102.19 | -2.34 |
| | Fe | 81.1 | NS | 79.13 | 0.40 |
| | B | 83.3 | NS | 79.06 | 0.88 |
| | Zn | 98.9 | NS | 90.98 | 1.66 |

[1] R - correlation coefficient
NS - not significant
* - significant at 5% level
** - significant at 1% level
*** - significance greater than 1%

APPENDIX TABLE 4. Mean chart index (C.I.), significance of correlation coefficient and regression equation values for estimating nutrient trends for various kinds of fruit.

| Kind of fruit | Element | Mean C.I. | R | Constant | Coefficient |
|---|---|---|---|---|---|
| McIntosh | N | 93.0 | ** | 42.43 | 0.82 |
| (313 samples) | K | 94.3 | *** | 214.78 | -1.95 |
| | P | 90.9 | NS | 64.59 | 0.42 |
| | Ca | 82.3 | *** | 11.99 | 1.52 |
| | Mg | 77.6 | *** | 11.81 | 1.06 |
| | Mn | 91.6 | NS | 77.33 | 0.23 |
| | Fe | 81.9 | NS | 95.87 | -0.22 |
| | B | 84.3 | NS | 86.10 | -0.03 |
| | Zn | 117.2 | *** | 505.03 | -6.27 |
| Golden Delicious | N | 94.2 | NS | -1.79 | 1.47 |
| (33 samples) | K | 104.7 | NS | 236.66 | -2.02 |
| | P | 96.3 | NS | 212.93 | -1.79 |
| | Ca | 99.1 | NS | 51.90 | 0.72 |
| | Mg | 93.7 | NS | 178.33 | -1.30 |
| | Mn | 98.4 | NS | 18.88 | 1.22 |
| | Fe | 86.2 | NS | 84.83 | 0.02 |
| | B | 90.2 | NS | 80.91 | 0.14 |
| | Zn | 121.1 | NS | 742.15 | -9.51 |
| Delicious | N | 92.8 | NS | 130.15 | -0.58 |
| (204 samples) | K | 98.7 | ** | 185.58 | -1.36 |
| | P | 97.7 | ** | 27.26 | 1.10 |
| | Ca | 88.9 | ** | 13.00 | 1.19 |
| | Mg | 91.2 | * | 30.06 | 0.96 |
| | Mn | 104.9 | NS | 175.62 | -1.11 |
| | Fe | 81.7 | * | 122.93 | -0.64 |
| | B | 93.6 | NS | 97.60 | -0.06 |
| | Zn | 102.4 | ** | 377.59 | -4.30 |
| Jonathan | N | 85.6 | NS | 95.00 | -0.14 |
| (406 samples) | K | 90.9 | ** | 155.91 | -0.99 |
| | P | 93.4 | NS | 68.64 | 0.38 |
| | Ca | 94.12 | *** | -3.06 | 1.48 |
| | Mg | 85.6 | * | 63.37 | 0.34 |
| | Mn | 95.9 | *** | 223.90 | -1.95 |
| | Fe | 89.6 | NS | 94.69 | -0.08 |
| | B | 91.5 | *** | 36.55 | 0.84 |
| | Zn | 100.82 | *** | 350.58 | -3.81 |

APPENDIX TABLE 4. (Continued)

