Annual Report of Accomplishments in 1958

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I Project S-151 - Peach Pruning, Nitrogen and Irrigation Studies with Mr. A. H. Hunter, Soils Department, as Co-leader.

The objectives of these studies include: the determination of the effect of different levels of pruning, nitrogen, soil moisture, and their interactions, on survival, growth and fruiting characteristics of peach trees. The Elberta and Redhaven variety trees were planted in January, 1953, in a factorial design which is shown in Figure 1. Three rates of pruning were followed, light, medium and heavy. These descriptions relate to the amount of wood which was removed each year. In addition, three rate of nitrogen were applied per tree, i.e., 0.36, 0.72 and 1.44 pounds. Additional nutrients of phosphorus and potassium were applied to bring the complete fertilizer ratio to that of an 8-8-8. Three quarters of the nitrogen and all the phosphorus and potassium were applied in March. The remaining nitrogen was applied in August. Concurrently, one-half the trees were irrigated the other half was not.

The fruit was hand thinned to provide a uniform distance between fruit rather than a given number per tree. Ten randomly selected shoots were used for terminal growth measurements and trunk circumference was measured early in March prior to pruning.

Yield records would have been possible in 1955 had it not been for a severe freeze. Some records were taken in 1956. The crop in 1957 was a large one and excellent records were obtained. These have been analyzed statistically and are reported herein. Another crop was harvested in 1958. However, this year was not as productive as that in 1957 due to the severe infection and almost complete defoliation by the bacterial spot disease. In addition, brown rot was a problem resulting in the dropping of large numbers of fruit to the ground in some sections of the planting.

Fruit was harvested by commercial picking crews which were employed and supervised by station personnel. The peaches were harvested on Monday, Wednesday and Fridays and weighed at each picking. A random sample of 25 fruit was taken for determinations of

Figure 1.

PEACH PRUNING - NITROGEN - IRRIGATION BLOCK
SANDHILLS STATION

Planted January 1953

Row No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
	Irrigated														Non-irrigated														
		Low				Medium				High								High				Low (?)				Medium			= Fertility level.
1	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
2	E	L	M	H	E	M	H	L	E	M	L	H	E	E	E	E	E	M	H	L	E	(H)	(M)	(L)	E	H	M	L	E
3	E	L	M	H	E	M	H	L	E	M	L	H	E	E	E	E	E	M	H	L	E	H	M	L	E	H	M	L	E
4	R	M	L	H	R	L	M	H	R	H	M	L	R	R	R	R	R	L	M	H	R	M	H	L	R	M	L	H	R
5	R	M	L	H	R	L	M	H	R	H	M	L	R	R	R	R	R	L	M	H	R	M	H	L	R	M	L	H	R
6	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	Non-irrigated														Irrigated														
		High				Low				Medium								Low				High				Medium			= Fertility level.
7	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
8	R	M	H	L	R	L	M	H	R	M	L	H	R	R	R	R	R	M	H	L	R	L	H	M	R	L	M	H	R
9	R	M	H	L	R	L	M	H	R	M	L	H	R	R	R	R	R	M	H	L	R	L	H	M	R	L	M	H	R
10	E	H	L	M	E	M	L	H	E	H	M	L	E	E	E	E	E	L	M	H	E	M	L	H	E	M	H	L	E
11	E	H	L	M	E	M	L	H	E	H	M	L	E	E	E	E	E	L	M	H	E	M	L	H	E	M	H	L	E
12	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
	Irrigated														Non-irrigated														
		Medium				Low				High								Low				Medium				High			= Fertility level
13	E	E	E	E	E	E	E	F	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
14	E	L	M	H	E	H	L	M	E	L	M	H	E	E	E	E	E	H	L	M	E	L	M	H	E	L	M	H	E
15	E	L	M	H	E	H	L	M	E	L	M	H	E	E	E	E	E	H	L	M	E	L	M	H	E	L	M	H	E
16	R	M	H	L	R	M	H	L	R	H	M	L	R	R	R	R	R	M	H	L	R	L	M	H	R	H	L	M	R
17	R	M	H	L	R	M	H	L	R	H	M	L	R	R	R	R	R	M	H	L	R	L	M	H	R	H	L	M	R
18	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Rows 1, 2, 3, 10, 11, 12, 13, 14, 15 are Elberta on Lovell or E.

Rows 4, 5, 6, 7, 8, 9, 16, 17, 18 are Redhaven on Lovell or R.

Tree 11 row 2
" 19 " 11
" 1 " 12
" 1 " 17
} Replanted 1954

fruit color, size, and weight per fruit. Additional samples of 25 were randomly selected fruit for holding and pressure tests at Raleigh during the peak of harvest in 1957 for Elberta and Redhaven, and in 1958 for Redhaven only, due to the severe defoliation and depreciation of fruit quality by bacterial spot on the Elberta trees. These fruit were placed in cold storage chambers maintained at 65°F and a high humidity. Samples for pressure testing were subdivided into lots of 4 fruit each. These lots were pressure tested on two peeled cheeks every other day until completely ripened. The other 25 fruit samples were placed in small, flat trays, lined with brown wrapping paper, which were stacked in the refrigerated room. The peaches were allowed to remain under these conditions until sufficient differential rotting occurred. Counts were then made of the number of fruit per sample with all sorts of rots, and the number with brown rot only. Results were expressed on a percentage basis.

Maturity data were coded by multiplying the percent of fruit harvested on a given date by the number of days that date occurred after the first picking. The products of the calculations for each picking date were added and consequently divided by one hundred. A small maturity coded maturity date indicates early maturity and, conversely, a large one indicates late maturity.

Results and Discussion

The results presented herein were analyzed by the Statistics Department section headed by Dr. Mason. Single factor effects were determined, as customary, by pooling all the data other than that under consideration. These are the results of the 1957 harvests only. Data for 1958 and 1956 are currently being prepared for issue to the Statistics Department for analysis.

Yield. As seen in Table 1, rate of nitrogen had only a slight effect upon yield. An increase in application from 0.36 to 0.72 pounds of nitrogen per tree increased yield by .19 pounds per tree. An additional increment to 1.44 pounds per tree, however,

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Table 1. Effects of pruning severity, rate of nitrogen and irrigation upon the fruiting characteristics of Elberta and Redhaven peaches. Data based on 1957 harvests of trees planted in 1952 - 1953.

	Yield (lbs./tree)	Percent surface having red color	Total No. Fruit	Fruit Sizes (diameter in inches)				Coded Maturity date
				Under 2	Over 2	2 to 2 1/4	Over 2 1/4	
Nitrogen rate effect								
R1	150	18.8	676	88	587	458	129	4.58
R2	169	17.2	745	103	642	452	190	5.49
R3	157	16.3	687	78	609	420	189	5.31
L.S.D. 5%	14.2	0.57	N.S.	N.S.	N.S.	N.S.	37.9	.345
L.S.D. 1%	N.S.	0.78					51.9	.473
Pruning severity effect								
L	183	20.6	837	125	712	558	154	4.62
M	152	18.1	692	90	602	438	165	5.00
H	138	13.6	579	55	524	334	190	5.75
L.S.D. 5%	12.9	1.16	59.7	26.3	49.8	42.6	23.7	.283
L.S.D. 1%	17.2	1.55	79.6	35.1	66.4	56.8	N.S.	.377
Irrigation effect								
I	169	17.7	740	92	647	450	196	5.14
N.I.	149	17.2	666	87	578	436	143	5.11
L.S.D. 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
L.S.D. 1%								
Variety effect								
Elberta	164	10.7	662	27	633	389	245	4.28
Redhaven	153	24.2	744	152	591	498	94	5.97
L.S.D. 5%	8.0	5.08	N.S.	N.S.	22.2	N.S.	142.9	.521
L.S.D. 1%	N.S.	11.70			N.S.		N.S.	1.201
C.V.	17	14	18	62	17	20	29	12

only increased yield by 7 pounds over the low level. Therefore, there seems to be an optimum level of nitrogen above which a further increase will not return an equivalent increase in yield.

Pruning severity effects were more marked. Each increase in severity was accompanied by a decrease in yield. These decreases were highly significant at the one percent level.

Irrigation effects were not significant although there was a mean difference of twenty pounds per tree. The loss of effect was due to the abnormally variation due to replications. In way of explanation, relatively few applications of water have been necessary over the past few years. They have averaged not much more than one or two per season.

A varietal effect upon yield was apparent. Elberta produced 11 pounds more than Redhaven. This difference was significant at the five percent level. No significant interactions among any of the factors studied were found. There was an interaction between pruning and variety which significantly varied the number of fruit harvested per tree.

Number of fruit. Rate of nitrogen had only a slight, insignificant effect upon the number of fruit harvested in 1957. As was the case with yield, the second level, 0.72 pounds per tree seemed to be more favorable than the highest level.

Pruning severity effects were quite marked. The lightly pruned trees produced 258 more fruit than the heavily pruned trees. Since the fruit was hand thinned to a uniform spacing on the trees, this increase in number must undoubtedly be due to a greater bearing surface and, consequently, a larger tree. The difference in size of the trees is quite noticeable visibly.

Effects of irrigation, as was the case with weight of harvests, were produced a insignificant difference in number of fruit in favor of the irrigated blocks. Varietal effects were also insignificant.

Fruit Color. The percent of the fruit surface having red color was affected by all the factors studied except irrigation. An increase in nitrogen rate as well as an increase in pruning severity resulted in a corresponding decrease in red coloration which was highly significant among all three levels of each. A varietal effect was particularly slightly significant and substantiates a well known observation that the Redhaven is more highly colored than the Elberta - more than twice as much, in fact.

A highly significant pruning variety interaction was found. An increase in pruning severity decreased fruit color more drastically with the Redhaven than the Elberta variety. In the former case, color was decreased from 58 percent down to 36 percent while Elberta color was only decreased from 24 to 19 percent as the pruning severity was increased.

Maturity date. Ripening was delayed by increasing the rate of nitrogen. The second rate, however, was related a greater delay than the third rate. Increasing pruning severity was accompanied by a parallel delay in ripening. The maturity date for light pruning was 4.62 while that for the heaviest was 5.75. This maturity date was further affected by variety. Elberta fruit ripened closer to the first day of harvest ~~that~~ than the Redhaven. Irrigation had an insignificant effect upon maturity date. No interactions were statistically significant for any of the factors studied in relation to maturity date.

Fruit size. Rate of nitrogen had no significant effect on the number of fruit falling into the following size classes: (1) under two inches in diameter, (2) over two inches in diameter, and (3) from two to two and one-quarter inches in diameter. However, there were highly significant differences in the class of two and one quarter inches in diameter and higher. Both the second and third nitrogen levels were associated with about 60 more fruit in the class than was the lowest level of nitrogen. In general, it would seem that the second level of nitrogen would be more desirable than the third level which did not produce a significant increase in number of fruit in this latter size class.

The effect of pruning severity was much more pronounced than that of nitrogen rate. Each increase in pruning severity was accompanied by a highly significant decrease in numbers of fruit falling in all classes except that of 2 1/4 inches in diameter and up. The increase in numbers in this class from 154 for the light pruned trees to 190 for the heavily pruned ones was only significant at the 5 percent level however. In general, it appeared that light pruning was most desirable.

Varietal effects produced no significant differences in number of fruit in the size classes (1) under 2 inches and (2) 2 to 2 1/4 inches. Significant differences at the 5 percent level only were found in favor of Elberta in the classes (1) over 2 inches and (2) over 2 1/4 inches.

Interactions found which affect fruit sizes were (1) a highly significant interaction between variety and fertilizer for the 2 1/4 inch and up category and (2) a significant interaction between pruning and variety for the less than 2 inch size class.

There were no significant differences in fruit size due to irrigation.

Trunk circumference. The only significant effect upon trunk size of all the factors studied was that of nitrogen rate. Both the second and third rates of nitrogen increased trunk size by approximately 7 to 8 inches in circumference. This agrees with the observations of other workers that trunk size is a poor measurement of response to various cultural treatments. These findings also agree with those found by Schneider and McClung with Halehaven trees (see Table 2).

Terminal growth. Length of terminal shoots was highly significantly increased by an average of two inches by increasing the nitrogen rate from 0.36 to 0.72 or from 0.36 to 1.44 pounds per tree. Consequently, the second rate seems to be the optimum one from a terminal growth standpoint since the third did not increase length over the second. Nitrogen rates did not affect the lateral growth appearing on these terminal shoots. A highly significant interaction was found between pruning and nitrogen rate

Table 2. Effects of pruning severity, rate of nitrogen, and irrigation upon the tree growth characteristics of Elberta and Redhaven peaches. Data are based on 1957 measurements of trees planted in 1952-1953.

	Trunk circumference (inches)	Weight of pruning wood	Annual Axial growth per terminal shoot	Lateral growth per terminal shoot
Nitrogen rate effect				
R1	13.2	12.1	17.5	3.9
R2	14.0	15.8	19.5	7.2
R3	13.9	16.1	19.5	7.2
L.S.D. 5%	.65	1.47	1.30	N.S.
L.S.D. 1%	N.S.	2.01	1.78	
Pruning severity effect				
L	13.8	11.8	16.3	2.0
M	13.3	12.0	18.5	4.9
H	13.8	20.5	21.7	11.4
L.S.D. 5%	N.S.	1.66	.88	2.63
L.S.D. 1%		2.21	1.17	3.50
Irrigation effect				
I	13.9	15.9	18.9	6.6
N.I.	13.4	13.5	18.7	5.6
L.S.D. 5%	.34	N.S.	N.S.	N.S.
L.S.D. 1%	N.S.			
Variety Effect				
Elberta	13.4	11.8	18.4	7.5
Redhaven	13.9	17.6	19.2	4.6
L.S.D. 5%	N.S.	2.48	N.S.	N.S.
L.S.D. 1%		5.72		
C.V.	9	24	10	91

for lateral growth.

The pruning severity was associated with highly significant changes in terminal growth. The more severely the trees were pruned, the longer the terminal shoots were produced. This was also the case with the lateral growth appearing on these terminal shoots. Neither irrigation nor variety had any significant effects upon terminal growth.

Pruning weight. There was almost a 4 pound increase in the weight of prunings from the trees fertilized with the second rate of nitrogen as compared to the lowest rate. A small but insignificant increase was also apparent over the second rate by the third rate.

An increase in pruning severity was accompanied in all cases by an increase in weight of wood removed. Approximately 9 additional pounds per tree of wood was removed from the heavily pruned trees than the lightest pruned ones. A relatively small increase in weight over the light pruning was affected by the medium pruning, however.

More wood was removed from the Redhaven trees than the Elberta, which substantiated general observation made in the field. Irrigation had no significant effect upon weight of wood removed during pruning.

Fruit flesh firmness. Nitrogen rate had little effect upon flesh firmness of Redhaven fruit. At harvest there was an insignificant difference with only a slight trend for the fruit from the trees treated with the two heavier rates of nitrogen being approximately one-half pound more firm than that from trees with the lowest rate of nitrogen. This situation continued at the time of the second testing, two days later. On July 9, however, six days after harvest, an increase in nitrogen rate was associated with a highly significant increase in firmness. This trend again continued, although insignificantly, until the last date of sampling. No real differences in rate of softening were found, however, since the slopes or regression coefficients were insignificantly different. Tables 3 & 4 presents these data. ~~in graphic form~~.

Pruning effects on Redhaven produced highly significant differences in flesh firmness both at harvest and at the time of second testing two days later. These effects were found to decrease in intensity at the time of the last two testings on 9 and 11 July. A study of the regression coefficients reveals that the rate of ripening of the Redhaven peaches is least for those fruit harvested from trees which were lightly pruned. A significant rate increase resulted from the more severe pruning. Heaviest pruning produced a further increase in ripening rate, although insignificantly different from that of the medium severity pruning tree fruit. Irrigation did not appear to affect fruit flesh firmness or rate of ripening. In general, these data have yielded some extremely interesting trends which would warrant a more intensive study in the future if time and manpower supply permit.

For the Elberta variety, there were no significant findings as was the case with the Redhaven fruit. However, some of the same general trends which were found with the Redhaven may still exist and require more intense studies to bring them out into light.

Longevity results. No obvious trends for effect of treatment on tree longevity or mortality are apparent as yet, other than the fact that more Redhaven trees have succumbed to "winter injury" than those of the Elberta variety. Two Elberta and six Redhaven trees have died thus far. Both the Elberta trees were heavily pruned, one with the first rate and the second with the third rate of nitrogen. Two of the Redhaven trees were light pruned and the other four were medium pruned.

Holding studies. Upon the advice of workers in the Statistics Department, the results of the holding studies for rots development were merely summarized and tabulated. This was due to the great number of lots which had no rot development at all. These results indicated that any effects, if present, would need to be uncovered more thoroughly in the future. In the orchard, a general observation was that more rotting occurred on trees in the northeast end of the planting. A summarization of the results of the rots developing in the holding studies, presented in Table 5 substantiated

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Table 3. Effects of pruning severity, nitrogen rate and irrigation upon the flesh firmness of Redhaven peaches* in 1957.

Treatment	Pressure Test Averages Date				Regression Coefficient (slope, b)
	4 July	6 July	9 July	11 July	
Nitrogen rate effect					
R1	14.1	13.5	9.0	5.2	(-) 2.62
R2	14.7	14.1	9.4	5.7	(-) 2.65
R3	14.6	14.2	9.8	5.8	(-) 2.59
L.S.D. 5%	N.S.	N.S.	.44	N.S.	N.S.
L.S.D. 1%					
Pruning severity effect					
L	13.8	13.3	9.2	5.5	(-) 2.44
M	14.6	13.8	9.5	5.4	(-) 2.68
H	15.0	14.7	9.6	5.8	(-) 2.74
L.S.D. 5%	.44	.74	N.S.	N.S.	.117
L.S.D. 1%	.60	1.01			N.S.
Irrigation effect					
I.	14.4	13.9	9.3	5.8	(-) 2.54
N.I.	14.6	14.0	9.5	5.3	(-) 2.70
L.S.D. 5%	N.S.	N.S.	N.S.	N.S.	N.S.
L.S.D. 1%					
C.V.	4	8	8	18	13

*Determined by use of a Magness-Taylor Ballauf Pressure Tester with a 7/16 inch plunger.

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Table 4. Effects of pruning severity, nitrogen rate and irrigation upon the flesh firmness of Elberta peaches in 1957.

Treatment	Pressure test Averages Date			Regression Coefficient (slope, b)
	6 August	8 August	10 August	
Nitrogen rate effect				
R1	13.1	5.1	3.3	(-) 2.45
R2	13.6	5.4	3.4	(-) 2.57
R3	14.3	5.4	3.4	(-) 2.72
L.S.D. 5%	N.S.	N.S.	N.S.	N.S.
L.S.D. 1%				
Pruning severity effect				
L	13.5	5.3	3.4	(-) 2.54
M	13.7	5.2	3.4	(-) 2.59
H	13.7	5.3	3.3	(-) 2.61
L.S.D. 5%	N.S.	N.S.	N.S.	N.S.
L.S.D. 1%				
Irrigation effect				
I	13.5	5.0	3.3	(-) 2.55
N.I.	13.8	5.6	3.4	(-) 2.61
L.S.D. 5%	.25	N.S.	N.S.	N.S.
L.S.D. 1%	N.S.			
C.V.	8	12	7	10

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Table 5. Occurrence of Brown Rot and other rots in various areas of the Elberta peach planting as percent of fruit affected after storage at 65°F for 10 days.

	Irrigated trees	Non-Irrigated trees
Replication I	3.4	2.7
	Non-Irrigated	Irrigated
Replication II	2.7	3.1
	Irrigated	Non-Irrigated
Replication III	10.9	4.0

this. Approximately 3 to 4 percent of the fruit in most of the blocks except the irrigated replication III one developed rot. The rot development was latter block. This is undoubtedly attributable to the slope of terrain and the development of an air pocket in that area which is conducive to rot development.

Summary of Peach Findings

1. Analyzed data for the 1957 harvests are presented and discussed.
2. Data for 1956 were only recently uncovered and are being set up with data for 1958. These data will be sent to the Statistics Department for analysis as soon as possible.
3. Upon completion of analysis of these 3 years results, publication will be feasible in the near future.
4. Increasing nitrogen rates increased yield and number of fruit at the second level but did not contribute to a similar increase for the third level; decreased fruit red coloration; delayed ripening; increased weight of wood removed by pruning; increased length of terminal shoot and lateral growth on those shoots; and slightly increased Redhaven fruit flesh firmness as measured 4 days after harvest.
5. Increasing pruning severity decreased yield (pounds per tree); total number of fruit; fruit red coloration; number of fruit in size groups (1) under 2 inches (2) over 2 inches, (3) 2 to 2 1/4 inches; increased fruit size in group over 2 1/4 inches; delayed maturity; increased weight of pruning wood and length of terminal shoots. Increasing pruning severity also increased flesh firmness of Redhaven peaches as measured at harvest and two days later; it tended to increase the rate of fruit softening after harvest.
6. Irrigation had very little significant effect on any of the factors studied although it significantly increased tree trunk circumference.
7. There were several varietal differences noted: (1) Redhaven had much more fruit red coloration (2) Elberta ripened more uniformly, (3) Redhaven fruit was a full pound more firm at harvest time than was Elberta fruit.

8. Holding studies revealed that fruit rot potential was more of a regional effect of the environment in the planting than a treatment effect although further studies may enlighten these present views.

9. No obvious longevity or mortality relations to treatment are obvious as of date.

II PROJECT H-152. SMALL FRUIT STUDIES

W. E. Ballinger 12 February 1959

Strawberry Sand Culture Studies

The yield per acre of strawberries in North Carolina has been extremely low for many years. Nutritional status of this crop may be one of the contributing factors. Therefore, a field survey would appear a logical step prior to the formulation of remedial measures. Before a field survey can be initiated, however, the plant part which is to be sampled must be previously determined. The objectives of this study, consequently, were to:

(1) Determine which plant tissue will be best suited for use in field samplings of nutritional status.

(2) Determine what effect the nutrient concentration of the nutrient solution has upon the nutrient content of the plant parts.

(3) Observe deficiency symptoms of the Albritton strawberry variety for future reference in field observations.

(4) Observe this variety closely in order to become more familiar with its growth characteristics.

Methods and Procedure

Strawberry plants of the Albritton variety were grown under sand culture in the greenhouse under vegetative conditions from February until May 9, 1958. Four levels, zero, one-fifth, one, and five times that in a modified Hoagland nutrient solution, of each of five elements, e.g., nitrogen, phosphorus, potassium, calcium and magnesium were employed variably with the remaining four elements in each test solution remaining constant. A more detailed description of the materials and methods is as follows:

Plants. Strawberry plants of the Albritton variety were obtained from a grower cooperating with North Carolina State College and the United States Department of Agriculture in the production of virus and nematode free stock plants. To ascertain virtually complete freedom from nematode infestation, small 2 1/2 inch clay pots were taken to the field; the developing roots of young daughter plants were placed in these pots on October 4, 1957, while still attached to the mother plant. The pots were subsequently buried up to the rim in the soil. Two and a half weeks later when the roots of these vegetatively vigorous plants were well established in the small pots, the runners were severed and the plants transported to the greenhouse at Raleigh, N. C. Overhead 100 watt incandescent lights were installed to provide a 16 hour day which, together with a 75°F day and 65°F night temperature, maintained the plants thereafter in a vegetative condition.

Runner plants from these former field plants were secured in other sterilized 2 1/2 inch clay pots which were filled with quartz sand. By regularly applying a Hoagland solution to the sand, rooting of the daughter plants was secured. This method of test plant procurement allowed the use of plants whose roots were morphologically pre-adapted to the eventual rooting medium. The average weight of the test plants was about 7 grams.

Quartz sand. The sand used for this study was obtained from nearby Lillington, N.C. for a nominal fee and is commercially known as "Lillington white sand". Saturation of this material with concentrated hydrochloric acid and subsequent repeated leaching of a similar sample with a .1 N HCl solution indicated a relative freedom of the main elements being studied. Tests of the field capacity revealed it to be approximately twelve percent. About twenty-five pounds of this sand were required to fill each container used for the test plants.

Water. A "pure" water supply was obtained by passing tap water through a Barnstead demineralizer. Chemical tests by Mr. Piland of the Soils Department verified that it was satisfactorily low in mineral content of the elements being studied.

Planting Containers. Ten quart aqua colored polyethylene "pails" (without handles) were used. The exterior was painted with two coats of aluminum paint for the

Table — Pepper and Strawberry Nutrien olutions Used in 1957-1958

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TABLE 6. Milliequivalents Per Liter of Solution

Soln.	Cations					Total Cations	Anions						Total Anions
	Ca	K	Mg	NH_4	H		H_2PO_4	NO_3	OH	SO_4	Cl	HCO_3	
-N(1G)	14	6	4	-	1	25	1	3	-	13	8	-	25
1/5N(2G)	10	6	4	-	-	20	1	6	-	10	6	-	20
1N(3G)	10	6	4	-	-	20	1	15	-	4	-	-	20
5N(4G)	10	6	4	30	-	50	1	45	-	4	-	-	50
-P(1B)	10	6	4	-	-	20	0	15	-	5	-	-	20
1/5P(2b)	10	6	4	-	0.2	20.2	0.2	15	-	5	-	-	20.2
1P(3B)	10	6	4	-	-	20	1	15	-	4	-	-	20
5P(4B)	10	6	4	2.5	4	26.5	5	12.5	5	4	-	-	26.5
-K(10)	10	0	4	2.5	1	17.5	1	12.5	-	4	-	-	17.5
1/5K(20)	10	1.2	4	5	-	20.2	1	15	-	4.2	-	-	20.2
1K(30)	10	6	4	-	-	20	1	15	-	4	-	-	20
5K(40)	10	30	4	-	-	44	1	15	-	28	-	-	44
-Ca(1y)	0	6	4	5	-	15	1	10	-	4	-	-	15
1/5 CA(2y)	2	6	4	6	-	18	1	13	-	4	-	-	18
1CA(3y)	10	6	4	-	-	20	1	15	-	4	-	-	20
5Ca(4y)	50	6	4	-	-	60	1	15	-	29	10	5	60
-Mg(1R)	10	6	0	-	1	17	1	15	-	1	-	-	17
1/5Mg(2R)	10	6	0.8	2	-	18.8	1	15	-	2.8	-	-	18.8
1Mg(3R)	10	6	4	-	-	20	1	15	-	4	-	-	20
5Mg(4R)	10	6	20	-	-	36	1	15	-	12	12	-	36

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Table — Variations of Hoagland Solution Used [illegible] Strawberry and Pepper Plant Growth

Table 7. Ml. of Stock Solutions to Make 18 Liter of Nutrient Solution

Solution	KNO_3	$Ca(NO_3)_2$	$MgSO_4$	KH_2PO_4	Na Fe EDTA	Minor El Mix	[a] H_3PO_4	K_2SO_4	$CaCl_2$	$KHCO_3$	KOH	$MgSO_4$+ $CaCl_2$	NH_4NO_3	Powdered $CaSO_4$
Check	90	90	90	90	36	36								
"0" Ca	90		90	90	36	36							90	
1/5 Ca	90	18	90	90	36	36							108	
5 Ca		135	90	90	36	36			90	90				23.2g.
"0" Mg	90	90			36	36	36	18						
1/5 Mg	54	90	18	90	36	36		36					36	
5 Mg	90	90	90	90	36	36						180		
"0" K		90	90		36	36	36						45	
1/5 K		90	90	90	36	36		4					90	
5K	90	90	90	90	36	36		432						
"0" N		*27	90		36	36	36	108	72					**6.12 g.
1/5 N	36	36	90	90	36	36		54						9.3 g.
5N	90	90	90	90	36	36							540	
"0"P	90	90	90		36	36		18						
1/5P	90	90	90		36	36	7	18						
5P		90	90	90	36	36	104				90		45	

* A little N is necessary to keep the plant alive.

** You may substitute 2700 ml of a .02 N stock solution for this.

[a] For this experiment, only 1/3 of these amounts were used to supply $H_2PO_4^-$.

C. Miller
W. E. Ballinger
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Table 8. Composition of Stock Solutions
Used for Pepper and Strawberry Plant Growth

Directions: Add the indicated number of grams of each compound to a respective 5 gallon carboy and bring the volume up to 18 liters with demineralized water.

Soln.	Compound	Amt. (grams)	Resulting Concentration
A	KNO_3	1819	1M or 2N
B	$Ca(NO_3)_2 \cdot 4H_2O$	4251	1M or 2N
C	$MgSO_4$	866.74	.4M or .8N
D	KH_2PO_4	490.00	.2M or .2N
E	12% Fe Sequestrene	374.40	5 ppm
F	Minor element mix		ppm in tmt.
	a. $ZnSO_4 \cdot 7H_2O$	9.70	(.25)
	b. H_3BO_3	10.29	(.20)
	c. $MnCl_2 \cdot 4H_2O$	8.15	(.25)
	d. Molybdic Acid	0.28	(.05)
	e. $CuSO_4 \cdot 5H_2O$	0.72	(.02)
G	H_3PO_4	(612 ml. of an 85% solution)	.5N or .5M
H	$CaSO_4 \cdot 2H_2O$	30.9	.02N
I	K_2SO_4	1568.25	1N
J	KOH	112.22 (for 2 liters only)	1N
K	$MgSO_4 \cdot 7H_2O + MgCl_2$	295.8 244.0 (for 3 liters only)	0.4M
L	NH_4NO_3	1440.86	1M
M	$CaCl_2 \cdot 2H_2O$	441 (per 3 liters)	2N
N	$KHCO_3$	300.33 (per 3 liters)	1M

protection of roots from light. A one-quarter inch hole was punched in the center of the bottom for drainage and a three inch watchglass was placed over it in an inverted position to retain sand and yet allow for drainage. The pails were filled to within an inch of the top with the quartz sand and three strawberry plants were grown in each.

Nutrient solutions. A modified Hoagland solution, obtained with the cooperation of Mr. E. Bergman of Michigan State University and Mr. C. Miller of this Station, was used to provide the four differential levels of nutrients as shown in Table 6. Tables 7 and 8 present the contents and the formulae for mixing up the sixteen different nutrient solutions from the stock solutions used.

Experimental design. The randomized block design is shown in Figure 2. Four replications of the five series of four levels of the respective nutrient under study occupied four benches in the greenhouse section - one replication per bench.

The placement of each of the five series in each replication was made randomly; the levels within each series were also randomly located to reduce the effects of environmental variations. Since each series of four levels contained a complete standard Hoagland solution each bench contained five and the four benches contained twenty containers of strawberry plants which received the same treatment. This allowed for a later statistical evaluation of the influence of light, heat and other environmental variations within the growing area.

General. The test plants were placed in the containers and the experimental design was initiated on January 21, 1958. During the early period of adjustment, a one-quarter complete solution was applied. Leaves already present together with those produced on the plant during this period were marked for identification and later removed to allow for eventual sampling of only leaves produced under the treatments provided.

