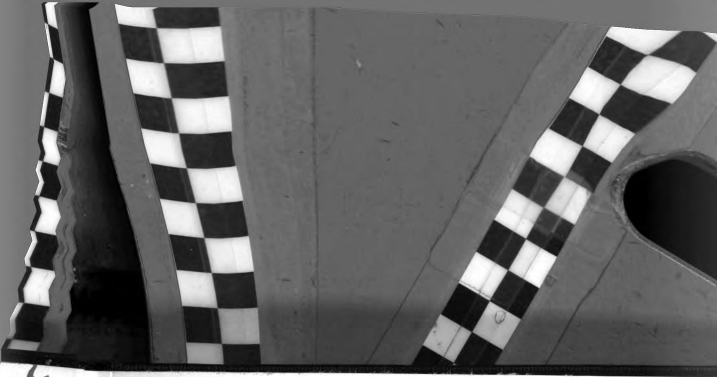

THE RELATIONSHIP OF STRAWBERRY LEAF NUTRIENT CONTENT TO PLANT PERFORMANCE

By

Lloyd Wayne Martin

AN ABSTRACT OF

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

1967

ABSTRACT

THE RELATIONSHIP OF STRAWBERRY LEAF NUTRIENT CONTENT TO PLANT PERFORMANCE

By Lloyd Wayne Martin

Field plots of Midway and Robinson strawberries were established in a complete factorial design using single applications of 0, 100 and 200 pounds per acre of N, P_2O_5 and K_2O at time of planting. Plots were established in 1964 at East Lansing on a Hillsdale sandy-loam and in 1965 at Sodus, Michigan on a Genesee silt-loam. Leaf samples collected in July and August the year of transplanting and at flowering and harvest the following spring were analyzed for nutrient content. Total fruit weight and number were determined on a three to five day interval as fruit matured.

Applications of N and K_2O significantly reduced yields in the East Lansing experiment. Yields at Sodus were not altered by applications of N, K_2O or P_2O_5.

Correlation coefficients for yield versus leaf composition was calculated for each sampling period. Yield potential may be more accurately estimated from leaf samples taken in July, considering the numerical size of the correlation coefficients and the number of elements significantly correlated with yield.

Leaf N concentration was highest in leaf samples collected at bloom whereas leaf P was highest in August samples. Leaf K concentration was approximately the same at bloom as the previous August. Leaf concentrations of N, P, and K were lowest in foliage sampled at harvest.

Soil applications of N, P_2O_5, and K_2O caused significant increases in leaf concentrations of N, P, and K. Differences between application rates diminished with time.

Available Ca, Mg and K in the soil at harvest were significantly related to yield, but available P was not.

Nutrients were not related to firmness or color of fruit. Neither was nutrient content of fruit related to color intensity. A number of fruit nutrient elements were correlated to firmness, however none were consistently related.

Correlation coefficients for leaf composition versus soil test values, from samples taken immediately below the plants from which leaf samples were taken, indicated that available P and K in the soil were not correlated to P and K found in the leaves. Available Ca and Mg were significantly correlated to the Ca and Mg found in the plant leaves.

A survey of 42 commercial strawberry plantings revealed wide variations in fertilizer use. Commercial applications of N, K_2O and P_2O_5 exceeded rates probably necessary for maximum yield. Leaf K content was higher in some plantings than necessary for optimum yield according to data from this experiment. Other leaf composition values were within a range at which optimum yields would be expected to occur. Mg content in the soils tested from Manistee County is believed to be lower than desired.

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Special appreciation is due my wife, Sharon, and three sons, Mitch, Mike and Monty, for their patience and sacrifice during the course of graduate study.

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INTRODUCTION

Mineral nutrition of the strawberry plant has been extensively studied but findings from numerous field and greenhouse studies have often been contradictory. The strawberry is one of the most widely adapted fruit crops and has been investigated under widely different soil, climatic and cultural conditions. Greenhouse investigations with individual plants may not apply to field conditions utilizing matted-row culture.

The lack of agreement among various investigations may be a reflection of the nutritional status of the field plots before some experiments were initiated. Recently a symbiotic relationship between strawberry plants and soil mycorrhiza has been demonstrated.[1] This enables plants to more efficiently extract P from the soil. Obviously a more precise method for determining the plants nutritional status and development of associated fertilizer practices should be possible.

Foliar analysis has been successfully utilized in Michigan for determining the nutritional status of tree fruits, grapes and blueberries. Soil tests have not been sufficiently reliable for these crops, partly because it is difficult to sample the entire plant root zone. This may explain why most plant analysis research has concentrated on deep-rooted perennial crops rather than shallow-rooted plants such as the strawberry.

Kenworthy has established standard leaf values for a number of

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[1] Personal communication, C. Bould, Long Ashton Research Station, University of Bristol, 1967.

Michigan fruit crops by collecting a great mass of samples from a number of selected orchards.[2] Bould (6), however, contends that "because non-nutritional factors often limit crop yield under field conditions, the survey method of establishing standard leaf nutrient values is not generally satisfactory." He has conducted precisely controlled greenhouse and nutrient solution studies to establish his standard values. Smith (45) points out that "artificial cultures and field surveys are helpful in setting tentative leaf value standards, but they have serious shortcomings in that they do not fully integrate all of the factors affecting growth and fruit quality."

A successful leaf analysis approach to plant nutrition problems requires proper sampling procedures, sample preparation, analytical procedures and establishment of standard values for evaluating results. The primary objective of this research has been establishment of standard leaf nutrient values incorporating some of the procedures of Kenworthy and Bould.

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[2] Personal communication, A. L. Kenworthy, Department of Horticulture, Michigan State University, 1967.

REVIEW OF LITERATURE

Foliar analysis has been successfully utilized as a tool for determining nutritional status of many tree fruit species, grapes and blueberries. Plant analysis research on the strawberry, however has been largely restricted to investigations comparing time of sampling and determining most satisfactory plant parts to analyze.

Lineberry et al (31) working on new lands in North Carolina compared the mineral content of fresh tissue extractions for mature leaves, young leaves and runners. K and P levels were higher in the immature leaves than in the mature leaves. Conversely, calcium (Ca) and Mg levels were lower in the immature leaves. Both the mature and immature leaves reflected the P and K applications previously imposed, whereas foliage from runners did not. They concluded that expanded mature leaves were most satisfactory for determining nutrient deficiencies by tissue analysis.

Kwong and Boynton (26) studied the effect of sampling time, leaf age and leaf fractions on nutrient composition of Catskill and Sparkle strawberry plants. They found that leaflets were a more desirable sampling media than petioles and observed no difference in chemical composition between terminal and lateral leaflets. During the first six weeks of leaf growth, foliar concentrations of nitrogen, phosphorus and potassium declined and calcium increased. They suggested the "youngest mature" leaves for nutritional analysis. No consistent difference in chemical composition was found between Catskill and

Sparkle varieties.

Ballinger and Mason (3) concluded from a study with Albritton strawberry plants that the tissue best suited for analysis depended on the element in which one is interested. They found leaflets most satisfactory for nitrogen and calcium determinations, crowns or leaflets for phosphorus, petioles for potassium, and roots for magnesium. Leaflets were recommended as the one plant part most satisfactory for an analysis for all the elements investigated.

Anderson et al (2) found the 3rd and 4th oldest leaves of the Catskill variety lower in P and K and higher in Ca and Mg than the youngest mature leaves. The P content of new leaf tissue was greatly increased by each increment of P added whereas older leaves were much less sensitive in reflecting the P fertilizer treatments. Increased N fertilizer levels also increased leaf P, suggesting an N/P interaction.

Lanning and Garabedian (27) found that Ca was highest in the crowns while Fe was highest in the roots and lowest in the petioles and crowns. They found little difference in Fe and Ca content between Dixieland, Surecrop, Armore and Blakemore varieties. Fe averaged 0.20% and Ca 0.85% in the leaves. Lineberry and Burkhart (29) reported soluble Ca in strawberry leaf blades more than four times as great as in any other plant part tested.

Gruppe and Nurbachach (17, 18) sampled recently matured leaves at time of flowering and found no yield increase with K levels above 0.7%, Mg above 0.4%, N above 2.35 - 2.40% and P above 0.28 - 0.32%

suggesting that additional increases in these elements would fail to further increase yield in the Climax variety.

Optimum foliar nutrient concentration immediately following harvest is reported by Naumann (38) to be 1.8 - 2.0% for N, 0.28 - 0.30% for P, 1.8 - 2.0% for K and 1.0% for calcium. Bould (5) suggests nutrient composition of recently matured strawberry leaves be above 2.0% N, 0.20% P, 1.0% K and 0.15% Mg after fruiting the first year.

Cline (9) found leaf blades preferable to petioles as an indicator of nutrient status of both fruiting and non-fruiting plants. Under Ontario conditions, early August was considered the most desirable time to collect leaf samples from non-fruiting plantings. June 15 to 30 was suggested as the time for sampling during fruiting year.

Bould (6) suggests sampling at a specific physiological stage of development. From time of flowering until immediately after harvest, he found that N, P, and K decreased whereas Mg increased. The leaves contained more Ca at harvest than at flowering or following harvest. When leaf composition was correlated with yield, those samples taken at harvest time gave the best reflection of total yield.

A more practical time to sample would be sufficiently early in development of the plant to allow time for corrective measures preceding fruiting. Strawberry flower primordia are defferentiated in Michigan under short day conditions in late August and early September. The nutritional status of plants at this time has a decided effect on

yield the following spring (11, 32). Gardner (16) found the number of flower stalks, flowers and size of the berries depend to a large extent on the nutritional condition the preceding fall. Strawberry plant numbers, height and spread measurements taken in the fall are significantly related to yield the following spring (46). Morrow and Darrow (37) found a close relationship between number of leaves in November and number of flowers the following spring. Thus, it appears that a plant analysis program that considers nutritional condition the year preceding fruiting has merit.

Matlock's extensive review of strawberry nutrition (35) makes it clear that results of strawberry fertilizer experiments are quite contradictory. A number of investigations (11, 21, 28, 43, 48) have reported reduced yields from N applications; others (40, 50) have reported no significant yield response to N fertilizer; and still others (24, 30, 47) have shown an increase in yield with N applications.

Strawberries are apparently very tolerant of excessive P applications. No reports indicating reduced yield from P fertilizers are evident. In some experiments (11, 14, 30) yield has been increased, whereas in others (4, 21, 40) it was not significantly changed with applications of P. Response apparently depends on local environment and soil conditions.

Yield response to K applications is also contradictory. In some investigations (25, 40) yield has been increased; others (8, 28, 31) report decreased yields; and still others (33, 41) report no yield differences from applications of K fertilizers.

Relatively little has been reported in relation to quality factors and foliar nutrient composition. Relationship between foliar concentrations of N, P, and K at start of harvest and fruit characteristics during harvest were recently investigated by Ricketson and Hill (42) in greenhouse, sand-culture studies. Nitrogen levels above about 2.4% generally adversely affected berry characteristics evaluated – fruit were smaller, lower in soluble solids and matured later. Berry size and earliness increased as leaf composition of P increased from 0.16 to 0.60%. Soluble solids, titratable acids, and earliness increased as K levels increased from 0.5 to 2.0%.

A number of investigations have studied the relationship between various fruit quality factors and plant growth rate, crop size, fertilizer treatments, etc. However, most fruit quality investigations have been primarily concerned with fruit firmness.

Sistrunk (44) studied the relationship between fertilizer level, berry firmness and freezing quality of strawberries. He found spring applications of fertilizer decreased firmness of the fresh fruit and increased solubility of cell wall constituents. The firmness measurements on fresh fruit were directly related to quality of strawberries which had been frozen and thawed.

A number of publications indicate nitrogen applied in the spring of the fruiting year caused softer fruit. Among such studies are those of Chandler (8), Brown (7), Auchter and Knapp (1) and Loree (34). Overholzer and Claypool (39) found N fertilization increased fruit size and respiration rate while firmness decreased. Darrow (13) reported no consistent difference in firmness of berries from plots receiving different rates and kinds of fertilizer. Others (20, 36) have found firmness related to dry weight and rate of respiration.

Cochran and Webster (10), working in Oklahoma, concluded that added nitrogen fertilizer was not associated with any reduction in fruit firmness. These same findings were later substantiated by Webster and Gray (49).

Application of K are not normally associated with fruit firmness. Kimbrough (23), Darrow (13), Cochran and Webster (10) and others, reported no beneficial effect on fruit firmness or shipping quality from use of potash. Haut et al (22) found that neither N, P, or K affected the firmness of strawberries.

Strawberry fruit firmness has been determined by several different methods, probably explaining some of the wide variation in results. Eaves and Leefe (15) measured firmness of strawberries through the use of a "penetrometer." Such a meter basically consists of a pinion - operated plunger eight millimeters in diameter tapered to four millimeters and mounted on a spring scale. Pressure for a given distance of penetration is read from the scale. A similar device was used by Culpepper et al (12), however, compression was determined rather than penetration. Shoemaker and Greve (43) modified a pressure tester commonly used with apples to determine berry firmness. The 7/16 inch plunger was replaced by a 1/4 inch plunger. Grams pressure required to force the plunger 3/8 inch into the fruit was determined.

Scott suggested a probe type pressure measure sufficiently sensitive to detect differences in toughness of skin and actual firmness of the flesh.[3] A complete review (19) of the different pressure testers used on various fruits indicates relatively little work in this regard with respect to the strawberry.

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[3]Personal communication, D. H. Scott, Agricultural Research Service, U. S. Department of Agriculture, 1965.

EXPERIMENTAL PROCEDURE

East Lansing Field Plots

Field plots of Midway and Robinson varieties were established on the Michigan State University horticultural farm at East Lansing in the spring of 1964 to study plant composition in relation to strawberry yield and fruit quality. Plants were spaced two feet apart in rows spaced four feet apart.