| Kind of fruit | Element | Mean C.I. | R | Constant | Coefficient |
|---|---|---|---|---|---|
| Apples (misc. var.) (154 samples) | N | 88.6 | NS | 58.62 | 0.47 |
| | K | 96.3 | ** | 117.31 | -1.28 |
| | P | 95.1 | NS | 46.01 | 0.78 |
| | Ca | 96.3 | NS | 179.78 | -1.32 |
| | Mg | 87.6 | NS | 82.90 | 0.07 |
| | Mn | 108.1 | NS | 165.95 | -0.91 |
| | Fe | 92.9 | * | 308.62 | -3.41 |
| | B | 82.9 | NS | 109.33 | -0.42 |
| | Zn | 103.5 | NS | 227.82 | -1.97 |
| Peach (90 samples) | N | 84.6 | NS | 96.43 | -0.19 |
| | K | 117.7 | *** | 298.08 | -2.88 |
| | P | 92.9 | *** | 37.30 | 0.89 |
| | Ca | 94.0 | NS | 150.0 | -0.90 |
| | Mg | 84.8 | NS | 50.59 | 0.55 |
| | Mn | 94.6 | NS | 10.55 | 1.34 |
| | Fe | 98.5 | NS | 124.75 | -0.42 |
| | B | 86.7 | ** | 40.36 | 0.74 |
| | Zn | 123.8 | NS | 15.49 | 1.73 |
| Sweet Cherry (193 samples) | N | 82.9 | NS | 103.08 | -0.31 |
| | K | 82.3 | NS | 104.08 | -0.34 |
| | P | 87.4 | NS | 82.93 | 0.07 |
| | Ca | 87.5 | NS | 90.88 | -0.05 |
| | Mg | 86.8 | NS | 88.03 | -0.01 |
| | Mn | 86.6 | NS | 17.61 | 1.07 |
| | Fe | 89.3 | NS | 100.74 | -0.18 |
| | B | 84.1 | NS | 37.88 | 0.71 |
| | Zn | 87.4 | NS | 71.84 | 0.23 |
| Pear (213 samples) | N | 86.4 | NS | 68.50 | 0.28 |
| | K | 88.3 | *** | 181.75 | -1.48 |
| | P | 84.1 | NS | 58.12 | 0.41 |
| | Ca | 101.9 | NS | 58.54 | 0.69 |
| | Mg | 79.5 | NS | 88.15 | -0.14 |
| | Mn | 100.7 | NS | 16.14 | 1.34 |
| | Fe | 86.8 | ** | 9.75 | 1.22 |
| | B | 80.3 | NS | 57.91 | 0.35 |
| | Zn | 116.2 | ** | -6.56 | 1.94 |

APPENDIX TABLE 4. (Continued)

| Kind of fruit | Element | Mean C.I. | R/1 | Constant | Coefficient |
|---|---|---|---|---|---|
| Sour cherry (673 samples) | N | 84.7 | *** | 143.40 | -0.94 |
| | K | 84.6 | * | 110.77 | -0.42 |
| | P | 87.1 | * | 68.66 | 0.29 |
| | Ca | 95.4 | ** | 50.33 | 0.72 |
| | Mg | 89.3 | ** | 49.90 | 0.63 |
| | Mn | 81.7 | * | 60.11 | 0.34 |
| | Fe | 82.1 | NS | 71.03 | 0.18 |
| | B | 80.1 | *** | -3.42 | 1.33 |
| | Zn | 96.1 | NS | 104.94 | -0.14 |
| Plum (53 samples) | N | 85.2 | * | 25.15 | 0.95 |
| | K | 138.1 | NS | 253.24 | -1.81 |
| | P | 93.2 | NS | 68.95 | 0.38 |
| | Ca | 105.7 | * | 243.97 | -2.17 |
| | Mg | 84.1 | NS | 27.20 | 0.89 |
| | Mn | 107.4 | NS | 11.17 | 1.51 |
| | Fe | 97.7 | NS | 176.96 | -1.25 |
| | B | 90.1 | NS | 44.18 | 0.72 |
| | Zn | 127.3 | NS | 67.48 | 0.94 |
| Grapes (97 samples) | N | 96.6 | NS | 115.75 | -0.30 |
| | K | 97.3 | NS | -8.91 | 1.63 |
| | P | 122.4 | NS | -28.32 | 2.32 |
| | Ca | 93.8 | NS | 48.48 | 0.70 |
| | Mg | 128.2 | NS | 154.29 | -0.40 |
| | Mn | 106.7 | NS | 136.34 | -0.46 |
| | Fe | 153.6 | NS | 87.23 | 1.03 |
| | B | 113.0 | * | 21.22 | 1.42 |
| | Zn | 118.7 | *** | -334.91 | 7.00 |
| Blueberries (36 samples) | N | 86.4 | NS | 227.27 | -2.14 |
| | K | 110.8 | * | 501.53 | -5.94 |
| | P | 80.5 | * | -47.73 | 1.95 |
| | Ca | 81.6 | *** | -162.88 | 3.72 |
| | Mg | 73.7 | NS | 27.24 | 0.71 |
| | Mn | 116.7 | NS | 92.57 | 0.37 |
| | Fe | 89.5 | ** | -273.75 | 5.52 |
| | B | 98.3 | ** | -344.08 | 6.73 |
| | Zn | 88.8 | NS | 545.63 | -6.95 |

/1 R - correlation coefficient
NS - not significant
* - significant at 5% level
** - significant at 1% level
*** - significance greater than 1%