The differential nutrient solution applications were initiated on March 11, 1958. Six hundred milliliters of either demineralized water or nutrient solution were applied

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Figure 2. Experimental Design

Strawberry (Greenhouse) Nutritional Experiment

↑ N

Door

Bench 9 — Replication 1

4 Mg	2 Ca	3 N	1P	3K
3 Mg	4 Ca	1 N	3P	1K
2 Mg	3 Ca	2 N	4 P	2K
1 Mg	1 Ca	4 N	2P	4K

Bench 8 — Replication 2

1 Ca	3K	4P	1N	1 Mg
3 Ca	2K	2P	2N	4 Mg
4 Ca	1K	1P	4N	2 Mg
2 Ca	4K	3P	3N	3 Mg

Bench 7 — Replication 3

1 N	3K	1 Mg	2 Ca	4P
2N	2K	4 Mg	4 Ca	1P
4N	4K	2 Mg	1 Ca	2P
3N	1K	3 Mg	3 Ca	3P

Bench 6 — Replication 4

2P	4N	1 Mg	2 Ca	2K
3P	3N	2 Mg	4 Ca	3K
1P	2N	3 Mg	1 Ca	4K
4P	1N	4 Mg	3 Ca	1K

twice daily. Nutrient solutions were applied on Monday, Wednesday and Friday afternoons. No water was applied at these times. This procedure was used in an attempt to provide a uniform rate of dilution of the nutrient solutions in the pails of sand in lieu of a variable one such as would be obtained by applying water only when the plants displayed symptoms of soil moisture stress. It was hoped that the effects of different osmatic pressures of the applied nutrient solutions might be minimized.

As foliar deficiency symptoms appeared, notes were taken of their description and time of appearance. Finally, during the first of May, when sufficient differential growth and quantity of plant tissue for analysis was evident, the plants were harvested. Each plant part, roots, crown, rachis (hereafter referred to as the petiole), left leaflet, central leaflet and right leaflet was segregated, weighed and counted. Petiole length measurements were also taken. After drying in a forced draft oven at 70°C, dry weight determinations were made.

Nutrient content determinations were made chemically by the plant testing service of the N. C. State College Soils Department.

Results and Discussion

Observations during growth

Signs of low nitrogen effects were noticeable. The leaves of plants receiving the lowest nitrogen level were noticeably lighter in color within three weeks after the initiation of treatment. Signs of calcium deficiency appeared by April 10, 1958, approximately one month after treatments started. A dying and restricted development of leaves during the process of initial leaf expansion was evident on the minus calcium plants. A necrosis was evident in the plant "whorl" or growing point. Concurrently, a "collapsing" or water soaked appearance was visible along the edges of young leaflets which were only two-thirds developed.

On April 11, 1958 the plant leaflets of the minus potassium treatments displayed a purplish, dark green hue. In addition, one leaf became water soaked and necrotic in the area where the petiole joined the leaflets.

One of the minus magnesium plants older leaflets developed a bronze like color by this date. Signs of necrosis and mottling were apparent in the central areas of the leaflets. Four leaves were thus affected on only one of the replications. The plants receiving five times the standard amount of magnesium also developed leaflet symptoms, i.e. - a firing of along a narrow strip of the edges which closely resembled potassium deficiency symptoms on leaves of other fruit crops. By April 16, 1958, one week later, the lowest nitrogen plants were distinctly stunted and definitely a lighter green than those receiving higher nitrogen supplies. The 5 x N plants were likewise smaller than the plant receiving the complete solution. The petioles were much shorter and the leaves were fairly dark green in color - symptoms which somewhat paralleled those of the 1/5 x K plant. Some lobe-firing was evident.

On this same date, a distinct gradient was apparent in the sizes of the plants in the P series. In fact, the 5 x P plant was muchlarger and appeared much more vigorous than the 1 x P plants. The minus P plant was by far the smallest.

The lowest K plant still displayed extremely short petioles, smaller leaflets, darker color, and a necrosis of several petioles in the region of the leaflet junction. The plants were smaller than those of the complete solution.

Calcium deficiency symptoms were rather severe at this date. The growing points were critically checked and the plants were only one half the size of plants receiving 1 X Ca. An increase in the number of leaf buds attempting to develop was noted.

Symptoms of magnesium deficiency more pronounced by this date. Many of the leaves on the minus magnesium plants showed a bronzing in the central areas on either side of the mid rib of each leaflet. Plant size was not appreciably reduced, however.

Observations were again made on 3 May, 1958, prior to termination of the experiment. Pictures were taken of some of the outstanding deficiency symptoms.

The 1/5 x N concentration also produced a lighter green color of the leaves. The 4 x N plants were much smaller than the complete solution ones and, again, the leaves were very deep green in color. Three or four leaves had distal marginal scorching of the leaflets. This may have been due to the extremely high concentration of ammonium in this solution which either affected the plant osmatically or by inhibiting the uptake of other cations such as K, Mg or Ca from the solution.

Some purpling on the underside of older leaflets was found on the minus P plants. The 1/5 x P plants were only four-fifths the size of the 1 x P plants.

Potassium deficiency symptoms were rather severe on the minus K plants as typified by the petiole necrosis, stunting of the plant, and the dark green foliar coloration previously described.

Calcium deficiency symptoms at this date were also appearing in a mild manner on the 1/5 x Ca plants. Tips of leaflets failed to separate during the unfolding of the young leaves. The minus Ca plants were severely stunted at this time and were only about one-sixth the size of the 1 x Ca ones.

Analysis of plant parts

The nutrient composition of the various plant parts sampled are presented in Table 10. These are the data provided by the Soils Department plant analysis service. The key to these sample numbers is contained in Table 9.

The statistical analysis of these data provided some interesting results. Table 11 indicates that the fresh weights of the various plant parts varied considerably as the nutrient solution was varied. The effects are as follows:

Roots. The level of nitrogen in solution had no significant effect upon the fresh weight of the roots. For all of the other elements varied, the minus solutions decreased root fresh weight on a highly significant basis as compared to the second level of 1/5 Hoagland. Further increases in nutrient supply, however, failed to significantly

Table 9. Sample Numbers

Replication 1 (Bench 9)

Plant Tissue

Tmt. No.	Central Leaflets	Left Leaflets	Right Leaflets	Petioles	Crowns	Roots
K level						
1 K	1	2	3	4	5	6
2 K	7	8	9	10	11	12
3 K	13	14	15	16	17	18
4 K	19	20	21	22	23	24
P Level						
1 P	25	26	27	28	29	30
2 P	31	32	33	34	35	36
3 P	37	38	39	40	41	42
4 P	43	44	45	46	47	48
N Level						
1 N	49	50	51	52	53	54
2 N	55	56	57	58	59	60
3 N	61	62	63	64	65	66
4 N	67	68	69	70	71	72
Ca Level						
1 Ca	73	74	75	76	77	78
2 Ca	79	80	81	82	83	84
3 Ca	85	86	87	88	89	90
4 Ca	91	92	93	94	95	96
Mg Level						
1 Mg	97	98	99	100	101	102
2 Mg	103	104	105	106	107	108
3 Mg	109	110	111	112	113	114
4 Mg	115	116	117	118	119	120

Replication 2 (Bench 8)

Tmt. No.	Central Leaflets	Left Leaflets	Right Leaflets	Petioles	Crowns	Roots
Mg Level						
1 Mg	121	122	123	124	125	126
2 Mg	127	128	129	130	131	132
3 Mg	133	134	135	136	137	138
4 Mg	139	140	141	142	143	144
N Level						
1 N	145	146	147	148	149	150
2 N	151	152	153	154	155	156
3 N	157	158	159	160	161	162
4 N	163	164	165	166	167	168
P Level						
1 P	169	170	171	172	173	174
2 P	175	176	177	178	179	180
3 P	181	182	183	184	185	186
4 P	187	188	189	190	191	192

Replication 2 (Continued)

Tmt. No.	Central Leaflets	Left Leaflets	Right Leaflets	Petioles	Crowns	Roots
K level						
1K	193	194	195	196	197	198
2K	199	200	201	202	203	204
3K	205	206	207	208	209	210
4K	211	212	213	214	215	216
Ca Level						
1 Ca	217	218	219	220	221	222
2 Ca	223	224	225	226	227	228
3 Ca	229	230	231	232	233	234
4 Ca	235	236	237	238	239	240

Replication 3 (Bench 7)

Tmt. No.	Central Leaflets	Left Leaflets	Right Leaflets	Petioles	Crowns	Roots
P level						
1P	241	242	243	244	245	246
2P	247	248	249	250	251	252
3P	253	254	255	256	257	258
4P	259	260	261	262	263	264
Ca Level						
1 Ca	265	266	267	268	269	270
2 Ca	271	272	273	274	275	276
3 Ca	277	278	279	280	281	282
4 Ca	283	284	285	286	287	288
Mg Level						
1 Mg	289	290	291	292	293	294
2 Mg	295	296	297	298	299	300
3 Mg	301	302	303	304	305	306
4 Mg	307	308	309	310	311	312
K Level						
1K	313	314	315	316	317	318
2K	319	320	321	322	323	324
3K	325	326	327	328	329	330
4K	331	332	333	334	335	336
N Level						
1N	337	338	339	340	341	342
2N	343	344	345	346	347	348
3N	349	350	351	352	353	354
4N	355	356	357	358	359	360

Replication 4 (Bench 6)

Tmt. No.	Central Leaflet	Left Leaflet	Right Leaflet	Petioles	Crowns	Roots
K level						
1 K	361	362	363	364	365	366
2 K	367	368	369	370	371	372
3K	373	374	375	376	377	378
4 K	379	380	381	382	383	384
Ca Level						
1 Ca	385	386	387	388	389	390
2 Ca	391	392	393	394	395	396
3 Ca	397	398	399	400	401	402
4 Ca	403	404	405	406	407	408
Mg Level						
1 Mg	409	410	411	412	413	414
2 Mg	415	416	417	418	419	420
3 Mg	421	422	423	424	425	426
4 Mg	427	428	429	430	431	432
P Level						
1 P	433	434	435	436	437	438
2 P	439	440	441	442	443	444
3 P	445	446	447	448	449	450
4 P	451	452	453	454	455	456
N Level						
1 N	457	458	459	460	461	462
2 N	463	464	465	466	467	468
3 N	469	470	471	472	473	474
4 N	475	476	477	478	479	480

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Table 11. Fresh Weight of Plant Parts in Grams

Level of Nutrient Varied	Plant Parts					
	Roots	Crown	Petioles	Right Leaflets	Central Leaflets	Left Leaflets
Nitrogen						
1	25.39	12.39	10.56	11.04	10.88	11.53
2	31.18	13.84	13.98	15.04	14.42	15.49
3	30.30	14.56	16.30	17.61	16.66	17.91
4	28.08	13.14	12.13	14.39	13.49	14.83
L.S.D. 5%	N.S.	N.S.	12.036	1.516	1.165	1.602
L.S.D. 1%			2.925	2.178	1.673	2.302
C.V.	19	9	10	7	5	7
Phosphorus						
1	17.69	9.28	6.13	8.95	8.65	8.98
2	29.48	12.16	11.89	12.89	12.40	12.94
3	26.99	14.28	16.35	17.06	16.33	17.61
4	28.07	14.55	16.99	18.18	16.42	18.04
L.S.D. 5%	6.349	1.214	2.688	1.337	1.494	1.248
L.S.D. 1%	9.123	1.744	3.863	1.921	2.146	1.793
C.V.	16	6	13	6	7	5
Potassium						
1	8.26	6.85	5.88	7.81	7.18	7.92
2	29.76	13.22	12.55	15.64	14.48	15.84
3	30.02	14.33	16.84	18.28	16.28	18.53
4	31.18	16.10	15.36	16.58	15.68	16.89
L.S.D. 5%	12.154	3.456	3.522	6.704	3.049	3.990
L.S.D. 1%	17.981	5.235	5.060	9.632	4.380	5.732
C.V.	29	16	17	17	14	17
Calcium						
1	12.29	10.15	3.55	5.01	4.46	5.19
2	30.11	12.91	9.75	11.59	11.01	12.03
3	30.05	15.80	15.15	16.49	16.30	17.16
4	28.53	13.54	13.64	15.91	15.10	15.98
L.S.D. 5%	6.307	.319	.849	2.618	.897	2.867
L.S.D. 1%	9.062	.459	1.219	3.762	1.289	4.119
C.V.	16	1	5	13	5	14
Magnesium						
1	17.90	11.61	12.31	13.89	11.45	12.31
2	33.00	15.19	15.55	17.70	15.46	16.28
3	30.10	12.84	14.73	15.99	16.41	17.58
4	30.04	13.88	15.29	16.53	15.39	16.81
L.S.D. 5%	N.S.	N.S.	N.S.	N.S.	3.052	3.790
L.S.D. 1%					N.S.	N.S.
C.V.	26	14	13	12	13	15

influence root fresh weight. Table 12 shows that the dry weight of roots followed the same pattern as that of the fresh weight.

Crown. Nitrogen had no significant influence on the fresh or dry weight of the crown in these studies. Each additional increase in supply of phosphorus, however, was paralleled by a highly significant increase in fresh and dry weight up to the third level. A further increase in phosphorus did not encourage a proportional increase in crown weight. Only the minus potassium plant had a significantly lower weight than any of the other three in the series. Apparently, a small quantity of potassium is sufficient for crown development above which luxury consumption occurs. The same was true for calcium. Increases of magnesium in the nutrient solution did not follow this pattern significantly although a trend is apparent.

Petioles. In general, for most of the nutrients varied, the plants increased in fresh weight up to the third level, that of the normal Hoagland solution. Increases above this were not accompanied by further increases in fresh weight. This indicates that this solution is more favorable for petiole development. Variations of magnesium levels had no significant effect upon petiole fresh or dry weight.

Leaflets. Relatively little difference in weight was noticeable of the three leaflets. A possible trend indicates that the central leaflet is of a slightly less fresh and dry weight than either of the two lateral leaflets, which seemed to be approximately equal in weight. Considering leaflets as a whole, therefore, it is apparent that leaflet fresh and dry weight increased with a concurrent increase in N, K and calcium content in the nutrient solution up to the third level. An increase above this level actually decreased weight in many instances.

Conversely, it seems that increases in phosphorus up to the fourth level increased fresh and dry weight of the leaflets. Responses to increases of magnesium above the second level were rather inconsistent. Conclusions which may be gotten from these results are that leaflets reflect variations in nutrient solution composition of most

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Table 12. Dry weight in grams of each plant part group harvested and dried at 70°C.

Nutrient Varied	Roots	Crown	Petiole	Right Leaflet	Central Leaflet	Left Leaflet
Nitrogen						
1	4.22	2.71	2.28	3.58	3.50	3.69
2	4.79	2.90	2.90	4.81	4.70	4.94
3	5.07	2.98	3.38	5.85	5.62	5.92
4	3.76	2.61	2.45	4.40	4.21	4.46
L.S.D. 5%	.808	N.S.	.496	.649	.481	.683
L.S.D. 1%	N.S.		.712	.932	.691	.981
C.V.	11	13	11	9	7	9
Phosphorus						
1	3.82	2.27	1.81	3.33	3.17	3.33
2	5.26	2.67	2.38	4.48	4.31	4.52
3	4.92	2.96	3.13	5.59	5.45	5.74
4	4.82	2.95	3.31	5.87	5.49	5.80
L.S.D. 5%	.682	.248	.273	.522	.395	.381
L.S.D. 1%	.979	.356	.393	.750	.567	.547
C.V.	9	6	6	7	5	5
Potassium						
1	2.16	1.44	1.35	3.19	3.01	3.25
2	4.58	2.62	2.71	5.11	4.79	5.17
3	5.12	2.86	3.38	6.00	5.71	6.01
4	4.88	2.81	3.02	5.22	5.02	5.29
L.S.D. 5%	1.217	.653	.727	1.233	.999	1.199
L.S.D. 1%	1.749	.939	1.044	1.771	1.436	1.722
CV	18	17	17	16	13	15
Calcium						
1	2.44	2.60	0.93	2.03	1.85	2.11
2	4.52	2.77	2.43	3.93	3.67	4.02
3	5.09	3.19	3.21	5.64	5.60	5.76
4	4.84	2.82	2.86	5.31	5.12	5.30
L.S.D. 5%	.562	.343	.504	.602	1.026	.930
L.S.D. 1%	.808	.492	.724	.864	1.474	1.334
C.V.	8	8	19	13	16	14
Magnesium						
1	2.61	2.04	2.10	4.02	3.73	3.92
2	4.65	2.85	3.07	5.62	5.13	5.47
3	4.45	2.52	3.01	5.14	5.07	5.23
4	4.30	2.75	3.06	5.23	5.09	5.29
L.S.D. 5%	1.330	N.S.	.619	.978	.710	.909
L.S.D. 1%	1.911		N.S.	N.S.	1.021	N.S.
C.V.	21	16	14	12	9	11

of the nutrients studied. The plant magnesium content of magnesium in the 1/5 Mg leaflets; the phosphorus content of either the 1 x or 5 x P leaflets; and the nitrogen, potassium and calcium content of the third levels of these series may perhaps offer some promise of approaching the critical levels of these nutrients in the Albritton strawberry plant. This information may be of possible use in later field surveys of the nutritional status.

Table 13 reveals that, in almost every case presented, the absolute quantity of nutrients in the plant parts, and we might surmise, the plant as a whole, increases as the supply is increased in the nutrient solution.

A review of the nutrient element contents of plant parts on a percent dry weight basis in Table 14 shows that highly significant differences in content occurred in all plant parts as a result of varying each of the nutrient elements separately. Also, with few exceptions where the same value remained, an increase in concentration of a given nutrient resulted in an increase in the percent of dry weight content of that element in the plant tissues. Thus, the increases in absolute quantities of these elements per plant part in Table 13 did not merely reflect a larger quantity of fresh or dry weight of the plant, as we have already seen in Tables 11 and 12. Since most of the fresh and dry weight increases in Tables 11 and 12 were highly significant it is difficult to select a given tissue for use in sampling. Consequently, our problem of selecting a plant tissue for use in field nutritional surveys must be pursured further. Consequently, in Table 15, the coefficient of variations of the nutrient compositions (from Table 14) have been summarized and ranked to facilitate comparisons. Since a higher coefficient of variation is indicative of less accuracy in interpreting foliar or tissue analyses, these have been ranked from lowest to highest for each of the tissues analyzed within each nutrient element series. Further, by totaling these ranked numbers, one can perhaps select the tissue for sampling which shows the least variation and, thereby, the most reliability. A central leaflet appears to be this tissue since it had total coefficients of variation of 38 and a total ranking of 38.

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Table 13. Absolute Nutrient Content in Grams Per Individual Plant Part.

Level of Nutrient Varied	Plant Part					
	Roots (all)	Crown (all)	Petiole (each)	Right Leaflet (each)	Central Leaflet (each)	Left Leaflet (each)
Nitrogen						
1	4.02	.81	.08	.28	.28	.29
2	5.41	1.06	.12	.43	.41	.44
3	9.51	1.37	.17	.57	.57	.58
4	10.04	2.50	.35	.78	.77	.81
L.S.D. 5%	2.182	.193	.016	.082	.056	.061
L.S.D. 1%	3.135	.277	.022	.117	.080	.087
C.V.	19	9	5	10	7	7
Phosphorus						
1	.36	.08	.01	.02	.02	.02
2	.58	.12	.01	.04	.04	.04
3	2.22	.30	.04	.09	.09	.10
4	2.63	.33	.05	.11	.10	.10
L.S.D. 5%	.497	.042	.004	.003	.006	.004
L.S.D. 1%	.714	.060	.006	.005	.009	.006
C.V.	21	13	8	4	7	9
Potassium						
1	.68	.30	.04	.10	.10	.10
2	2.74	1.09	.16	.27	.24	.27
3	11.96	2.73	.61	.57	.57	.55
4	15.80	3.05	.66	.70	.69	.70
L.S.D. 5%	2.707	.668	.110	.139	.126	.142
L.S.D. 1%	3.889	.959	.158	.199	.181	.203
C.V.	22	23	19	21	20	22
Calcium						
1	.61	.37	.01	.02	.02	.02
2	1.30	.46	.04	.04	.04	.04
3	2.53	1.11	.16	.33	.38	.34
4	3.39	1.21	.17	.37	.40	.37
L.S.D. 5%	.352	.189	.029	.059	.048	.060
L.S.D. 1%	.505	.272	.044	.084	.069	.086
C.V.	11	15	17	19	14	19
Magnesium						
1	.65	.10	.01	.03	.02	.01
2	1.12	.16	.02	.04	.03	.04
3	2.33	.21	.04	.08	.09	.08
4	3.59	.41	.07	.15	.17	.16
L.S.D. 5%	.889	.098	.015	.040	.032	.025
L.S.D. 1%	1.277	.141	.021	.057	.046	.036
C.V.	29	28	26	33	26	22

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Table 14. Nutrient Content of Plant Parts (% of Dry Weight)

Level of Nutrient Varied	Plant Part					
	Roots	Crown	Petiole	Right Leaflet	Central Leaflet	Left Leaflet
Nitrogen						
1	.95	.90	.69	1.54	1.54	1.53
2	1.14	1.12	.80	1.82	1.77	1.81
3	1.86	1.39	1.05	2.04	2.14	2.08
4	2.67	2.88	2.98	3.70	3.78	3.78
L.S.D. 5%	.200	.130	.195	.113	.099	.078
L.S.D. 1%	.287	.187	.280	.153	.142	.112
C.V. (%)	8	5	9	3	3	2
Phosphorus						
1	.09	.10	.08	.11	.11	.11
2	.11	.15	.11	.15	.15	.16
3	.45	.30	.27	.32	.32	.33
4	.54	.33	.29	.36	.36	.36
L.S.D. 5%	.046	.012	.016	.016	.016	.021
L.S.D. 1%	.067	.017	.022	.022	.022	.030
C.V. (%)	10	3	5	4	4	5
Potassium						
1	.32	.62	.50	.51	.53	.51
2	.60	1.27	1.23	1.09	1.02	1.09
3	2.39	2.87	3.87	2.00	2.14	1.93
4	3.26	3.21	4.68	2.86	2.95	2.83
L.S.D. 5%	.224	.229	.199	.160	.276	.167
L.S.D. 1%	.322	.328	.285	.230	.397	.240
C.V. (%)	9	7	5	6	10	7
Calcium						
1	.25	.44	.18	.15	.14	.15
2	.29	.51	.34	.21	.24	.20
3	.50	1.05	1.03	1.14	1.30	1.15
4	.70	1.29	1.30	1.46	1.64	1.48
L.S.D. 5%	.043	.118	.072	.054	.069	.067
L.S.D. 1%	.062	.169	.109	.077	.099	.096
C.V. (%)	6	9	6	5	5	6
Magnesium						
1	.25	.13	.06	.15	.11	.06
2	.24	.17	.11	.15	.14	.14
3	.54	.26	.33	.34	.36	.32
4	.84	.44	.51	.60	.69	.63
L.S.D. 5%	.100	.060	.146	.143	.084	.077
L.S.D. 1%	.144	.086	.209	.205	.121	.111
C.V. (%)	13	15	36	29	16	17

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Summary of Coefficients of Variation

from

Table 15. Nutrient Composition (% Dry Weight) of Plant Parts

Nutrient Varied	Plant Part: Roots	Crown	Petioles	Right Leaflet	Center Leaflet	Left Leaflet
N	8 (5)	5 (4)	9 (6)	3 (3)	3 (2)	2 (1)
P	10 (6)	3 (1)	5 (5)	4 (2)	4 (3)	5 (4)
K	9 (5)	7 (3)	5 (1)	6 (2)	10 (6)	7 (4)
Ca	6 (5)	9 (6)	6 (3)	5 (1)	5 (2)	6 (4)
Mg	13 (1)	15 (2)	36 (6)	29 (5)	16 (3)	17 (4)
	(22)	(16)	(21)	(13)	(16)	(17)
Total	46	39	61	47	38	37

It is interesting to note, however, the petiole varies least in potassium content, any of the leaflets are less variable in nitrogen content, the crown is least variable in phosphorus content and the roots are the least variable of any of the tissues in regard to magnesium content. On an overall basis, however, the central leaflet was selected.

The selection can further facilitate by summarizing the Variance Ratios (F values) since most differences in plant nutrient composition due to treatment were highly significant. Table 16 contains these F. values. Here one can see that the leaflets, when the ranks of F values from highest to lowest are totaled, that any of the leaflets might be selected. Again, as in Table 15 of the coefficients of variation, if one wished to most accurately determine the potassium status of this plant, the petiole would be the tissue to sample. The crown would best reflect phosphorus. The leaflets would again best reflect nitrogen and the leaflets would reveal the calcium status.

A further narrowing down of the field may be obtained by calculating the linear slopes or "b" values of the nutrient contents on the percent dry weight basis. These values are summarized in Table 17. A higher value reflects a greater response in nutrient content than does a lower value. Here, the central leaflet appears to offer the most promise for use in sampling with a low ranking total of 14. Again, the petiole best reflects potassium, one of the leaflets, nitrogen; but now, the roots instead of the crown promises response to phosphorus and one of the leaflets is best for a calcium or magnesium reflection. In general, however, indications are that the central leaflet, from all standpoints, seems to be the tissue for use in field surveys to determine the overall nutritional status of the Albritton strawberry.

Since much attention has been centered upon the use of the petiole of some plants for "leaf" analysis, especially, the grape, attention toward the response of the strawberry petiole to nutritional variations may be of interest to many workers. Table 18 summarizes the effects of level of nutrient upon length of the strawberry

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Summary of Variance Ratios - (F values)

from

Table 16. Nutrient Composition (% of Dry Weight) of Plant Parts

Nutrient Varied	Plant Part: Roots		Crown		Petioles		Right Leaflet		Central Leaflet		Left Leaflet	
N	157	(6)	490	(4)	318	(5)	740	(3)	1109	(2)	1782	(1)
P	251	(6)	880	(1)	486	(4)	662	(2)	648	(3)	346	(5)
K	411	(3)	305	(5)	1057	(1)	426	(2)	161	(6)	374	(4)
Ca	244	(5)	126	(6)	669	(4)	1552	(1)	1237	(2)	1036	(3)
Mg	81	(3)	59	(4)	21	(6)	23	(5)	104	(2)	108	(1)
		23		20		20		13		15		14

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Table 17. Summary of b's (slopes; linear)

Nutrient Varied	Plant Part											
	Roots		Crown		Petiole		Right Leaflet		Central Leaflet		Left Leaflet	
N	.294	(6)	.310	(5)	.357	(2)	.358	(1)	.354	(3)	.351	(4)
P	.192	(1)	.096	(5)	.090	(6)	.107	(2)	.106	(3)	.104	(4)
K	.638	(2)	.566	(3)	.914	(1)	.479	(5)	.505	(4)	.469	(6)
Ca	.109	(6)	.216	(5)	.284	(4)	.340	(3)	.389	(1)	.345	(2)
Mg	.171	(2)	.086	(6)	.131	(4)	.128	(5)	.162	(3)	.178	(1)
		17		24		17		16		14		17

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Table 18. Effect of Level of Nutrient Upon Length of Strawberry Petiole.

Level of Nutrient Varied	Total Length (cm)	Average Length (cm)
Nitrogen		
1	162.0	8.32
2	190.3	9.40
3	200.5	9.48
4	173.0	8.32
L.S.D. 5%	N.S.	.975
L.S.D. 1%		N.S.
C.V.	10	9
Phosphorus		
1	121.4	7.40
2	155.1	8.40
3	187.4	9.38
4	194.3	9.49
L.S.D. 5%	14.23	.456
L.S.D. 1%	20.44	.655
C.V.	5	3
Potassium		
1	117.0	6.94
2	170.1	8.32
3	197.4	9.30
4	195.0	9.18
L.S.D. 5%	22.57	1.035
L.S.D. 1%	32.44	1.487
C.V.	8	8
Calcium		
1	105.0	6.66
2	156.9	8.07
3	158.8	8.14
4	175.5	9.02
L.S.D. 5%	N.S.	N.S.
L.S.D. 1%		
C. V.	32	19
Magnesium		
1	153.6	8.50
2	182.0	8.57
3	186.8	8.78
4	190.9	9.02
L.S.D. 5%	20.54	N.S.
L.S.D. 1%	N.S.	
C.V.	7	6

petioles in this study. Nitrogen and calcium had no significant effects upon the total of the lengths of petioles produced by the three plants in each treatment. This lack of significance in the case of calcium is probably due to the high level of variation, i.e. a 32 percent coefficient of variation. Little significance is likewise apparent in the case of response to magnesium. On an average length per petiole basis, nitrogen, calcium and magnesium variations again have less influence. Phosphorus and potassium, however, appear to have a pronounced influence upon petiole length. Since potassium variation concurrently produced one of the highest regression coefficients (Table 17) of any calculated, on the percent of dry weight composition basis, this specific tissue appears to be an extremely sensitive one in the strawberry to variations in potassium nutrition. Therefore, its use would be preferable in studies where only responses to potassium are being studied.

B. Blueberry Research in 1958

Relatively little background information is available for blueberry nutrition and its varied physiological relationships. Consequently, a general approach was initiated to provide some background material from which later, more specific work might be undertaken.

General Survey

Contact was made in the summer of 1957 and at the January Annual Blueberry Open House meeting in 1958 with blueberry growers who had plantings of the Wolcott and Murphy varieties which were at least 4 or 5 years old. The majority of the plantings of these varieties are no older than this due to their recent introduction at the beginning of this decade by Professor Morrow. Approximately 30 growers offered to cooperate by offering their plants, leaves and fruit for a general survey to determine the nutritional status and overall condition of the blueberry plantings in the state. The names and addresses of these growers are given in Table 19 together with the number of survey plots located in their respective plantings.

Each plot consisted of ten blueberry bushes and was selected, not to be representative of the entire planting, but to provide contrasting conditions which might have existed, in some cases, within a planting. The philosophy was to select each plot so that comparisons and analyses of many of its characteristics of plant and soil could be made.

Dr. Eugene Goldston and Mr. Arvil Hunter of the N. C. State College Soils Department cooperated in the survey by constructing an eight inch in diameter hole down to a depth of approximately four feet. A soil sample was taken at each of the horizons including the hardpans. The holes were made in the center of either the south or west side (depending upon the direction of row planting) of each ten bush plot under the outer periphery of bush branches. Classification of the soil was made in situ by Dr. Goldston as to soil type, structure, consistency and an overall description. The

Table 19. List of cooperating growers in general nutritional survey of blueberry plantings in North Carolina. 1957 - 1958.