The experimental design was a factorial with replicates. Treatments were single applications of three rates of fertilizer: 0, 100, and 200 pounds each of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O). Hereafter P_2O_5 and K_2O treatments may be referred to as P and K treatments. Two replicates of each variety were grown, giving a total of 108 plots. Each plot contained 10 mother plants spaced two feet apart. Nitrogen was applied as ammonium nitrate; potassium as muriate of potash; and phosphorus as concentrated super phosphate. Phosphorus was banded five inches deep and four inches to the side of the row one week before planting. The ammonium nitrate and potash were side-dressed one and two weeks respectively following transplanting.

Plots were maintained weed-free by cultivation and hand hoeing. Irrigation was applied during the growing season whenever rainfall was less than approximately one inch during any 10 day interval.

Detailed records were taken from a six foot area in each plot. This record area consisted of three representative mother plants and all runner plants developing in the six foot area.

Statistical analysis were concentrated on treatment effects and the relationship of plant performance to N, P, and K plant composition. Interactions were not studied in detail.

The following data were collected:

Leaf Samples. Nutritional status was evaluated at different stages of plant development through leaf analysis. Leaf samples were taken from each of the plots in July and August of the planting year and at bloom and harvest the following spring. Youngest, mature leaves were collected at random from established mother and runner plants for chemical analysis. No effort was made to separate the leaves of runner plants from those of mother plants. The fresh leaf samples were taken to the laboratory, washed in mild detergent solution, thoroughly rinsed with tap water, and then oven-dried at 180° F.

The dried samples were ground in a Wiley mill through a 20 mesh screen and analyzed for 11 elements. Nitrogen was determined by a modified Kjeldahl method, potassium by flame spectrophotometer, and P by photoelectric spectrometer. Ca, Mg, Mn, Fe, Cu, B, Zn, and Al were also determined by photoelectric spectrometer, however were not studied in detail.

Soil Samples. Soil samples were collected from the upper six inches of soil from each 108 plots prior to fertilizer applications. A second soil sample was taken the following spring after the last harvest. All samples were analyzed for available P, K, Ca, and Mg, cation exchange capacity, percent base saturation, pH, and percent saturation of K, Ca, and Mg, by the Michigan State University Soil Testing

laboratory. The soil was a Hillsdale sandy loam with good percolation and drainage.

Plant Density. Number of established runner plants was determined by counting all rooted plants in the six foot record area in late August, following transplanting.

Yield and Fruit Size. Fruit was harvested as it matured at two to five day intervals. All berries from each plot were counted and weighed to determine total yield. Fruit size was calculated as average gram weight per berry for each harvest period.

Fruit Quality. Berries were stored at 40°F for 18 to 24 hours after harvest. Ten fruits which were relatively uniform in size, color and degree of maturity were selected from each plot for further evaluation.

Fruit firmness: Firmness was measured with a Hunter push-pull gauge. A flat tipped plunger, 7/16 inch in diameter, was forced approximately 1/8 inch into the cheek surface of the strawberry. The required force, measured in grams of pressure, was determined for each of 10 fruit.

Fruit analysis: Each berry was then cut in half along the longitudinal axis. That half of the fruit damaged by the firmness probe was utilized for pitment and percent sugar determinations. The other half was analyzed for nutrient composition in a similar method utilized for the leaves.

Percent sugar: Percent sugar was determined on a combined juice sample consisting of one drop of juice from each of the 10 berry halves. Refractive index was measured on an Abbee refractometer and converted to

percent sucrose sugar.

Fruit color: The fruit tissue was ground in a Waring blender after the juice sample was collected. A 25 gram composite sample of the ground tissue was added to 75 ml of 0.5 percent oxalic acid. The samples were sealed in glass bottles and stored in a darkened, 40°F cooler until analyzed. After removal from the cooler, each sample was filtered through No. 5 Whatman filter paper. Fruit pigmentation was determined by measuring optical density of the filtrate at 515 millimicrons using an Evelyn colorimeter.

Sodus Horticultural Farm Plots

A second series of plots was established in 1965 at the Sodus Experimental Farm at Sodus, Michigan. The design of the experiment, the fertilizer treatments and measurements taken were the same as those from the East Lansing plots the previous year, with the following exceptions: A more slowly available form of nitrogen, Ureaform, was used in place of ammonium nitrate. In addition to taking leaf samples as previously described, a crown sample was also taken during March. Crowns from runner plants near the center of the row were thoroughly washed and expanded leaves and roots removed. They were subjected to the same chemical analysis as the leaves. Fruit pigmentation was not measured.

The soil type for this second experiment was a Genesee silt loam.

Survey of Commercial Plantings

Leaf samples were taken in July and August of the planting year in 42 commercial plantings of Midway and Robinson strawberries in southwest

Michigan and Manistee county. Soil samples were taken in August immediately below the plants from which leaf samples were taken. Correlation coefficients for August leaf composition versus soil test values were calculated. A severe infestation of sap beetles made accurate yield records prohibitive in the majority of plantings.

RESULTS

Leaf Analysis and Yield

Table 1 indicates the effect of N, P, and K fertilizer rates on nutrient composition of Midway strawberry leaves at 4 selected sampling times. Soil applications of N, P, and K caused a significant increase in leaf N, P, and K in July and August at East Lansing. Differences still existed the following spring at bloom. However, the differences between treatments for N and P were less than the previous year. P and K applications resulted in no significant difference in leaf composition for P and K at harvest. Plants fertilized with 200 pounds per acre of N continued higher in leaf-N than those receiving no N.

Applications of N were never significantly reflected in leaf composition for the Sodus experiment. P applications significant increased leaf P in July, however this effect was not evident in August or at bloom. At harvest a significant reduction in leaf P occurred in plants receiving P fertilizer. Leaf K was not altered in July as a result of treatments, however it was increased at the other three sampling times.

Table 2 indicates the effect of fertilizer rate of N, P, and K on nutrient composition of Robinson strawberry leaves at 4 selected sampling times. The same general trends that occurred with Midway were evident.

Leaf composition values for each of the two experiments, presented in Tables 1 and 2, were combined and average values for the two years graphically presented in Figures 1 through 6. Figure 1 shows the effect

Table 1. Effect of Rate of Applied N, P and K on Composition# of Midway Strawberry Leaves at Selected Sampling Times.

Sampling Time	Fertilizer Rate##	East Lansing 1964-1965			Sodus 1965-1966		
		N	P	K	N	P	K
July	0	2.37	0.390	1.58	2.64	0.411	1.37
	100	2.62	0.423	1.64	2.71	0.435	1.42
	200	3.02	0.470	1.71	2.63	0.471	1.43
		**	**	**	N.S.	**	N.S.
August	0	2.81	0.516	1.79	2.75	0.460	1.28
	100	3.09	0.576	1.86	2.82	0.463	1.49
	200	3.24	0.580	2.01	2.89	0.481	1.58
		**	**	**	N.S.	N.S.	**
Bloom	0	3.03	0.440	1.77	3.09	0.400	1.42
	100	3.06	0.452	1.92	3.15	0.406	1.60
	200	3.26	0.475	2.06	3.07	0.410	1.61
		*	*	**	N.S.	N.S.	*
Harvest	0	2.12	0.404	1.39	2.22	0.313	0.72
	100	2.30	0.360	1.43	2.28	0.275	0.92
	200	2.37	0.370	1.49	2.28	0.242	1.00
		**	N.S.	N.S.	N.S.	**	**

% of dry matter.

Lb/A of actual N, P_2O_5 and K_2O.

* Significant at 5% level.

** Significant at 1% level.

Table 2. Effect of Rate of Applied N, P and K on Leaf Composition# of Robinson Strawberry Leaves at Selected Sampling Times.

Sampling Time	Fertilizer Rate ##	East Lansing 1964-1965			Sodus 1965-1966		
		N	P	K	N	P	K
July	0	2.05	0.355	1.44	2.37	0.407	1.17
	100	2.29	0.391	1.57	2.40	0.362	1.27
	200	2.40	0.401	1.61	2.40	0.420	1.19
		**	**	**	N.S.	**	N.S.
August	0	2.67	0.555	1.77	2.61	0.409	1.20
	100	2.78	0.592	1.98	2.60	0.422	1.39
	200	2.89	0.636	2.03	2.58	0.419	1.52
		**	**	**	N.S.	N.S.	**
Bloom	0	2.43	0.452	1.60	2.93	0.361	1.41
	100	2.43	0.510	1.75	2.96	0.376	1.59
	200	2.79	0.517	1.86	2.92	0.392	1.70
		*	**	**	N.S.	*	**
Harvest	0	1.68	0.338	1.51	2.19	0.312	0.77
	100	1.81	0.345	1.54	2.24	0.304	0.90
	200	1.86	0.322	1.59	2.23	0.284	0.99
		**	N.S.	N.S.	N.S.	*	**

% of dry matter.

Lb/A of actual N, P_2O_5 and K_2O.

* Significant at 5% level.

** Significant at 1% level.

Figure 1. The effect of three rates of N applied at time of planting on N content of Robinson strawberry leaves in July and August of the planting year and at bloom and harvest the following year.

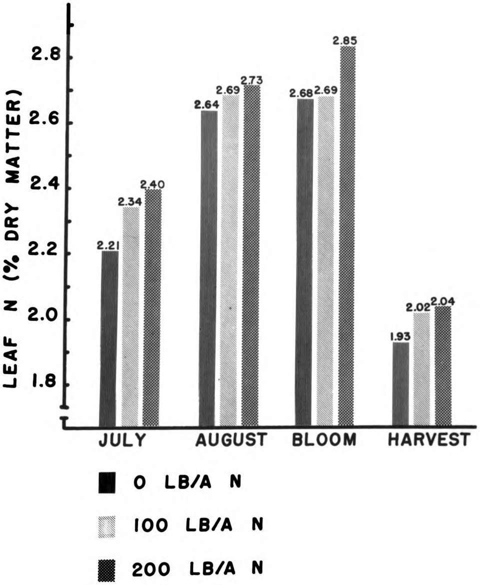
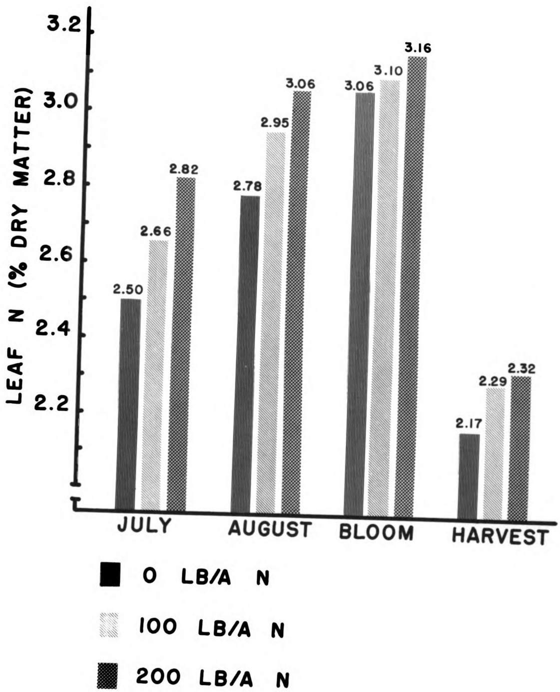
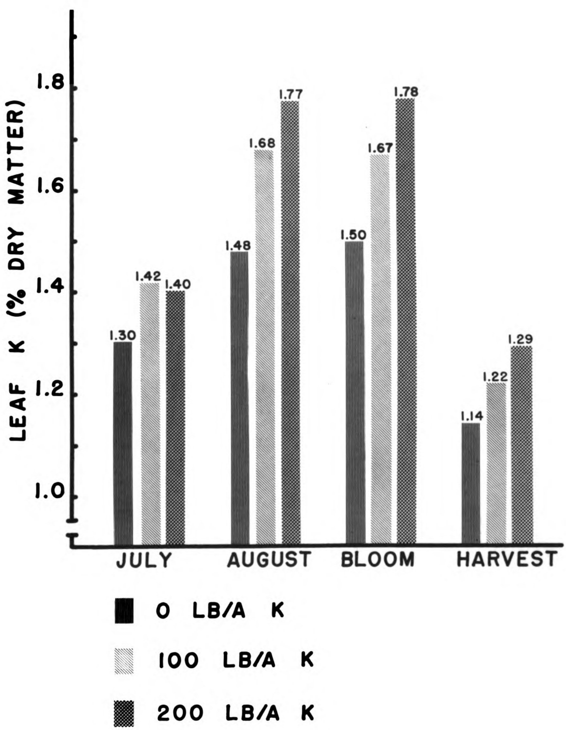

LEAF N (% DRY MATTER)
2.8
2.6
2.4
2.2
2.0
1.8
2.21
2.34
2.40
2.64
2.69
2.73
2.68
2.69
2.85
1.93
2.02
2.04
JULY
AUGUST
BLOOM
HARVEST
0 LB/A N
100 LB/A N
200 LB/A N

Figure 2. The effect of three rates of N applied at time of planting on N content of Midway strawberry leaves in July and August of the planting year and at bloom and harvest the following year.