Name	No. of Plots	Address
*1. Barnes Brothers	2	Route 701, Garland, North Carolina
2. Frank Blanchard	4	Box 46, Rose Hill, N. C.
3. Dean Bowker	1	C/o Mr. Elbert Colbert, Currie, N. C.
*4. Ernest Bowker, Sr.	1	C/o Mr. Elbert Colbert, Currie, N. C.
5. Herbert Cleavenger	3	C/o Mr. Ernest Jones, Mgr. Rt. 1, Burgaw, N.C.
6. Collier Cobb	3	P.O. Box 146, Bridgeton, N. C.
7. Cutts Bros.	1	Route 1, Ivanhoe, N. C.
*8. J. A. Edwards	3	Route 2, Box 452, Wilmington, N. C.
9. Raymond Emery	3	New Egypt, New Jersey, or C/o Mr. Thomas Karwoski, Route 1, Burgaw, N. C.
10. M. S. Emmart	3	R.F.D. 2, Box 131, Wilmington, N. C.
11. Deleon Wells Ennis	2	Route 2, Burgaw, N. C.
12. Simon Gurganeous	2	Box 106, Route 2, Elizabethtown, N. C.
*13. Gale Harrison	2	Ivanhoe, N. C.
*14. Heath Brothers	2	Route 1, Kinston, N. C.
15. Harold Huntington	2	Atkinson, North Carolina.
16. T. P. Key	2	Box 735, Southport, N. C.
17. Koehlert and Roescher	2	Currie, N. C.
18. John Moore	1	Ivanhoe, N. C.
19. Jason Morris	2	Bridgeton, N. C.
20. Orr Bros.	4	Currie, N. C.
21. J. D. Rowe	1	Route 1, Burgaw
22. M. M. Sandy	2	Roseboro, N. C.
23. G. W. Spayd	3	Currie, N. C.
*24. Thomas S. Strong	2	3104 "O" St. N.W., Washington, D. C.
25. Wells Bros.	3	Rosehill, Box 56, N. C.
*26. I. C. Wright	3	Box 208, Wilmington, N. C.
27. J. W. Young	1	Stella, N. C.

Note * = also cooperating by supplying leaves and fruit for the periodic sampling survey.

soil samples were returned to Raleigh and sent to the State Soils Testing Laboratory for analysis of exchange capacity, exchangeable cations, phosphorus, manganese, percent organic matter content and so forth.

Concurrently, 100 leaf samples were taken from the central portion of the initial burst of the current season's shoot growth. The leaves were placed in small plastic polyethylene bags and kept in an ice chest until returned to Raleigh where they were dried at 70°C in a forced air drying oven. Analyses of N, P, K, Ca and Mg are to be made by the Plant Analyses Laboratory of the Soils Department. As of date the N determinations have been returned and the others are expected in the near future. The minor element contents were to be determined by the Chemistry Department Spectrographic Laboratory. However, due to the difficulties encountered in the perfection of the procedure, analyses of the leaves by them must be postponed or accomplished elsewhere by other means.

Yield recoreds were kept by many of the growers during the harvest season. They are presented on a pounds per bush basis in Table 20 which also contains information of the soil type and relative condition of the plant vigor as visually determined at the time of leaf sampling.

In addition to the leaf and soil sampling visit made during the first week of June to the plantings during the survey, additional visits were made as time permitted throughout the growing season (20 June, 21 July, 3 September and 14 October). On these dates, additional observations were made on such general appearances as occurrence of fungal or unknown origin leaf spots, average height and width of the bushes, number of bushes in 10 exhibiting interveinal chlorosis of young tip leaves of basal shoots found in semi-shaded areas of the bush, general vigor of the current season's new growth, and so forth.

Some rather interesting relationships were found. First, of the 55 plots studied, 20 were found to be situated on Saint John, 23 on Leon, 2 on Amokolee, 2 on Pokomoke,

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Table 20 BLUEBERRY SURVEY

Yield Records for 1958
(Kept by growers)

Plot No.	Grower	Variety	Soil Type (a)	Relative Condition of Plant Vigor	lbs. berries per bush
51	Barnes	Wolcott	L	Good	5.4
110	Blanchard	Wolcott	L	Good	9.5
112	Blanchard	Murphy	L	Good	5.3
113	Blanchard	Murphy	L	Poor	2.8
111	Blanchard	Wolcott	L	Poor	5.7
40	Bowker, Sr.	Wolcott	SJ	Good	7.2
109	Cutts Bros.	Wolcott	L	Good	8.5
28	Edwards	Murphy	L	Poor	2.3
29	Edwards	Wolcott	L	Poor	4.7
104	Edwards	Murphy	L	Medium - Good	8.1
13	Emery	Wolcott	E	Poor	7.1
15	Emery	Murphy	A	Good	6.1
14	Emery	Wolcott	SJ	Good	11.8
49	Ennis	Murphy	SJ	Medium - Poor	4.0*
50	Ennis	Wolcott	P	Medium	5.3*
116	Harrison	Wolcott	L	Good	10.0*
9	Harrison	Wolcott	L	Medium - Good	4.5*
17	Heath	Wolcott	L	Medium - Good	6.9
16	Heath	Wolcott	L	Good	6.2
48	Koehlert & Roescher	Wolcott	L	Very good	8.54
47	Koehlert & Roescher	Murphy	L	Medium - Good	7.6
106	Orr Bros.	Murphy	SJ	Very Good	9.7
46	Orr Bros.	Wolcott	SJ	Good	11.4
45	Orr Bros.	Murphy	SJ	Medium - Good	7.1
36	Spayd	Murphy	L	Good	4.6
38	Spayd	Wolcott	L	Good	10.2
114	Wells	Murphy	L	Very Poor	0.5*
43	Wright	Wolcott	SJ	Medium - Good	4.9*
42	Wright	Murphy	SJ	Poor	4.8

*Rough estimates only

(a) Key: L = Leon
SJ = St. John
E = Elwell
A = Amokalee
P = Pokomoke

and 2 on Rutledge type soil. Since the majority of the plantings were on the Saint Johns and Leon soils, the plots of the general survey were grouped under these. They were further categorized as to variety.

Consequently, a relationship between the yield of the Wolcott variety and the manganese content of the soil was uncovered. Table 21 shows a linear correlation coefficient (r) of (+) 0.582 which is significant at the 5 percent level.

The pH of the soil seems to be due to the organic matter content - at least in the Leon soils. Table 22 shows that the correlation coefficient (-) 0.634 was highly significant. This is understandable since the soil is practically composed of only pure quartz sand and organic matter. The pH must thereby be derived from the organic matter. The more organic matter, the greater the potential for a lower pH. Since pH is a function of the degree of base saturation of the cation exchange capacity of a soil, the low pH values encountered indicate a relatively low nutritional content of the soil. This is probably enhanced by the heavy "flash" rainfalls for which this part of the country is noted.

The organic matter content of the Leon soil is also greatly related to the size of the Wolcott plant. The products of the height and width of the bushes in each plot are compared with percent organic matter content in Table 23. An unusually high significance is indicated by the correlation coefficient of (+) 0.871. This is more significant for the Leon soil since this soil is much lower in organic matter content than the Saint Johns. Table 24 shows (in a summary form only) that the average St. Johns organic matter content is 8.4 percent while that of the Leon type soil is only 3.8. Thus, the critical point for organic matter content will more likely be found in the Leon soils than in the Saint Johns. This encourages one to use the Leon for comparison of plant response to nutritional or other soil characteristic variations.

Table 24 also shows that the yield of bushes grown in Leon soil are much lower on the average than those of the Saint Johns. This in undoubtedly due in part to the

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Table 21. Relationship of Wolcott variety blueberry yield and manganese content of the soil.

Plot No.	Yield (lb./bush)	Soil Mn (me./100 gm)
51	5.4	4
110	9.5	4
111	5.7	2
40	7.2	4
109	8.5	2
29	4.7	0.1
13	7.1	7
14	11.8	9
17	6.9	12
16	6.2	4
48	8.5	9
46	11.4	9
38	10.2	4
116	10.0	7

Correlation coefficient (r) = + 0.582

Significance at 12 D.F.: 5% = .532
1% = .661

Table 22. Relationship of Leon type soil pH and organic matter content (sampled in 1958).

Plot No.	Soil pH	Soil % OM
117	4.0	2.8
116	4.3	2.6
9	4.1	4.2
17	3.6	5.4
16	3.6	6.0
48	3.6	6.3
51	4.6	2.6
110	3.8	4.6
111	3.9	2.5
41	3.6	2.0
103	4.0	5.7
109	4.1	2.4
29	4.0	2.0
38	3.5	7.2
36	3.7	5.1
114	4.2	2.5
52	3.8	4.0
112	4.0	4.5
113	4.1	2.8
102	4.0	5.7
28	4.1	2.3
104	4.4	1.7
47	4.0	4.5

Correlation coefficient (r) = (-) 0.634**

For significance at 21 D.F.: 5% = .413
1% = .526

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Table 23. Relationship of Leon soil organic matter content and the product of the height and width of Wolcott blueberry bushes growing thereon.

Plot No.	Plant H x W (ft^2)	Soil % OM
117	18.0	2.8
19	20.3	4.2
17	21.5	5.4
16	30.0	6.0
48	39.0	6.3
51	17.1	2.6
110	30.0	4.6
111	13.2	2.5
103	34.7	5.7
109	21.5	2.4
29	15.8	2.0

Correlation coefficient (r) = + 0.871**

For significance at 9 D.F.: 5% = 0.602
1% = 0.735

Table 24. A summary of the effect of variety and soil on several characteristics of blueberry plantings surveyed in 1958 (a).

Soil Variety	Leaf Color(b)	Leaf N (c)	I.V. Chlor.(d)	Bush HxW (e)	Bush Vigor(f)	Leaf Spot(g)	Yield (lb/bush)	Soil % OM
St. Johns								
Wolcott	3.1	1.90	5.8	24.5	2.0	17.1	8.8	
Murphy	3.4	2.01	3.9	16.4	1.8	8.6	6.4	
Ave.	3.2	1.94	5.1	21.2	1.9	13.7	7.5	8.4
Leon								
Wolcott	3.0	1.92	7.1	21.3	1.8	20.4	8.0	
Murphy	3.1	1.96	4.6	14.5	1.9	7.6	4.5	
Ave.	3.0	1.94	6.1	18.1	1.9	14.0	6.6	3.8

(a) Not analyzed statistically.

(b) Based on coded system of 1 to 5 wherein the larger number is associated with a darker green color.

(c) % of dry weight.

(d) Number of bushes in ten exhibiting interveinal chlorosis of the tip leaves of shoots located within the lower extremities of the bush.

(e) H x W = the product of the average height and the average width of the blueberry bush.

(f) Based on a coded system of 1 to 10 with 10 being most vigorous; refers to annual shoot growth, not size of bush.

(g) Refers to fungal as well as unidentified spotting of leaves. Based on periodic inspections and summation of coded ratings of 1 to 10 of severity.

presence of a smaller bush as was discussed previously. The average bush size (H x W) was 21.2 square feet for the Saint Johns and only 18.1 square feet for the Leon soil plants. In this respect, one may observe that the Wolcott bush is a larger one than is the Murphy. This substantiates a general field impression. Concurrently, the yield of the Wolcott is greater than that of the Murphy variety.

Both leaf color and percent nitrogen content were higher for Murphy than Wolcott. Leaf color was slightly higher on plants grown on Saint Johns than Leon soil.

The interveinal chlorosis of young tip leaves seems to be more severe on plants of the Leon soil which is probably related to the poorer nutritional status of this soil. The Wolcott variety, in addition, appears to be more sensitive than the Murphy variety to this disorder, which closely resembles that of an iron, manganese, or some other minor element deficiency. The return of leaf analysis will be anxiously awaited to shed further light on this condition.

Very little difference is apparent between the occurrence of leaf spots on bushes grown on either soil type. An outstanding difference does seems to occur between varieties. Wolcott had more than twice the leaf spot trouble than Murphy. This is probably a pathological problem but may partially be related to nutritional condition.

Periodic Survey

From the plots sampled on a preliminary basis in August of 1957, eight locations were selected on the basis of nutritional status differences as determined by leaf-nutrient content. High and low levels of calcium, phosphorus, and potassium in the leaves were selected in all possible combinations to provide eight plots. These were located as closely as possible to the corresponding plots. The locations and names of cooperating growers were given in Table 19.

Leaf and fruit samples were taken from these bushes every ten days beginning on 29 April, 1958, approximately one to two weeks after the first fruit had been set. The fruit was taken at random from the south or west side of the approximately 30 bushes included in each plot. This was necessary since each berry of the cluster follows no set pattern as to its time or position of ripening. The berries for the May 30 and June 30 samplings were those which were just beginning to change from a green to a reddish color. More exactly, the calyx half was of a pink color and the scar end was still green or "whitish green". This was done to achieve a uniformity in material since one or two berries were already full blue at the May 30 date and berries had already been harvested before the June 9 date.

The leaf samples were continually taken from the central portion of the first flush of shoot growth, located as closely as possible to the fruit cluster so that some effects of the leaf contents upon fruit content and quality, and vice versa, might perhaps be uncovered during the study. These leaves were collected with the fruit samples until June 9. Thereafter, the leaves were collected at approximately 20 day intervals.

Each sample of either leaves or fruit was divided into sub-samples. Fresh weights were taken immediately from each sub-sample. Subsequently, one was placed in a small plastic bag, the bag was closed with a wire "twister" and then placed on dry ice in an ice box for immediate freezing. This sample was returned to Raleigh in the frozen state and now is being held in the frozen-storage room of Kilgore Hall. Plans include the analysis of these samples for organic components such as starch, sugars, amino acids, and so forth.

The sister sample was placed in another plastic bag, placed in an ice chest with ice for cooling, and returned to Raleigh. There, a count was made of the number of leaves or fruit per sample. These sub-samples were then dried at 70°C in a forced air oven. From these fresh and dried weights with counts, the fresh and dried weights per berry or ~~fruit~~ leaf were calculated. The dried samples were sent to the Soils and Chemistry Department for mineral analysis. To date, the percent nitrogen content analyses have been returned.

The objectives of this periodic sampling survey are several. First, the seasonal trends in nutrient content of leaves and fruit can be determined which will aid in establishing a two or three week period during the growing season during which little change in percent nutrient content occurs. This will be of benefit both for future surveys and studies as well as use in any possible grower services which may develop.

Another objective will be to determine the relationship between leaf or fruit composition and fruit quality. Samples of three pints each were taken in cooperation with Mr. Lee Kushman of the U.S.D.A., A.M.S. These were placed in an ice chest for uniform, cool holding until they were returned to the campus.

They were then placed at 70°F in a cold storage room and held for six days. At the end of this period they were removed from storage and the fruit segregated on the basis of sound fruit, "leakers" (which term describes those berries which looked mormal from the outside but immediately fell apart as a watery-like mass upon light contact with the fingers. This condition may have been due to the present of fungal, yeast or bacterial infestation, but the exact cause in unknown at present. The segregated sound fruit were placed in a Waring blendor and subsequently tested for pH and total acidity.

The results of data collected for this periodic survey were extremely interesting and show great promise for future studies of a more detailed nature. Tables 25, 26 and 27 contain the results of the fresh and dry weight determinations. These are graphically presented in the accompanying graphs. Figure 3 shows that the fresh weight per berry increased linearly from April 29 until May 19. Then it increased rapidly during its latter stages of development. This is in agreement with recent work by Christopher and Shutak in Rhode Island. The sample of fruit taken at the half-pink stage a few days after the first commercial harvest appeared to be much smaller than the one taken a few days before the first harvest. This substantiates a general field observation that berries of the first harvest are larger than succeeding ones.

The trend for the dry weight per berry follows that of the fresh weight except that the slope is much greater for the dry weight increase, especially during the

Table 25 Blueberry Periodic Samples (Summary) Leaves

Letter	Grower	Dry Wt. (gms.)	Number of Leaves	Wt/leaf	Fresh Wt (gms.)	Fresh Wt dry Wt.	% H_2O	Fr. Wt/ Berry	Ave. % Dry. Wt.
			First Picking 29 April 1958						
A	Heath	5.00	86	.0581	19.5	14.50	74.4	.2267	
B	Emery	4.78	75	.0637	19.3	14.52	75.2	.2573	
C	Strong	7.08	166	.0426	26.0	18.92	72.8	.1566	
D	Bowker	6.56	114	.0575	22.8	16.24	71.2	.2000	
E	Edwards	5.95	93	.0639	20.0	14.05	70.3	.2151	
F	Harrison	5.42	131	.0413	21.0	15.58	74.2	.1603	
H	Barnes	6.10	114	.0535	27.7	21.60	78.00	.2430	
			Total	.3806		115.41	516.1	1.4590	
			Ave.	.0544		16.49	73.7	.2084	26.3
			Second Picking 8 May 1958						
A	Heath	2.90	30	.0966	10.52	7.62	72.4	.3507	
B	Emery	4.11	41	.1002	15.40	11.29	73.3	.3756	
C	Strong	4.47	55	.0812	15.88	11.41	71.9	.2887	
D	Bowker	4.61	39	.1182	16.28	11.67	71.7	.4174	
E	Edwards	5.85	54	.1083	18.55	12.70	68.5	.3435	
F	Harrison	4.96	62	.0800	17.48	12.52	71.6	.2819	
G	Wright	4.82	56	.0860	17.40	12.58	72.3	.3107	
H	Barnes	6.01	59	.1018	20.25	14.24	70.3	.3432	
				.7723		94.03	572.0	2.7117	
				.0953		11.75	71.5	.3390	28.5
			Third Picking 19 May 1958						
A	Heath	5.78	45	.1284	16.76	10.98	65.5	.3724	
B	Emery	7.30	51	.1431	20.85	13.55	65.0	.4088	
C	Strong	8.17	69	.1184	22.86	14.69	64.3	.3313	
D	Bowker	5.16	34	.1517	15.75	10.59	67.2	.4632	
E	Edwards	8.40	58	.1448	22.40	14.00	62.5	.3862	
F	Harrison	5.49	42.5	.1291	15.40	9.91	64.4	.3624	
G	Wright	5.50	53	.1037	16.80	11.30	67.3	.3170	
H	Barnes	9.45	64	.1476	25.90	16.45	63.5	.4047	
				1.0668		101.47	519.7	3.0460	
				.1334		12.68	65.0	.3808	35.0
			Fourth Picking 30 May 1958						
A	Heath	6.46	41	.1575	16.15	9.69	60.0	.3939	
B	Emery	6.22	39	.1594	15.91	9.69	60.9	.4079	
C	Strong	6.00	39	.1538	15.10	9.10	60.3	.3872	
D	Bowker	6.62	42	.1576	17.45	10.83	62.1	.4155	
E	Edwards	7.84	48	.1633	19.55	11.71	59.9	.4073	
F	Harrison	6.47	50	.1294	16.88	10.41	61.7	.3376	
G	Wright	5.27	43	.1225	14.06	8.89	62.8	.3293	
H	Barnes	5.16	33	.1563	13.35	8.19	61.3	.4045	
				1.1998		78.51	489.0	3.0832	
				.1500		9.81	61.1	.3854	39.9

Letter	Grower	Dry Wt. (gms.)	Number of Leaves	Wt/leaf	Fresh Wt (gms.)	Fresh Wt dry wt.	% H_2O	Fr. Wt/ leaf	Ave. % Dry Wt.
				Fifth Picking 9 June 1958					
A	Heath	6.71	57	.1177	17.33	10.62	61.3	.3040	
B	Emery	6.61	51	.1296	16.52	9.91	60.0	.3239	
C	Strong	6.13	48	.1277	15.15	9.02	59.5	.3156	
D	Bowker	5.74	40	.1435	15.15	9.41	62.1	.3788	
E	Edwards	7.08	69	.1041	18.41	11.33	61.5	.2707	
F	Harrison	5.66	41	.1380	14.00	8.34	5.96	.3415	
G	Wright	6.41	53	.1209	16.74	10.33	61.7	.3158	
H	Barnes	7.91	53	.1492	20.12	12.21	60.7	.3796	
			Total	1.3342		81.17	486.4	2.6299	
				.1668		10.15	60.8	.3287	39.2
				Sixth Picking 30 June 1958					
A	Heath	6.24	43	.1451	14.50	8.26	57.0	.3372	
B	Emery	7.30	51	.1431	17.59	10.29	58.5	.3449	
C	Strong	6.39	44	.1452	14.41	8.02	55.7	.3275	
D	Bowker	6.20	37	.1675	14.04	7.84	55.8	.3795	
E	Edwards	7.62	51	.1494	17.51	9.89	56.5	.3433	
F	Harrison	6.67	46	.1450	15.00	8.33	55.5	.3261	
G	Wright	5.70	43	.1325	12.14	6.44	53.0	.2823	
H	Barnes	8.71	48	.1814	19.10	10.39	54.4	.3979	
				1.2092		69.46	446.4	2.7387	
				.1512		8.68	55.8	.3423	44.2
				Seventh Picking 21 July 1958					
A	Heath	6.01	42	.1430	13.42	7.41	55.2	.3195	
B	Emery	7.26	49	.1481	16.75	9.49	56.7	.3418	
C	Strong	7.26	49	.1481	16.22	8.96	55.2	.3310	
D	Bowker	5.95	37	.1608	14.99	9.04	60.3	.4051	
E	Edwards	7.11	47	.1512	15.95	8.84	54.4	.3394	
F	Harrison	8.25	58	.1422	18.08	9.83	54.4	.3117	
G	Wright	5.99	48	.1247	14.16	8.17	57.7	.2950	
H	Barnes	7.50	40	.1875	16.09	8.59	53.4	.4023	
				1.2056		70.33	447.3	2.7458	
				.1507		8.79	55.9	.3432	44.1
				Eighth Picking 11 August 1958					
A	Heath	6.93	47	.1474	14.82	7.89	53.2	.3153	
B	Emery	7.15	42	.1702	15.67	8.52	54.4	.3731	
C	Strong	10.74	77	.1394	23.66	12.92	54.6	.3073	
D	Bowker	7.12	42	.1695	16.07	8.95	55.7	.3826	
E	Edwards	7.37	51	.1445	15.72	8.35	53.1	.3082	
F	Harrison	7.31	47	.1555	16.03	8.72	54.4	.3411	
G	Wright	7.74	58	.1334	17.20	9.46	55.0	.2966	
H	Barnes	8.44	55	.1534	19.19	10.75	56.0	.3489	
				1.2133		75.55	436.4	2.6631	
				.1517		9.44	54.6	.3329	45.4

Letter	Grower	Dry Wt. (gms.)	Number of Leaves	Wt/leaf	Fresh Wt gms.	Fresh Wt dry Wt.	% H_2O	Fr. Wt/ leaf	Ave. % Dry Wt.
				Eighth Picking	Second Growth				
A	Heath	8.99	71	.1266	19.41	10.42	53.7	.2734	
B	Emery	8.54	70	.1220	18.92	10.38	54.9	.2703	
C	Strong	9.25	81	.1141	20.35	11.10	54.5	.2512	
D	Bowker	8.25	67	.1231	18.62	10.37	55.7	.2779	
E	Edwards	9.35	88	.1062	20.40	11.05	54.2	.2318	
F	Harrison	7.65	59	.1296	16.10	8.45	52.5	.2729	
G	Wright	6.86	58	.1182	15.67	8.81	56.2	.2702	
H	Barnes	8.34	69	.1208	18.59	10.25	55.1	.2694	
			Total	.9606		80.83	436.8	2.1171	
			Ave.	.1201		10.10	54.6	.2646	45.4
				Eigth Picking	Third Growth				
A	Heath	6.52	68	.0958	14.95	8.43	56.4	.2199	
B	Emery	6.83	66	.1034	16.31	9.48	58.1	.2471	
C	Strong	7.42	78	.0951	17.69	10.27	58.1	.2268	
D	Bowker	6.73	65	.1035	16.18	9.45	58.4	.2489	
E	Edwards		No sample						
F	Harrison	5.94	59	.1006	13.88	7.94	57.2	.2353	
G	Wright	7.00	58	.1206	17.24	10.24	59.4	.2972	
H	Barnes	6.79	58	.1170	17.07	10.28	60.2	.2943	
				.7360		66.09	407.8	1.7695	
				.1061		9.44	58.3	.2528	41.7
				Ninth Picking	4 September				
A	Heath	6.97	52	.1340	15.42	8.45	54.8	.2965	
B	Emery	11.31	72	.1570	26.22	14.91	56.9	.3642	
C	Strong	8.03	48	.1672	17.14	9.11	53.2	.3571	
D	Bowker	12.87	76	.1693	29.40	16.53	56.2	.3868	
E	Edwards	10.99	65	.1690	24.79	13.80	55.7	.3814	
F	Harrison	11.82	81	.1459	26.88	15.06	56.0	.3319	
G	Wright	10.07	67	.1502	22.50	12.43	55.2	.3358	
H	Barnes	13.03	70	.1861	28.48	15.45	54.2	.4069	
				1.2787		105.74	442.2	2.8606	
				.1598		13.22	55.3	.3576	44.7
				Tenth Picking	October 14				
A	Heath	8.09	41	.1974	17.52	9.43	53.8	.4273	
B	Emery	9.89	54	.1832	21.93	12.04	54.9	.4061	
C	Strong	8.75	50	.1749	17.51	8.76	50.0	.3502	
D	Bowker	8.99	42	.2141	18.88	9.89	52.4	.4495	
E	Edwards								
F	Harrison	8.70	48	.1812	18.20	9.50	52.2	.3792	
G	Wright	7.66	43	.1782	16.88	9.22	54.6	.3926	
H	Barnes	8.85	46	.1923	19.10	10.25	53.7	.4152	
				1.3213		69.09	371.6	2.8201	
				.1888		9.87	53.1	.40287	46.9

FRUIT

Table 26 Summary Blueberry Periodic Samples in 1958

Letter	Grower	Dry Wt. (gms.)	Number of Fruit	Dry Wt. Berry (gms.)	Fresh Wt. gms.	Fresh Wt. dry wt.	% H_2O	Fresh wt./ Berry
			First Picking	29 April 1958				
A	Heath	8.10	393	.0206	87.2	79.10	90.7	.2219
B	Emery	6.81	280	.0243	74.3	67.49	90.8	.2654
C	Strong	6.93	379	.0182	70.7	63.77	90.1	.1865
D	Bowker	6.71	247	.0271	75.3	68.59	91.0	.3049
E	Edwards	5.42	277	.0195	50.9	45.48	89.3	.1838
F	Harrison	9.30	457	.0203	99.5	90.20	90.6	.2177
H	Barnes	8.46	371	.0228	94.5	86.04	91.0	.2547
			Total	.1528		500.67	633.5	1.6349
			Ave.	.0218		71.52	90.5	.2336
			Second Picking	8 May 1958				
A	Heath	9.72	253	.0384	95.25	85.53	89.7	.3764
B	Emery	10.47	258	.0405	95.94	85.47	89.0	.3718
C	Strong	9.93	267	.0371	93.48	83.55	89.3	.3501
D	Bowker	9.03	199	.0453	83.68	74.65	89.2	.4205
E	Edwards	9.91	245	.0404	86.82	76.91	88.5	.3543
F	Harrison	10.88	282	.0385	91.50	80.62	88.1	.3244
G	Wright	8.81	230	.0383	79.04	70.23	88.8	.3436
H	Barnes	8.67	181	.0479	78.04	69.37	88.8	.4311
Ave. Wt./Berry				.3164		626.33	711.5	2.9722
				.0395		78.29	88.9	.3715
			Third Picking	19 May 1958				
A	Heath	9.08	154	.0589	66.60	57.52	86.3	.4324
B	Emery	9.07	153	.0592	65.90	56.83	86.2	.4307
C	Strong	11.02	185	.0595	76.85	65.83	85.6	.4154
D	Bowker	9.24	133	.0694	70.70	61.46	86.9	.5315
E	Edwards	10.25	152	.0674	72.02	61.77	85.7	.4738
F	Harrison	9.93	166	.0598	70.60	60.67	85.9	.4256
G	Wright	9.52	161	.0591	70.00	60.48	86.4	.4347
H	Barnes	9.20	115	.0800	67.87	58.67	86.4	.5901
				.5133		483.23	689.4	3.7342
				.0641		60.40	86.2	.4667
			Fourth Picking					
A	Heath	9.70	71	.1366	77.00	67.30	87.4	1.0845
B	Emery	9.64	76	.1268	77.45	67.81	87.5	1.0190
C	Strong	10.55	81	.1302	80.70	70.15	86.9	.9962
D	Bowker	10.15	73	.1390	79.92	69.77	87.2	1.0947
E	Edwards	11.01	86	.1280	83.15	72.14	86.7	.9668
F	Harrison	9.30	92	.1010	68.65	59.35	86.4	.7462
G	Wright	9.94	79	.1258	76.32	66.38	86.9	.9660
H	Barnes	10.20	79	.1291	76.68	66.48	86.6	.9706
				1.0165		539.38	695.6	7.8440
				.1270		67.42	87.0	.9805

Letter	Grower	Dry Wt. (gms.)	Number of Fruit	Dry Wt. Berry (gms.	Fresh Wt. gms.	Fresh Wt. dry wt.	% H_2O	Fresh Wt./ Berry
			Fifth Picking	9 June 1958				
A	Heath	9.70	110	.0881	74.32	64.62	86.9	.6756
B	Emery	9.60	120	.0800	73.60	64.00	86.9	.6133
C	Strong	9.93	113	.0878	72.10	62.17	86.2	.6381
D	Bowker	8.06	119	.0677	60.61	52.55	86.7	.5093
E	Edwards	11.77	145	.0811	82.45	70.68	85.7	.5686
F	Harrison	11.83	191	.0619	85.20	73.37	86.1	.4461
G	Wright	11.63	172	.0676	90.05	78.42	87.0	.5235
H	Barnes	9.48	113	.0838	63.10	53.62	84.9	.5584
			Total	.6189		519.43	690.4	4.5329
			Ave.	.0772		64.92	86.3	.5666

W. E. Ballinger

Table 27 Blueberry Periodoic Grand Summary (1958)

Picking No.	Days After 1st Sampling	Date	Ave. dry wt. per berry	Ave. Fresh wt.	One % D. Wt.	Ave. per cent H_2O	Plant Part
1	0	29 April	.0218	.2336	9.5	90.5	Fruit
2	9	8 May	.0395	.3715	11.1	88.9	Fruit
3	20	19 May	.0641	.4667	13.8	86.2	Fruit
4	31	30 May	.1270	.9805	13.0	87.0	Fruit
5	41	9 June	.0772	.5666	13.7	86.3	Fruit
1	0	29 April	.0544	.2084	26.4	73.7	Leaves
2	9	8 May	.0953	.3390	28.5	71.5	Leaves
3	20	19 May	.1334	.3808	35.0	65.0	Leaves
4	31	30 May	.1500	.3854	38.9	61.1	Leaves
5	41	9 June	.1668	.3287	39.2	60.8	Leaves
6	62	30 June	.1512	.3423	44.2	55.8	Leaves
7	83	21 July	.1507	.3432	44.1	55.9	Leaves
8	104	11 August	.1517	.3329	45.4	54.6	Leaves
9	128	4 Sept.	.1598	.3576	44.7	55.3	Leaves
10	164	10 October	.1888	.4029	46.9	53.1	Leaves

BLUEBERRIES - FRUIT - PERIODIC SURVEY -1958- -OCT

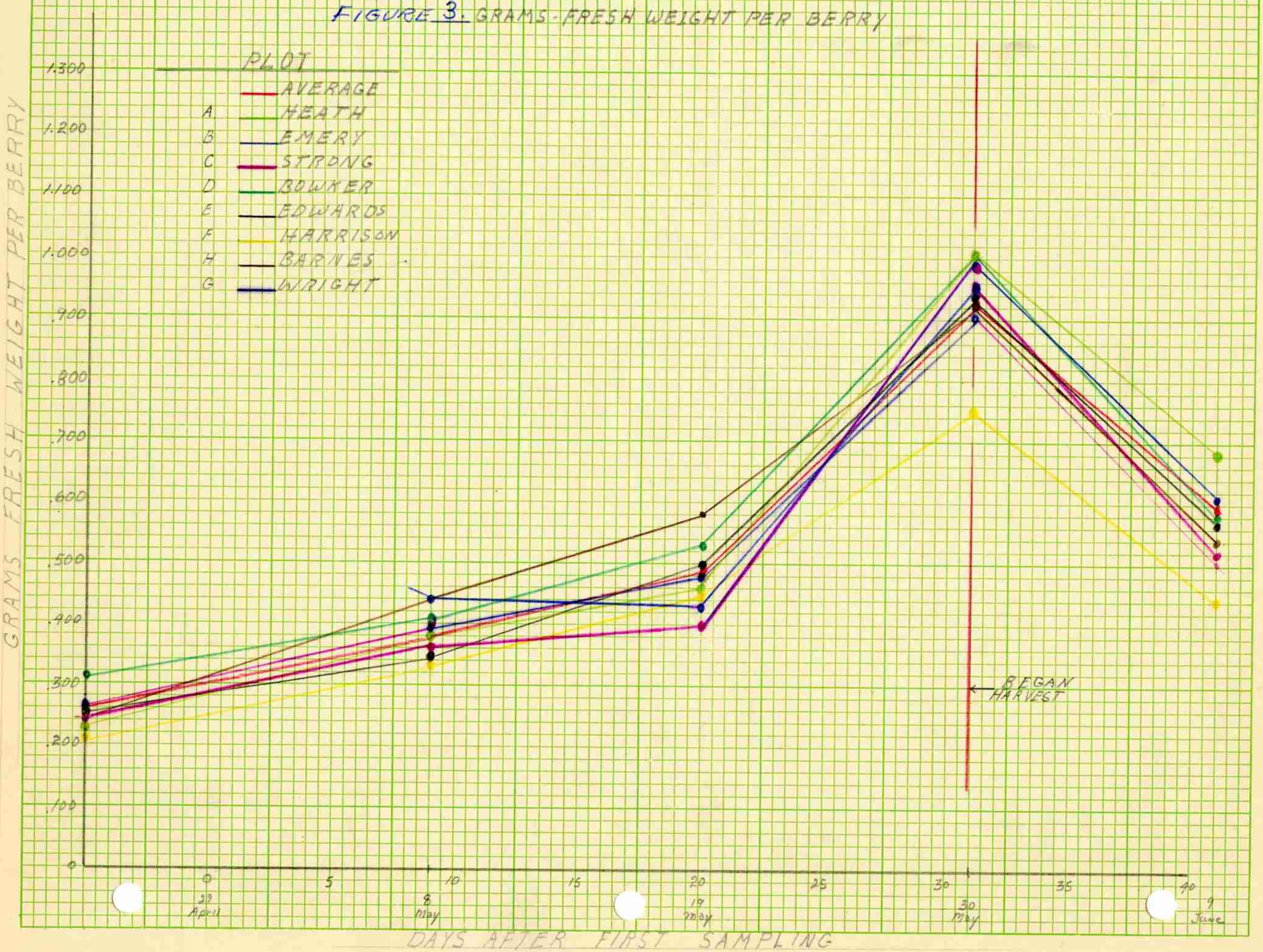


FIGURE 3. GRAMS - FRESH WEIGHT PER BERRY

latter period of development from May 19 until May 30. During this period, the slope is much greater. The percent moisture, on the contrary, decreases up to the May 19 date after which it increases slightly. This indicates that the final stage of development is not entirely due to a dry matter increase but partially a water content increase. However, these data suggest a rapid intake of, probably, organic substances during this last period. ~~is indicated~~. Analysis of the frozen berries, if time permits, may shed more light on this.

In regard~~s~~ to leaf development, Figure 4 reveals the fresh weight increased tremendously during the first 30 days of sampling. At a time corresponding to that of fruit ripening, the fresh weight of leaves dropped sharply and remained somewhat stable from the first week of June until the middle of August. Thereafter, the fresh weight increased gradually. On a percent moisture basis (see Figure 5), the water content percentage of the leaves decreased almost as rapidly during the pre-harvest period and thereafter gradually decreased up to the last date of sampling in October. Conversely, the percent dry weight increased rather rapidly before harvest and increased only slightly after June 30.

It is difficult to interpret the significance of the severe drop in leaf fresh weight beginning with the time of harvest. It may have been due to a rapid moisture or organic material movement from the leaves to the fruit, or this period may coincide with a period of higher air temperatures and a higher soil moisture stress. A review of the weather data of these production areas may be of value in clarifying this phenomenon.

When the percent nitrogen content of the leaves is plotted on a time basis (Fig. 6) it is apparent that it decreases rapidly up to harvest, levels out a little for a week and then continues to decrease at a much slower rate. The other nutrients will be thus charted when they are received so that a period of relatively little change may

BLUEBERRY LEAVES - PERIODIC SURVEY -1958- 31 OCT-'58

BLUEBERRY LEAVES - PERIODIC SURVEY -1958- 31-OCT '58

BLUEBERRY LEAVES - PERIODIC SURVEY - 1958 - 31 - OCT

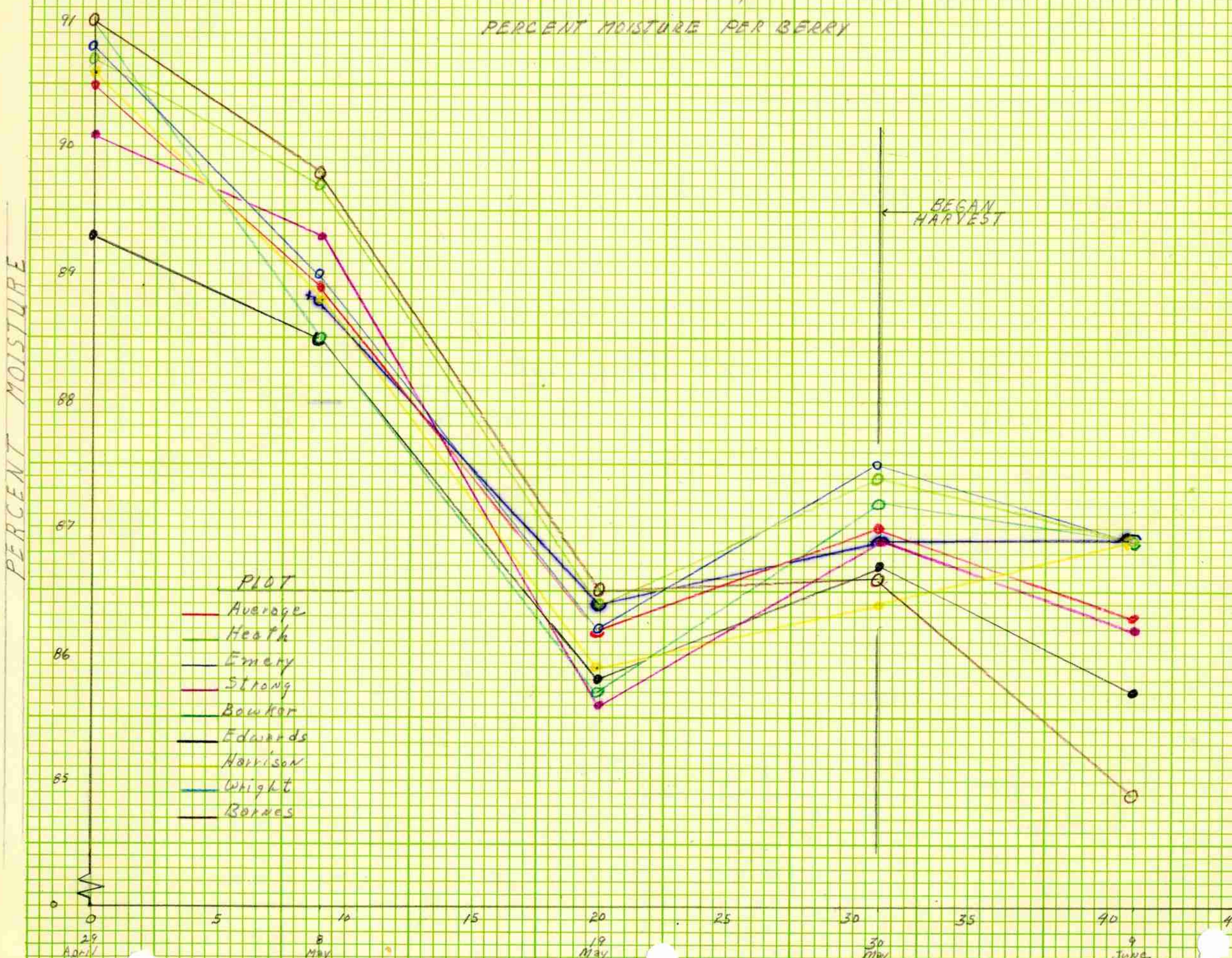
BLUEBERRY FRUIT - PERIODIC SURVEY - 1958 - 29-OCT '58

BLUEBERRY FRUIT - PERIODIC SURVEY -1958-

24-OCT-58

FIGURE 8. BLUEBERRY

PERCENT MOISTURE PER BERRY



be selected for use in further samplings. Of interest in Figure 6 is the fact that the leaf dry weight tends to increase as the percent nitrogen decreases. This indicates, perhaps, that the absolute quantity of nitrogen may remain constant during the season and chemical analyses on a percentage basis decrease due to a gradual "dilution" of the nitrogen in the dry weight component of the leaf. Figures 7 & 8 give other data.

The responses of the fruit harvested from each of the eight periodic sampling survey plots to storage for 6 days at 70°F are given in Table 28. The main point of interest is that there were tremendous differences in response among the lots of berries. This indicates that a variation must definitely exist in the various lots berries which are marketed from North Carolina. It is hoped that these differences can be measured more simply for field determinations of quality. Concurrently, it is to be hoped that the cause or causes of these differences can be clearly defined. One lead seems to be with the berry pH and total acidity. Table 28 indicates that perhaps the berry pH is directly related to keeping quality. As the berry pH increased, keeping quality as measured by percent sound berries after storage. At the same time, as total acidity decreased, the keeping quality seemed to decrease.

The leaf and fruit mineral analyses have not been completed as of this date. However, a comparison of leaf analyses for K and Ca completed in August of 1957, one season prior to the harvest of these test fruit, indicates that calcium content of leaves is not related. Potassium content, however, appears to be directly proportional to a decrease in keeping quality. These data are only of a trial basis and further studies will be needed before any definite conclusions can be attempted. Work in Michigan by Dewey and Woodruff has indicated that pH and acidity are a possible measure of degree of fruit ripeness. Therefore, results of the present study may have been influenced by this factor. Consequently, future studies should include determinations of maturity.

W. E. Ballinger 10 February 1959

Table 28. Response of various sources of Wolcott variety blueberry fruit to storage at 70°F for 6 days during the 1958 harvest season.[a]

Grower Plot	Sound Berries (%)	Leakers (%)	Berry pH (b)	Total acidity (c)	Leaf Comp. during previous season % K	% Ca
H	89.4	5.0	3.45	84.2	.55	.46
C	85.7	6.8	3.37	86.0	.45	.52
E	82.9	7.5	3.50	83.8	.60	.30
A	78.9	10.8	3.92	52.5	.55	.32
G	76.2	15.1	3.90	54.9	.64	.16
D	63.1	8.2	3.70	67.2	.50	.34
B	61.8	22.6	4.10	48.7	.83	.48
F	58.5	25.3	4.00	57.2	.79	.60

(a) Data taken in cooperation with Mr. L. Kushman

(b) pH of pulp of sound berries after storage

(c) Expressed as ml. of 0.1N NaOH required for nuetralization.

Blueberry Sand Culture Studies

A. SO_4 versus Cl content of nutrient solution study:

Reports from various states, including Michigan and New York, have indicated that the chlorine from the muriate of potash in some commercial blueberry fertilizers has injured young blueberry plants in the field. The sulfate form of potassium should be used instead. Conversely, other states, including New Jersey and North Carolina, use this muriate of potash almost exclusively in their commercial blueberry fertilizers since it is much cheaper.

Therefore, a greenhouse study was initiated in the Horticulture greenhouse in an attempt to compare the effects of the chlorine and sulfate anions on two ages of blueberry plants:(1) rooted cuttings, and (2) nursery plants (rooted cuttings which have been planted in a nursery for an additional year).

The plants were purchased from a commercial blueberry grower in early October, 1958,and immediately placed in cold storage at 35 - 40°F until early December. They were then removed, the roots washed to remove soil and organic matter, and the tops of the nursery plants were trimmed to remove all thin, weak wood. The shoot tips were cut back to remove most of the succulent growth. The plants were then planted in 10 quart plastic pails which were filled with "Lillington white sand". Medium textured sand was used for the bottom half of the pail to permit adequate drainage and the upper half, in which the roots were embedded, was filled with a more finely textured sand. This insured a higher soil moisture holding capacity which is more favorable for blueberry root growth.

The pails were placed in four benches in the experimental design illustrated in Figure 9. All plants were fed a standard complete solution consisting of 8 m.e. of NH_4, 3 of Ca, 1 of K, 2 of Mg, 4 of H_2PO_4 and 10 of SO_4 until sufficient plant growth was developed, so that the treatment solution could be initiated. On February 9, 1959, the treatments were started on the nursery plants. The

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FIGURE 9. EXPERIMENTAL DESIGN for
Blueberry SO_4-Cl Greenhouse Experiment

W = white
P = pink
B = brown

↑ N

PLANT TYPE: Nursery | PLANT TYPE: Cutting

Bench 9 — Replication 1

Nursery			Cutting		
B3 9	P2 5	B1 7	W2 2	B3 9	P2 5
P1 4	B2 8	P3 6	P3 6	B1 7	P1 4
W1 1	W2 2	W3 3	W3 3	B2 8	W1 1

Bench 8 — Replication 2

~~Nursery~~ Cutting			~~Cutting~~ Nursery		
B1 7	B2 8	W1 1	B2 8	B3 9	W2 2
W3 3	W2 2	B3 9	P2 5	B1 7	W3 3
P2 5	P3 6	P1 4	W1 1	P1 4	P3 6

Bench 7 — Replication 3

Nursery			Cutting		
B3 9	P1 4	W1 1	W3 3	B1 7	P2 5
B1 7	P3 6	W3 3	8 B2	W2 2	W1 1
P2 5	B2 8	W2 2	P3 6	B3 9	P1 4

Bench 6 — Replication 4

Cutting			Nursery		
B3 9	W1 1	W3 3	P1 4	W2 2	B1 7
P3 6	P2 5	B1 7	B2 8	P3 6	P2 5
W2 2	P1 4	B2 8	B3 9	W3 3	W1 1

plants then had from 2 to 3 bursts of shoot growth. The rooted cutting plants were fed on February 16 and thereafter.

The treatment solutions, composition of stock solutions and formulae for making the treatment solutions from the stock solutions are presented in Tables 29, 30, 31 and 32. The procedure for feeding and watering the plants is the same as that used for the strawberry experiment conducted the previous year. Incandescent lamps of 150 watts each were placed overhead with reflectors. The day photoperiod is kept at 16 hours by an electrical time clock. Day and night temperatures are maintained at 80° and 75° respectively.

This study will be continued until sufficient differential effects are apparent. At its termination, the leaves, stems and roots will be measured for length, fresh and dry weight and mineral composition (N, P, K, Ca, Mg, Cl and SO_4).

B. Nutrient-deficiency symptom study

A study was initiated at the same time as the SO_4 - Cl study in conjunction with a student, Mr. James Hicks, to determine the foliar deficiency symptoms which might appear on the Wolcott variety. The same techniques of feeding, watering, light and temperature control are being used for both studies. A copy of Mr. Hick's preliminary report is included herein. This study promises much information which will be of value in our later nutritional field and greenhouse work.

III. Literature Review

While the author was in the process of conducting an extensive literature review of blueberry nutrition, Dr. N. F. Childers of Rutgers University requested that the author compile this information together with some weed control and soil management aspects into a chapter for a textbook on "Blueberry Culture" which he is editoring. The author was pleased to do so and Dr. Childers has accepted the writing, a copy of which is included herein, for inclusion in his book which is to be published in the near future as soon as all chapter have been returned by the various authors.

W. E. Ballinger
N.C.S.C.

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Table 29. Blueberry SO_4 - Cl Expt. Solns.

Soln. no.	Na	NH_4	Ca	K	Mg	Total Cations	H_2PO_4	SO_4	Cl	Total Anions	pH	MHO'S
1	20	10	3	1	2	36	6	30	0	36	5.6	270
2	20	10	3	1	2	36	6	18	12	36	5.6	342
3	20	10	3	1	2	36	6	6	24	36	5.5	420
4	10	10	3	1	2	26	6	20	0	36	5.7	215
5	10	10	3	1	2	26	6	12	8	36	5.6	240
6	10	10	3	1	2	26	6	4	16	36	5.5	305
7	0	10	3	1	2	16	6	10	0	36	5.6	185
8	0	10	3	1	2	16	6	6	4	36	5.5	200
9	0	10	3	1	2	16	6	2	8	36	5.5	200

Note: (1) Nursery plants planted on Monday, December 8, 1958

(2) Cuttings (from storage) planted en masse, Thursday, 11 Dec. 1958

(3) Add 18 ml. of a 2.5 ppm Fe to each solution

(4) Add 9 ml. minor element mix to each solution, composition:

El.	ppm
Zn	.05
Cu	.004
B	.04
Mn	.05
Mo	.01

(5) Cuttings planted (with leaves out) 30 Dec '58

(6) Temp. feeding w/ soln #8

(7) 80°F day; 70° night

(8) 16 hr. day – 150 Watt incand. bulbs (3 ft away)

Table 30 Blueberry SO_4 - Cl Experiment 12 Dec. 1958

No. Meq. of Compounds Needed Per Liter of Solution

Soln no.	$(NH)_2SO_4$	NH_4Cl	$NH_4H_2PO_4$	K_2SO_4	KCl	$MgSO_4$	NaCl	Na_2SO_4	$CaSO_4$	$CaCl_2$	Fe Sequestrene (ppm)
1	4		6	1		2		20	3		2.5
2	4		6	1		2	9	11		3	2.5
3	4		6		1	2	20			3	2.5
4	4		6	1		2		10	3		2.5
5		4	6		1	2		10		3	2.5
6	2	2	6		1	2	10			3	2.5
7	4		6	1		2			3		2.5
8	4		6		1	2				3	2.5
9		4	6		1	2				3	2.5
Meq. Per 18 l.	72 36	72 36	108	18	18	36	360 180 162	360 198 180	54	54	
Ml. stock Needed	50 25	50 25	50	18	50	45	100 50 45	360 198 180	2700	27	18
N of Solution	1.44N	1.44N	2.16N	1.0N	0.36N	0.8N	3.6N	1.0N	0.02N	2.0N	
No. meq. per liter	26	10	54	4	5	18	39	51	9	18	
No. meq. per 18 liters	468	180	972	72	90	324	702	918	162	324	
No. meq. needed for 23 weeks of feeding (3 per week)	10,764	4140	22,356	1656	2070	7,452	16,146	21,114	3,726	7,452	
Total ml. of stock solution needed	18,000	4320	38,880	2000	3600	14,400	64,800	18,000	360	36,000	
Liters of stock solution to make up, therefore	18 l.	3 l.	18 l.	2 l.	10 l.	18 l.	5 l.	18 l.	18 l.	18 l.	

Note:

(1) Add 18 ml. of Fe (Sequestrene) solution

(2) Add 9 ml. of min. el. mix

(3) Apply 540 ml nutrient solution each feeding

12 Dec. 1958

Table 31. Blueberry SO_4 - Cl Expt.

Stock Solutions to Make Up

	N	Equiv wt.	Gms. to make 1 liter	No. Liters	Gms. Total Needed
1. $(NH_4)_2SO_4$	1.44	66.08	95.1552	18	1712.79
2. NH_4Cl	1.44	53.50	77.040	3	231.12
3. $NH_4H_2PO_4$	2.16	115.04	248.4864	18	4474.76
4. KCl	0.36	74.55	26.8380	10	268.38
5. NaCl	3.6	58.45	210.420	5	1052.10
6. $CaSO_4 \cdot 2H_2O$	0.02	~~172.18~~ 86.09	~~3.4436~~ 1.7218	18	~~60.98~~ 30.99

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Table 32. Blueberry Cl vs SO_4 Expt.

Solution Formulae (ml of stocks for 18 l)

Bottle Ltr.	Compound	Soln no. → 1	2	3	4	5	6	7	8	9
	Color Code	White #1	White #2	White #3	Pink #1	Pink #2	Pink #3	Brown #1	Brown #2	Brown #3
C	$MgSO_4$	45	45	45	45	45	45	45	45	45
E	FeNa Seq.	18	18	18	18	18	18	18	18	18
F	Min el mix	9	9	9	9	9	9	9	9	9
G	Na_2SO_4	360	198		180	180				
H	K_2SO_4	18	18		18			18		
I	$CaCl_2$		27	27		27	27		27	27
L	$CaSO_4$	2700			2700			2700		
M	$(NH_4)_2SO_4$	50	50	50	50		25	50	50	
N	KCl			50		50	50		50	50
O	NaCl		45	100			50			
P	$NH_4H_2PO_4$	50	50	50	50	50	50	50	50	50
R	NH_4Cl					50	25			50

For textbook:
BLUEBERRY CULTURE: N.F. CHILDERS, Editor

CHAPTER 6

By Walter E. Ballinger

Soil Management and Fertilization

Soil management and fertilization practices vary considerably with the species, geographic region and specific soil types within a given area. Cultural practices for the three main blueberry species produced commercially and in home gardens vary somewhat and are consequently discussed separately. Practices and factors considered under the soil management section include clean cultivation, sod culture, mulching and weed control. Nutrient requirements, deficiency symptoms, and fertilizers are discussed under the fertilization section. Omission of a species in a discussion indicates a scarcity of available information for that category.

Soil Management

Since the blueberry has naturally been adapted to soils which allow relatively shallow penetration of its roots, it is consequently a shallow rooted plant. Blueberry roots have no root hairs and thus require an open and porous soil for ease of elongation; the fine, fiborous roots cannot penetrate a firm, compact soil. (Cain and Slate, 1953). The soil must also provide a moist medium throughout the season. These factors set the blueberry apart from other fruit crops and necessitate the employment of a more precise soil management program.

Clean Cultivation

The highbush blueberry, from the time of the first large scale commercial planting at Whitesbog, N. J. has generally been grown commercially under clean cultivation. As early as 1921, Coville (1921) suggested that the soil should be tilled to keep out all competing vegetation, particularly in a young planting. Experiments in Massachusetts (Bailey and Franklin, 1935) with wild highbush blueberries indicated the occurrence of increased growth upon removal of competing vegetation.

Tillage of the soil apparently stimulates blueberry plant growth. Doehlert (1937, Bul. 625) observed that growth was checked when cultivation was discontinued in early or mid-August. Apparently, the soil became firmly packed; leaf and shoot growth slowed and the leaves turned reddish in color. He found, however, that blueberry plants would continue to grow throughout October; if cultivated continually this may be due to an increased decomposition of soil constituents and a concurrent releasal of plant nutrients. For Massachusetts, Bailey et al (1939 Bul. 358) recommended cultivation from early spring to mid-August. After that, the blueberry bushes may make growth which is susceptible to winter injury. Cultivation in early spring is advised for mixing fertilizers into the soil as well as assisting in the control of mummy berry by disturbing favorable developmental conditions for the fungus fruiting bodies in the soil. (Darrow, 1951).

Shallow cultivation is essential since, as stated previously blueberry roots are shallow and generally don't grow into the subsoil (Beckwith and Doehlert, Bul. 558 1933).

A popular misbelief at one time was that cutting of the roots at the surface made them grow deeper into the soil. However, since the depth for their development is often fixed by the depth of the topsoil layer, this merely results in a reduction of root volume. This in turn reduces the capacity of the plant to absorb fertilizer nutrients and soil moisture and restricts plant growth. Shallow cultivation is also desirable in some regions to prevent excessive aeration which greatly accelerates decomposition of organic matter in the soil (Doehlert Bul. 625, 1937). This is especially true of the more sandy soil types.

Beckwith and Doehlert (1933) thought that shallow tillage afforded by an Acme harrow was better than an ordinary one hourse shovel cultivation. To substantiate their theory, part of a two year old planting of Rancocas and Cabot varieties was tilled by the Acme harrow to a depth of 1 to 2 inches only 12 to 14 inches from the center of the row. A common cultivator was used to stir the soil 2 to 4 inches deep, 18 to 20 inches from the row center. Roots, spreading deep under the zone of tillage, were not disturbed. Yield records indicated a gain of 6 to 60 percent in yield for bushes cultivated to a depth of 2 to 4 inches as compared to those tilled to a 1 to 2 inch depth. As a result of these trials, a depth of 3 inches under the fringe of the outer branches and out was recommended; for weed control, the careful use of an Acme harrow and hand hoeing was suggested. Beckwith and Doehlert (1933) theorized that shallow cultivation left the soil below hard and packed on the outside of the root zone. Cultivation to a greater depth seemed to loosen the packed fine sand and induce a greater lateral spreading of the roots.

In general, spring toothed harrows with a close spacing of the teeth are recommended for use after the soil has been made friable and the more deeply rooted weeds have been eliminated by a small diameter disc harrow early in the spring, or, following a period of little cultivation activity. Basic requirements for a tiller have also been suggested by Doehlert (1937) as being: ". . . less than twelve inches high where it must go under the branches. The tall parts of the equipment should be more than two feet from the outer edges of teeth or discs. It must pulverize the soil enough to kill weeds and yet not deep enough to injure roots or check plant growth. It should be adjustable to the slopes of mounds".

Since blueberry roots need soil aeration, many low, poorly-drained plantings require mounding. Many growers have quickly observed that plants in poorly-drained fields grew and produced better on a mound (Doehlert, 1937). Mounds provide an island above the water-filled soil of the row centers, whereon roots may again grow in an aerated medium. The row centers of such plantings are generally cultivated deeply to control weed growth which is favored there. Mounds, however, when the roots make a mat near the surface, are difficult to be tilled and are more expensive since more weed control must be accomplished by hand. Also if mounds are used, a tilling tool that is shallow and yet conforms and adjusts itself to the varying slopes must be used (Doehlert, 1937). One such implement attaches quickly to the rear of many tractors used today in blueberry plantings. It consists of discs which have been cut by torch and decrease in diameter as they are located from row middle to the far ends of the implement.

The sowing of cover crops soon after harvest is recommended in many areas to allow for the timely hardening of the blueberry plants in the fall which decreases susceptibility to winter injury. Johnston (1951) recommended shallow cultivation throughout the harvest season, followed by the sowing of an annual cover crop such as oats, Sudan grass, or a mixture of these. A sufficient weed cover crop is also desirable if it can be produced. This practice has also been suggested for blueberry plantings in Ottawa, Canada (Eaton, 1950).

Use of a cover crop after harvest is also suggested for New Jersey blueberry fields. It increases organic matter in the soil and decreases soil erosion besides competing with the blueberry plants for nutrients and soil moisture so that the plants may be properly hardened for fall. Cover crops have not as yet been generally employed in the blueberry plantings of North Carolina.

Hoeing about and between the plants, and hand pulling of weeds are expensive and time consuming practices. However, they are necessary for best growth, particularly with young plants. Costs are reduced in some states by using a grape-hoe attachment on the tractor. Great caution must be exercised in the use of these to keep injury to the crowns of bushes near ground level to a minimum as a result of an improper setting of the tripping bars. The implement must be carefully regulated to permit only very shallow penetration into the soil under the bushes wherein the feeding roots of the plant are located. These automatic weeders are used to a greater extent in Michigan (Johnston 1951) and New Jersey (Doehlert and Marucci 1953) than in North Carolina (Carleton and Kampe 1954) where farm labor is more available.

To summarize, cultivation of highbush blueberries should be relatively shallow, must avoid root injury, control weeds, aerate the soil, aid in the control of the mummy berry fungus and generally stimulate plant vigor. This in turn tends to increase yield.

Rabbiteye blueberry bushes have been found to respond to clean cultivation (Darrow, 1957) and benefit from the elimination of competing weeds. They possess a fibrous root system which, although it penetrates more deeply into a well-drained soil than the highbush species, is nevertheless relatively shallow. The plants must consequently be cultivated accordingly. A cultivation system somewhat similar to that of the highbush may be followed.

Lowbush blueberries are produced in areas which were formerly forests and have been cut and burned. Clean cultivation is not commonly employed. Chandler (ASHS 49, 1947), however, has reported that the lowbush blueberry may be cultivated by providing cover crops and peat for inclusion into the siol. Plants selected for cultivation should spread well, be affected as little as possible by burning on a three year schedule, and produce fruit of a good character on a large number of stems.

Sod Culture

Relatively few commercial highbush blueberry plantings have been grown under sod culture. One grown in Southeastern Michigan for approximately fifteen years was observed to be as vigorous in size and growth as a planting grown adjacent to it under clean cultivation. The Kentucky bluegrass sod therein contained a thick mat of partially decomposed grassy materials which appeared to simulate a mulch in many respects. Yield records kept on ten bush plots in each of the plantings indicated that the sod planting produced at least as much fruit as the adjacent planting under clean cultivation (Ballinger, unpublished, 1956).

A distinct advantage of a well-kept blueberry planting under sod culture is the convenience afforded workers. A commercial "pick-your-own" planting near Flint, Michigan, for example, has been particularly profitable to the grower. Customers are protected from the inconveniences of walking about in a highly organic soil by the use of a sod cover. Disadvantages include difficulty in controlling mummy berry.