LEAF N (% DRY MATTER)
3.2
3.0
2.8
2.6
2.4
2.2
2.50
2.66
2.82
2.78
2.95
3.06
3.06
3.10
3.16
2.17
2.29
2.32
JULY
AUGUST
BLOOM
HARVEST
0 LB/A N
100 LB/A N
200 LB/A N

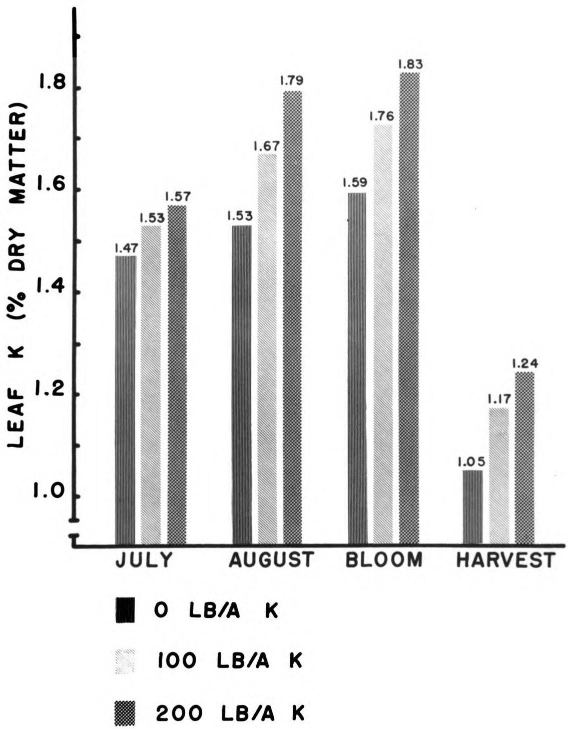
Figure 3. The effect of three rates of K applied at time of planting on K content of Robinson strawberry leaves in July and August of the planting year and at bloom and harvest the following year.



LEAF K (% DRY MATTER)
1.8
1.6
1.4
1.2
1.0
1.30
1.42
1.40
1.48
1.68
1.77
1.50
1.67
1.78
1.14
1.22
1.29
JULY
AUGUST
BLOOM
HARVEST
0 LB/A K
100 LB/A K
200 LB/A K

20r

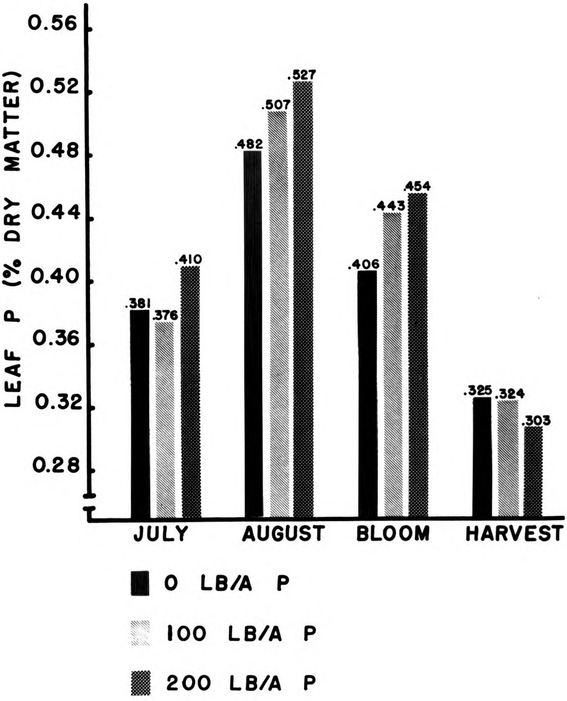
Figure 4. The effect of three rates of K applied at time of planting on K content of Midway strawberry leaves in July and August of the planting year and at bloom and harvest the following year.



LEAF K (% DRY MATTER)
1.0
1.2
1.4
1.6
1.8
1.47
1.53
1.57
1.53
1.67
1.79
1.59
1.76
1.83
1.05
1.17
1.24
JULY
AUGUST
BLOOM
HARVEST
0 LB/A K
100 LB/A K
200 LB/A K

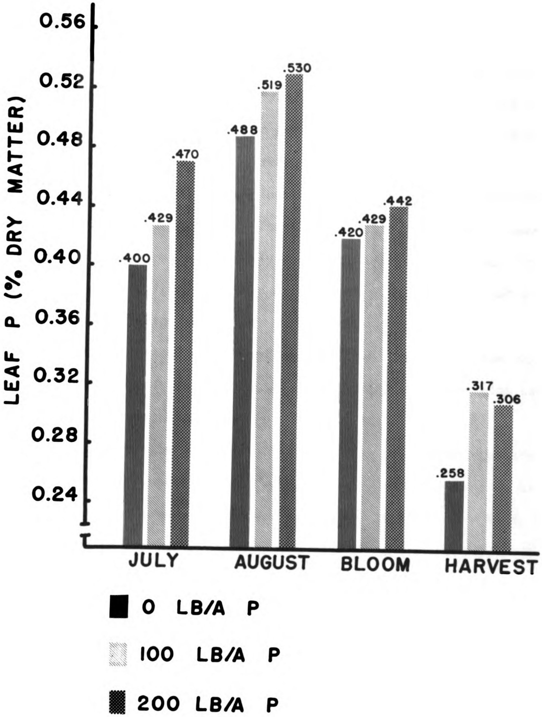
210

Figure 5. The effect of three rates of P applied at time of planting on P content of Robinson strawberry leaves in July and August of the planting year and at bloom and harvest the following year.



LEAF P (% DRY MATTER)
0.56
0.52
0.48
0.44
0.40
0.36
0.32
0.28
.381
.376
.410
.482
.507
.527
.406
.443
.454
.325
.324
.303
JULY
AUGUST
BLOOM
HARVEST
0 LB/A P
100 LB/A P
200 LB/A P

Figure 6. The effect of three rates of P applied at time of planting on P content of Midway strawberry leaves in July and August of the planting year and at bloom and harvest the following year.



LEAF P (%. DRY MATTER)
0.56
0.52
0.48
0.44
0.40
0.36
0.32
0.28
0.24
.400
.429
.470
.488
.519
.530
.420
.429
.442
.258
.317
.306
JULY
AUGUST
BLOOM
HARVEST
0 LB/A P
100 LB/A P
200 LB/A P

of three rates of N fertilizer on leaf N content of Robinson strawberry plants at four selected periods of development. In each of the four periods, plants receiving N were higher in leaf N than non-fertilized plants. Similar data are shown in Figure 2 for the Midway variety. The difference between treatments, as reflected by leaf N, diminished with time. Leaf N was highest at bloom and lowest at harvest. The leaf N level in August exceeded that in July.

The effect of applied K on leaf composition was most pronounced in August and at bloom (Figure 3). The K composition of Robinson leaves in August and at bloom was essentially the same. In the Midway variety (Figure 4), K was slightly higher at bloom than in August. Leaf K content for both varieties was lowest at harvest.

Phosphorus content was higher in the leaves in August than at the other sampling periods (Figures 5, 6). The lowest P content also occurred in the harvest sample.

Table 3 lists the correlation coefficients calculated when total yield of Midway strawberries was correlated with leaf composition at the different sampling times. Yield was significantly related to N, K, P, Ca, Mg and Mn in the leaves sampled the previous July. Similar trends occurred for August samples, with the exception of P. Neither leaf K nor P at bloom was related to yield. All macronutrients at time of harvest were correlated to yield. However, the correlation coefficients tended to be smaller than those for the July samples.

Table 4 indicates correlation coefficients for yield of Midway at Sodus versus leaf composition values. At any of the four sampling periods,

Table 3. Correlation Coefficients for 1965 Midway Strawberry Yield at East Lansing Versus Leaf Composition at Selected Sampling Times.

Element	July 1964	August 1964	Bloom 1965	Harvest 1965
N	.664** (1)#	.525** (1)	.510** (2)	.530** (1)
K	.483** (1)	.443** (1)	____##	.312* (1)
P	.370** (2)	____	____	.417** (1)
Ca	.434** (3)	.381** (3)	.362** (1)	.376** (1)
Mg	.324* (1)	.316* (2)	.370** (2)	.315* (1)
Mn	.589** (1)	.488** (1)	.552** (1)	.645** (1)
Fe	____	____	____	____
Cu	____	____	.309* (2)	____
B	.359** (1)	____	.317* (3)	____
Zn	____	.419** (3)	____	.404** (3)
Al	.346* (2)	____	____	____

* Significant at 5% level.

** Significant at 1% level.

\# Type of regression: (1) = straight line, (2) = parabola, (3) = cubic parabola.

\## Correlation coefficients for straight line, parabola, and cubic parabola curves below that required for significance.

Table 4. Correlation Coefficients for 1966 Midway Strawberry Yield at Sodus Versus Leaf Composition at Selected Sampling Times.

Element	July 1965	August 1965	Bloom 1966	Harvest 1966
N	.265* (2)	___##	___	.269* (2)
K	___	.476** (1)	.355** (3)	.372** (2)
P	.378** (3)	___	___	___
Ca	___	.264* (2)	___	___
Mg	.284* (2)	___	___	___
Mn	.292* (1)	.404** (1)	.266* (2)	.332* (2)
Fe	___	___	.409** (1)	___
Cu	.280* (3)	___	___	___
B	___	___	___	___
Zn	.370** (1)	___	.264* (2)	___
Al	___	___	.448** (1)	___

* Significant at 5% level.

** Significant at 1% level.

Type of regression: (1) = straight line, (2) = parabola, (3) = cubic parabola.

Correlation coefficient for straight line, parabola and cubic parabola curves below that required for significance.

fewer elements were related to yield than found the previous year at East Lansing. More elements in the July sampling correlated with yield than any of the other leaf sampling periods.

Correlation values for 1966 yield of Robinson versus leaf composition at the four sampling times (Table 5) were less conclusive. More elements in the July samples correlated with yield than in any of the other three periods. However, only in leaf samples at harvest were N, P, and K each related to yield. Neither N, P, nor K were significantly related to yield at July and at bloom.

Figures 7 through 15 are regression lines for yield as a function of N, P, and K found in the leaves at selected times of plant development. Regression lines were drawn only if the correlation coefficients, as shown in Tables 3, 4, and 5 indicated significance. Yield is also shown as a function of each of the three elements applied at time of transplanting.

Figure 7 suggests a linear decrease in yield at East Lansing as the composition of N in the leaves at either of the four times tested increased. It also indicates a sharp reduction in yield as a result of applied N.

The relationship between yield versus leaf N in July 1965 and at time of harvest in 1966 is shown in Figure 8 and again illustrates a decrease in yield as leaf N increases. Yield was not significantly altered by the N applications.

Figure 9 shows a positive relationship between leaf N at harvest and total yield of Robinson. Again, applications of N did not affect yield.

Table 5. Correlation Coefficients for 1966 Robinson Strawberry Yield at Sodus Versus Leaf Composition at Selected Sampling Times.

	Time Leaf Sample was Taken			
Element	July 1965	August 1965	Bloom 1966	Harvest 1966
N	____##	____	____	.505** (2)#
K	____	____	____	.348* (2)
P	____	.282* (3)	____	.355** (3)
Ca	.401** (3)	.230* (2)	____	____
Mg	.267* (2)	.312* (2)	____	____
Mn	.301* (3)	.286* (3)	.460** (1)	____
Fe	.333* (2)	.230* (1)	.487** (1)	.430** (3)
Cu	.301* (2)	____	.461** (3)	.410** (2)
B	.352* (2)	____	____	____
Zn	.272* (2)	____	.308* (2)	____
Al	.378** (2)	.377** (2)	.473** (1)	____

* Significant at 5% level.

** Significant at 1% level.

\# Type of regression: (1) = straight line, (2) = parabola, (3) = cubic parabola.

\## Correlation coefficients for straight line, parabola, and cubic parabola curves below that required for significance.

Figure 7. Total 1965 Midway strawberry yield as a function of a single application of three rates of N in 1964 and of percent N in the leaves at selected periods of plant development.

Y* (As a function of N applied) = 4094.815 - 7.840 N

Y* (July) = 8443.460 - 2216.279 N

Y* (August) = 8926.042 - 2099.637 N

Y* (Bloom) = 1831.967 + 3639.938 N - 1073.253 N^2

Y* (Harvest) = 8955.0244 - 2840.616 N

* Grams per six linear feet of row.

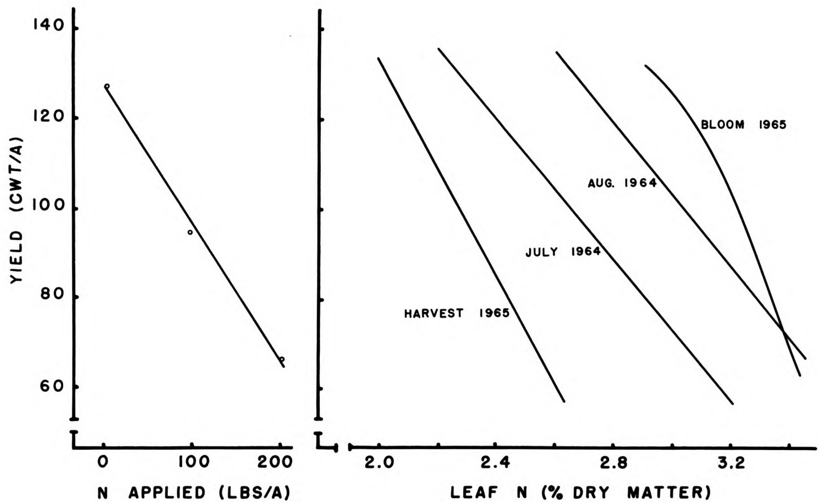

YIELD (CWT/A)
140
120
100
80
60
0
100
200
N APPLIED (LBS/A)
HARVEST 1965
JULY 1964
AUG. 1964
BLOOM 1965
2.0
2.4
2.8
3.2
LEAF N (% DRY MATTER)

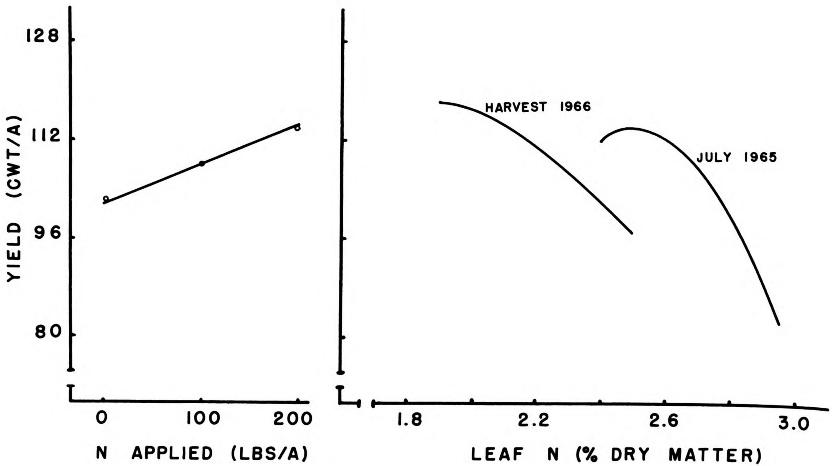
Figure 8. Total 1966 Midway strawberry yield as a function of a single application of three rates of N in 1965 and of percent N in the leaves at selected periods of plant development.