Johnston (1937 Q.B. 19, 4) grew plants of the Rubel variety in Michigan under sod culture in which the planting was allowed to grow up in grass and weeds. The grass cover was cut twice and allowed to remain where it fell. In 1936, a season of a long drought, the 68 plants in sod yielded only 53 quarts as compared to 156 quarts from a comparable cleanly-tilled plot. Indications as to new growth pointed to similar results for 1937. In general, Johnston suggested that on sandy soils, such as used, clean cultivation should be employed through the harvest season with subsequent cover crops to maintain the organic matter.

Mulching of Highbush Blueberries

The blueberry is naturally adapted to a lowland acid soil. Attempts to adopt it to drier soils of a lower acidity has necessitated the employment of practices to maintain constant soil moisture contents near the surface of the soil together with practices which would tend to increase soil acidity. The use of mulches has been one of the more successful practices. Annual mulching has been found to: reduce weed growth, keep soil temperatures lower in summer, help retain uniform soil moisture as well as moisture near the surface, maintain better soil structure, prevent heaving of the soil with its concurrent root injury, control soil erosion, and reduce the costs of cultivation (Darrow, et al, 1951, and Shoemaker, 1955).

Highbush blueberry performance was found to be improved in 1936 by Clark at New Brunswick, N. J. Plants grown on an upland soil previously under clean cultivation were mulched with salt, hay, leaves, straw and sudan grass. Thereafter, Clark found less weed growth and no need for cultivation, which had previously caused severe root injury. The elimination of this root damage may have been one of the factors responsible for the resultant improvement in performance. The hay mulch was particularly beneficial on this soil which was naturally unsuited for blueberry production.

Kramer, et al (1941) studied the effects of several mulches, cover crops and fertilizer treatments on the survival and yield of young transplants and as a means of providing maximum protection against soil erosion for both highbush and dryland (Vaccinimum Vacillans) blueberry plantings. The soil was an acid loam located at Beltsville, Maryland. All mulching materials increased plant survival with the exception of oak leaf mulch. The acidity of the soil was not affected very greatly by treatment of mulch or fertilizer. Soil moisture under all mulches was about double that under clean cultivation. Of particular note was the fact that lateral root growth and spread in peat mulch was much greater than that under clean cultivation. This greater root spread was associated with a reduction of soil erosion and a doubling of the yield. The trenching of peat alongside the root gave improved survival and yield, whereas the use of a lespedeza cover crop reduced yields greatly. As a result of this experiment, Kramer, et al (1941) recommended the placement of organic matter in the hole when planting; one should allow the plants to become established, and then apply a peat mulch and a complete fertilizer.

Slate and Collison (1942) found mulching to be an excellent method of soil management in some blueberry plantings. They grew plants under hardwood sawdust at the New York station on a dry knoll of a sandy loam hill. Those plants grown under sawdust mulch were much better than those under clean cultivation. Sawdust seemed to be a most desirable mulching material for blueberries; therefore, the mulching of relatively dry soils in commercial plantings, if the material is available, was suggested.

Chandler and Mason (1942) studied the effects of mulching and clean cultivation on three soils in Maine, e.g. a sandy loam, a clay loam, and a very sandy soil. At the conclusion of the study, the mulched plots were found to contain more soil moisture than the clean cultivated plots at both the 6 and 12 inch depths. They concluded that mulching maintained a lower soil moisture, but increased the growth in clay loam soils, reduced the growth of blueberry plants in the sandy soils.

Savage and Darrow (1942) reported that mulching in one form or another was necessary for successful highbush growth under existing conditions of high temperature and frequent deficiencies of soil moisture in northern Georgia. On a Clarksville gravelly loam, sawdust was by far the best mulch tested due to its greater capacity for reducing surface runoff and its effect on the retention of soil moisture; it is relatively cheap and available in the Southeast. The use of loose materials, such as rye straw and oak leaves, was better than clean cultivation, but not quite as effective as the sawdust. Comparing the treatments on a combined plant growth and survival basis, the mulched materials were rated as follows: 100 for sawdust, 54 for oak leaf, 41 for rye straw and 0 for clean cultivation.

Doehlert, Griggs and Rollins (1947) planted highbush blueberry bushes of three varieties, half in a medium of soil mixed with one-half bushel peat moss, and the others in the plain Gloucester type soil (a hill-land soil of light to medium textured, moderately drained, glacial till). In the fall of the first season, three systems were initiated: clean cultivation, sawdust mulch, and hay mulch. After 5 years of growth, analyses indicated that the phosphorus content increased in the soil under all treatments. Potassium and magnesium were little affected, but nitrates increased under clean cultivation and hay mulch. Conversely, nitrates decreased but ammonia increased under sawdust. Little difference in moisture equivalent or organic matter content of the variously treated soils was found. The fact that plants grown with a sawdust mulch yielded more than 6 pints more than those with hay mulch and 8 pints more than those under clean cultivation was particularly noteworthy.

As regards the convenience to the people who worked on the pruning, harvesting and weed control, in these plots, a sawdust mulch was more desirable as a soil cover than clean cultivation or hay mulch. Sawdust was also associated with a greater linear shoot growth. No differences in plant survival occurred as regards the soil management type. However, greater yields were produced on bushes planted in the peat soil mixture, regardless of soil surface treatment.

Griggs and Rollins (1948) harvested fruit from the same bushes used for the soil management experiments above and analyzed for ascorbic acid and moisture content. These constituents were found to be related to neither the variety nor the soil management type. However, some later pickings suggested that variations in ascorbic acid content may have been associated with temperature variations prior to harvest.

Christopher and Shutak (1947) grew Pioneer highbush blueberries on a Narragansett loam in Rhode Island. The four soil management programs consisted of (1) clean cultivation with a cover crop of buckwheat sowed about the first of August; (2) mulch of straw and hay; (3) mulch of sawdust, and (4) clean cultivation. Yields from the sawdust plots were doubled as compared to clean cultivation or clean cultivation plus a cover crop. However, a severe infestation of quack grass in the clean cultivated plots may have reduced the yield therein.

Shutak, et al (1949) later found that the straw mulch was related to higher soil moisture contents than sawdust; clean cultivation was associated with the least soil moisture. Mulches reduced soil temperature fluctuations while clean clutivation allowed a rapid fluctuation of soil temperatures, which often approximated the air temperature after a short lag. Soil acidity was slightly lower under sawdust than in clean cultivation.

Shutak and Christopher (1952) felt that reports on mulching blueberries up to that time were limited and contradictory. Consequently, in a later work, they reported that sawdust mulches consistently gave higher yields. Clean cultivation alone gave the lowest yield. The size of the berries was generally larger on the sawdust mulch plots but there was a slight delay in ripening. However, due to a greater total yield, from the muchled plots more berries were available earlier. The size of bush and yield were found to be related; bushes under sawdust mulch were largest.

Softwood sawdust was better for new growth than hardwood sawdust. Hardwood sawdust was initially finer and apparently packed too firmly. It also broke down sooner than softwood, which undoubtedly incluenced the aeration of the soil. Cultural practices did not affect soil organic carbon or total nitrogen content.

Soil temperature early in the season was lower under these mulches but the differential decreased as the season progressed. In the fall, the reverse was true since soil temperatures were lower under clean cultivation than under sawdust mulch. Mulching reduced soil temperature fluctuations to 2 percent under mulch; temperature under clean cultivated soil fluctuated 12 percent while air temperature varied 40 percent. Soil moisture was highest under sawdust mulch and lowest under clean cultivation. Root growth under the mulches was heavily fibrous. Roots grew within the sawdust mulch, but only on the surface of the soil beneather the straw; clean cultivation was associated with a very poor root development.

Boller (1956) found that sawdust mulches settled 3/4 inch per year and required annual maintenance, depending upon the specific rate of decomposition. He also reported that mulches of fir sawdust eliminated the cost of cultivation and improved the growth of blueberries on many soils not ideal for growing blueberries. Boller reported ". . . the poorer the soil, the greater the benefit". Most weeds except morning glory and Canadian thistle are eliminated by mulching; those established can be easily pulled, hoed or sprayed.

The Rabbiteye blueberry responds well to mulching, according to Darrow (1957). Very little data for this species, however is available. Lowbush blueberry plantings, declining in vigor and production, may possibly have their soil fertility restored by the application of mulches of peat, sawdust and hay. However, Trevett (1956) reported that the mulches may be hard to stabilize on the surface and, in addition, difficult to obtain. Once the mulch has been applied, commercial fertilizers would be needed to force new blueberry stems up through the thick mulch layer.

Home garden blueberries, since they are generally grown on upland soil which has been heavily limed for general vegetable and flower production, will almost always respond to a mulch of sawdust, garden peat, or other available materials. Planted in conjunction with large applications of peat mixed with the soil before planting, they often produce blueberries in soils otherwise unsuited for this crop. The material should be applied and maintained annually to a depth of 6 to 8 inches. More fertilizer, particularly ammonium nitrogen, must be applied than is normally recommended for blueberries to permit microbial action and decomposition to commence without a concurrent competition with the blueberry plant itself for the available nitrogen.

Disadvantages of mulching blueberries are many. Primarily, the mulching materials are generally difficult to obtain (Bailey, et al 1939). When dry, they constitute a fire hazard. Some mulches increase mice injury damages, and others, especially leguminous hays, may sometimes be harmful; they should first be tested on a small scale. Finally, the hauling and spreading of the tremendous quantities of mulching material needed per acre may comprise an outstanding expense unless efficient methods are used (Shoemaker, 1955).

More nitrogen fertilizer for good growth must beused when mulches of leaves, sawdust hay or straw are used. As an example, for clean cultivation, only 110 pounds of ammonium sulfate are necessary. With mulches, two applications of 300 pounds each, 6 weeks apart, are often necessary.

Commercially, only relatively small areas have been mulched in New England, New Jersey, Ohio, North Carolina and Northern Georgia with favorable results thus far. However, as the demand for blueberry fruit in the country grows (the acreage of blueberries in the United States has long been said to be doubling every six years) lands ideally suited for blueberry production will become increasingly more difficult to obtain. Consequently, out of necessity, the trend must be toward the use of less ideally suited lands wherein the use of special soil management practices such as mulching will be required.

Methods and Materials for Mulching

Sawdust is the best mulching material if available. Softwood sawdust is favored over hardwood due to its more coarse structure and resistance to decomposition. Other materials such as horticultural or garden peat, straw, oak leaves and mowed annual weeds have been used. Care must be exercised in the use of leguminous hay since it may often be injurious.

Recommendations for thickness of application range from 2 to 4 inches or up to 6 to 9 inches in a solid mat. A 6 to 8 inch sawdust mulch will effectively control most weeds. Some investigators, however, believe that only 3 to 6 inches of mulch need be maintained. The amount of mulch to be added yearly depends upon the rate of decomposition. A one inch renewal layer has been found sufficient under various conditions.

To reduce costs, strip mulching has been advocated. A 3 to 4 foot strip, centered on each row, is suggested in Washington. Weed killers or cultivation may be used to control weeds in the unmulched row centers.

Weed Control

Lowbush blueberries

Lowbush blueberry plants may persist on forest floors under conditions of low light but seldom fruit under such conditions. Chandler and Mason (1946), as a result of tests, found that more than 80 percent full sunlight is required every year for the production of fruit buds and large yields. The clearing of the trees and brush from a forest is generally followed by a multiplying of scattered "ghost" blueberry plants, due to more favorable conditions of light and other growth factors. However, this land be burned occasionally to prevent growth of brush into woodland, which would again crowd and shade out the blueberries (Smith, 1946). The land is generally burned every two or three years to stimulate new shoot growth and eliminate many weed plants which will not tolerate burnings. However, many other weed plants are not eliminated and must consequently be controlled by some other means. This is one of the most difficult problems with which a blueberry grower must contend.

Control of weeds in blueberry fields is different than in cultivated fields. A blueberry weed may be classified as any plant other than blueberries themselves. Chandler and Mason (1946) classified blueberry weeds according to their effect on the blueberry industry. The first category consisted of ". . . plants which have fleshy fruits that may be harvested with the blueberries and are an adulteration in the pack, such as bunchberry, sugar-pear, huckleberry, wintergreens, bearberry, mountain cranberry, rose and chokeberry".; and second, ". . . weeds which have wind borne seeds such as spreading dogbone, goldenrod, fireweed, milkweed, orange and yellow hawkweeds, kind devilweed, wild fall astor and willows". The third category consisted of ". . . weeds which form dense masses and crowd out the blueberry plants, such as bush honeysuckle, sheep-laurel, bunchberry, and wintergreen". A fourth category included woody weeds normally occupying newly cleared land, such as older, birch, sweet-fern, willow, hazel, and sprouting oak. The last category included weeds which blossom when insecticides are applied to the blueberries, thus poisoning bees.

Chandler and Mason (1946) reported that the type of soil and its fertility greater influence the kinds of weeds found in a blueberry field. In the blueberry "barrens", lder, birch, sheep-laurel and sweet-fern, (but not bunch grass and poverty grass) are prevalent. In old fields, however, grass is more abundant and is generally accompanied by cinquefoil. Cutover woodlands have the blueberries shaded by older, poplar, birch, bayberry and scrub oak. Old pastures contain weeds found in both fields and cutover woodland.

Eaton (1950) reported the following weeds as being common in blueberry plantings: Common brake or bracken (Pteris species L.), sheep laurel or lambkill (Kalmia angustifolia L.), bayberry (Murica colinensis Mill.), sweet gale (Myrica gale L.), wild spirea, hardhack, or meadow sweet (Spirea latifolia Borlch) and wild roe or briar (Rosa blanda Ait.).

Disadvantages of weeds are many. Among the more important are the harboring of disease and insects and the fact that they do not allow the application of fertilizers in quantities necessary to increase bush growth and yield. Over fertilization can easily overstimulate weed growth resulting in a crowding and shading of the blueberry bushes (Chandler and Mason, 1946).

An ideal way to control weeds in blueberry fields, according to Trevett (1952) would allow the following attributes: would not interfere with regular cropping, would be harmless to blueberry plants, could be used any time of the year, would not require a large outlay of cash for equipment, and would be inexpensive which would more than compensate for any expenses involved.

Weed control practices fall into three general classes: mechanical means such as handpulling and mowing, burning, and chemical treatment with herbicides (Trevett, 1952). Smith (1946) recommended burning eliminates many weed plants. Those not controlled by burning can only be reduced by cutting. None of the chemical weed killers are recommended in New Hampshire so far since they also injure the blueberry plants. Smith (1946) suggested that cutting leafy plants in July hinders their development and after 2 to 3 years of cutting, they are eradicated.

Eaton (1950) recommended annual mowing in July, August, and September for the control of sweet-fern in Yarmouth, Nova Scotia. For many other plants, which resemble blueberries in their growing requirements, only mid-summer mowing to slow their spread was suggested until proven control measures can be offered.

Trevett (1952) reported in some detail on the control of woody weeds in the lowbush blueberry fields of Maine. Except for Brake fern, mowing was not recommended as a primary weed control practice. It may be usefully employed in July, however, after the application of chemical herbicides, to cut the 10 percent of the weeds which recovered from the treatment. Hand pulling is economically justifiable only for removing misses following other less costly weed control practices. Fall or spring burning does not control most weeds. For evergreen types, however, fall burning has some possibilities.

Chemical treatments appeared to be the most efficient (Trevett, 1952) and acceptable means for woody weed control. They should be applied with extreme caution, however, since they are usually not selective and will blueberry plants as well. If used with care, only a minor amount of damage may occur to the blueberry plants.

The basic herbicides recommended by Trevett (1952) were 2, 4, D; 2, 4, 5 T, and Ammate. These are plant hormones which become systemic in a plant and kill both roots as well as tops. The 2, 4 D comes as a powder (Sodium salt) or as a liquid (amines and esters). The 2, 4, 5-T may be acquired only in the liquid form (amines and esters). A mixture of 2, 4 D and 2, 4, 5 T is sold under the trade name "Brush Killers".

Ammate is composed of 80 percent ammonium sulfamate and comes as a powder. It is effective against more kinds of weeds than either of the two above. Blueberry plants are more easily damaged by it, however, and it is hard on spray equipment due to its ability to corrode.

Foliar Application of Weed Killers

There are two methods of chemical weed control. The first of these is foliar treatment. It must be applied to the plant only when the plant is in leaf and is thereby limited to the growing season (Trevett, 1952). The other, stub treatment, in which the herbicide is applied after mowing; it can be applied throughout the year and gives better control of some weeds.

Folier applications of chemicals may be made in several ways. First, the entire field or area may be covered rapidly and economically using a power spray rig, using a 2, 4 D type weed killer. Its use, however, is only for thick and extensive growths of two or more year old Sweet fern and Bayberry. Under these conditions the spray wets only the protective umbrella of bushy-topped weeds; thereby, most of the spray is kept off the lower layer of blueberry plants. Area spraying is generally limited to relatively new fields.

Spot spraying is an alternative to area spraying and enjoys a more widespread acceptance. A hand sprayer is used to apply the herbicide to individual clumps of weeds during summer months (Trevett, 1952). A hand boom with a single nozzle of a garden type knapsack sprayer or a power sprayer is used to limit the spray to the weed clumps and minimize contact with the blueberry bushes. This method is useful to control alder, willow, birch, maple and other clump weeds.

A disadvantage of sprays for weed control is that the wind may cause the herbicide to drift to nearby blueberry plants. An alternative practice, which reduces the effects of wind, is the brush method. A film of an herbicide solution is deposited on the leaves of susceptible weeds using a large, 8 ~~to 12~~ inch wide brush, ~~wrapped with an absorbent~~ cloth. A large brush (8 to 12 inches wide), wrapped in an absorbent cloth, is dipped in the weed killer solution and applied from the base of the weed upward with jabbing or sawing strokes. Both sides of the leaves and stem are thus thorougly covered.

The glove method is a good substitute over hand pulling of sweet fern. A cotton glove, worn over a rubber glove, is kept moist by dipping in a pail of weed killer. Weeds are grasped as closely to the blueberry bush as possible and the glove is then pulled lightly upward thus wetting the weed. Herbicide must not be allowed to drip on the blueberry plants.

Stub treatment with weed killers

Spraying stubs of woody weeds after mowing is an effective means of controlling woody weeds at any time of the year. It reduces the resprouting of weeds such as birch, alder, and Red-maple, which send shoots only from the clump. Less resprouting of treated clumps occurs if the ground is not frozen at the time of the treatment. Stub treatments are less effective on plants such as poplar which send shoots up from roots at a distance from the clump.

A very concentrated spray solution is used. Therefore, caution must be exercised during placement. The use of a protective "shoe" on the end of the spray wand and the use of low spray pressures are effective means of reducing spray splattering which might contact blueberry plants.

Toxic vapors are given off by the esters of 2, 4 D and 2, 4, 5 T used for stub treatments. Injury to blueberry stems three to four inchesaway from treated stubs been observed. Therefore, it is best to use these when the blueberry plants are not in leaf. Ammate is not volatile.

The contact method for foliar applications of chemical weed killers is mainly used for weeds such as poplar. A blanketing material on a wooden frame moistened with weed killer solution, is dragged across the tops of weeds and as far down as possible without touching the blueberry plant tops which are below the layer are being covered.

Classification of Weeds and General Recommendations for Chemical Weed Control (Trevett, 1953)

The more common weeds can be grouped into three classes on the basis of ease of killing with 2, 4 D. Trevett (1953) classification is presented in Table 1. Weeds under Class I are susceptible to 2, 4 D and may be killed by one foliar application of a 2000 parts water solution of 2, 4 D acid from amine formulations. These weeds may also be controlled by stub treatments using four pounds of 2, 4 D acid or four pounds of total acids from a mixture of 2, 4 D and 2, 4, 5 T ester formulations per 100 gallons of kerosene or fuel oil.

Class II weeds are moderately resistant to 2, 4 D and may probably be killed by repeated applications of a 4000 parts per million water solution of total acids from a mixture of 2, 4 D and 2, 4, 5 T amine formulations.

Class III weeds are very resistant to 2, 4 D. They may or may not react to 2, 4 D and a kill is not probable after several applications. For control of these weeds, a

4000 parts per million water solution of 2, 4, 5 T acid from amine formulations may be applied. For Red maple, one pound of Ammate per gallon of water with a sticking agent (Du Pont "Sticker-Spreader and Triton B 1956" are examples) may be used.

The costs of weed control are difficult to calculate (Chandler and Mason, 1946), due to variation in weed sizes, kinds and numbers present in a given field. Woody shrubs have to be sawed or cut; herbaceous weeds need only chemical sprays. The costs for chemical sprays, strange as it seems, was found to be much higher than hand cutting. Chandler and Mason (1946) reported that costs in Maine in 1946 ranged from 50 cents an acre to 50 dollars an acre depending upon the method used for control and the number and kinds of weeds encountered.

Highbush blueberries

The normal means of weed control in most highbush blueberry plantings are still the hoe and cultivator used in clean cultivation. The use of a mulching system reduces the need for weed control but nevertheless requires a constant battle to prevent weeds from becoming too firmly established.

The possibility of chemical weed control in highbush plantings has been demonstrated (Hill, 1958). Swartz and Myhre (1954) recommended that a mixture of 1 1/2 quarts of Dinitro Weed Killer, 30 gallons of Diesel oil, and 70 gallons of water be applied in Washington State during late fall. In Delaware, Hitz and Amling (1952) reported that

C. M. U. (3-p-Chlorophenyl-1, 1-dimethylurea) at 1 and 2 pounds per acre gave adequate weed control with only two sprays during the growing season.

Applications of Simagin in North Carolina have shown promise. In Massachusetts, Monwron (C.M.U.) was found to be too potent for safe use on all varieties of blueberries. Diwron, which is less soluble, but almost as effective, has been found to give good control of annual weeds when applied as a pre-emergence spray. The Food and Drugs Administration has recently granted a label for use of Diwron in New Jersey and Massachusetts blueberry plantings (Bailey, 1958).

Hill (1958) reported excellent results when Karmex DW and amino triazole were used. With small fruits, chemical weed control should be used as a means of preventing rather than overcoming the weed problem (Hill, 1958).

Trevett and Murphy (1958) suggested the use of Premerge and Sinox PE weed control in cultivated highbush blueberry plantings. It is for control of annual weeds only. Apply at the rate of 1.5 to 2 gallons per acre in early summer or as weeds appear. New blueberry shoots will be injured if sprayed. Therefore, apply well beneath the foliage of the blueberry plant.

Fertilization

The blueberry plant must make strong vigorous growth to be fruitful each year. This necessitates the manipulation of favorable cultural practices including fertilization.

Berry size and other responses have been related to the vigor of shoot growth as expressed by size (Shutak, et al, 1957). Bailey (1939) has stated that ". . . since success with blueberries depends on growing large berries, the plants must be kept highly vigorous. The need for strong growth is all the greater because of the severe pruning required. A fertile soil is therefore important. Some blueberry soils are naturally sufficiently fertile and contain adequate proportions of organic matter and nitrogen. Others are no longer fertile, particularly the lighter mineral soils which have been long cropped, and require replacement of the depleted nitrogen to duplicate this natural fertility. Nitrogen applications, therefore, have been found to provide the greatest response to fertilization of blueberries.

Since blueberry production is relatively an infant in comparison to the long-term establishment of other fruit industries, comparatively little investigative work has been empirically accumulated on its fertilization. The larger fraction of that accomplished has been on the highbush blueberry species.

Nutrient requirements and Deficiency Symptoms

Nutrition studies in the greenhouse

Sand culture experiments with rooted cuttings of the Rubel highbush blueberry were conducted by Doehlert and Shive (1936) using a four salt nutrient solution in which the salts were varied while the osmotic concentration was held constant. The most favorable solutions for growth and yield were high in nitrogen and low in phosphorus and potassium. Nitrates appeared to be superior to ammonium nitrogen. However, the solutions became more acid, indicating greater cation than anion uptake. The three best solutions from a growth and yield standpoint contained 40 percent of the nitrogen in the ammonium sulfate form. Several of the plants made excellent growth and yielded crops comparable to those in the field. Manganese and boron deficiency symptoms were obtained in a relatively short time, on plants grown in solutions deficient in these elements indicating the sensitivity of this crop to these two trace elements.

Kramer and Schrader (1942) grew the Cabot highbush blueberry in sand culture in the greenhouse to study the effects of nutrient solutions deficient in a given element, and the effect of rooting media on growth. Plant growth was excellent in sand but even better in sand with a layer of peat above it. Nutrient deficiency symptoms appeared on plants grown in straight sand culture but often did not appear as quickly when a layer of peat was placed on the sand.

Peat on sand cultures as compared to sand alone were conducive to far better growth of plants in all treatments except those deficient in potassium. If one considers the sand alone as a poor sandy soil in the field, this experiment suggests that the order in which elements may become deficient in blueberry plantings will be: nitrogen, phosphorus, sulfur, boron, calcium, potassium, iron, mangesium and lastly, manganese. If one assumes that peat on sand is similar to a field soil, then the order of appearance of nutrient element deficiency symptoms on blueberries appears to be: nitrogen, potassium, phosphorus, magnesium, boron, calcium, sulfur, iron and manganese. Peat apparently contained available sulfur, calcium, iron and boron since plants not supplied these elements grew normally in sand under peat.

The omission of nitrogen was associated with rapidity of terminal growing-point abortion. The first deficiency symptom of nitrogen on the leaves appeared as a uniform yellowing of the entire leaf followed by a reddening and dying. Older leaves were affected first. All leaves were affected eventually however, and the plant was severely stunted.

Potassium deficiency symptoms were characterized by marginal scorching and the appearance of necrotic spots covering the leaves occurred first on older leaves. Interveinal chlorosis later appeared on new growth from auxillary buds.

Sulfur deficiency symptoms were similar to the early stages of nitrogen deficiency. A bleached yellowing of the younger leaves occurred, which later turned pink. The older leaves maintained their green color.

Calcium deficiency symptoms appeared as an interveinal chlorosis with the green regions adjacent to the veins remaining more narrow than in the case of potassium deficiency. Symptoms first appeared on younger growth. Calcium and sulfur symptoms in later stages were similar.

A lack of boron produced deficiency symptoms which appeared abruptly, first as a bluish coloring on growing points and later as a chlorotic spotting on leaves subjacent to the shoot terminals. Severe cases were exemplified by blotched and misshapen leaves.

Magnesium deficiency was noted as a uniform chlorosis of leaf margins; the leaf area near the midrib of the leaf remained green. In later stages, the chlorotic areas became red and necrotic. Older leaves were affected first.

Phosphorus deficiency symptoms were characterized by a slight purpling of the leaves and stems. Color was dull compared to the normal green leaf color.

Iron deficiency symptoms appeared first on the younger leaves as an interveinal chlorosis, decidedly similar, but less severe than potassium deficiency symptoms on younger leaves. In general, the interveinal chlorosis of leaves deficient in iron, potassium, and calcium were somewhat similar, suggesting a common maladjustment of the leaf processes by any or all of these three elements.

Manganese deficiency symptoms were not apparent during the period of experimentation. The manganese deficient cultures were continued until it appeared that a lack of manganese resulted in a breakdown of the auxillary buds.

Rabbieteye blueberry deficiency symptoms were produced by Minton, et al (1951) using plants grown in crocks of quartz sand. Deficiency symptoms were very similar to those of

Kramer and Schrader (1942) for the highbush blueberry but were sufficiently different to justify their inclusion herein.

Nitrogen deficiency symptoms were noticeable 40 days after initiation of differential treatment. Leaves were smaller, turned yellow and reddish, and exhibited small necrotic pinhead spots in later stages. Plants were stunted.

Sulfur deficiency was noted after 65 days which developed from a chlorosis of the leaves to a mottled and completely bleached appearance. Affected leaves were only of medium size and plant growth was reduced.

Potassium deficiency symptoms appeared after 70 days, and first appeared as an interveinal chlorosis of young leaves; later complete leaf surfaces were blanketed with pinhead spots which developed into a severe necrosis. Marginal scorching with rolling appeared during more advanced stages.

Magnesium deficiency was characterized after 75 days as a distinct redding interveinally followed by an upward cupping of older leaves. The affected leaves were smaller and later dropped, leaving the basal areas of shoots bare. Poor growth resulted.

Phosphorus deficiency symptoms appeared after 90 days as a darker green color on leaves which were smaller than normal.

Calcium deficiency, after 90 days, was observed as a scorching of both old and new leaves which cupped upward. The leaves and plant growth were of moderate size.

Deficiency symptoms in the field

Iron. Highbush blueberry plantings on many marginal, less acid and drier soils have long been observed to exhibit a yellowing or interveinal chlorosis of the leaves. Bailey (1936) observed that many leaves on several varieties in a planting in Massachusetts were turning reddish-brown interveinally while the veins remained green. As the symptoms became more severe, the leaves turned yellow interveinally; later the entire leaf surface turned yellow.

In advanced cases, new basal shoot leaves were stunted and both leaves and shoots were yellow. Generally, the tip leaves showed the symptoms first. Bailey observed that the symptoms occurred mostly on plants whose soil had a low organic matter and was quite dry. No relationship was obvious between soil pH and chlorosis. Several trial treatments were made using manganese sulfate, sodium nitrate, ammonium sulfate, ferrous sulfate, German peat placed in trenches, a complete fertilizer, magnesium sulfate and zinc sulfate. Only the plants treated with ammonium sulfate showed signs of alleviation at the time of Bailey's first report in 1936.

Bailey and Everson made another report in 1937 on these trials. The greatest recovery was from the ammonium sulfate. A month was required for the re-greening of leaves sprayed with ferrous sulfate solution; recovery was temporary, however. Manganese sulfate treatments proved toxic. The difficulty was assumed to be a lack of iron since the ferrous sulfate spray affected the reappearance of green color only in spots where the spray contacted the leaves. Color did not spread from these spots. Additional confirmation was obtained from soil analyses wherein the amounts of ferric and ferrous iron in the topsoil and subsoil of chlorotic plants was approximately one-third that of the soil of healthy plants.

To further substantiate the diagnosis, blueberry plants were grown in crocks which had from 5 to 40 grams of lime added. Chlorosis appeared on all lime treated plants, increasing in severity as the quantities of applied lime increased. Perhaps this was due to an increase in pH of limed soils from pH 4.2 to 6.4 which decreased iron solubility. Ferric citrate crystals placed in a slit in the stem of one plant caused the chlorotic leaves above and below this point to turn green. Therefore, Bailey and Everson (1937) concluded that an iron deficiency was causing the chlorosis.

Kramer and Schroeder (1945) theorized that frequent reports of iron deficiency in plants may be explained by the action of amphoteric proteins in blueberry leaves as cations. This, they claimed, may explain the differential absorption of anions. If anion radicals are absorbed in excess, it may be difficult to keep iron in the blueberry plant in the reduced available form. Along these lines, Lindner and Harley (1944) studied the lime induced chlorosis of pear, apple, peach and cherry trees growing on highly limed soils. The iron content was found to be no lower in chlorotic than in green leaves. They theorized that excessive potassium absorbed from high-lime soils may be the cause and not the result of iron chlorosis. The potassium in the plant may displace iron from enzymes involved in chlorophyll formation.