Y^{*} (As a function of N applied) = $2425.518 + 1.359\ N$

Y^{*} (July) = $28154.791 + 24679.0204\ N - 4909.215\ N^2$

Y^{*} (Harvest) = $43.593 + 3406.0139\ N - 982.499\ N^2$

* Grams per six linear feet of row.



YIELD (CWT/A)
128
112
96
80
0
100
200
N APPLIED (LBS/A)
HARVEST 1966
JULY 1965
1.8
2.2
2.6
3.0
LEAF N (% DRY MATTER)

Figure 9. Total 1966 Robinson strawberry yield as a function of a single application of three rates of N in 1965 and of percent N in the leaves following last harvest.

$$Y^{*} \text{ (As a function of N applied)} = 2691.833 + 0.462\ N$$

$$Y^{*} \text{ (Harvest)} = -\ 49114.145 + 45925.0587\ N - 10130.491\ N^{2}$$

* Grams per six linear feet of row.

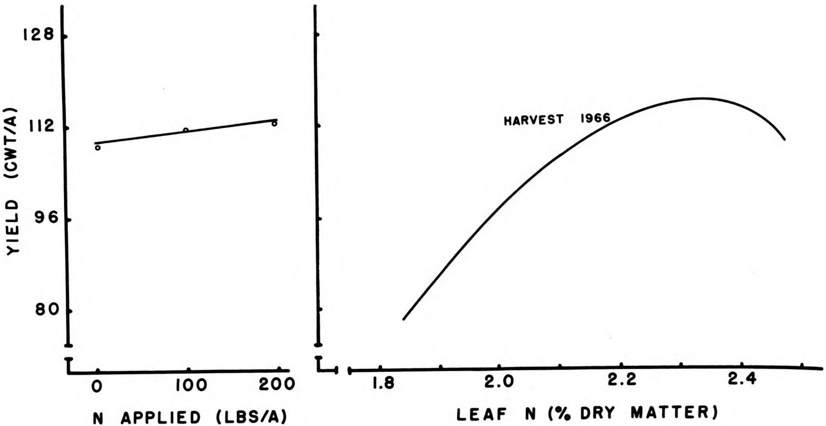

YIELD (CWT/A)
128
112
96
80
0
100
200
N APPLIED (LBS/A)
HARVEST 1966
1.8
2.0
2.2
2.4
LEAF N (% DRY MATTER)

Figure 10. Total 1965 Midway strawberry yield as a function of a single application of three rates of K in 1964 and of K in the leaves at selected periods of plant development.

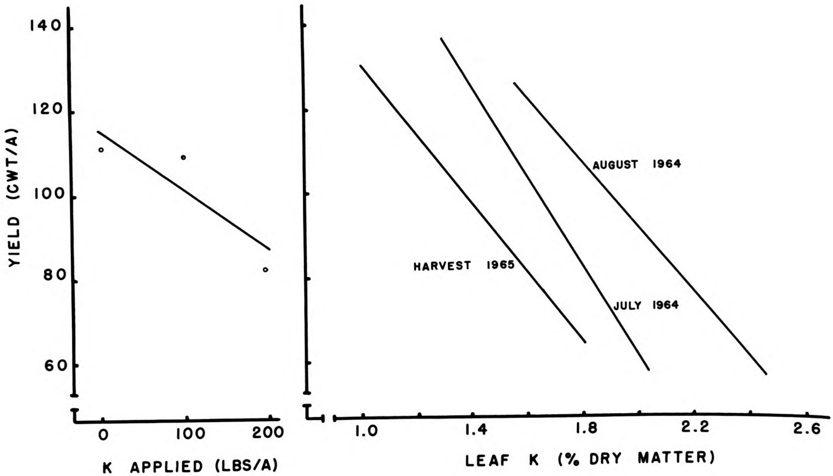
Y* (As a function of K applied) = 3187.315 - 3.303 K

Y* (July) = 7372.877 - 2952.915 K

Y* (August) = 6577.755 - 2144.195 K

Y* (Harvest) = 5448.300 - 2031.422 K

* Grams per six linear feet of row.



YIELD (CWT/A)
140
120
100
80
60
0
100
200
K APPLIED (LBS/A)
HARVEST 1965
JULY 1964
AUGUST 1964
1.0
1.4
1.8
2.2
2.6
LEAF K (% DRY MATTER)

Figure 11. Total 1966 Midway strawberry yield as a function of a single application of three rates of K in 1965 and of percent K in the leaves at selected periods of plant development.

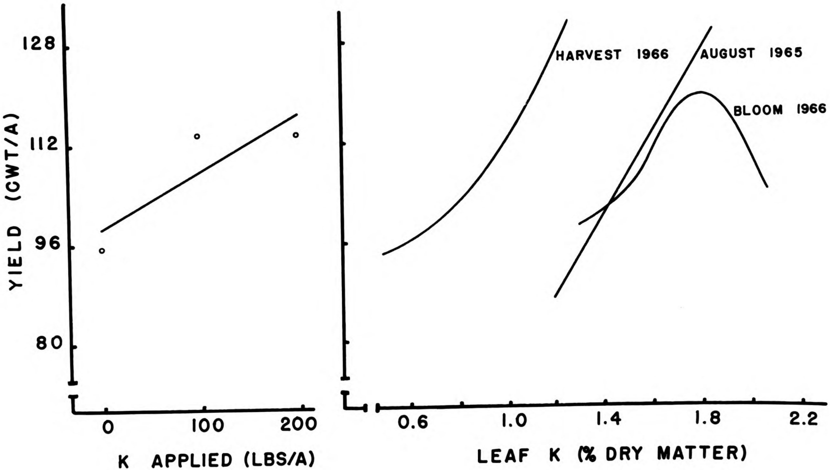
Y* (As a function of K applied) = 2247.685 + 2.249 K

Y* (August) = 93.766 + 1794.277 K

Y* (Bloom) $39745.660 - 74098.802\ K + 48253.709\ K^2 - 10236.252\ K^3$

Y* (Harvest) = $2482.983 - 829.408\ K + 1172.223\ K^2$

*Grams per six linear feet of row.



YIELD (CWT/A)
128
112
96
80
0
100
200
K APPLIED (LBS/A)
HARVEST 1966
AUGUST 1965
BLOOM 1966
0.6
1.0
1.4
1.8
2.2
LEAF K (% DRY MATTER)

Figure 12. Total 1966 Robinson strawberry yield as a function of a single application of three rates of K in 1965 and of percent K in the leaves following last harvest.

Y* (As a function of K applied) = 2601.777 + 0.912 K

Y* (Harvest) = 841.539 + 3688.478 K - 1609.380 K^2

*Grams per six linear feet of row.

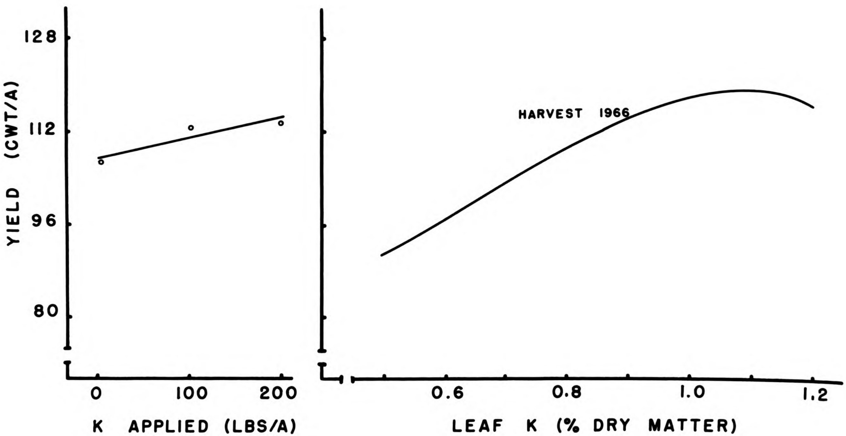

YIELD (CWT/A)
128
112
96
80
0
100
200
K APPLIED (LBS/A)
HARVEST 1966
0.6
0.8
1.0
1.2
LEAF K (% DRY MATTER)

Figure 13. Total 1965 Midway strawberry yield as a function of a single application of three rates of P in 1964 and of percent P in the leaves of selected periods of plant development.

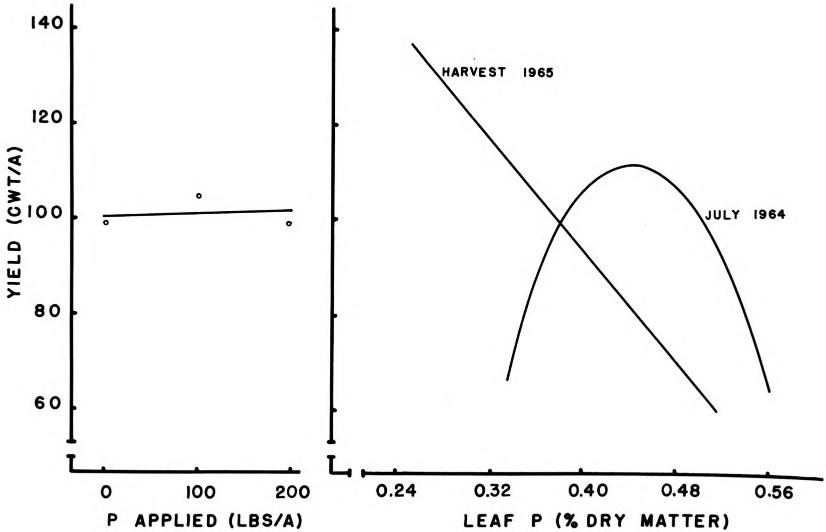
Y^* (As a function of P applied) = 2505 + 0.105 P

Y^* (July) = 17679.220 + 91145.0198 P - 101302.235 P^2

Y^* (Harvest) = 5162.455 - 6974.851 P

* Grams per six linear feet of row.

P^2



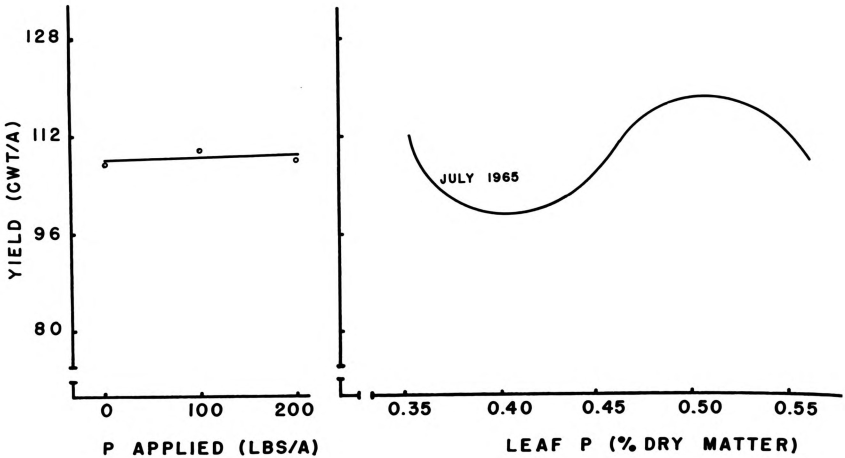
YIELD (CWT/A)
140
120
100
80
60
0
100
200
P APPLIED (LBS/A)
HARVEST 1965
JULY 1964
0.24
0.32
0.40
0.48
0.56
LEAF P (% DRY MATTER)

Figure 14. Total 1966 Midway strawberry yield as a function of a single application of three rates of P in 1965 and of percent P in the leaves in July of planting year.

Y* (As a function of P applied) = 2693.685 + 0.0188 P

Y* (July) = 68907.767 - 443007.582 P + 972420.435 P^2 - 700869.423 P^3

* Grams per six linear feet of row.


YIELD (CWT/A)
128
112
96
80
0
100
200
P APPLIED (LBS/A)
JULY 1965
0.35
0.40
0.45
0.50
0.55
LEAF P (% DRY MATTER)

[illegible]

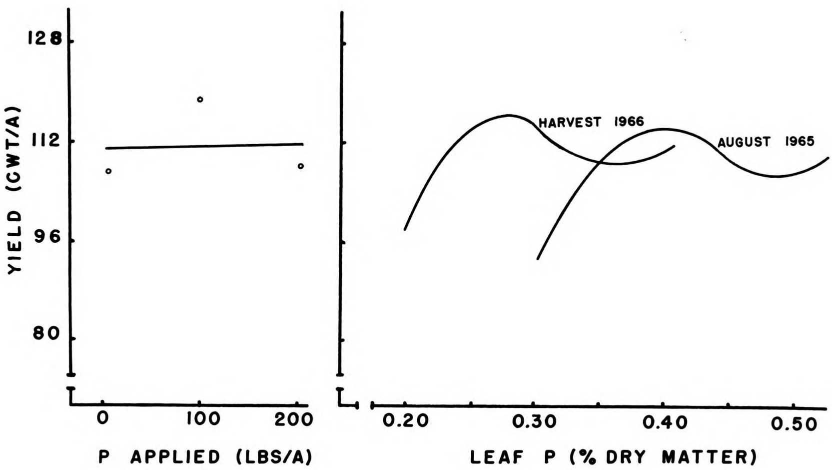
Figure 15. Total 1966 Robinson strawberry yield as a function of a single application of three rates of P in 1965 and of percent P in the leaves at selected periods of plant development.

Y* (As a function of P applied) = 2769.11 + 0.0733 P

Y* (August) = $28320.719 + 224128.385\,P - 529265\,P^2 + 409879.536\,P^3$

Y* (Harvest) = $8249.722 + 108288.335\,P - 344396.511\,P^2 + 356660.630\,P^3$

* Grams per six linear feet of row.


YIELD (CWT/A)
128
112
96
80
0
100
200
P APPLIED (LBS/A)
HARVEST 1966
AUGUST 1965
0.20
0.30
0.40
0.50
LEAF P (% DRY MATTER)

372

Midway yield in 1965 was slightly reduced as a result of the K applied at time of planting (Figure 10). Yield decreased in a linear fashion as leaf K increased in July. Similar trends also occurred in leaf samplings in August and at harvest.

Figure 11 indicates lower concentration of leaf K in 1966 than those reported in Figure 10. Yield was a positive function of leaf K at harvest and in August.

A comparison of Figure 10, 11 and 12 indicates that peak yield in these experiments probably occurred when leaf K at harvest is in the same range for both Midway and Robinson.

Application of P did not affect Midway yield in either experiment (Figures 13, 14). Yield as a function of leaf P at time of harvest for Midway in 1965 was a negative linear response. Yield as a function of leaf P in July suggests optimum yields occurred when leaf P was in the range of 0.42 to 0.48 percent. The following year highest yields occurred when leaf P in July was in the range of 0.48 to 0.53 percent.

Robinson yield was statistically related to the leaf P in August and at harvest (Figure 15). However, little difference occurred in yield between the two extremes in leaf P for either sampling period.

<u>Soil Analysis</u>

Average soil test values from Midway and Robinson plot samples taken in the spring prior to fertilizer applications are shown for 1964 and 1965 in Table 6. A number of differences between the 1964 planting at East Lansing and the 1965 planting at Sodus were evident. Available P and K

Table 6. Average Soil Test Values From Midway and Robinson Strawberry Plots Taken in May Prior to Fertilizer Application.

	East Lansing, 1964		Sodus, 1965	
	Midway	Robinson	Midway	Robinson
pH	5.5	5.9	7.1	7.8
Available P*	134	174	11	13
Available K*	250	240	75	111
Available Ca*	558	720	3499	8658
Available Mg*	58	103	440	850
CEC	8.2	7.3	10.8	25.1
% K Saturation	3.8	4.4	0.8	0.5
% Ca Saturation	16.7	27.9	80.9	85.8
% Mg Saturation	2.3	6.3	16.4	14.0
% Base Saturation	22.6	38.1	93.3	99.9

* Pounds per acre

were considerably higher in the East Lansing plots whereas available Ca and Mg values were considerably higher in the Sodus plots. pH of Midway and Robinson plots at East Lansing were 5.5 and 5.9 compared to 7.1 and 7.8 at Sodus. Percent base saturation was 22.6 and 38.1 at East Lansing compared to 93.3 and 99.9 at Sodus.

Soil samples were taken from each plot immediately following harvest. Summarized post harvest soil sample results are listed in Table 7.

Soil sample values following harvest were correlated with total yield. The correlation coefficients are listed in Table 8. Available P was not related to yield in any of the three experiments. Available Ca and Mg were significantly correlated to yield in each of the three experiments. Available K was correlated to Midway yields but not to Robinson.

Regression lines for yield as a function of available K (Figure 16) indicate a uniform decrease in yield in the East Lansing plots as K increased from 120 to 330 pounds per acre. Midway yields from the Sodus plots suggest that maximum yield occurred in the approximate range of 130 to 145 pounds of available K per acre.

Midway yields increased sharply as available Ca increased in the soil from 500 to 1200 pounds per acre (Figure 17). Usually high amounts of available Ca were found in both the Midway and Robinson plots at Sodus. Yield from both varieties tended to decrease as available Ca increased beyond 2500 pounds per acre. The optimum range of Ca in this study probably occurred between 1000 and 2000 pounds of available Ca per acre.

Table 7. Average Soil Test Values from Midway and Robinson Strawberry Plots at Last Harvest.

	East Lansing, 1965		Sodus, 1966	
	Midway	Robinson	Midway	Robinson
pH	5.3	5.7	7.0	7.8
Available* P	163	210	98	77
Available* K	227	210	103	138
Available* Ca	717	350	4245	8506
Available* Mg	103	123	509	941
CEC	6.0	5.1	13.7	25.2
% K Saturation	4.8	5.5	0.89	0.64
% Ca Saturation	27.9	19.8	77.2	83.7
% Mg Saturation	5.9	11.0	15.0	15.7
% Base Saturation	37.9	35.3	92.9	99.9

* Pounds per acre

Table 8. Correlation Coefficients for Total Yield Versus Soil Test Values at Last Harvest.

	East Lansing	Sodus	
	Midway 1965	Midway 1966	Robinson 1966
% Base Saturation	.566** (1)#	____##	____
% Mg Saturation	.395** (1)	____	.403** (2)
% Ca Saturation	.609** (1)	____	.407** (2)
% K Saturation	.452** (2)	.433** (2)	____
Available P	____	____	____
Available Ca	.554** (2)	.283* (2)	.270* (3)
Available Mg	.415** (2)	.283* (2)	.409** (2)
Available K	.270* (1)	.543** (3)	____

* Significant at 5% level.

** Significant at 1% level.

\# Type of regression: (1) = straight line, (2) = parabola, (3) = cubic parabola.

\## Correlation coefficients for straight line, parabola, and cubic parabola curves below that required for significance.

Figure 16. Total 1965 and 1966 Midway strawberry yields as a function of available K in soil following last harvest.

$$Y^{*}\ (1965) = 3696.524 - 5.143\ K$$

$$Y^{*}\ (1966) = 14589.641 - 383.179\ K + 3.866\ K^2 - 0.0122\ K^3$$

*Grams per six linear feet of row.

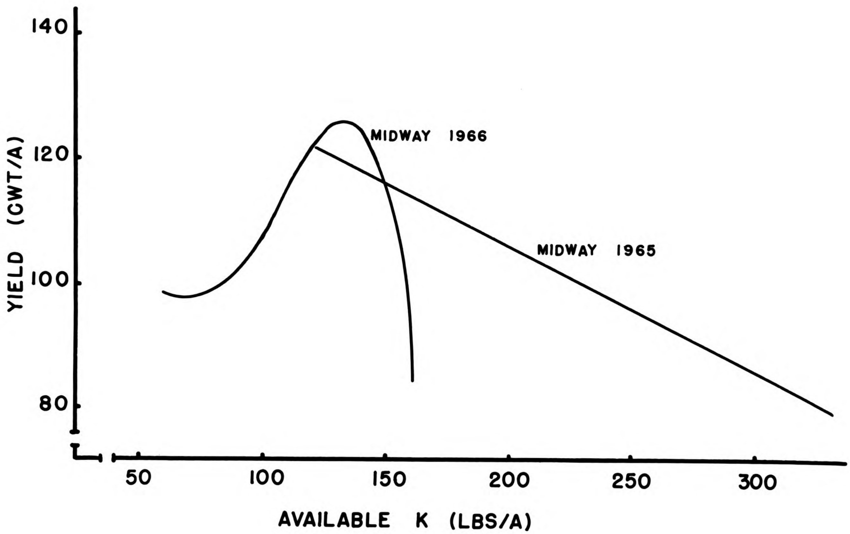

MIDWAY 1966
MIDWAY 1965
YIELD (CWT/A)
140
120
100
80
50
100
150
200
250
300
AVAILABLE K (LBS/A)

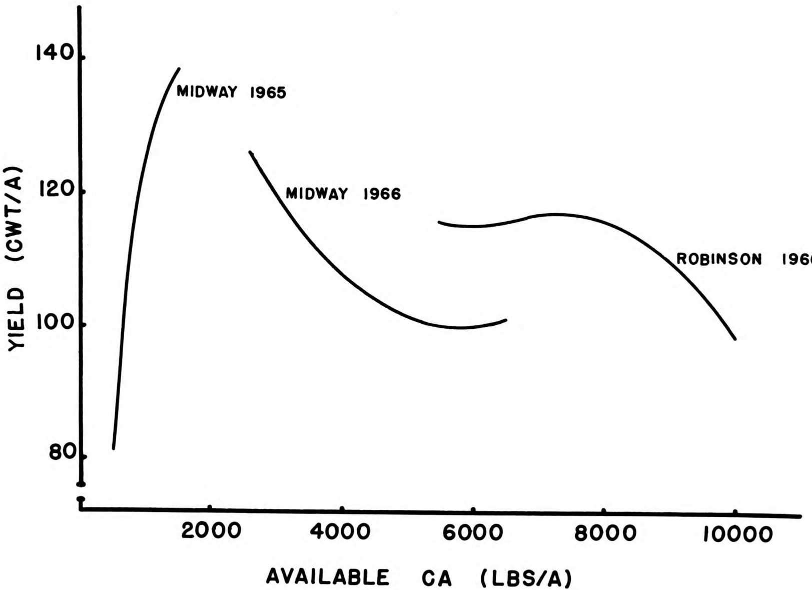
Figure 17. Total yield of Midway and Robinson strawberries as a function of available Ca in soil following last harvest.

$$Y^{*} \text{ (Midway 1965)} = 830.194 + 3.236\ Ca - 0.000983\ Ca^2$$

$$Y^{*} \text{ (Midway 1966)} = 1619.603 + 0.760\ Ca + 0.0000859\ Ca^2$$

$$Y^{*} \text{ (Robinson 1966)} = 4201.362 - 0.787\ Ca + 0.000144\ Ca^2 - 0.00000001\ Ca^3$$

* Grams per six linear feet of row.



140
120
100
80
YIELD (CWT/A)
MIDWAY 1965
MIDWAY 1966
ROBINSON 1966
2000
4000
6000
8000
10000
AVAILABLE CA (LBS/A)

Figure 18 indicates a substantial increase in yield as available Mg increased from 60 to 200 pounds per acre at East Lansing. Midway yield in 1966 decreased as available Mg increased from 300 to 700 pounds. Optimum yields for Midway occurred between 175 and 300 pounds of available Mg per acre. Maximum Robinson yield occurred between 1000 and 1100 pounds per acre.

Plant Density

Much of the variation in 1965 Midway yield was related to variation in number of established plants per plot. Figure 19 shows yield in 1965 and 1966 as a function of Midway plant density for the two locations. Peak yields occurred at East Lansing when eight to ten runner plants had been established for each mother plant. A larger number of runner plants was associated with peak yield at Sodus, however the precision of the regression was considerably less than for the East Lansing experiment. Variation in number of runner plants explained 62 percent of the variation in yield in East Lansing plots but only seven percent for Sodus. Number of runner plants per mother plant ranged from 3 to 14 in the Robinson variety but was not significantly related to yield.

Crown Analysis

Table 9 indicates the effect of N, P, and K applied in 1965 on the nutrient composition of Midway and Robinson runner plant crowns in March of 1966. Neither N or K composition in the crowns was affected by the fertilizer applications the previous year. P was increased in the crowns of the Robinson variety as the result of P application but not

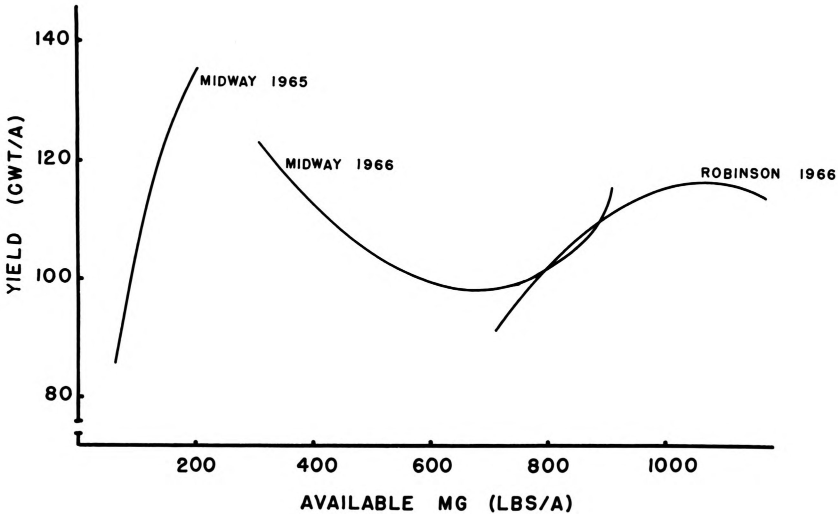
Figure 18. Total yield of Midway and Robinson strawberries as a function of available Mg in soil following last harvest.

$$Y^{*}\ (\text{Midway } 1965) = 852.734 + 22.268\ Mg - 0.0473\ Mg^2$$

$$Y^{*}\ (\text{Midway } 1966) = 4798.466 - 7.128\ Mg + 0.00549\ Mg^2$$

$$Y^{*}\ (\text{Robinson } 1966) = -2489.999 + 10.168\ Mg - 0.00476\ Mg^2$$

* Grams per six linear feet of row.