Cain (1952), conducting a number of small-scale experiments to study nutritional requirements of the blueberry plant, corrected a marked yellowing of young foliage on blueberry plants grown with a high calcium nutrient solution in sand culture. Additions of iron tartrate to this culture temporarily corrected the chlorosis. Later, addition of ammonium nitrogen to this previously ammonium-free culture caused the chlorosis to disappear for the remainder of the season. Analysis of the foliage revealed that the foliar nitrogen and iron content varied with the ammonium nitrogen supply in the culture solution. Data indicated that: "Iron deficiency symptoms (chlorosis) are not necessarily related to soil pH, calcium content, or the iron content of the foliage, since the healthiest plants had more calcium and sometimes less iron than those showing acute chlorosis and making very poor growth, . . .". In addition, ammonium nitrogen was thought to be superior to nitrates for growth of blueberries, and may be involved in the internal iron nutrition of the plant. Therefore, one of the factors for poor blueberry growth and foliar yellowing on marginal soils may be a lack of ammonium nitrogen, i. e., chlorosis may be associated with a preponderance of nitrates in the soil.

Later, Cain and Holley (1955), in further studies of the effect of nitrogen metabolism upon chlorosis of blueberry leaves, compared chlorotic and green blueberry leaf tissue with respect to free amino acid and basic cation contents. Amino acids, especially arginine, were found to increase tremendously with chlorosis. On a leaf basis, green leaf tissue showed greater dry weight and basic cations in green leaf tissue. Cain and Holley stated that a detailed interpretation of these relationships awaits further research.

Wynd and Bowden (1951) found that chlorotic blueberry bushes near Athens, Georgia, responded to a very insoluble iron containing glossy frit. Rabbiteye blueberries were grown on a Cecil clay loam with a topsoil pH of 5.2. These five year old plants had previously been sprayed with ferrous sulfate sprays of one pound per 25 gallons water; leaf color was improved subsequently but the effect didn't last and was costly to apply periodically as a means of continually supplying iron.

Consequently, a finely powdered glossy fruit containing 5 percent ferric oxide was applied at the rate of five pounds per bush and mixed well in the upper 12 inches of the soil. After 194 to 445 days, complete recovery of leaf color was obtained.

Hill (1956) used iron chelates to help correct chlorosis in blueberries. One-hundred grams per bush of iron chelate, evenly distributed and worked into the soil about the base of a four year old plant, effected the disappearance of chlorosis within 30 days. During the next season, the treated bushes displayed a vigorous shoot growth accompanied by heavy bud development and dark green foliage. Recommendations included the use of 1.5 ounces iron chelate to small, newly established plants and up to 4 ounces on larger, well established ones.

Ballinger (1957) (thesis), during a nutritional survey in Michigan in which percentages in excess of 10 percent of calcium on the soil exchange were associated with poor gowth of highbush blueberry plantings, observed some bushes with chlorotic leaves which were growing on a marginal upland soil of pH 5.2. The calcium in the soil of these bushes occupied 48 percent of the soil cation exchange system. Analyses of foliar tissue of these bushes; displaying a complete yellowing as well as less advanced stages of interveinal chlorosis, revealed that the leaf iron content was about half that of a standard content established for leaves in normal Michigan plantings. Concurrently, the potassium content of these leaves was 123 percent of the standard leaf value determined for that element. This may lend support to the theory of Caine ( ) that excessive bases in the blueberry leaf may interfere with the utilization of iron within the leaf.

Magnesium. Mikkelson and Doehlert (1950) reported magnesium deficiency symptoms in highbush blueberry plantings in New Jersey. The symptoms were expressed during the time of berry ripening and began on lower leaves of rapidly growing shoots as a marginal and interveinal pale green coloration. Later, the affected areas turned a yellowish olive green which evolved into a vivid orange and red in advanced stages. The plants were located on a Leon sandy soil with a pH of 4.0 to 4.5. Six hundred pounds of a 7-7-7 fertilizer had been used in the regular fertility program.

The application of 70 pounds per acre of magnesium oxide in the form of magnesium sulfate (Epsom salts) and 300 pounds per acre in the form of Dolomitic limestone in September corrected the deficiency the following season. Magnesium content of leaves from plants under this treatment was greatly increased over that of leaves from the untreated plots of chlorotic bushes.

Popenoe (1952) studied an abnormal foliar condition of highbush blueberries of the Rancocas variety grown on a Sassafras gravelly loam soil at Beltsville, Maryland. Analyses of the leaves indicated a low level of magnesium and suggested that these symptoms similar to those described by Mikkelson and Doehlert (1950), were related to a magnesium deficiency. The symptoms appeared as a marginal reddening of the basal leaves and covered nearly half of some of the more severely affected leaves. After fruit harvest, the second flush of growth was free of the abnormality. As the following year's fruit was maturing, the symptoms appeared once more. These differed from those described by Mikkelson and Doehlert (1950) in that they did not become more severe as the season progressed. Applications of Epsom salts at the rate of 200 pounds per acre did not effect a recovery from the disorder. Popenoe theorized that the magnesium - potassium ratio might play an important role in the expression of these symptoms.

Bailey and Drake (1954) found magnesium deficiency symptoms on leaves of highbush blueberry plants grown on a Gloucester sandy soil of pH 3.8 to 4.2. The older leaves of the plants displayed typical yellow and red coloration between the veins. An analysis of the leaves substantiated that magnesium was very low. From 25 to 150 pounds of magnesium oxide as Espom salts and 100 to 600 pounds in the form of Dolomitic lime were applied to the soil. All treatments increased leaf magnesium but had no effect on leaf potassium, calcium or nitrogen content. Particularly noteworthy was the fact that 1.5 tons per acre of limestone did not cause leaf chlorosis and only increased the soil pH from 4.0 to 5.2, which is slightly above that of an ideal blueberry soil. As little as 25 pounds of MgO as Epsom salts and 200 pounds MgO as Dolomitic limestone almost eliminated the magnesium deficiency symptoms.

Boller (1956) suggested that conditions causing mineral deficiency indications on blueberries may be due to several factors such as: (1) not enough or poor distribution of soil moisture, (2) a small or weak root system, due to poor drainage, insect injury, fertilizer burn, disease, or an excessive packing of the soil, (3) insufficient quantities of available ammonium nitrogen (nitrates are often toxic), and (4) a lack of some other fertilizer element such as phosphorus, iron, and so forth.

Fertilizer Practices and Recommendations

The discussions during the foregoing sections of this chapter have emphasized some of the culture and nutritional factors required for normal growth of the blueberry. Since these factors vary considerably with the species involved, the discussion of blueberry fertilizer practices and recommendations warrants a grouping of blueberry discussions below in respect to the three main species, the lowbush, rabbiteye, and highbush.

Lowbush blueberries

Objectives in fertilizer practice

For many years the lowbush blueberry industry in the northern section of the United States has consisted primarily of the harvesting of the fruit in wild stands on cut woodland. Periodic burning every second or third year has been the principle means of pruning and maintaining vigor. As the industry grew, however, a decline in soil fertility and productivity in older fields was recognized. Consequently, means of maintaining and increasing production, including fertilization, have assumed added importance.

Mason (1950) well summarized the goal of lowbush blueberry fertilization as follows: "Tall stems ordinarily produce more fruit buds than short stems. Consequently the objective of the grower during the year of the burn is to produce a tall stem early so as to insure abundant fruit bud formation for the first fruit crop. The objective during the year after burning is to produce numerous side branches, without decreasing the production of the fruit crop. These side branches are essential for obtaining a high-yielding second crop if a three year cycle is followed." Although yields may be improved in some instances by the use of fertilizer, fertilizers should be used with caution. Excessive fertilization may cause excessive growth during the first year of the burn, resulting in tall, thin stems with few fruit buds. Rates of fertilizer applied must not upset the delicate balance between vegetative growth and fruitfulness. The most desirable procedure is a compromise between the objectives which will produce the best blueberries and at the same time the least stimulation of excessive weed growth which may shade out the lowbush plants.

Experimental background

Chandler and Mason (1933) studied the effects of fertilizer on the native Maine lowbush blueberry. All possible combinations of nitrogen, phosphorus and potassium in fertilizers were compared. The results revealed that a complete fertilizer gave a 128.6 percent increase in yield. Nitrogen in the fertilizers increased growth, number of fruit buds per stem, and yield over untreated plots. Plots receiving phosphorus and potassium showed no appreciable increase in yield over plots receiving no fertilizer. All fertilizer treatments decreased fruit reducing sugars. The acidity of the fruit tested varied from pH 3.63 to 4.11 and was highest in fruit grown on bushes fertilized with ammonium sulfate. Lowest fruit acidity was associated with fish meal fertilizer applications. A plot treated with a manganese fertilizer yielded fruit whose acidity was similar to the check, but whose amino acid and total nitrogen content was higher than that of the check plant fruit. It appears that the different amounts of nitrogen in these various fertilizers affected maturity, and indirectly, the berry constituents.

Smith, et al (1946) set up hundreds of fertilizer plots on different blueberry plantings; most were on older, poor yielding areas. These represented plantings which had been burned the year before, the second, and the third years respectively. The following applications failed to give beneficial results: phosphoric acid, muriate of potash, hydrated lime, potassium sulfate, sulfur dust, lamp black, charcoal, and wood ashes. In 1944, a 7-7-7 ratio fertilizer at the rate of 200, 500 and 1000 pounds per acre and nitrate of soda at the same rates were applied in May and June. All 7-7-7 treated plots yielded better than the sodium nitrate ones and provided good shoot growth. Sodium nitrate applications over-stimulated weed, grass, and blueberry stem growth. Applications of ammonium sulfate increased shoot growth, the number of blossoms per shoot, and the fruiting area of the shoots. However, it produced less fruiting area than the 7-7-7 fertilizer. No differences in ripening or size of fruit were found related to treatment. Increases in yield were due primarily to greater numbers of fruit.

Chandler (1943) emphasized that excessive weed growth resulting from fertilization of lowbush blueberry plantings is frequently responsible for reductions in yield due to a shading of the blueberry bush. Mason (1950) confirmed that the use of fertilizers may cause low growing weeds and grasses to become rank and crowd out the blueberry plants. The amount of fertilizer used, therefore, should be between that needed by the blueberry bush and the amount causing excessive weed growth.

Mason (1950) reported that complete fertilizers are not always better than nitrogen alone. Responses to nitrogen applications have been most striking; the use use of phosphorus and potassium has not generally been shown to be beneficial. At the time of his report, it was only profitable to apply nitrogen fertilizer alone.

Eaton (1950) reported that fertilization in Canada had not generally been included in lowbush blueberry management. Nitrogen, phosphorus and potassium fertilizers were tested in Yarmouth County, Ottawa, for three years as separate applications and in all possible combinations. No consistent response was observed besides increasing growth of grass in plots receiving nitrogen. Eaton (1950) cautioned that the contact of fertilizer with blueberry foliage may result in damage; application was recommended during the period prior to bud opening.

Trevett (1955) found that the size and vigor of shoot laterals, together with intensity of the formation of laterals seemed to be related to nitrogen availability to the lowbush blueberry plant. Higher levels of nitrogen produced a greater number, as well as more vigorous laterals, than plants of lower nitrogen levels. However, he reported that the control of grasses and herbaceous plants must be controlled before an increase in nitrogen to the plants can be made.

Recommendations

Amount of fertilizer to apply - No two fields are alike and the grower must determine for himself what amount of fertilizer can be applied. Small sections of each field should be tested to provide the effects of fertilizers on weed growth as well as the desirability of fertilizing. A summary of recommendations for trial applications (Trevett, 1950) in relatively grass-free fields are as follows:

1. Fertilizer applied during the burn year.

    a. If the majority of one-year stems are less than 4 inches in length, apply 30 pounds per acre of actual nitrogen.

    b. If the majority of one-year stems are more than 6 inches in length, apply 15 pounds per acre of actual nitrogen.

2. Fertilizer applied in the first crop year in a three year cycle:

    a. Apply 35 pounds per acre of actual nitrogen if the majority of one-year stems is 4 inches long.

    b. Apply 20 pounds per acre of actual nitrogen if the majority of one-year stems is less than 6 inches long.

3. Fertilizer applied in the second crop year in a three year cycle

a. Apply 40 pounds of actual nitrogen per acre

Kinds of fertilizer to use

Responses to fertilizer have indicated that only applications of nitrogen are generally profitable for lowbush blueberry fertilization. Nitrogen may be obtained from complete fertilizers such as 7-7-7, 10-10-10, or 5-10-10; or more economically from sodium nitrate, ammonium nitrate, ammonium sulfate, or a similar product.

Method of application

The fertilizer should be spread uniformly over the entire field by hand or by machine. Hand broadcasting is made more accurate by dividing the field into strips ten feet wide and one hundred feet long, and then determining the number of handfulls of fertilizer that must be spread over this area to provide the desired acreage rate.

When to apply fertilizer

Fertilizers may cause injury to blueberry foliage or newly opened buds. Therefore, it is desirable to apply it in the spring 7 to 10 days before the initiation of growth.

The Rabbiteye Blueberry

Relatively little information is available on this species, but Darrow (1957) reported that Rabbiteye plantings respond to fertilization. Applications of 4-8-4, 4-8-6, and 4-8-8 fertilizers in Florida (1941) have all been found to be beneficial. The formulations with 6 to 8 percent K_2O are more desirable for older plantings. An 8-6-4 formulation applied at the rate of 100 pounds every two or three years is also satisfactory. The following rates of application have been suggested:

1. One-half to one pound per plant for first year plantings
2. One and a half to two pounds in the second year.
3. Two and one-half to three pounds in the third year.
4. Five hundred to eight hundred pounds per acre for mature plantings.

Fertilizer recommendations for the Rabbiteye blueberry in Georgia (1957) included the use of an 8-8-8 fertilizer formulation applied at the rate of 400 to 600 pounds per acre together with an annual supplemental sidedressing of 200 to 300 pounds per acre of ammonium sulfate.

The Highbush Blueberry

Manuring

As early as 1910 (Coville 1910), manures have been thought to be detrimental to the blueberry. Coville (1921) reported that stable manure stimulates vegetative growth but may cause injury later.

Johnston (1943) treated 10 blueberry plants of the Rubel variety, growing in a good blueberry soil in Michigan, with a cubic yard of horse manure early in the spring of 1940.

This was plowed under and worked into the soil during the growing season. The application was repeated in the spring of 1941, and in the spring of 1942, a cubic yard of cow manure was added. Yield records revealed that the 18 plants receiving manure yielded 631 pints of berries over a 3 year period; eighteen comparable plants not manured yielded 639 pints, an insignificant difference in yield. A phenomenon of note, however, was that considerably more berries ripened at the first picking of the manured bushes. Johnston surmised that this effect may have been due to the extra nitrogen contained in the manure. Foliage of the manured bushes was a darker green than of the plants not receiving manure. In general, however, in contradition to early reports, no injury occurred from the use of the manure. The lack of response may have been due to an already sufficient organic matter content and nutrient supply of the soil. Johnston theorized that Coville's failure, wherein manure was mixed with soil in the hole during planting, may have been due to resultant air pockets next to the roots of the plant which resulted in dessication. Johnston concluded that manure would be more beneficial on poor, sandier soils low in organic matter.

Bailey (1944) applied up to ten tons of manure per acre to blueberry soil with no detrimental effects to the plants. Horse manure was applied in 1941 at the rate of 10 tons per acre and cow and poultry manure were used at rates to provide the same quantity of nitrogen. In 1942 and 1943, the amounts of manure applied were doubled. The soil involved was underlain by a fine gray sand layer whose depth was variable and may have caused more variations than the treatments. Soil pH was 4.87 to 5.33, mostly around 5.0. Manure was not compared to commercial fertilizer. No great differences in yield were obtained, but yield and fruit size were at least as good as those resulting from the use of chemical fertilizer.

Bailey (1958) commented on this experiment a few years later and stated that manure is a good fertilizer for blueberries but must be used with reason. Up to 10 tons per acre of horse or cow manure were recommended. Since chicken manure is higher in nitrogen content, only quantities up to 5 tons per acre should be used. Most recent publications still do not recommend the use of manure.

<u>Mineral Fertilization</u>

Beckwith (1920) was one of the first to report on mineral fertilization of the highbush blueberry. Applications of nitrate of soda produced very little increases in yield over the checks. A complete fertilizer increased yield about 40 percent. Benefit from a yield standpoint was greater when the nitrogen was furnished from organic sources in addition to the nitrate of soda.

Coville (1921) presented the findings of some of Beckwith's experiments in New Jersey. Yield was tripled over unfertilized plants on a sandy soil by the addition of 600 pounds per acre in the spring of a mixture of sodium nitrate, dried blood, steamed bone, phosphate rock and potash. Coville reported that if a blueberry soil contained enough peat, fertilizer was not needed.

Crowley (1933) in experiments with highbush blueberries in Western Washington, doubled the yield in 1931 over check plots by using a mixture of 100 pounds nitrate of soda, 200 pounds of rock phosphate and 50 pounds of sulfate of potash. During the next season, 1932, the yield of fertilized plots was increased 2 1/2 times over that of check plots. An increased berry size resulting from a greater amount of new wood was responsible for the greater yields. Crowley (1933) recommended the use of fertilizers for blueberry production on some soils.

Beckwith reported in 1933 that studies over a long period of time indicated that a mixture of 450 pounds of nitrate of soda, 450 pounds of dried blood (an organic nitrogen source) 800 pounds of rock phosphate, and 300 pounds of sulfate of potash applied at the rate of 600 pounds per acre was a desirable fertilizer for blueberries.

Beckwith and Doehlert (1933) discussed this above mixture in more detail in another report. Thirty-one plots of 20 plants each were laid out using Rubel and Rancocas variety blueberry plants. Regular applications in May of various fertilizer mixtures, including the standard cranberry mixture used for blueberries from 1920 to 1930, were made. In addition, second and third applications were placed at intervals of 2 1/2 weeks on some plots. All fertilizers were applied to provide 33.6 pounds of actual nitrogen per acre.

Results indicated that the yield for the first year was not greatly affected by treatment. On a three year average, however, the standard cranberry fertilizer, nitrate of soda, and nitrate of soda plus dried blood, all gave increased yields over the checks (unfertilized plots). Dried blood alone, the cranberry mix with acid phosphate substituted for the rock phosphate pound for pound, cyanamid fertilizer (16 1/2-20-0), and cyanamid fertilizer (10-20-10) gave some increases, but not as much.

Beckwith and Doehlert (1933) also reported in this study that after continued use of complete fertilizers on blueberries, insufficient benefits were obtained from the application of 480 pounds of rock phosphate per acre. A point of interest was that larger yields were obtained when nitrate of soda was applied over a period of five weeks rather than all at once. Ammonium sulfate was not compared at the time to see if the same effect could be achieved. The reverse was true of dried blood, which acts more slowly. Later applications apparently did not help with the current crop. As a result of these studies, Beckwith and Doehlert (1933) recommended the listed mixture of nitrate of soda, dried blood, rock phosphate, and sulfate of potash as a desirable blueberry fertilizer. It should be applied at the rate of 600 pounds per acre in two split applications 3 weeks apart, beginning at the start of spring growth.

Beckwith, Coville and Doehlert (1937) found that yields over a 9 year period of investigation were doubled by the use of fertilizer. Ammonium salts, dried blood, and acid phosphate had not given satisfactory results. The fertilizer mixture recommended at this date consisted of 450 pounds of nitrate of soda, 450 pounds of calcium nitrate, 800 pounds of rock phosphate, and 300 pounds of sulfate of potash. This was to be applied to bushes producing an average of two quarts at the rate of 300 pounds per acre in early May and another 300 pounds three to four weeks later. Small bushes were to receive reduced amounts.

In Michigan, Johnston (1934) tested fertilizers on Rubel variety plants. Three hundred and thirty-five pounds of superphosphate gave very good results. The same quantity of a 5-10-12 fertilizer mixture also gave good results; indications were that applications of potash were beneficial. Nitrogen alone proved of little value. The lack of response to nitrogen applications might have been due to the use of a soil already rich in nitrogen.

Doehlert (1941) studied the effect of time of application at five different periods for six years, starting in 1935. A single row of 70 six year old blueberry plants of the Rubel variety was used. A 7-12-7 fertilizer mixture, reported in 1937, was applied at the rate of 600 pounds per acre. The yield on this sandy soil was practically doubled by the use of the 7-12-7 fertilizer. Time of application was not too important.

Apparently, blueberries may be fertilized to good advantage in New Jersey at any time during the period of April 15 to June 15. Fertilizer applied before April 15, i.e., before bud-breaking, was not as effective. Dividing the time of fertilizer applications, into 3 periods, May 1, May 15 and third part in October, gave as good yields as those bushes receiving all of the fertilizer in the spring.

Slate and Collison (1942) grew highbush blueberry plants under both clean cultivation and a sawdust mulch. Potassium chloride in a fertilizer killed many clean cultivated plants but none under mulch. The injury was attributed to the chloride since sulfate applications were not injurious. They recommended that no chlorides be incorporated in blueberry fertilizers. In general, Slate and Collison (1942) felt that nothing definite was known about the fertilization of blueberries.

Merrill (1944) found under Michigan field conditions that muriate of potash (potassium chloride) had a retarding effect and in many cases injured blueberry plants. Applications of nitrogen and phosphorus were found most effective for increased growth in sand; nitrogen and potassium treatments were found more beneficial with a muck soil. A direct relationship between the accumulation of nitrogen and phosphorus was found in the wood of highbush blueberry plants grown in sand. Concureatly, a direct relationship between the nitrogen and potassium content of plants was found in the muck. Merrill recommended that, until a given nutrient element is in evidence as being the limiting factor in growth, a complete fertilizer should be used.

Bailey (1958) studied the effects of different rates of nitrogen to determine how much is safe for application and economical for use in blueberry plantings in Massachusetts. Blueberries appear to respond readily to applications of nitrogen. Response to other fertilizer elements is undertain. In tests Bailey reported that nitrogen was applied as ammonium sulfate at the rate of 1/2, 1 and 2 pounds per bush. Sul-Po-Mag was used to supply potassium and magnesium (0, 1/2 and 1 pound per bush). All possible combinations of these were employed and all were spread in one application just before bloom. Results indicated that growth was so stimulated by the nitrogen in the 2 pound applications of ammonium sulfate that much late fall growth occurred which would be conducive to cold weather injury. Therefore, the 2 pounds is perhaps excessive. Bailey (1948) speculated that, over a period of years, even one pound may prove to be too much. No response was obtained at the reporting date on Sul-Po-Mag applications. Thus, it was too early at that time to draw any definite conclusions from that experiment.

Kinds of Fertilizer to Use

Complete fertilizers appear to be necessary for top production in highbush blueberries. Although recommendations vary widely, the trend seems to be toward a 1-1-1 ratio. Mixtures of 7-7-7, 8-8-8, 10-10-10 or 11-11-11 are available. It is often more economical, because of handling, to use the higher analyses. More recent recommendations include those of Blasberg (1948) who suggested the use of a 5-10-10 mixture in Vermont, and Shutak and Christopher (1952) who advised applications of a 5-10-10, in Rhode Island; Johnston (1951) and Kenworthy, et al. (1956) in Michigan urged the use of a 1-1-1 mixture on mineral and a 1-2-3 or 3-9-12 mixture on organic soils. In North Carolina (1956), an 8-8-8 is included in the recommendations for 1957. Blueberry fertilizer recommendations in New Jersey call for the use of an 8-8-8 mixture. Doehlert (1953) advised the addition of 2 percent MgO to this mixture. Darrow (1957) suggested the use of an 8-8-8 mixture (not neutralized) for locations where satisfactory practices are still unknown. Eaton (1950) at Kentville, Ottawa in Canada reported that a 5-10-5 mixture was used prior to World War II, but a standard 9-5-7 previously suggested on apples, was substituted during the war and has given favorable results.

Supplemental applications of nitrogen fertilizers are often recommended for use in conjunction with complete fertilizer applications, particularly on mineral soils low in organic matter. (Kenworthy, et al, 1956, Anonymous, N. C., 1956). The ammonium form of nitrogen is generally recommended for use on soils who pH is higher than 5.0-5.5.

Time of Application

The main objective in fertilizing is to stimulate vigorous growth, particularly from the time of leaf and blossom appearance until fruit ripening. The recommendation for bearing fields in New Jersey is the application of about half of the fertilizer during the last week in April and the remainder during the first week of June. A third application may be employed in October if nitrogen deficiency or other hunger signs are apparent (Anonymous, 1957).

For North Carolina (Anonymous, 1956) a complete fertilizer is recommended for application when the first plants begin to bloom. Four to six weeks later, the plants are to be topdressed with nitrogen fertilizer, preferably of an ammonium form. For Michigan, Kenworthy, et al (1956) suggested two applications, the first "early in spring" and the second in early June. A supplementary application of ammonium sulfate on mineral soils low in organic matter in late June was also suggested. In general, however time of fertilization of highbush blueberries should be adjusted to their needs during times of greatest growth. Bailey et al (1950) suggested that on soils where nitrogen is lost easily by leaching, weeds or mulches, split application of fertilizer seem desirable.

Amounts of Fertilizer

Blueberries are extremely sensitive to excessive quantities of fertilizer around the root zone at any one given time. Kramer and Schrader (1945) suggested that since highbush blueberries grow on an acid soil naturally low in exchangeable bases, a low cation requirement is necessary for growth under these conditions. Ballinger, et al (1957) compared soils from bushes of poor vigor with those of good vigor and observed that the total of the three main cations (K, Ca and Mg in percent saturations), on the soil exchange was much higher for the poor vigor plants. Accordingly, such conditions may possibly cause reduced growth in blueberry soils which are low in organic matter and relatively dry. This would lend support to the suggestion made by Doehlert (1948 annual blueberry openhouse) that several integral applications of fertilizer should be made instead of a single application. This method reduces the possibility of getting too great a concentration of cations on the soil at any one time. With another Ericaceous plant, Azalia, Colgrove and Roberts (1956) found the total base content of the root medium to be inversely proportional to good growth and foliage color. Best growth and foliage color occurred when the total base content of the nutrient solutions was reduced to a low level. Doehlert (1957) advised that blueberries grow best in an acid soil which is low in nutrients.

General recommendations for amounts of fertilizer to apply to blueberries vary with the type of fertilizer used, age and location of plants, type and fertility of the soil and the general vigor of the plant. For best results, trials using various levels of the ranges locally recommended should be made to determine the optimum responses to a given fertilizer, particularly those containing nitrogen. Ballinger, et al (1957) found that yields of highbush blueberries in Michigan were directly proportional to the nitrogen content of the leaves up to a given level. Contents of nitrogen in excess of this level were associated with a decrease in yields. Table ( ) lists the various fertilizers and the recommended rates of application.

Methods of Application

Fertilizer, to be effective, must be so placed that the roots of the plant are able to absorb it; therefore, it must be applied where the roots are. Generally the area of feeder roots go out as far as the outer spread of the branches above. The spread of roots may often be increased by spreading the fertilizer farther and farther out into the row each year. Very few blueberry plantings have the soil and culture practices which permit root growth across the row balks.

A broad strip application is best. Do not place fertilizer in a narrow band which causes poor distribution, (Doehlert, 1953), making the plants more susceptible to drought effects. Scatter the fertilizer well; do not drop in lumps.

Actual application may be made either by hand or by machine. Many of the larger plantations use fertilizer spreading machines, but hand spreading is often justified.

Fertilizing newly-planted Fields

Newly planted fields should never be fertilized until the roots have become reestablished and second growth starts. Apply 100 pounds of an 8-8-8 per acre (1 1/4 oz. per bush) in a band at least four inches away from the crown of young plants. One month later apply a similar amount if needed. As the planting develops, the fertilizer rate can be increased by 200 pounds per acre up to the fourth year in the field. Caution - fertilizer is not a cure-all and, during the early years of a blueberry planting, other cultural practices such as cultivation and weed control must be accomplished faithfully in order for the applied fertilizer to be efficiently utilized.

Nursery Fertilization

Blueberry cuttings from the propagating bed are usually placed in a nursery for one or two years prior to setting in the field. Again, fertilizer must not be placed in the hole and the plants must not be fertilized at planting time. After the second burst of growth starts. Then, the established plants may be sidedressed at the edge of the root balls at the rate of 5 pounds of an 8-8-8 fertilizer mixture on each side of a 1000 feet of row (Deohlert, 1953). This sidedressing may be repeated six weeks later but not during a drought during which the chances of injury to the young plants from excessive fertilizer in the soil are increased.

Propagation bed Fertilization

Fertilizer must never be mixed with the sand and peat rooting medium prior to placement of the cuttings in the bed. No form of fertilizer is to be applied prior to rooting of the cuttings. After rooting, which is usually shown by a new burst of growth of the cuttings, the generally accepted practice is to apply a liquid fertilizer. Doehlert (1953) recommends a weekly application of a 15-30-4 or 13-26-13 soluble mixture until mid-August in New Jersey. The solution may be prepared by mixing one ounce of the mixture in two gallons of water. The solution must be rinsed from the foliage after application. Johnston (1951) recommended that a stock solution of fertilizer in water be made up in water at the rate of one pound of 8-8-8 blueberry fertilizer to 4 gallons of water. Since the fertilizer dissolves slowly, the stock solution should be made up well in advance of the time of use. The stock solution should be screened to remove all undissolved matter which would otherwise clog the sprinkler head when used. One quart of this stock solution mixed with one gallon of water can be used to sprinkle about 25 square feet of propagating bed. In Michigan, this may be applied after cuttings are rooted. This is first applied normally around the middle of July and is to be repeated at ten day intervals until the third week in August. After this, applications will cause growth to occur too late into the fall. To summarize: (1) do not fertilize until rooting has occurred, (2) do not apply in the sunshine, (3) rinse the foliage after application, and cease applications in time to prevent winter injury as a result of late growth.

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Table____. A List of Commercial Fertilizer Recommendations for Blueberries from Various States

Source	State	Formulation	Rate of Application (Pounds per Acre)
Lowbush			
Chandler and Mason	(1933) Maine	N	50-60
Dow, et al	(1950) Maine	N	15-40
Anonymous	(1953) Maine	10-10-10	200-350
Smith	(1946) New Hampshire	7-7-7	200-1000
Rabbiteye			
Anonymous	(1941) Florida	4-8-6, 8-6-4	500-800
Anonymous	(1957) Georgia	8-8-8	600-1200
Highbush			
Beckwith	(1920) New Jersey	Complete + Organic N	600
Beckwith and Doehlert	(1933) New Jersey	6-3-4*	600
Beckwith and Doehlert	(1937) New Jersey	4-4-4, 3-12-6*	600
Doehlert	(1944) New Jersey	7-7-7, 7-2-4*	600
Doehlert	(1953) New Jersey	7-7-7 8-8-8 10-10-10	460-915* 400-800 320-640
Anonymous	(1957) New Jersey	8-8-8	500-800
Christ	(1958) New Jersey	8-8-8	1000
Johnston	(1934) Michigan	5-10-12	500
Johnston	(1943) Michigan	6-10-6	500
Johnston	(1951) Michigan	8-8-8 on sand 3-9-18 on much	500 500

Table____. Continued.

Source	State	Formulation	Rate of Application (Pounds per Acre)
Kenworthy, et al	(1956) Michigan	Any 1-1-1 ratio on sand	To supply 60-100 lbs. N
		Any 1-2-3 ratio on muck	
Anonymous	(1957) North Carolina	8-8-8 + Suppl. N	300-400 20-30
Bailey and Franklin	(1935) Massachusetts	7-3-10*	500-600
Bailey, et al	(1939) Massachusetts	7-8-7*	500-600
Bailey	(1951) Massachusetts	7-7-7, 10-10-10	500-600
Slate and Collison	(1942) New York	5-10-5	550*
Shutak and Christopher	(1952) Rhode Island	7-7-7, 10-10-10	1000
Crowley	(1933) Washington	4-4-4*	350
Boller	(1956) Oregon	Ammonium Sulfate	340-425*
Judkins	(1951) Ohio	7-7-7	500
Kolbe	(1951) West Virginia	6-10-6, 5-10-10	500
Darrow	(1951) U.S.D.A.	5-10-5	600
Darrow	(1957) U.S.D.A.	8-8-8 + Ammonium Sulfate	400-600 200-300

Footnote:

*Figures estimated using information from the respective literature. Mixed nitrogen sources are contained in many of these formulations.

TABLE ___

Classification of Weeds According to Ease of Killing with Foliage Applications of 2,4-D (Trevett, 1953)

Class I Weeds: Susceptible to 2,4-D

Common Name	Scientific Name
Alder*--5, AM	Alnus rugosa
Birch, black--5, AM	Betula lenta
Birch, gray*--5, AM	Betula populifolia
Birch, white*--5, AM	Betula papyrifera
Box-elder--5, AM	Acer Negundo
Cherry, black--5, AM	Prunus serotina
Cherry, pin*--5, AM	Prunus pensylvanica
Dogbane*--5	Apocynum androsaemifolium
Elderberry--5, AM	Sambucus canadensis
Elm, American*--5, AM	Ulmus americana
Fern, sweet*--5, AM	Comptonia peregrina
Firewood*--5	Epilobium angustifolium
Grapes--5	Vitis spp.
Hazel nut--5	Corylus spp.
Plum, wild*-5, AM	Prunus spp.
Poplar, large tooth--5, AM	Populus grandidentata
Sassafras--5, AM	Sassafras variifolium
Sumac*-5, AM	Rhus spp.
Willow*--5, AM	Salix gracilis
Willow, black--5, AM	Salix nigra
Willow, prairie*--5, AM	Salix humilis
Willow, pussy*--5, AM	Salix discolor
Witherod*--5	Viburnum cassinoides

Class II Weeds: Moderately Resistant to 2,4-D

Apple, wild*--5	Malus spp.
Ash, mountain*	Pyrus americana
Aspen, small touth*--5, AM	Populus tremuloides
Barberry, American--5	Berberis canadensis
Blueberry*--5, AM	Vaccinium spp.
Buckthorn--AM	Rhamnus alnifolia
Butternut, white walnut	Juglans cinerea
Chokeberry*--AM	Pyrus melanocarpa
Chokeberry--5, AM	Prunus virginiana
Dogwood, flowering--5	Cornus florida
Elm, slippery--5, AM	Ulmus fulva
Hardhack*-5, AM	Spiraia tomentosa
Hemlock--5	Tsuga spp.
Hickory--5, AM	Carya spp.
Holly, mountain*	Nemopanthus mucronata
Honeysuckle, bush*-5, AM	Diervilla lonicera
Ivy, poison*-5, AM	Rhus radicans

Class II Weeds: Moderately Resistant to 2,4-D

Common Name	Scientific Name
Locust, black or common--5, AM	Robinia Pseudo-Acacia
Locust, honey--5	Gleditsia triacanthos
Meadowsweet*--55, AM	Spiraea latifolia
Mulberry--5	Morus spp.
Oak*--5, AM	Quercus spp.
Plum, sugar*--5	Amelanchier stolonifera
Rhodora*	Rhododendron canadense
Serviceberry*--AM	Amelanchier leavis
Sheep-laurel* (Lambkill)--5	Kalmia angustifolia
Willow, Bebb*-55	Salix Bebbiana

Class III Weeds: Very Resistant to 2,4-D

Ash, white--AM	Fraxinus americana
Barberry, common	Berberis vulgaris
Basswood--AM	Tilia americana
Bayberry*--5	Myrica carolinensis
Bearberry*--5	Arctostaphylos Uva-ursi
Beech--AM	Fagus spp.
Blackberry*--5, AM	Rubus spp.
Brier, green (Horse Brier)	Smilax rotundifolia
Bunchberry*	Cornus canadensis
Cedar, red	Juniperus virginiana
Cedar, white	Thuja occidentalis
Dewberry, swamp*--5	Rubus hispida
Dogwood, red osier--5	Cornus stolonifera
Ferns	Asplenium spp.
Fern, brake*	Pteridium aquilinum
Grasses*	Gramineae
Hawthorne--5, AM	Crataegus spp.
Juniper, common--5	Juniperus communis
Lilac--5	Syringa vulgaris
Maple, red*-AM	Acer rubrum
Maple, silver--AM	Acer saccharinum
Maple, sugar--AM	Acer saccharum
Pine--5	Pinus spp.
Raspberry*--5, AM	Rubus spp.
Rose, wild*--5, AM	Rosa spp.
Sarsaparilla, bristly	Aralia hispida
Spruce	Picea spp.
Tea, Labrador*	Ledum groenlandicum
Walnut, black--5	Juglans nigra
Wintergreen*	Gaultheria procumbens

Footnote: A "5" after a weed indicates its susceptibility to 2,4-D and 2,4,5-T. An "AM" following a weed indicates susceptibility to Ammate.

NUTRIENT DEFICIENCY SYMPTOMS IN THE WOLCOTT VARIETY OF *VACCINIUM CORYMBOSUM*

by

JAMES RUSSELL HICKS

Objective(s)

The major objective of this problem is to learn the major nutrient deficiency symptoms as they are expressed in Vaccinium Corymbosum variety Wolcott. Work of this sort has been done on other varieties of the high-bush blueberry, but never on Wolcott; which is grown almost exclusively in North Carolina. Second and of lesser importance is how the Wolcott will react to excessive amounts of the different major nutrients. It has been found in some varieties that the excess of one nutrient will cause the plant to exhibit the accepted deficiency symptoms for another nutrient.

The third objective and completely different from the other two is to gain experience in carrying out experiments of this sort.

Reasons for Undertaking Investigations

In recent years the state of North Carolina has progressed much in the production of Vaccinum Corymbosum, the highbush blueberry. Two factors that are very evident in this movement are: 1) total acres of blueberries has been increased and 2) higher yields per acre have been attained due to new canker resistant varieties.

Of major importance in our blueberry industry and comprizing over fifty percent of the total acreage of blueberries in our state is the Wolcott variety. It is of commercial importance only to North Carolina, its home state. Because of its youth and its fairly restricted habitat, very little is known about the deficiency symptoms caused by the major elements. Anyone connected with fruit growing knows the importance of having adequate sources of nutrients available to the plant. This is important in getting maximum yield and in having a healthy plant.

Quite a bit of work has been done on deficiency symptoms of other varieties but so far no report has been made as to how the nutrient deficiency symptoms manifest themselves on the Wolcott variety.

Previous Work and Present Status of Investigation in the Field of this Project

Cain (4) reports that the type of nitrogen applied was very instrumental in the development of deficiency symptoms. He found the nitrogen and iron content of the leaf varied as the amount of ammonium nitrogen was varied. Even though the nitrate form of nitrogen did not effect the amount of iron absorbed by the roots, it did, in many cases, cause the appearance of interveinal chlorosis often associated with iron deficiency. Another important discovery based on this work was the fact that iron deficiency symptoms are not necessarily related to either the iron or calcium content of the leaf, nor is it related to the pH of the soil.

Smith, Eggert, Hodgdon, and Yegger (13) reported that the application of a complete fertilizer (ratio 1-1-1) increased both yield and plant vigor over plots receiving only nitrogen. This was a very early field experiment on the lowbush blueberry.

Later Bailey, Smith, and Weatherby (2) suggested that the blueberry has an extremely low requirement for phosphorous, potassium, calcium, and magnesium. In North Carolina (8) the recommended fertilizer program is to bring the soil up to a high level of both phosphate and potash before planting, then add 200 lbs. of 8-8-8 per acre for the first few years. This should be followed by fifteen to twenty pounds actual nitrogen per acre about four to six weeks later.

Steves (14) observed that varying the pH of the soil had a very profound effect on growth of the blueberry. His experiment was with highbush varieties which he found to grow best around pH 7.0; however, when nitrogen was omitted from the solutions he got very poor growth.

Doehlert and Shive (7), using the Rubel variety of the highbush blueberry, reported that plants had a high requirement for nitrogen and low requirements for both magnesium and phosphate.

Orr, Furuta, and Bell (12) did some greenhouse nutrition work with Azaleas. They grew plants in glazed pots filled with quartz sand and applied solutions to them. They found that the check plants, receiving a full nutrient solution, had better vigor and better color than most commercial plants. They also found that deficiency symptoms were rather slow to appear.

Amling (1) ran some greenhouse experiments using sand media, nutrient solutions, and Vaccinium Corymbosum variety Jersey. Minton et.al. (11) developed the deficiency symptoms on the Rabbiteye blueberry which they grew in sand culture. Kramer and Schrader (9) developed the symptoms on Cabot variety of Vaccinium Corymbosum. They too used sand media and nutrient solutions. Lockhart (10) developed the nutrient deficiency symptoms in the lowbush blueberry. Other reports were based either on field observations or field experiments. All of the deficiency symptoms described hereafter appeared on some type of blueberry plant, except for the symptoms based on the observation of Orr, Furuta, and Bell (12). These symptoms are described as they appear on the Azaleas. Following is a brief summary of the foliage deficiency symptoms caused by lack of one of the five major elements.

Nitrogen: The amount of time required for nitrogen deficiency to show up varied with the different solutions used on the minus nitrogen plant. Orr, Furuta, and Bell (12) found that it took forty days for the nitrogen deficiency symptoms to appear on azaleas. However, Kramer and Schrader (9) had the characteristic symptoms only ten days after the buds began to leaf out on rooted soft wood cuttings of blueberries. All (1, 7, 9, 10, 11, 12) agree that the first symptom of nitrogen deficiency is the lighter green color of the leaves and all but Lockhard (10) say this is followed by a yellowing effect. Amling (1) and Cain (5) state that the leaves turned progressively more yellowish-green basipetally. Amling (1) also states that reddish necrotic spots follow the yellowing of the leaves and soon cover the entire surface of the basal leaves. Orr, Furuta, and Bell (12) stated that "older leaves turned yellow or red or developed reddish blotches." They also observed that small necrotic areas sometimes appeared on the leaf before it absiced. Cain (5) reported that the leaves were often tinged with red while Lockhart (10) makes no mention of reddish color, but merely reported that the nitrogen deficient plants were a paler green than normal plants and these pale green leaves showed an interveinal flecking mainly along the margin of the leaf. Minton et. al. (11) found that the entire leaf surface turned red and "very small necrotic pinhead spots occurred on the leaves during the latter part of the treatment." Amling (1) also found that shoots coming out from the base of nitrogen deficient plants had a distinct pink tint. This later changed to a pale green as growth was stopped. In all cases lack of nitrogen greatly reduced growth.

Phosphorus: As a general rule, phosphorus deficiency took longer to show up than did nitrogen deficiency. Minton et. al. (11) discovered the first noticeable symptoms ninety days after the treatments were begun. In their experiment they found phosphorus deficiency to exhibit itself by a darker green color in the new leaves. Also the leaves were smaller and total growth was less. Amling (1) reported phosphorus deficiency to manifest itself by the basal leaves becoming a coarser texture and turning a dark purple. The tip leaves became a greenish purple. Kramer and Schrader (9) reported a slight purpling of both stems and leaves with the leaves having a dull color. Lockhart (10) reported the first phosphorus deficiency symptom as being "a slight interveinal chlorosis with a dark green background around the veins." As the deficiency became more severe, pink to reddish blotches appeared on the younger leaves. This was followed by necrotic spots on the older terminal leaves. These spots basipetally. Amling (1) also states that reddish necrotic spots follow the yellowing of the leaves and soon cover the entire surface of the basal leaves. Orr, Furuta, and Bell (12) stated that "older leaves turned yellow or red or developed reddish blotches." They also observed that small necrotic areas sometimes appeared on the leaf before it absiced. Cain (5) reported that the leaves were often tinged with red while Lockhart (10) makes no mention of reddish color, but merely reported that the nitrogen deficient plants were a paler green than normal plants and these pale green leaves showed an interveinal flecking mainly along the margin of the leaf. Minton et. al. (11) found that the entire leaf surface turned red and "very small necrotic pinhead spots occurred on the leaves during the latter part of the treatment." Amling (1) also found that shoots coming out from the base of nitrogen deficient plants had a distinct pink tint. This later changed to a pale green as growth was stopped. In all cases lack of nitrogen greatly reduced growth.

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Potassium: Kramer and Schrader (9) had trouble getting potassium deficiency to appear due to the fact that there was continual periodic abortion of the terminal growing points on the plants receiving the minus potassium solution. However, when it did appear it was more severe on the older leaves where it first appeared as marginal scorching and development of necrotic spots. Interveinal chlorosis (often attributed to iron deficiency) appeared on the new growth that arose from the axillary bud. Growth of the axillary bud was caused by the aborption of the terminal bud. Amling (1) reported potassium deficiency symptoms as small necrotic spots that first appeared just in from the periphery on the basal leaves. However, as the deficiency grew more acute, the spots formed a necrotic area that extended to the leaf margin. Minton et. al. (11) reported that potassium deficiency first caused interveinal chlorosis of the young leaves. The chlorosis, which was of a mottled appearance, was followed by severe necrosis. The necrosis first started as pinhead spots distributed all over the leaf. The more advanced stages caused marginal scorching of the leaf. Lockhart (10) also reports chlorotic blotches, reddish flecking and red veins. According to his report, the foliage later becomes a bluish green and on the more advanced stage purplish interveinal blotches form on the basal leaves and, if the deficiency is bad enough, purple color may effect the whole plant. Orr, Furuta, and Bell (12) found symptoms of potassium deficiency in the form of interveinal chlorosis near the apical end and edges of young leaves. They too, report a slight redding at the apical end of the leaves. As the deficiency progressed, interveinal chlorosis continued to plague the new leaves. Bronzing, necrotic areas, marginal scorch, and an upward rolling of the tip all made themselves known on the mature leaves. As the deficiency grew worse, necrotic lesions became less apparent and marginal scorching increased.

Magnesium: Magnesium deficiency was first reported by Mikkelson and Doehlert (15). They described it as marginal interveinal coloration that appeared first on the basal leaves of the more vigorous shoots. They found that as the fruit ripened and the nutrient became more limiting the leaves had a regular progression of color in the chlorotic areas. This started first as a pale green, then yellowish-olive green, then vivid orange and red colors. Bailey and Drake (3) also reported magnesium deficiency symptoms as being red and yellow colorations between these leaf veins. Amling (1) reported that magnesium deficiency symptoms are different under different light intensities. Under low intensity Amling reports "an arc of necrotic oval areas close to the midrib on basal leaves." However, as the light intensity increased these necrotic oval areas began appearing along the leaf margin. Shortly after, these necrotic areas ceased to form and the symptoms appeared as a mottled yellowish-red submarginal interveinal chlorosis. As the light intensity went up, the symptoms changed again and appeared as a bright red submarginal chlorosis. At this stage the leaf margin tended to curl abaxially. Orr, Furuta and Bell (12) tend to agree with most of the others on the color progression. They, like Kramer and Schrader (9), reported interveinal chlorosis on the mature leaves. However, Orr, Furuta, and Bell stipulate that these mature leaves were located near the terminal portion of the stem and that the chlorosis appeared at the apex of the leaf. The leaf color changes they observed were from green to yellow-green, or bleached yellow. This was accompanied by reddish purple blotches on the plant's upper leaves. Reddened veins were observed on the underside of all chlorotic leaves. As the deficiency grew worse some of the older leaves turned a bronze color and developed necrotic areas at the tips; these tips curled downward. Kramer and Schrader (9) reported that magnesium deficiency caused severe dwarfing of the plants. They stated in their report that the leaf margins became uniformly chlorotic and later became red and necrotic. Lockhart (10) reported that "magnesium deficiency caused interveinal red to brown blotches in the central portions of the middle and lower leaves." Necrotic spots would sometimes develop in these blotches and, when the plant reached the stage where it started defoliating, it started with the midshoot leaves and then the lower leaves.

Calcium: Amling (1) could not produce calcium deficiency symptoms until he used de-ionized water. Then, slight yellowish-green blotches began to appear on the terminal leaves. Also the plants developed a marginal chlorosis on the tip leaves and had a tendency to rossette. This was caused in part by the fact that the basal leaves abscised soon after tip and marginal scorching developed on them. Kramer and Schrader (9) got results similar to those obtained from potassium deficiency; that is, interveinal chlorosis on the younger leaves. The chlorosis developed here, due to calcium deficiency, is very similar to iron deficiency symptoms except that on calcium deficient plants the areas adjacent to the leaf that remains green are not as wide as are these same areas on iron deficient plants. Lockhart (10) reported that growth on calcium deficient plants was very poor. The foliage was also necrotic with red to dark flecks that soon became dark brown blotches which coalesced as the leaves curled up and died. In contrast to Lockhart, Minton and Hagler (11) reported moderate growth on calcium deficient plants. In addition to this, they found that calcium deficiency caused the tips of both old and new leaves to be scorched. Orr, Furuta, and Bell (12) reported interveinal chlorosis of young leaves followed by tip burning of the expanding leaves were the first signs of calcium deficiency. All growing points did not exhibit this trait, but all did have pale yellow leaves that were smaller than the leaves of the check plant. As the deficiency became more severe, some terminal leaves became twisted and the terminal bud died.

Minton et. al. (11), on some Rabbiteye blueberries that received only distilled water, found that nitrogen deficiency was the first to show with only a little potassium deficiency showing up near the end of the experiment.

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Outline of Procedure

Rooted cuttings of the Wolcott variety were used. These cuttings were purchased from a commercial grower in the eastern part of the state. On October 1, the plants were placed in a refrigeration room held below 40 degrees F. and allowed to remain there until December 11, 1958. At this time they were planted in plastic pails filled with sand and some peat was placed around the roots of the cuttings. From fifty to one hundred cuttings were placed in each pail. Here they were allowed to grow until they had three to six inch shoots with young leaves and some secondary growth starting. At this time (January 14, 1959) four sets of eleven plants each were selected for uniformity in size and vigor (roots and top), roots washed clean of peat, then planted into individual pails of sand. Two days after these cuttings were placed in pails (January 16), one half of them (two replications) received 600 ml of nutrient solution consisting of 300 ml of the standard check (see page 13) and 300 ml of water. From this time on all plants received only de-ionized water. Since there was no apparent injury to the plants receiving the half nutrient solutions, on January 19, all plants received this solution.

The cuttings have received the check solution three times a week, Monday, Wednesday, and Friday afternoons since the first nutrients were applied. This schedule will be maintained after the treatments are started. On the days when no nutrients are applied, the plants receive water twice, morning and afternoon, with 600 ml being used each time. On the days nutrients are applied the plants receive water in the morning and 600 ml of the nutrient solution in the afternoon.

On January 22, two replications began receiving the full check solution (pH of 5.2) while the other two replications remained on the one half strength check solution. So far no difference has been observed in the growth of the different plants.

Two greenhouse benches are being used in this experiment. Due to the location of the steam pipes, different light intensity and other factors, the placement of each pail in each replication was determined by the random number method. Placement of the replications on the benches was determined in the same way. By using artificial lighting, the plants have been having and will continue to have fifteen hours of light each day.

The different treatments will be started as soon as the plants have made enough growth. At this time one plant of each replication will receive one of the following treatments. Low nitrogen, high nitrogen, minus phosphorus, high phosphorus, minus potassium, high potassium, minus magnesium, high magnesium, minus calcium, high calcium and with each replication there will be one plant receiving the check solution.

As soon as the different treatments are started, observations will be made on a day to day basis for the appearance of deficiency symptoms.

The reason for randomfying the different replications is the sand of one replication is different. Three replications have coarse sand in the borrom of the pail with the top half being filled with fine sand. The sand in these treatments was first treated with one half normal hydrochloric acid, then the sand was leached excessively for several days, then allowed to stand twenty-four hours in one half normal ammonium acetate. After several leachings, the leachate from this, using tap water, was about pH 5.8. The fourth replication contains only fine sand. The only treatment this sand received was a thorough washing with water.

Deficiency - Blueberries - Greenhouse
Meq. per Liter Needed

	$(NH_4)_2SO_4$	$NH_4(H_2PO_4)$	$K(H_2PO_4)$	KSO_4	$MgSO_4$	$CaSO_4$	$H(H_2PO_4$
CK	4	4	0	1	2	3	0
1/5N	0	1.6	1	0	2	3	1.4
-P	8	0	0	1	2	3	0
-K	4	4	0	0	2	3	0
-Mg	4	4	0	1	0	3	0
-Ca	4	4	0	1	2	0	0
+3N	20	4	0	1	2	3	0
+3P	0	8	1	0	2	3	2
+5K	8	0	4	1	2	3	0
+5Mg	5	3	0	1	10	3	1
+5Ca	7	1	0	1	2	15	3

Compositions of Nutrient Solutions

Deficiency - Blueberries - Greenhouses

	NH_4	Ca	K	H	Mg	Total Cations	H_2PO_4	SO_4	Total Anions
Check	8	3	1		2	14	4	10	14
1/5N	1.6	3	1	1.4	2	10	4	5	10
-P	8	3	1		2	14	0	14	14
-K	8	3	0		2	13	4	9	13
-Mg	8	3	1		0	12	4	8	12
-Ca	8	0	1		2	11	4	7	11
+3N	24	3	1		2	30	4	26	30
+3P	8	3	1	2	2	16	11	5	16
+5K	8	3	5		2	18	4	14	18
+5Mg	8	3	1	1	10	23	4	19	23
+5Ca	8	15	1	3	2	29	4	25	29

A Chart for Use in Preparing Trial Solutions

(No. Ml of 1 N Stocks to Add to Make Trial 500 ml Solutions)

Soln.	$(NH_4)_2SO_4$	$NH_4(H_2PO_4)$	$K(H_2PO_4)$	K_2SO_4	$MgSO_4$	$CaSO_4$	$H(H_2PO_4)$
Check	2	2	0	0.5	1	1.5	0
1/5N	0	0.8	0.5	0	1	1.5	0.7
-P	4	0	0	0.5	1	1.5	0
-K	2	2	0	0	1	1.5	0
-Mg	2	2	0	0.5	0	1.5	0
-Ca	2	2	0	0.5	1	0	0
+3N	10	2	0	0.5	1	1.5	0
+3P	0	4	0.5	0	1	1.5	1
+5K	4	0	2	0.5	1	1.5	0
+5Mg	2.5	1.5	0	0.5	5	1.5	0.5
+5Ca	3.5	0.5	0	0.5	1.0	7.5	1.5

Arrangement of Replications and Treatments Within the Replications

Sand

Reps I, II, III were treated

Rep. IV was not

Treatments:

Color Code

1 G = Low Nitrogen

2 G = High Nitrogen

1 B = Minus Phosphorus

2 B = High Phosphorus

1 Y = Minus Calcium

2 Y = High Calcium

1 R = Minus Magnesium

2 R = High Magnesium

1 "O" = Minus Potassium

2 "o" = High Potassium

CK = Check

G = Green Stakes

B = Blue Stakes

Y = Red Stakes

O = Orange Stakes

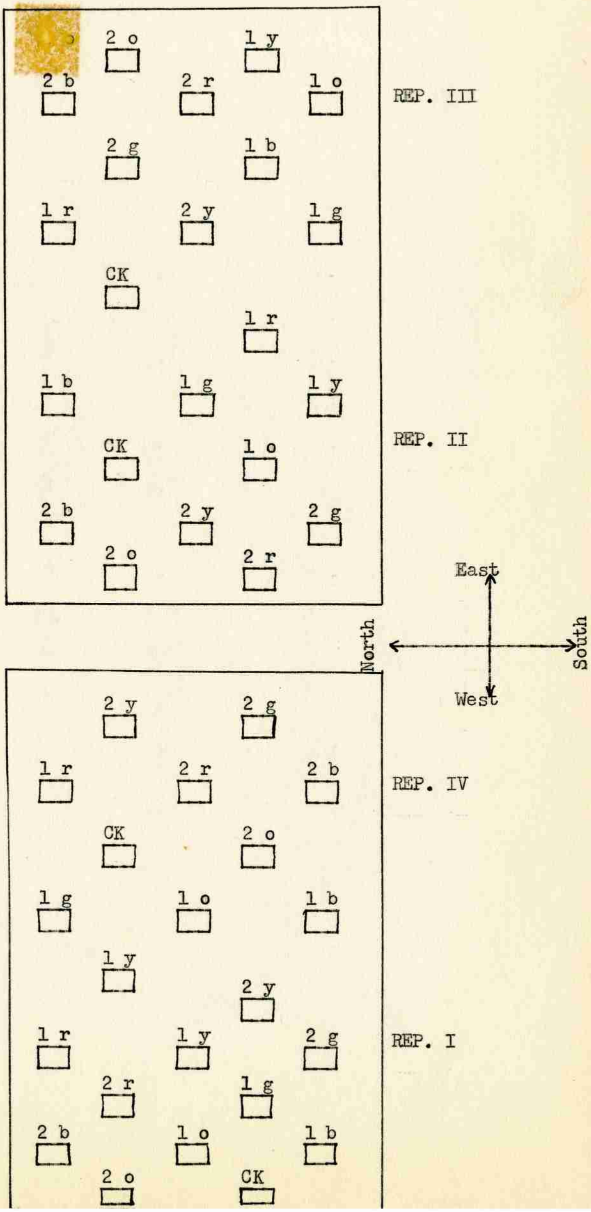

TABLE 10. **RECORD OF SOIL OR PLANT SAMPLES**

Soil: Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant: Strawberry (Specific parts) Project Leader: Walter E. Ballinger

Identification: Leaflets, crowns, roots

Nature of Experiment: Greenhouse sand culture, Nutritional Serial No.

Method of Sampling

Date Sampled: May, 1958 Taken by: W. E. Ballinger Analyses Desired: N,P,K,Ca and Mg

1 of 40 pages

RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N%	CaO%	MgO%	K2O%	P2O5%			
1	50	2.88	.98	.95	.70	.65			
2	51	2.46	.91	.85	.70	.63			
3	52	2.74	.98	.80	.70	.63			
4	53	1.12	.98	.70	.70	.40			
5	54	1.67	1.19	.50	.80	.48			
6	55	1.54	.77	.45	.40	.43			
7	56	2.91	1.19	.75	1.30	.73			
8	57	2.83	.98	.65	1.53	.73			
9	58	2.83	.98	.60	1.47	.75			
10	59	1.65	.98	.55	1.72	.50			
11	60	1.88	1.12	.40	1.65	.63			
12	61	1.88	.63	.55	.80	.60			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*
N-Ca-Mg-P	A.O.A.C.		
K 20	flame photometer		

Remarks: 1 gm to 100 - 40 ml for P

10 ml for K 40 ml for Ca and Mg

RECORD OF SOIL OR PLANT SAMPLES

Soil .... (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader Walter E. Bollinger

Identification: Roots, Crowns, Petioles, leaflets

Nature of Experiment Greenhouse Sand Culture, Nutritional Serial No. ....

Method of Sampling ....

Date Sampled 1958 Taken by W.E.Bollinger Analyses Desired N, P, K, Ca and Mg

2 of 40 pages

RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N%	CaO%	MgO%	K2O%	P_2O_5%			
13	62	2.49	1.89	.65	2.77	.78			
14	63	2.38	1.68	.65	2.77	.80			
15	64	2.48	1.75	.65	2.77	.80			
16	65	1.26	1.54	.50	4.86	.65			
17	66	1.57	1.68	.55	3.64	.70			
18	67	1.99	.77	1.10	3.06	1.05			
19	68	2.55	1.19	.55	3.93	.83			
20	69	2.18	.98	.50	3.57	.83			
21	70	2.46	1.05	.45	3.57	.80			
22	71	1.29	1.05	.40	6.13	.65			
23	72	1.51	1.33	.40	3.85	.70			
24	73	1.96	.84	.70	4.00	.98			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks ....

RECORD OF SOIL OR PLANT SAMPLES

Soil: Hort (Type and Horizon)
Project and Subproject No.: H-152

Plant: Strawberry (Specific parts)
Project Leader: Walter E. Bollinger

Identification:

Nature of Experiment:
Serial No.:

Method of Sampling:

Date Sampled: 1958
Taken by: WEB
Analyses Desired: N, P, K, Ca, Mg

3 of 40 pages

RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N%	CaO%	MgO%	K2O%	P2O5%			
25	74	1.88	1.61	.45	2.91	.25			
26	75	1.76	1.47	.50	2.85	.25			
27	76	1.76	1.47	.50	2.91	.25			
28	77	.86	1.47	.35	4.73	.18			
29	78	1.25	1.89	.45	3.00	.23			
30	79	1.93	.91	.95	2.70	.23			
31	80	1.93	1.68	.60	2.77	.38			
32	81	2.04	1.54	.55	2.77	.45			
33	82	2.04	1.47	.50	2.70	.35			
34	83	1.01	1.40	.40	4.80	.28			
35	84	1.18	1.54	.40	3.20	.35			
36	85	2.07	.77	1.00	2.91	.25			
Lab Check	86	2.72	1.75	.70	2.05	.38			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks:

RECORD OF SOIL OR PLANT SAMPLES

Soil: Hort (Type and Horizon) Project and Subproject No. H-152

Plant: Strawberry (Specific parts) Project Leader: Walter E. Bollinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N, P, K, Ca, Mg.