140
120
100
80
YIELD (CWT/A)
MIDWAY 1965
MIDWAY 1966
ROBINSON 1966
200
400
600
800
1000
AVAILABLE MG (LBS/A)

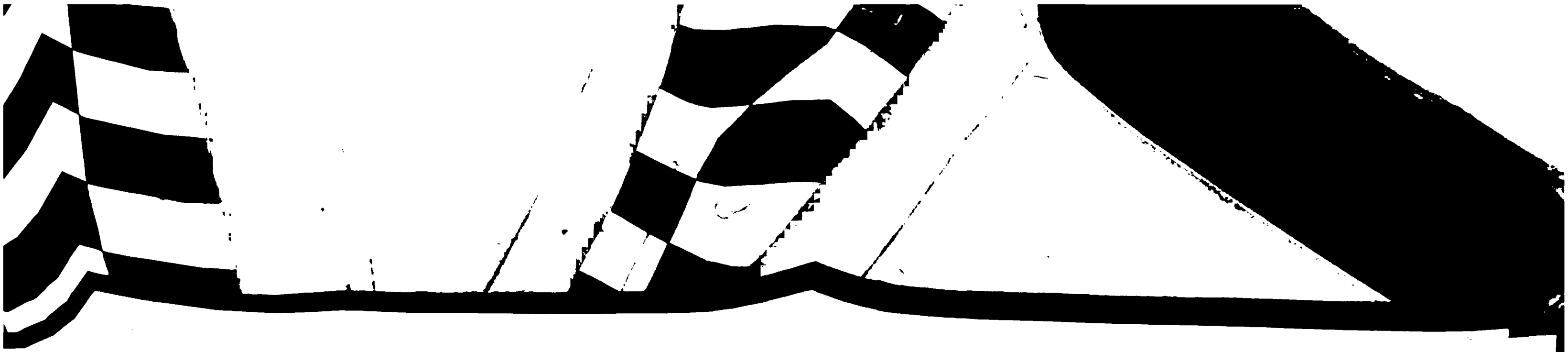


Figure 19. Total 1965 and 1966 Midway strawberry yield as a function of plant density in August following transplanting.

1965 $r = .794^{**}$

$Y\# = -448.159 + 255.248X\#\# - 4.287X^2$

1966 $r = .271^{*}$

$Y\# = 1652.918 + 68.184X\#\# - 0.975X^2$

* Significant at 5% level.

** Significant at 1% level.

Yield per six linear feet of row.

Total number of established plants in six linear feet of row in August.

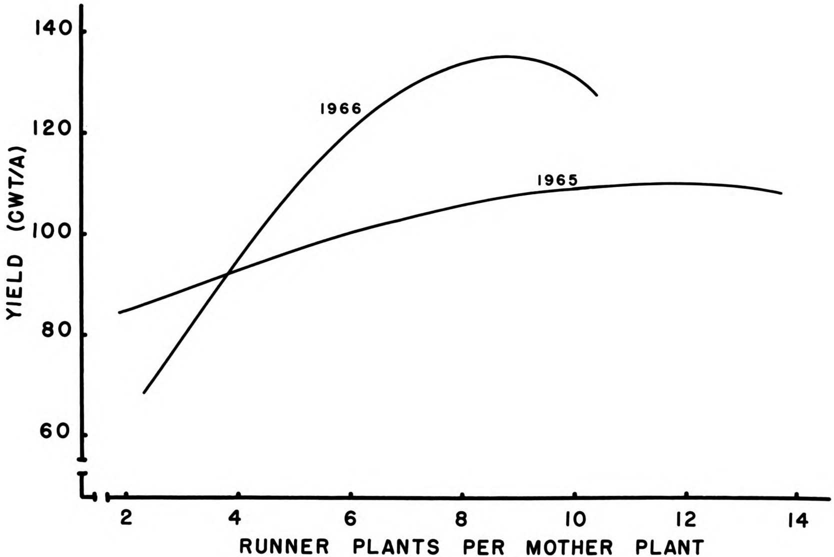

YIELD (CWT/A)
140
120
100
80
60
1966
1965
2
4
6
8
10
12
14
RUNNER PLANTS PER MOTHER PLANT

Table 9. Effect of Three Rates Each of N, P and K in 1965 on Nutrient Composition of Midway and Robinson Runner Crowns in March, 1966.

Element	Rate#	Midway	Robinson
N	0	2.71	2.33
	100	2.68	2.36
	200	2.69	2.37
		N.S.	N.S.
P	0	0.381	0.376
	100	0.390	0.442
	200	0.382	0.443
		N.S.	*
K	0	1.16	1.22
	100	1.38	1.29
	200	1.23	1.37
		N.S.	N.S.

* Significant at 5% level.

Lb/A of actual N, P_2O_5 and K_2O.

for the Midway variety.

Table 10 shows the correlation coefficients for yield with each of the 11 elements analyzed in the crowns. Crown N was not related to yield for either variety. P and Ca were the only elements correlated with yield for both varieties.

Fruit Composition

Composition of N, P, and K in Midway fruit at three selected harvests in 1965 are shown in Table 11. At each of the three harvests N significantly increased in the fruit as a result of applied N. At two of the three harvest periods K increased as a result of K applied the previous year. P was not significantly different in the fruit in any of the three harvests.

Table 12 shows N, P, and K fruit composition values for the Midway variety in the Sodus experiment. Percentages of N and P in the fruit were not affected whereas K was significantly increased as a result of fertilizer applications.

Fruit N, P, and K composition values for the Robinson variety are reported in Table 13. As with Midway, N and P in the fruit were not affected but K was significantly increased as a result of fertilizer application. Fruit N and P composition of Robinson were substantially lower than the N and P composition previously shown for Midway fruit.

A number of erratic interactions occurred. At one harvest fruit Ca was increased as a result of N applications; at another, applications of N caused increased Mn content. However, no significant interactions were consistently present at all harvest dates.

Table 10. Correlation Coefficients for 1966 Midway and Robinson Strawberry Yield at Sodus Versus Nutrient Composition of Runner Crowns in March, 1966.

Element	Midway	Robinson
N	___##	___
K	___	.276* (2)#
P	.378** (3)	.494** (3)
Ca	.339* (1)	.276* (1)
Mg	.307* (2)	___
Mn	.460** (2)	___
Fe	___	___
Cu	.285* (2)	___
B	___	___
Zn	___	___
Al	___	.283* (3)

* Significant at 5% level.

** Significant at 1% level.

\# Type of regression: (1) = straight line, (2) = parabola, (3) = cubic parabola.

\## Correlation coefficients for straight line, parabola, and cubic parabola curves below that required for significance.

Table 11. Effect of Three Rates Each of N, P and K Applied in 1964 on Composition# of Midway Strawberry Fruit at Three 1965 Harvest Dates at East Lansing.

	Rate ##	N	P	K
June 22	0	1.20	0.19	2.39
	100	1.35	0.22	2.46
	200	1.35	0.24	2.41
		**	N.S.	N.S.
June 24	0	1.27	0.22	2.44
	100	1.34	0.23	2.50
	200	1.38	0.25	3.00
		**	N.S.	**
June 30	0	1.12	0.19	2.26
	100	1.28	0.21	2.38
	200	1.28	0.22	2.30
		**	N.S.	**

** Significant at 1% level.

= % of Dry matter.

Lb/A of actual N, P_2O_5 and K_2O.

Table 12. Effect of Three Rates Each of N, P and K Applied in 1965 on Composition# of Midway Strawberry Fruit at Two 1966 Harvest Dates at Sodus.

	Rate##	N	P	K
June 15	0	1.24	0.70	1.63
	100	1.22	0.66	1.84
	200	1.16	0.61	1.96
		N.S.	N.S.	**
June 21	0	1.31	0.75	1.59
	100	1.32	0.71	1.89
	200	1.20	0.68	1.96
		N.S.	N.S.	**

** Significant at 1% level.

= % of Dry matter.

Lb/A of Actual N, P_2O_5 and K_2O

Table 13. Effect of Three Rates Each of N, P and K Applied in 1965 on Composition# of Robinson Strawberry Fruit at Two 1966 Harvest Dates at Sodus.

	Rate##	N	P	K
June 21	0	0.93	0.70	1.45
	100	0.92	0.66	1.61
	200	0.89	0.63	1.61
		N.S.	N.S.	**
June 23	0	0.93	0.63	1.38
	100	0.89	0.66	1.58
	200	0.94	0.59	1.64
		N.S.	N.S.	**

** Significant at 1% level.

= % of dry matter

Lb/A of actual N, P_2O_5 and K_2O.

Fruit Firmness. Effect of fertilizer applications on fruit firmness of Midway strawberries at four harvest periods in 1965 is shown in Table 14. Fertilizer treatments did not significantly affect fruit firmness at any of the harvests.

Table 15 lists Midway fruit firmness data for three harvests in 1966. Again, N and K did not affect firmness, but in the first of the three harvests applied P was associated with firmer fruit.

P also was found to increase firmness in one harvest of Robinson (Table 16). N and K apparently caused no difference in fruit firmness for this variety either.

Table 17 lists correlation coefficients for Midway fruit firmness and fruit nutrient composition. Calcium was more consistently correlated with firmness than the other elements. Correlation coefficients were significant in three of the four harvests evaluated. Although other correlation coefficients were significant, none were consistent throughout the harvest.

Table 18 lists correlation coefficients for Robinson fruit firmness versus fruit composition. Ca was significantly related to firmness for one harvest. Fe and Al were significant at both harvests from which analysis were made. However, in both cases, when the regression lines were plotted, the curve for the second date was opposite that of the first.

Size. Effect of fertilizer treatments on size of Midway fruit at each 1965 harvest are shown in Table 19. Size typically decreased from first to last harvest. Application of N decreased fruit size at the third

Table 14. Effect of Three Rates Each of N, P and K Applied in 1964 on Firmness of Midway Strawberry Fruit at Selected 1965 Harvests at East Lansing.

		Firmness			
		June			
Element	Rate##	18	21	23	28
N	0	685	802	684	640
	100	646	778	630	623
	200	664	666	633	646
		N.S.	N.S.	N.S.	N.S.
P	0	662	781	621	609
	100	663	785	649	660
	200	671	781	678	641
		N.S.	N.S.	N.S.	N.S.
K	0	683	758	663	629
	100	666	813	655	653
	200	647	775	629	629
		N.S.	N.S.	N.S.	N.S.

Grams pressure required to force 7/16" plunger 1/8" into fruit surface.

Lb/A of actual N, P_2O_5 and K_2O.

Table 15. Effect of Three Rates Each of N, P and K Applied in 1965 on Firmness of Midway Strawberry Fruit at Selected Harvests in 1966 at Sodus.

		Firmness#		
		June		
Element	Rate##	13	20	22
N	0	994	1006	610
	100	993	922	597
	200	1043	934	622
		N.S.	N.S.	N.S.
P	0	955	942	631
	100	1027	962	594
	200	1048	959	603
		*	N.S.	N.S.
K	0	1009	943	599
	100	1012	967	607
	200	1009	952	622
		N.S.	N.S.	N.S.

* Significant at 5% level.

Grams pressure required to force 7/16" plunger 1/8" into fruit surface.

Lb/A of actual N, P_2O_5 and K_2O.

Table 16. Effect of Three Rates Each of N, P and K Applied in 1965 on Firmness of Robinson Strawberry Fruit at Selected Harvests in 1966 at Sodus.

		Firmness#	
		June	
Element	Rate##	20	22
N	0	787	686
	100	770	647
	200	743	656
		N.S.	N.S.
P	0	734	674
	100	808	655
	200	757	660
		*	N.S.
K	0	781	654
	100	747	667
	200	771	668
		N.S.	N.S.

* Significant at 5% level.

Grams pressure required to force 7/16" plunger 1/8" into fruit surface.

Lb/A of actual N, P_2O_5 and K_2O.

Table 17. Correlation Coefficients for Firmness of Midway Strawberry Fruit Versus Nutrient Composition of Fruit at Selected Harvest Dates in 1965 and 1966

	East Lansing			Sodus
Element	June 21, 1965	June 23, 1965	June 25, 1965	June 20, 1966
N	____	____	____##	.284* (3)#
K	____	____	____	____
P	____	____	____	.273* (3)
Ca	.308* (3)	.268* (2)	____	.271* (1)
Mg	____	.302* (1)	.277* (3)	____
Mn	.307* (3)	____	.267* (3)	____
Fe	.265* (2)	____	____	____
Cu	____	.398** (3)	____	.275*
B	.277* (2)	____	____	____
Zn	____	____	____	____
Al	.404** (2)	____	____	____

* Significant at 5% level.

** Significant at 1% level.

Type of regression: (1) = straight line, (2) = parabola, (3) = cubic parabola

Correlation coefficients for straight line, parabola and cubic parabola curves below that required for significance.

Table 18. Correlation Coefficients for Firmness of Robinson Strawberry Fruit Versus Nutrient Composition of Fruit at Selected Harvest Dates in 1966.

	June 20	June 22
N	____##	____
K	____	____
P	____	____
Ca	.343* (3)#	____
Mg	.417** (3)	____
Mn	____	.828** (2)
Fe	.306* (2)	.816** (2)
Cu	____	____
B	____	____
Zn	____	____
Al	.308* (2)	.448** (2)

* Significant at 5% level.

** Significant at 1% level.

\# Type of regression: (1) = Straight line, (2) = Parabola, (3) = Cubic parabola

\## Correlation coefficients for straight line, parabola, and cubic parabola curves below that required for significance.

Table 19. Effect of Three Rates Each of N, P and K on Size of Midway Strawberry Fruit at Each 1965 Harvest Date at East Lansing.

		Size (Gms each)							
		June						July	
Element	Rate #	15	18	21	23	25	28	1	6
N	0	14.2	14.2	13.3	9.9	7.6	6.7	5.1	5.2
	100	15.1	14.0	12.6	9.9	8.0	7.4	5.7	6.0
	200	13.5	14.9	11.0	7.9	7.2	6.7	6.2	6.4
		N.S.	N.S.	*	*	N.S.	N.S.	**	**
P	0	13.2	13.4	11.8	8.0	6.7	5.9	5.4	5.9
	100	15.3	15.0	13.0	10.6	8.4	8.0	5.8	5.7
	200	14.3	14.7	12.1	9.1	7.9	6.9	5.8	5.9
		N.S.	N.S.	N.S.	*	**	N.S.	N.S.	N.S.
K	0	15.0	15.7	12.5	10.1	8.2	6.9	5.8	5.9
	100	14.2	14.6	12.6	9.0	7.4	7.8	5.6	5.9
	200	13.7	12.8	11.7	8.5	7.3	6.1	5.5	5.8
		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* Significant at 5% level.

** Significant at 1% level.

Lb/A of actual N, P_2O_5 and K_2O.

and fourth harvest but resulted in larger fruit for the last two harvests. In two midseason harvests larger fruit were associated with 100 pounds of P but not with either 0 or 200 pounds per acre. K was not significantly related to size of Midway fruit.

Effect of fertilizer application on size of Midway fruit from the Sodus experiment is shown in Table 20. Although 5% significant differences in size occurred at three different harvests, no consistent difference in size can be attributed to treatments.

The effect of treatment on size of Robinson fruit is shown in Table 21. Applications of N and P did not affect size of fruit at any of the eight harvests. Larger fruit occurred the first harvest in plots receiving 200 pounds of K_2O, however the effect was not evident in the remaining seven harvests.

<u>Percent Sugar</u>. Applications of P resulted in a slight decrease in percent sugar in Midway fruit at one of the harvests selected for detailed evaluation in 1965 (Table 22). Percent sugar of Midway fruit was not affected by applications of N and K in either 1965 (Table 22) or 1966 (Table 23). While Robinson fruit was consistently higher in percent sugar than Midway, the N, P, and K treatments did not significantly change the percent sugar content (Table 24).

<u>Color</u>. Table 25 indicates the effect of fertilizer treatments on red pigmentation of Midway fruit. No significant difference in pigmentation occurred during any of the four selected harvests as a result of fertilizer treatment.

Table 26 lists correlation coefficients for optical density readings

Table 20. Effect of Three Rates Each of N, P and K on Size of Midway Strawberry Fruit at Each 1966 Harvest Date at Sodus.

		Size (Gms each)							
		June							
Element	Rate #	10	13	15	17	20	22	24	27
N	0	10.6	10.2	8.6	7.5	3.3	4.4	3.8	3.6
	100	12.1	10.2	9.9	8.0	2.2	4.7	4.1	3.6
	200	11.1	9.7	9.9	8.6	3.4	4.9	4.0	3.7
		N.S.	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.
P	0	12.0	10.4	9.3	8.1	3.4	4.5	3.8	3.5
	100	10.7	9.0	9.1	7.8	2.6	4.6	4.0	3.6
	200	11.1	10.8	10.0	8.3	2.8	4.9	4.2	3.8
		N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
K	0	11.1	10.2	9.5	7.9	4.7	4.7	4.2	3.6
	100	10.8	10.2	9.6	8.1	1.7	4.7	3.9	3.6
	200	11.8	9.8	9.2	8.1	2.4	4.6	3.9	3.6
		N.S.	N.S.	N.S.	N.S.	*	N.S.	N.S.	N.S.

* Significant at 5% level.

Lb/A of actual N, P_2O_5 and K_2O.

Table 21. Effect of Three Rates Each of N, P and K on Size of Robinson Strawberry Fruit at Each 1966 Harvest Date at Sodus.

		Size (Gms each)							
		June							July
Element	Rate#	15	17	20	22	24	27	29	1
N	0	14.6	13.7	8.6	7.7	6.4	6.1	4.9	4.4
	100	15.0	13.0	9.3	8.4	6.9	6.3	5.1	4.3
	200	15.1	12.9	9.5	8.2	6.7	6.2	5.4	4.6
		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P	0	15.9	13.0	9.2	8.3	6.8	6.2	5.2	4.6
	100	14.4	13.5	9.5	8.1	6.8	6.2	5.0	4.4
	200	14.4	13.0	8.6	8.0	6.4	6.3	5.1	4.3
		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
K	0	13.9	12.3	8.6	7.9	6.8	6.2	5.3	4.4
	100	14.8	13.6	8.8	8.2	6.6	6.2	5.0	4.5
	200	16.0	13.6	10.0	8.2	6.5	6.3	4.9	4.4
		*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* Significant at 5% level.

Lb/A of actual N, P_2O_5 and K_2O.

Table 22. Effect of Three Rates Each of N, P and K Applied in 1964 on Percent Sugar in Midway Strawberry Fruit At Two Harvests in 1965 at East Lansing

	Nutrient Element					
	N		P		K	
Rate#	June 18	June 23	June 18	June 23	June 18	June 23
0	6.77	6.64	7.08	6.86	6.80	6.77
100	6.86	6.83	6.92	6.81	6.88	6.83
200	7.00	6.86	6.64	6.66	6.94	6.72
	N.S.	N.S.	*	N.S.	N.S.	N.S.

* Significant at 5% level.

Lb/A of Actual N, P_2O_5 and K_2O

Table 23. Effect of Three Rates Each of N, P and K Applied in 1965 on Percent Sugar in Midway Strawberry Fruit at Two Harvests in 1966 at Sodus.

	Nutrient Element					
	N		P		K	
Rate#	June 20	June 22	June 20	June 22	June 20	June 22
0	6.82	6.72	7.04	6.80	6.93	6.95
100	6.91	6.71	6.71	6.57	6.70	6.53
200	6.90	6.91	6.87	6.89	7.00	6.86
	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Lb/A of actual N, P_2O_5 and K_2O

Table 24. Effect of Three Rates Each of N, P and K Applied in 1965 on Percent Sugar in Robinson Strawberry Fruit at Two Harvests in 1966 at Sodus.

	Nutrient Element					
	N		P		K	
Rate#	June 20	June 22	June 20	June 22	June 20	June 22
0	7.47	7.30	7.26	7.37	7.28	7.20
100	7.31	7.33	7.54	7.34	7.28	7.36
200	7.22	7.29	7.21	7.22	7.44	7.36
	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Lb/A of actual N, P_2O_5 and K_2O.

Table 25. Effect of Three Rates Each of N, P and K Applied in 1964 on Pigmentation of Midway Strawberry Fruit at Four Harvests in 1965 at East Lansing

Harvest Date	Application Rate #	Optical Density		
		N	P	K
June 18	0	44.9	45.1	44.2
	100	45.9	45.1	45.7
	200	46.2	47.0	47.2
		N.S.	N.S.	N.S.
June 21	0	41.2	40.6	39.7
	100	40.6	39.7	41.3
	200	39.7	41.3	40.6
		N.S.	N.S.	N.S.
June 23	0	38.3	38.9	40.8
	100	42.0	39.9	39.1
	200	39.7	41.3	40.2
		N.S.	N.S.	N.S.
June 28	0	27.3	27.2	27.8
	100	29.8	28.4	27.8
	200	27.4	28.4	27.8
		N.S.	N.S.	N.S.

Lb/A of actual N, P_2O_5 and K_2O.

Table 26. Correlation Coefficients for Midway Strawberry Fruit Pigmentation Versus Nutrient Composition of Fruit at Different 1965 Harvest Dates at East Lansing.

Element	June 21	June 23	June 28
N	____##	.273* (2)#	.428** (2)
K	____	____	.314* (1)
P	____	____	____
Ca	____	.393** (3)	.404** (3)
Mg	____	____	____
Mn	____	.387** (3)	____
Fe	____	.353** (3)	____
Cu	.302* (3)	____	____
B	____	.309* (2)	.437** (3)
Zn	.276* (2)	____	____
Al	____	____	____

* Significant at 5% level.

** Significant at 1% level.

\# Type of regression: (1) = Straight line, (2) = Parabola, (3) = Cubic parabola.

\## Correlation coefficients for straight line, parabola, and cubic parabola curves below that required for significance.

versus fruit nutrient composition. Although a number of statistically significant correlations occurred, none were consistent for all three harvests from which optical density readings and composition were correlated.

Survey Data. Leaf composition values for July (Table 27) and August (Table 28) from 29 Southwest Michigan commercial strawberry plantings are listed. Leaf composition tends to be higher in August than July, agreeing with findings from controlled plots.

Tables 29 and 30 list leaf composition values for July and August from 13 commercial plantings in Manistee county. Again, leaf composition tends to be higher in July than August. Leaf N and K content of strawberries in August from Manistee county were higher than August samples from Southwestern Michigan.

Soil test findings (Table 31) suggest an adequate level of available P, K, and Ca in commercial plantings in Michigan. The availability of these elements is less in Manistee county than Southwestern Michigan. Available Mg in Manistee county was less than half that in Southwestern Michigan.

Table 27. Composition of Strawberry Leaves Sampled in July of Planting Year From Commercial Plantings in Southwestern Michigan.

	Midway*		Robinson**	
Element	Average	Range	Average	Range
N (%)	2.52	2.24-2.76	2.37	2.08-2.60
K (%)	1.58	1.32-1.86	1.75	1.36-2.00
P (%)	0.42	0.30-0.62	0.40	0.34-0.53
Ca (%)	0.72	0.58-0.82	0.65	501-659
Mg (%)	0.36	0.27-0.43	0.33	0.24-0.44
Mn (ppm)	211	90-562	216	129-368
Fe (ppm)	134	62-306	206	128-326
Cu (ppm)	16	11-42	16	13-21
B (ppm)	33	26-40	30	27-32
Zn (ppm)	26	17-35	26	22-32
Al (ppm)	165	92-289	218	155-279

* Average of 23 locations.

** Average of 6 locations.

Table 28. Composition of Strawberry Leaves Sampled in August of Planting Year From Commercial Plantings in Southwestern Michigan.

	Midway*		Robinson**	
Element	Average	Range	Average	Range
N (%)	2.68	2.20-314	2.54	2.04-2.74
K (%)	1.68	1.44-2.10	1.78	1.62-2.00
P (%)	0.51	0.39-0.63	0.53	0.43-0.63
Ca (%)	0.79	0.62-0.92	0.73	0.58-0.86
Mg (%)	0.40	0.30-0.51	0.38	0.30-0.47
Mn (ppm)	290	123-854	298	129-430
Fe (ppm)	143	106-188	171	140-203
Cu (ppm)	14	10-23	14	13-16
B (ppm)	33	26-53	31	28-37
Zn (ppm)	34	29-39	35	32-36
Al (ppm)	136	97-190	145	97-210

* Average from 23 plantings

** Average from 6 plantings.

Table 29. Composition of Strawberry Leaves Sampled in July of Planting Year From Commercial Plantings in Manistee County, Michigan.

Element	Midway*		Robinson**	
	Average	Range	Average	Range
N (%)	2.39	2.12-2.80	2.49	2.38-2.66
K (%)	1.71	1.44-1.94	2.13	1.94-2.52
P (%)	0.382	0.329-0.443	0.426	0.401-0.443
Ca (%)	0.71	0.58-0.86	0.63	0.40-0.80
Mg (%)	0.313	0.25-0.35	0.25	0.20-0.32
Mn (ppm)	241	95-383	399	171-597
Fe (ppm)	81	45-132	141	111-201
Cu (ppm)	12	11-13	13	12-14
B (ppm)	26	24-28	33	30-38
Zn (ppm)	23	19-30	27	27-28
Al (ppm)	120	77-151	154	106-195

* Average from 10 locations.

** Average from 3 locations.

Table 30. Composition of Strawberry Leaves Sampled in August of Planting Year From Commercial Plantings in Manistee County, Michigan.

Element	Midway*		Robinson**	
	Average	Range	Average	Range
N (%)	2.84	2.38-3.26	2.86	2.68-2.96
K (%)	1.81	1.52-2.10	2.14	2.00-2.32
P (%)	0.47	0.385-0.599	0.53	0.454-0.565
Ca (%)	0.76	0.60-0.86	0.61	0.47-0.70
Mg (%)	0.35	0.25-0.44	0.31	0.27-0.33
Mn (ppm)	369	156-707	593	364-844
Fe (ppm)	124	89-143	141	138-145
Cu (ppm)	15	12-20	18	17-20
B (ppm)	30	28-35	30	27-33
Zn (ppm)	37	30-47	41	38-43
Al (ppm)	117	97-195	151	126-185

* Average of 10 plantings.

** Average of 3 plantings.

Table 31. Soil Test Findings From Commercial Strawberry Planting From Samples Taken in August of Planting Year.

	Southwestern, Michigan		Manistee County, Michigan	
	Midway(23*)	Robinson(6)	Midway(10)	Robinson(3)
pH	6.0	6.3	5.7	5.4
P#	215	186	190	216
K#	206	172	160	155
Ca#	1075	1305	823	704
Mg#	183	153	77	54

* Number of plantings from which samples were taken.

Pounds available per acre.

DISCUSSION

An attempt was made in the design of the reported experiments to affect wide variations in leaf composition values. Thus, unusually large amounts of fertilizer were applied. A single application was made to avoid the time of application variable.

Difficulty was encountered in establishing runner plants in some of the East Lansing plots. Apparently the application of ammonium nitrate and potassium chloride resulted in an excessive accumulation of salts. Ureaform was used as the N source at Sodus to avoid this difficulty. A more rigorous irrigation schedule was also followed and the difficulty did not occur.

The major objective of this study was to determine the relationship between variations in leaf composition and plant performance. Therefore, much of the data has been subjected to correlation and regression analysis although a statistically significant correlation coefficient may occur when there is no natural relation between the two variables.

With most biological data the relationship between two variables can be expressed either as linear or quadratic. Exceptions to this may occur with a very wide range in independent variables. Thus, all correlations were calculated as linear, quadratic and cubic.

In event correlation coefficients were significant for more than one function a choice was made based on degree of precision indicated by the correlation coefficient, the standard error of estimate and a knowledge of the natural relationship that may be expected to occur. No

regressions were presented which did not have a statistical significance of five percent or greater.

July appeared a better time to take leaf samples than either August, bloom or harvest, when all elements related to yield are considered and the size of the correlation coefficients compared. Leaf samples taken in July would also have the practical advantage of providing time after chemical analysis for corrective measures before fruit bud differentiation.

Harvest appeared the best time to take Robinson leaf samples if only composition of N, P, and K are considered. Determination of nutrient status at harvest precludes corrective measures that would alter current yield. However, adjustment of fertilizer practices the following season based on nutrient status at harvest would be possible in plantings to be fruited a second year.

In July the optimum range of leaf N for Midway would probably be below 2.6 percent. Yield from Midway plots at East Lansing was a negative linear function of leaf N at harvest. Yield from Midway plots at Sodus was a negative, slightly curvilinear, function of N at harvest. Both regressions tend to suggest that desired leaf N at harvest would probably be below 2.0 percent. This compared favorably to an optimum Robinson range of 2.2 to 2.4 percent N at harvest.

An optimum range for P, at any of the four times of sampling, cannot be determined from the data presented. Although percent P in July samples was significantly correlated to Midway yield in both experiments, the characteristics of the two curves were quite different. It is impractical to choose an optimum range or to postulate which of the

two curves reflect the true relationship. The P content in August and at harvest sampling periods were correlated with Robinson yield. Both curves were third order and indicate that a relatively wide range in leaf P may occur with little change in yield.

Leaf K values found in the two experiments are in closer agreement than those found for N and P. Concentration of K in August samples from Sodus indicate that yield increased as percent K in the leaves increased from 1.2 to 1.8 percent. Samples for the same period at East Lansing suggest that yield decreased as leaf K increased from 1.6 to 2.4 percent. Thus, one may conclude that peak Midway yields occur when leaf K in August is between 1.6 and 1.8 percent.

Yield decreased in the East Lansing experiment as leaf K at harvest increased from 1.0 to 1.8 percent. Yield at Sodus increased as leaf K at harvest increased from 0.5 to 1.2 percent. Optimum yield apparently occurred when leaf dry matter content was between 1.0 and 1.2 percent. Peak yield of Robinson also occurred in this same range.

Many of the differences in plant composition values between years and varieties can be traced to soil differences. Considerable differences in soil test values were found both in the 1964 East Lansing plots and in 1965 Sodus plots prior to application of treatments, thus, discussion concerning differences in plant composition values between varieties is minimized. A statistical comparison between East Lansing and Sodus plots was not made; however, major soil differences were obvious.

Percent K in the leaves was consistently higher at East Lansing than the following year at Sodus (Appendix Tables 6A and 7A). This

difference appeared small considering the soil differences reported in Table 6. The same was true for percent P in the leaves. P in the Robinson leaves taken in August at Sodus was approximately 30 percent less than in the same sampling from East Lansing. Available P in the soil, however, was approximately 90 percent less. This tends to suggest that strawberries may be very efficient in retrieving K and P from soils even though soil test indicates a low available supply.

Available Ca and Mg were considerably higher in the soils at Sodus than at East Lansing. Percent Ca and Mg in the leaves were only slightly higher. This again may have been the result of efficient extraction from the soil. The plants may have been near their maximum capacity for Ca and Mg or there may be an interaction with K.

Manganese was approximately three times more concentrated in leaves from the East Lansing plots. Applications of ammonium nitrate caused an increase in leaf manganese, whereas applications of Ureaform did not result in such an increase. Major differences in manganese leaf content apparently occurred as a result of the source of N applied.

A comparison of values in Tables 11 and 12 indicates that the K content of Midway fruit is considerably lower from the soil which was lower in available K. The opposite is true for P; however, no explanation for the higher P content is evident.

Attempting to explain leaf concentration of P and K by use of soil test values is probably futile, as Appendix Table 9A tends to confirm. No significant relationship could be established between leaf P and K and available P and K in the soil. This is of particular interest since

the soil samples were taken directly beneath the plants from which the leaf samples were taken.

Bould[4] has recently shown that the presence of certain mycorrhiza greatly enhance the ability of strawberry plants to absorb P. This may partly explain the erratic response of strawberries to applications of P. Symbiosis may also affect the supply of other elements.

There can be little concluded concerning leaf and fruit composition values and its effect on fruit quality as evaluated in this study. The lack of conclusive findings may be the result of working within a luxury range of nutrients. Essentially no differences were found in fruit color and percent sugar despite widely varying leaf nutrient composition values.

Fruit measurements failed to reveal any striking firmness differences due to fertilizer applications. This is somewhat surprising in view of considerable research findings to the contrary. Firmness of Midway fruit was correlated with the calcium content of the fruit in three of the four harvests evaluated for firmness. The correlation coefficients, however, suggest the regressions are of poor fit and each are of a different order. One must conclude that no differences in fruit firmness actually occurred or that the measurements were not reflecting actual firmness.

It is possible that firmness, as evaluated in this study, may not fully reflect treatment effect. Firmness measured with the Hunter spring gauge is more indicative of skin toughness than flesh firmness. Both skin toughness and flesh firmness need to be determined to extensively

[4]Personal communication, C. Bould, Long Ashton Research Station, University of Bristol, 1967.

study strawberry fruit firmness. A realistic measure should also reflect firmness and resistance to breakdown following freezing and thawing.

SUMMARY

Field plots of Midway and Robinson strawberries were established in 1965 and in 1966 to study plant composition in relation to yield and fruit quality factors. Treatments were single applications of 0, 100, and 200 pounds each of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O).

Leaf N and K composition tended to be highest at bloom whereas P was highest in August. Lowest composition values occurred at harvest. Leaf samples taken in July were more closely correlated to yield than samples taken at other periods.

Yield was significantly reduced as a result of N and K applications in the 1965-66 East Lansing experiment. Much of this variation in yield could be traced to variations in plant density. Applications of P did not affect yield.

None of the fertilizer applications affected yield in the Sodus experiment. Midway yield was significantly related to plant density, however Robinson yield and plant density were not significantly correlated.

Available Ca and Mg in the soil at harvest were significantly correlated to yield in each experiment, whereas P was not. Available K was significantly correlated with yield of Midway but not Robinson.

Neither N nor K composition in the crowns was affected by fertilizer applications the previous year. P was increased in crowns of the Robinson variety as the result of P applications but not in the Midway variety.

Soil applications of N and P caused no effect on N and P composition

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of the fruit. K was significantly increased in the fruit as a result of the K application the previous year.

Fruit firmness, percent sugar and intensity of red pigment were not affected by fertilizer treatments. Pigmentation was not consistently correlated with any nutrient element in the fruit. Fruit firmness tended to be associated with fruit calcium content.

A survey of 42 commercial Michigan strawberry plantings was conducted in 1966. Leaf samples were taken in July and August and chemically analyzed. Soil samples were also collected in August. Correlation coefficients for leaf composition versus soil test values indicated that available P and K in the soil are not correlated to P and K found in the leaves. Available Ca and Mg were significantly correlated to the Ca and Mg found in the plant leaves.

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APPENDIX TABLES

Table 1A. Effect of Three Rates Each of N, P and K on Yield of Midway Strawberries.

	N		P		K	
Rate ##	1965	1966	1965	1966	1965	1966
0	3304	2565	2476	2678	2752	2397
100	2541	2690	2608	2732	2736	2849
200	1735	2837	2497	2682	2091	2846
	**	N.S.	N.S.	N.S.	*	N.S.

Grams of total season yield from 6 feet of matted row.

Lb/A of actual N, P_2O_5 and K_2O.

* Significant at 5% level.

** Significant at 1% level.

Table 2A. Effect of Three Rates Each of N, P and K on Yield of Robinson Strawberries in 1966.

Rate ##	N	P	K
0	2736	2671	2661
100	2789	2997	2849
200	2828	2685	2843
	N.S.	N.S.	N.S.

Grams per plot.

Lb/A of actual N, P_2O_5 and K_2O.

Table 3A. Nutrient Content of Midway Strawberry Fruit at Different Harvest Dates.

	1965			1966	
Element #	June 22	June 24	June 30	June 15	June 21
N (%)	1.3	1.3	1.2	1.2	1.3
K (%)	2.4	2.6	2.3	1.8	1.8
P (%)	0.21	0.23	0.21	0.66	0.71
Ca (%)	0.12	0.11	0.13	0.52	0.60
Mg (%)	0.10	0.11	0.09	0.27	0.30
Mn (ppm)	60.7	55.3	63.6	86.6	79.0
Fe (ppm)	65.2	76.8	64.1	319.8	231.7
Cu (ppm)	2.6	2.8	2.6	19.0	17.2
B (ppm)	10.6	11.9	7.5	32.7	32.4
Zn (ppm)	19.9	18.9	15.1	6.0	30.3
Al (ppm)	46.7	44.3	23.1	149.7	84.9

% or ppm of dry matter

Table 4A. Nutrient Content of Robinson Strawberry Fruit at Different 1966 Harvest Dates.

Element #	June 21	June 23
N (%)	0.91	0.92
K (%)	1.56	1.53
P (%)	0.66	0.63
Ca (%)	0.57	0.58
Mg (%)	0.26	0.27
Mn (ppm)	51.1	52.3
Fe (ppm)	189.6	199.5
Cu (ppm)	12.6	14.9
B (ppm)	26.7	25.4
Zn (ppm)	30.4	28.1
Al (ppm)	104.4	92.9

% or ppm of dry matter

Table 5A. Average Nutrient Composition of Runner Plant Crowns From Midway and Robinson Strawberries Prior to Spring Growth.

Element#	Midway	Robinson
N (%)	2.70	2.35
K (%)	1.26	1.30
P (%)	0.38	0.42
Ca (%)	1.33	0.97
Mg (%)	0.34	0.45
Mn (ppm)	175	92
Fe (ppm)	455	606
Cu (ppm)	31	30
B (ppm)	31	32
Zn (ppm)	80	50
Al (ppm)	315	380

% or ppm of dry matter

Table 6A. Nutrient Composition of Youngest Mature Leaves from Midway Strawberry Plants at Selected Period of Development.

	July		August		Bloom		Harvest	
Element#	1964	1965	1964	1965	1965	1966	1965	1966
N (%)	2.67	2.66	3.05	2.82	3.12	3.10	2.26	2.26
K (%)	1.64	1.41	1.89	1.45	1.92	1.55	1.44	0.88
P (%)	0.43	0.44	0.56	0.47	0.46	0.41	0.38	0.28
Ca (%)	0.79	0.85	0.67	0.89	0.78	1.00	0.86	1.88
Mg (%)	0.33	0.41	0.37	0.47	0.36	0.31	0.34	0.47
Mn (ppm)	625	140	722	196	725	157	537	133
Fe (ppm)	168	182	214	216	259	223	132	129
Cu (ppm)	14	13	23	15	19	20	20	13
B (ppm)	42	38	31	39	38	39	32	37
Zn (ppm)	42	35	52	33	69	35	40	31
Al (ppm)	116	114	195	134	236	158	115	123

% or ppm of dry matter.

Table 7A. Nutrient Composition of Youngest Mature Leaves From Robinson Strawberry Plants at Selected Periods of Development.

	July		August		Bloom		Harvest	
Element#	1964	1965	1964	1965	1965	1966	1965	1966
N (%)	2.25	2.39	2.78	2.60	2.55	2.93	1.78	2.22
K (%)	1.54	1.21	1.92	1.37	1.74	1.57	1.54	0.89
P (%)	0.38	0.40	0.59	0.42	0.49	0.38	0.33	0.30
Ca (%)	0.74	0.98	0.56	0.85	0.67	1.06	0.60	1.88
Mg (%)	0.34	0.49	0.36	0.49	0.33	0.37	0.27	0.57
Mn (ppm)	422	137	509	103	467	136	294	127
Fe (ppm)	177	197	218	231	245	298	128	116
Cu (ppm)	17	13	20	16	16	15	20	14
B (ppm)	37	39	27	35	29	30	25	37
Zn (ppm)	40	40	48	29	54	35	21	35
Al (ppm)	134	154	218	156	191	212	102	125

% or ppm of dry matter.

Table 8A. Total Units of N, P_2O_5 and K_2O Applied From Transplanting to Harvest in Commercial Plantings of Midway and Robinson Strawberries.

	Pounds Per Acre					
	N		P_2O_5		K_2O	
	Average	Range	Average	Range	Average	Range
Southwestern Michigan						
Midway (19)*	122	43-214	191	43-414	89	0-189
Robinson (5)*	112	54-192	140	54-267	76	54-98
Manistee County						
Midway (7)*	137	75-196	224	75-493	86	32-196
Robinson (2)*	127	116-129	302	296-309	166	37-296

* Number included in survey.

Table 9A. Correlation of Strawberry Leaf Analysis Versus Soil Analysis Taken from 42 Commercial Plantings in Michigan (Soil Samples Were Taken Immediately Adjacent to Each Plant From Which Leaf Samples Were Taken).

Dependent Variable#	Independent Variable##	Correlation Coefficient
Leaf P	Soil P	N.S.
Leaf K	Soil K	N.S.
Leaf Ca	Soil Ca	.402** (2)*
Leaf Mg	Soil Mg	.582** (1)

% of dry matter.

Pounds per acre

** Significant at 1% level

* Type of regression: (1) = Straight line, (2) = parabola