4 of 40 pages

RECORD OF ANALYSES

Sample Number									
Field	Lab.	N%	CaO%	MgO%	K2O%	P2O5%			
37	87	2.41	1.89	.65	2.70	.75			
38	88	2.35	1.75	.55	2.64	.78			
39	89	2.13	1.75	.60	2.64	.78			
40	90	1.18	1.54	.45	4.73	.63			
41	91	1.57	1.49	.50	3.43	.65			
42	92	1.88	.77	1.15	2.91	.98			
43	93	2.58	1.61	.75	2.70	.85			
44	94	2.46	1.47	.70	2.64	.85			
45	95	2.52	1.61	.65	2.64	.88			
46	96	1.40	1.33	.50	4.73	.70			
47	97	1.71	1.47	.45	3.50	.75			
48	98	2.30	.63	.95	3.35	1.25			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Hort. (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Bollinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N, P, K, Mg, Ca.

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RECORD OF ANALYSES

Sample Number		N%	CaO%	MgO%	K2O%	P2O5%			
Field	*Lab.*								
49	99	1.65	1.75	.50	3.28	.60			
50	100	1.68	1.54	.45	3.06	.60			
51	101	1.71	1.40	.45	3.06	.60			
52	102	.78	1.47	.40	4.80	.50			
53	103	1.01	2.03	.40	3.35	.53			
54	104	.98	.77	.75	2.77	.55			
55	105	1.82	2.03	.50	2.70	.70			
56	106	1.90	1.54	.60	2.64	.70			
57	107	1.90	1.61	.60	2.70	.70			
58	108	.92	1.40	.40	4.70	.58			
59	109	1.18	1.61	.50	3.20	.63			
60	110	1.34	.77	.70	3.02	.90			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Hort. (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Bollinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N, P, K, Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N%	CaO%	MgO%	K2O%	P2O5%			
61	111	2.18	1.89	.55	2.55	.78			
62	112	2.07	1.68	.55	2.50	.73			
63	113	2.16	1.68	.55	2.50	.75			
64	114	1.15	1.47	.45	2.70	.65			
65	115	1.46	1.47	.45	3.30	.75			
66	116	2.02	.70	.95	2.85	.25			
67	117	3.79	.70	.45	2.05	.70			
68	118	3.89	.63	.45	2.35	.80			
69	119	3.81	.56	.40	2.50	.78			
70	120	2.97	.70	.30	1.70	.58			
71	121	3.05	..77	.35	1.40	.65			
72	122	2.72	.49	.25	1.15	.60			
Lab Check	123	1.46	2.03	.70	1.70	.30			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil ..... Hort. ..... Project and Subproject No. H-152
(Type and Horizon)

Plant ..... Strawberry ..... Project Leader ..... W. E. Bollinger
(Specific parts)

Identification: .....

Nature of Experiment ..... Serial No. .....

Method of Sampling .....

.....

Date Sampled ..... 1958 ..... Taken by ..... WEB ..... Analyses Desired ..... N, P, K, Ca, Mg

..... 7 of 40 pages .....

RECORD OF ANALYSES

Sample Number		N%	CaO%	MgO%	K2O%	P2O5%			
Field	*Lab.*								
73	124	2.30	.21	.60	2.40	.70			
74	125	2.30	.28	.60	2.35	.65			
75	126	2.60	.21	.55	2.35	.68			
76	127	1.76	.21	.40	1.22	.25			
77	128	2.35	.63	.50	1.65	.70			
78	129	1.90	.35	.40	.85	.55			
79	130	2.77	.35	.50	2.40	.73			
80	131	2.72	.28	.50	2.35	.78			
81	132	3.05	.35	.45	2.35	.80			
82	133	1.43	.49	.55	2.00	.50			
83	134	1.85	.77	.60	1.48	.55			
84	135	1.90	.42	.30	.90	.55			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks .....

.....

RECORD OF SOIL OR PLANT SAMPLES

Soil Hort. (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Bollinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N, P, K, Ca, Mg.

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N%	CaO%	MgO%	K2O%	P2O5%			
85	136	2.41	1.89	.55	2.35	.78			
86	137	2.21	1.68	.55	2.35	.78			
87	138	2.32	1.68	.50	2.70	.83			
88	139	1.09	1.47	.35	4.80	.63			
89	140	1.54	1.54	.35	3.70	.70			
90	141	1.96	.77	1.05	3.05	1.05			
91	142	2.07	2.24	.50	3.05	.53			
92	143	2.21	2.10	.55	3.05	.50			
93	144	2.21	2.03	.40	3.05	.50			
94	145	1.12	X	X	X	X			
95	146	1.34	1.75	.45	3.55	.40			
96	147	2.04	1.05	.70	2.90	.35			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks X = Lost

RECORD OF SOIL OR PLANT SAMPLES

Soil Hort. (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N, P, K, Ca, Mg

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RECORD OF ANALYSES

Sample Number Field	Lab.	N%	CaO%	MgO%	K2O%	P2O5%			
97	148	2.66	3.57	.30	8.18	.93			
98	149	2.72	1.96	.05	4.50	.73			
99	150	2.58	2.17	.05	4.50	.73			
100	151	1.32	2.97	.05	7.00	.60			
101	152	1.65	3.29	.15	4.60	.60			
102	153	1.62	.98	.35	3.65	.63			
103	154	2.77	1.54	.25	3.65	.80			
104	155	2.69	1.40	.30	3.55	.85			
105	156	2.72	1.40	.40	3.50	.85			
106	157	1.43	1.61	.25	5.80	.60			
107	158	1.62	1.82	.30	3.80	.68			
108	159	1.88	.77	.40	3.05	.65			
Lab check	160	1.68	1.61	.65	2.64	.45			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Hort. (Type and Horizon) Project and Subproject No. H-152

Plant (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K,MgCa.

10 of 40 pages

RECORD OF ANALYSES

Sample Number									
Field	Lab.	N%	CaO%	MgO%	K20%	P205%			
109	161	2.38	1.89	.55	2.78	.83			
110	162	2.46	1.82	.55	2.70	.85			
111	163	2.46	1.68	.65	3.00	.83			
112	164	1.29	1.61	.40	5.30	.65			
113	165	1.51	1.68	.45	3.70	.73			
114	166	1.93	.91	.95	3.50	1.05			
115	167	2.49	1.33	1.15	2.40	.88			
116	168	2.35	1.19	1.00	2.62	.88			
117	169	2.52	1.19	1.00	2.55	.88			
118	170	1.29	.91	.80	5.50	.65			
119	171	1.62	1.05	.75	3.85	.70			
120	172	2.04	.77	1.30	3.12	1.00			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil .... Hort .... (Type and Horizon) .... Project and Subproject No. H-152

Plant .... Strawberry .... (Specific parts) .... Project Leader .... W. E. Ballinger

Identification: ....

Nature of Experiment .... Serial No. ....

Method of Sampling ....

....

Date Sampled .... 1958 .... Taken by ..... WEB .... Analyses Desired N, P, K, Ca, Mg ....

.... 11 of 40 pages ....

RECORD OF ANALYSES

Sample Number		N%	CaO%	MgO%	K2O%	P2O5%			
Field	*Lab.*								
121	173	2.58	1.62	.15	5.65	.65			
122	174	2.49	1.68	.10	5.25	.68			
123	175	2.46	1.61	.10	5.15	.60			
124	176	1.37	2.24	.05	7.00	.55			
125	177	1.34	2.59	.15	4.35	.60			
126	178	1.51	.98	.35	3.80	.65			
127	179	2.44	1.33	.30	3.42	.75			
128	180	2.41	1.05	.10	3.50	.75			
129	181	2.30	1.12	.25	3.42	.73			
130	182	1.34	1.26	.10	4.92	.60			
131	183	1.68	1.54	.25	3.50	.68			
132	184	1.85	.63	.35	2.70	.70			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks ....

....

RECORD OF SOIL OR PLANT SAMPLES

Soil Hort. (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N, P, K, Ca, Mg

12 of 40 pages

RECORD OF ANALYSES

Sample Number									
Field	Lab.	N%	CaO%	MgO%	K2O%	P2O5%			
133	185	2.07	1.61	.55	2.78	.73			
134	186	2.18	1.33	.50	2.78	.73			
135	187	2.10	1.47	.60	2.78	.73			
136	188	1.04	1.33	.45	4.92	.55			
137	189	1.26	1.47	.40	4.35	.80			
138	190	1.74	..84	.70	3.20	.90			
139	191	2.24	1.12	1.00	2.40	.78			
140	192	2.16	.98	.95	2.55	.78			
141	193	2.21	1.05	.90	2.40	.78			
142	194	.98	.84	.80	4.85	.60			
143	195	1.32	.98	.65	3.85	.73			
144	196	1.82	.63	1.40	3.02	1.13			
Lab Check	197	1.90	.84	.25	3.14	.63			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K, Ca & Mg

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RECORD OF ANALYSES

Sample Number		N%	CaO%	MgO%	K_2O %	P_2O_5 %			
Field	Lab.								
145	198	1.51	1.61	.45	3.12	.53			
146	199	1.51	1.47	.45	3.12	.55			
147	200	1.54	1.33	.40	2.78	.55			
148	201	.67	1.93	.25	4.85	.53			
149	202	.98	1.54	.35	3.12	.53			
150	203	.92	.70	.75	2.55	.55			
151	204	1.74	1.48	.45	2.78	.70			
152	205	1.82	1.33	.40	2.78	.68			
153	206	1.79	1.33	.45	2.90	.70			
154	207	.81	1.26	.30	4.92	.53			
155	208	1.20	1.33	.40	3.80	.65			
156	209	1.04	.56	.75	3.65	1.05			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 198 Taken by WEB Analyses Desired N,P,K, Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N%	CaO%	MgO%	K_2O %	P_2O_5%			
157	210	2.07	1.68	.55	2.50	.73			
158	211	2.13	1.54	.55	2.55	.75			
159	212	2.16	1.54	.55	2.55	.73			
160	213	1.04	1.33	.35	5.10	.60			
161	214	1.51	1.40	.40	3.70	.73			
162	215	1.88	.70	.90	3.12	1.03			
163	216	3.84	.63	.40	2.20	.75			
164	217	3.81	.56	.40	2.28	.73			
165	218	3.75	.56	.45	2.35	.75			
166	219	3.33	.63	.25	1.60	.60			
167	220	2.77	.77	.30	1.48	.68			
168	221	2.41	.49	.20	1.15	.60			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K, Ca, Mg

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RECORD OF ANALYSES

Sample Number Field	Sample Number Lab.	N%	CaO%	MgO%	K_2O%	P_2O_5%			
169	222	1.85	1.40	.45	2.85	.25			
170	223	1.68	1.26	.45	2.85	.25			
171	224	1.65	1.26	.45	2.85	.25			
172	225	1.46	1.26	.25	5.40	.20			
173	226	1.06	1.47	.40	3.05	.25			
174	227	1.99	.77	.90	2.90	.23			
175	228	1.85	1.47	.50	2.40	.35			
176	229	1.82	1.33	.45	2.62	.33			
177	230	1.96	1.26	.45	2.40	.33			
178	231	.90	1.19	.35	4.38	.25			
179	232	1.24	1.33	.40	2.78	.35			
180	233	2.10	.77	.80	3.20	.30			
Lab check	234	2.97	1.40	.60	2.34	.73			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K, Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	Lab.	N%	CaO%	MgO%	K_2O%	P_2O_5 %			
181	235	2.16	1.68	.50	2.34	.68			
182	236	2.04	1.54	.45	2.40	.68			
183	237	1.96	1.54	.40	2.40	.68			
184	238	1.15	1.40	.35	4.85	.58			
185	239	1.34	1.40	.45	3.05	.73			
186	240	1.74	.70	.90	3.12	1.00			
187	241	2.32	1.54	.60	2.40	.80			
188	242	2.04	1.33	.50	2.35	.78			
189	243	2.24	1.33	.55	2.35	.80			
190	244	1.15	1.19	.40	4.70	.68			
191	245	1.71	1.26	.50	3.35	.80			
192	246	2.10	.63	.65	3.30	1.18			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number Field	Lab.	N%	CaO %	MgO %	K_2O %	P_2O_5 %			
193	247	3.14	.91	.85	.70	.75			
194	248	3.02	.91	.80	.70	.73			
195	249	2.91	.91	.95	.62	.70			
196	250	1.46	.91	.75	.70	.48			
197	251	1.85	1.26	.45	.80	.60			
198	252	1.37	.70	.40	.45	.48			
199	253	2.66	1.05	.95	1.22	.70			
200	254	2.52	.84	.50	1.40	.70			
201	255	2.69	.91	.55	1.40	.75			
202	256	1.62	.84	.45	1.52	.58			
203	257	1.82	1.12	.45	1.60	.65			
204	258	1.65	.56	.50	.80	.60			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil **Horticulture** (Type and Horizon) Project and Subproject No. **H-152**

Plant **Strawberry** (Specific parts) Project Leader **W. E. Ballinger**

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled **1958** Taken by **WEB** Analyses Desired **N,P,K,Ca, Mg**

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
205	259	2.21	1.82	.65	2.90	.75			
206	260	1.90	1.61	.70	2.35	.75			
207	261	2.24	1.68	.70	2.50	.73			
208	262	1.12	1.47	.40	4.92	.60			
209	263	1.46	1.61	.40	3.35	.48			
210	264	1.71	.77	.85	3.12	.98			
211	265	2.24	.98	.45	3.50	.73			
212	266	2.02	.84	.40	3.50	.73			
213	267	2.13	.84	.55	3.50	.75			
214	268	.98	.91	.35	5.70	.60			
215	269	1.46	1.12	.45	4.30	.68			
216	270	1.71	.63	.55	4.20	.98			
Lab check	271	2.16	.42	.35	2.05	.60			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil: Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant: Strawberry (Specific parts) Project Leader: W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled: 1958 Taken by: WEB Analyses Desired: N, P, K, Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	Lab.	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
217	272	2.69	.14	.50	2.40	.70			
218	273	1.32	.21	.65	2.50	.63			
219	274	1.32	.21	.50	2.55	.73			
220	275	1.85	X	X	X	X			
221	276	2.18	.70	.40	1.52	.58			
222	277	1.62	.35	.35	1.00	.53			
223	278	2.86	.35	.55	2.50	.75			
224	279	2.94	.28	.50	2.55	.80			
225	280	2.94	.28	.50	2.55	.75			
226	281	1.46	.49	.50	2.40	.53			
227	282	.90	.77	.80	1.48	.58			
228	283	1.65	.42	.80	.80	.55			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks: X = Lost

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K, Ca, Mg

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RECORD OF ANALYSES

Sample Number Field	Lab.	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
229	284	2.21	1.82	.55	2.40	.78			
230	285	2.18	1.61	.55	2.35	.75			
231	286	1.99	1.61	.60	2.78	.70			
232	287	1.06	1.47	.40	4.60	.63			
233	288	1.40	1.68	.50	3.14	.70			
234	289	1.79	.70	.95	2.27	.95			
235	290	1.99	2.38	.50	2.27	.55			
236	291	1.96	2.10	.60	2.34	.55			
237	292	2.10	2.10	.50	2.42	.60			
238	293	1.04	1.96	.45	4.36	.43			
239	294	1.29	1.75	.35	3.42	.58			
240	295	1.85	.91	.70	2.56	.48			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil **Horticulture** (Type and Horizon) Project and Subproject No. **H-152**

Plant **Strawberry** (Specific parts) Project Leader **W. E. Ballinger**

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled **1958** Taken by **WEB** Analyses Desired **N,P,K,Ca, Mg**

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RECORD OF ANALYSES

Sample Number									
Field	Lab.	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
241	296	1.76	1.40	.40	2.63	.23			
242	297	1.76	1.26	.45	2.63	.25			
243	298	1.76	1.33	.25	2.63	.25			
244	299	.84	1.26	.30	4.29	.20			
245	300	.95	1.40	.25	2.77	.25			
246	301	1.85	.63	.85	2.56	.20			
247	302	1.88	1.40	.45	2.56	.33			
248	303	1.90	1.33	.50	2.56	.33			
249	304	1.76	1.40	.45	2.49	.33			
250	305	.95	1.40	.25	4.36	.23			
251	306	1.15	1.54	.30	2.92	.33			
252	307	2.07	.63	.75	2.49	.23			
Lab check	308	1.99	.63	.80	2.42	.25			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K, Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
253	309	2.18	1.75	.55	2.34	.73			
254	310	1.96	1.54	.50	2.27	.75			
255	311	2.13	1.47	.50	2.34	.75			
256	312	1.12	1.40	.35	4.50	.60			
257	313	1.40	1.40	.50	3.14	.68			
258	314	1.85	.77	.85	3.06	1.18			
259	315	2.24	1.54	.60	2.27	.83			
260	316	2.21	1.40	.60	2.20	.80			
261	317	2.13	1.40	.60	2.20	.83			
262	318	1.23	1.19	.55	4.36	.68			
263	319	1.48	1.19	.50	3.27	.75			
264	320	1.82	.63	.85	3.06	1.23			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil **Horticulture** (Type and Horizon) Project and Subproject No. **H-152**

Plant **Strawberry** (Specific parts) Project Leader **W. E. Ballinger**

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled **1958** Taken by **WEB** Analyses Desired **N,P,K,Ca,Mg**

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
265	321	2.69	.21	.65	2.34	.98			
266	322	2.64	.14	.60	2.34	.78			
267	323	2.68	.21	.40	2.27	.73			
268	324	X	X	X	X	X			
269	325	2.60	.56	.60	1.85	.78			
270	326	1.71	.35	.50	.86	.58			
271	327	2.91	.28	.55	2.13	.78			
272	328	2.66	.28	.50	2.13	.75			
273	329	2.97	.21	.55	2.13	.78			
274	330	1.46	.42	.60	2.13	.60			
275	331	1.93	.77	.50	1.72	.65			
276	332	1.71	.35	.35	1.22	.63			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks X = Lost

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number Field	Sample Number Lab.	N %	CaO%	MgO%	K_2O %	P_2O_5 %			
277	333	2.07	1.75	.50	2.05	.70			
278	334	2.10	1.47	.55	2.13	.75			
279	335	1.99	1.47	.55	2.13	.75			
280	336	1.06	1.33	.40	4.14	.63			
281	337	1.51	1.33	.40	3.20	.78			
282	338	1.82	.63	.80	2.56	1.03			
283	339	2.10	2.17	.50	2.49	.50			
284	340	2.07	1.89	.45	2.42	.53			
285	341	2.07	1.96	.45	2.42	.50			
286	342	1.01	1.75	.45	4.29	.40			
287	343	1.46	1.89	.55	3.27	.50			
288	344	1.93	.98	.55	2.85	.43			
Lab check	345	2.63	1.61	.70	2.20	.38			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil . . . Horticulture . . . . Project and Subproject No. H-152
(Type and Horizon)

Plant . . . Strawberry . . . . Project Leader . . W. E. Ballinger
(Specific parts)

Identification: . . . .

Nature of Experiment . . . . Serial No. . . . .

Method of Sampling . . . .

. . . .

Date Sampled . . . . 1958 . . . . . . Taken by . . . . . WEB . . . . Analyses Desired N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	Lab.	N %	CaO %	MgO%	K_2O %	P_2O_5 %			
289	346	2.41	2.03	.25	4.07	.60			
290	347	2.44	1.89	.15	4.14	.68			
291	348	2.41	1.89	.35	4.00	.65			
292	349	1.29	2.45	.10	6.54	.58			
293	350	1.46	2.45	.40	4.14	.70			
294	351	1.68	.84	.50	3.27	.68			
295	352	2.32	1.05	.25	2.92	.73			
296	353	2.32	.98	.45	2.92	.73			
297	354	2.24	1.12	.25	2.92	.68			
298	355	1.15	1.19	.25	4.22	.55			
299	356	1.62	1.33	.30	3.14	.65			
300	357	1.82	.56	.50	2.49	.63			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks . . . .

. . . .

RECORD OF SOIL OR PLANT SAMPLES

Soil **Horticulture** (Type and Horizon) Project and Subproject No. **H-152**

Plant **Strawberry** (Specific parts) Project Leader **W. E. Ballinger**

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled **1958** Taken by **WEB** Analyses Desired **N, P, K, Ca, Mg**

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RECORD OF ANALYSES

Sample Number									
Field	Lab.	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
301	358	2.30	1.75	.65	2.27	.75			
302	359	2.21	1.54	.60	2.34	.78			
303	360	1.93	1.47	.50	2.42	.78			
304	361	1.06	1.40	1.00	4.36	.60			
305	362	1.57	1.40	.55	3.64	1.03			
306	363	1.96	.63	1.05	3.27	1.13			
307	364	2.18	1.19	1.30	2.00	1.05			
308	365	2.18	1.12	1.10	2.00	.83			
309	366	2.18	1.12	1.05	2.00	.83			
310	367	1.09	.84	.90	4.44	.68			
311	368	1.51	.84	.80	3.27	.73			
312	369	1.76	.56	1.30	2.92	1.18			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil: Horticulture (Type and Horizon) — Project and Subproject No.: H-152

Plant: Strawberry (Specific parts) — Project Leader: W. E. Ballinger

Identification:

Nature of Experiment — Serial No.

Method of Sampling

Date Sampled: 1958 — Taken by: WEB — Analyses Desired: N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
313	370	2.72	.84	.80	.63	.65			
314	371	2.58	.77	.75	.63	.63			
315	372	2.63	.70	.80	.63	.60			
316	373	X	.84	.65	.56	.38			
317	374	1.79	.98	.50	.69	.48			
318	375	1.23	.70	.40	.39	.40			
319	376	2.66	.91	.70	1.22	.73			
320	377	2.63	.84	.80	1.10	.70			
321	378	2.60	.84	.70	1.10	.73			
322	379	1.43	.77	.55	1.28	.58			
323	380	1.85	X	.55	1.28	.60			
324	381	1.60	.56	.80	.56	.60			
Lab check	382	1.40	2.03	.85	1.65	.35			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks: X = Lost

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	Lab.	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
325	383	2.10	1.75	.65	2.00	.75			
326	384	2.07	1.54	.65	2.00	.75			
327	385	2.04	1.61	.65	2.05	.75			
328	386	1.09	1.40	.55	4.29	.63			
329	387	1.40	1.47	.55	3.50	.70			
330	388	1.93	.63	1.00	2.92	.95			
331	389	2.02	1.05	.50	3.35	.80			
332	390	4.23	.91	.55	3.20	.75			
333	391	2.07	.84	.40	3.35	.70			
334	392	. 98	.98	.40	5.24	.63			
335	393	1.18	1.05	.65	3.64	.65			
336	394	1.54	.56	.70	3.64	.78			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K,Ca, Mg

29 or 40 pages

RECORD OF ANALYSES

Sample Number		N %	CaO %	MgO %	K_2O %	P_2O_5 %			
Field	Lab.								
337	395	1.51	1.33	.75	3.20	.58			
338	396	1.51	1.19	.60	3.27	.58			
339	397	1.43	1.19	.60	3.00	.60			
340	398	.67	1.40	.40	5.64	.50			
341	399	.84	1.56	.35	3.57	.50			
342	400	.90	.70	.75	2.63	.53			
343	401	1.82	1.40	.70	2.63	.73			
344	402	1.76	1.56	.50	2.77	.73			
345	403	1.79	1.40	.55	2.63	.73			
346	404	.76	1.33	.50	4.65	.58			
347	405	1.18	.98	.60	3.50	.68			
348	406	1.18	.49	.90	3.20	1.03			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil **Horticulture** (Type and Horizon) Project and Subproject No. **H-152**

Plant **Strawberry** (Specific parts) Project Leader **W. E. Ballinger**

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled **1958** Taken by **WEB** Analyses Desired **N, P, K, Ca, Mg**

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
349	407	2.13	1.68	.65	2.49	.78			
350	408	2.07	1.56	.65	2.49	.78			
351	409	1.93	1.56	.60	2.42	.75			
352	410	1.01	1.33	.55	4.21	.65			
353	411	1.34	1.33	.55	3.35	.70			
354	412	1.76	.63	.95	2.63	.93			
355	413	3.84	.63	.65	2.13	.75			
356	414	3.75	.56	.45	2.27	.78			
357	415	3.72	.56	.60	2.20	.78			
358	416	2.91	.63	.40	1.47	.58			
359	417	2.94	.77	.55	1.22	.65			
360	418	2.72	.49	.20	1.04	.70			
Lab check	419	1.90	1.75	.75	2.49	.48			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil ..... Horticulture ..... (Type and Horizon) Project and Subproject No. H-152

Plant ..... Strawberry ..... (Specific parts) Project Leader ..... W. E. Ballinger

Identification: .....

Nature of Experiment ..... Serial No. .....

Method of Sampling .....

.....

Date Sampled ..... 1958 ..... Taken by ..... WEB ..... Analyses Desired N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
361	420	2.72	.84	.95	.51	.65			
362	421	2.32	.84	.80	.45	.60			
363	422	2.44	.84	.85	.51	.60			
364	423	X	1.05	.65	.45	.40			
365	424	1.40	1.19	.35	.69	.43			
366	425	1.24	.77	.50	.28	.40			
367	426	2.66	.84	.60	1.16	.73			
368	427	2.63	.84	.70	1.22	.75			
369	428	2.58	.84	.70	1.28	.75			
370	429	1.29	.91	.50	1.40	.55			
371	430	1.68	.98	.60	1.60	.65			
372	431	1.48	.56	.65	.75	.60			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks ..... X = Lost .....

.....

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number		N %	Cao %	MgO %	K_2O %	P_2O_5 %			
Field	Lab.								
373	432	1.93	1.96	.70	2.63	.80			
374	433	1.99	1.61	.80	2.20	.73			
375	434	1.82	1.61	.60	2.34	.73			
376	435	.87	1.26	.50	4.58	.60			
377	436	1.15	1.26	.65	3.35	.65			
378	437	1.62	.56	.50	2.42	.98			
379	438	2.10	1.05	.50	3.42	.78			
380	439	1.96	.91	.60	3.35	.78			
381	440	2.07	.91	.60	3.35	.73			
382	441	1.04	.98	.40	5.48	.65			
383	442	1.32	.98	.45	3.70	.70			
384	443	1.71	.63	.50	3.86	1.05			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by W. E. Ballinger Analyses Desired N,P,K,Ca, Mg.

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RECORD OF ANALYSES

Sample Number									
Field	Lab.	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
385	444	2.64	.21	.60	2.13	.70			
386	445	2.58	.21	.75	2.27	.73			
387	446	1.23	.21	.70	2.27	.70			
388	447	X	.28	.55	1.90	.45			
389	448	2.27	.56	.70	1.65	.70			
390	449	1.60	.35	.45	.93	.58			
391	450	2.88	.35	.65	2.27	.83			
392	451	2.60	.28	.65	2.27	.80			
393	452	2.74	.35	.30	2.27	.78			
394	453	1.57	.49	.55	2.27	.63			
395	454	1.87	.56	.45	1.77	.63			
396	455	1.88	.42	.45	1.04	.60			
Lab check	456	2.02	.91	.25	2.77	.63			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks X = Lost

RECORD OF SOIL OR PLANT SAMPLES

Soil **Horticulture** (Type and Horizon) Project and Subproject No. **H-152**

Plant **Strawberry** (Specific parts) Project Leader **W. E. Ballinger**

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled **1958** Taken by **WEB** Analyses Desired **N,P,K,Ca, Mg**

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
397	457	1.96	2.38	.50	2.63	.50			
398	458	1.99	2.17	.45	2.56	.53			
399	459	1.93	2.10	.35	2.56	.50			
400	460	.92	1.75	.20	4.65	.38			
401	461	1.18	1.33	.35	3.50	.60			
402	462	1.60	.70	.80	2.70	.85			
403	463	2.04	1.82	.60	2.63	.80			
404	464	1.85	1.68	.50	2.63	.78			
405	465	2.02	1.61	.55	2.63	.78			
406	466	.95	1.47	.35	4.65	.63			
407	467	1.34	1.82	.30	3.35	.50			
408	468	2.07	.98	.70	2.34	.40			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	Lab.	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
409	469	2.63	2.17	.05	5.15	.78			
410	470	2.52	1.96	.10	5.00	.73			
411	471	2.49	2.00	.50	5.07	.73			
412	472	2.66	2.59	.20	6.86	.63			
413	473	2.68	2.94	.15	4.58	.73			
414	474	1.60	.91	.45	3.20	.70			
415	475	2.32	1.40	.15	3.20	.78			
416	476	2.30	1.26	.10	3.00	.78			
417	477	2.30	1.26	.10	3.00	.78			
418	478	1.01	1.40	.15	4.65	.60			
419	479	1.48	1.26	.25	3.50	.70			
420	480	1.57	.70	.35	2.49	.65			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil: Horticulture (Type and Horizon)

Project and Subproject No. H-152

Plant: Strawberry (Specific parts)

Project Leader: W. E. Ballinger

Identification:

Nature of Experiment:

Serial No.

Method of Sampling:

Date Sampled: 1958

Taken by: WEB

Analyses Desired: N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number		N %	CaO %	MgO %	K_2O %	P_2O_5 %			
Field	*Lab.*								
421	481	2.04	1.89	.65	2.49	.75			
422	482	2.10	1.61	.50	2.42	.73			
423	483	2.04	1.68	.50	2.42	.75			
424	484	.98	1.40	.35	4.50	.60			
425	485	1.20	1.40	.30	3.52	.65			
426	486	1.76	.70	.85	2.85	1.05			
427	487	2.16	1.19	1.15	2.00	.78			
428	488	1.99	1.12	1.10	2.05	.78			
429	489	2.13	1.12	1.05	1.90	.78			
430	490	1.04	.84	.90	4.47	.63			
431	491	1.37	.98	.75	3.50	.63			
432	492	1.65	.56	1.55	2.49	1.08			
Lab check	493	3.00	1.54	.70	2.49	.73			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks:

RECORD OF SOIL OR PLANT SAMPLES

Soil **Horticulture** (Type and Horizon) Project and Subproject No. **H-152**

Plant **Strawberry** (Specific parts) Project Leader **W. E. Ballinger**

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled **m 1958** Taken by **WEB** Analyses Desired **N, P, K, Ca, Mg**

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
433	494	1.68	1.40	.45	2.92	.25			
434	495	1.57	1.19	.30	2.92	.25			
435	496	1.60	1.19	.45	2.92	.25			
436	497	.67	1.33	.20	4.58	.18			
437	498	.90	2.10	.35	2.70	.23			
438	499	1.99	.70	.80	2.42	.20			
439	500	1.82	1.47	.45	2.63	.35			
440	501	1.90	1.33	.50	2.77	.40			
441	502	1.71	1.33	.50	2.70	.38			
442	503	.78	1.33	.10	4.58	.23			
443	504	1.01	1.40	.35	2.85	.33			
444	505	1.79	.70	.85	2.42	.25			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil ... Horticulture ... (Type and Horizon) Project and Subproject No. ... H-152

Plant ... Strawberry ... (Specific parts) Project Leader ... W. E. Ballinger

Identification: ...

Nature of Experiment ... Serial No. ...

Method of Sampling ...

...

Date Sampled ... 1958 ... Taken by ... WEB ... Analyses Desired ... N, P, K, Ca, Mg

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
445	506	1.99	1.82	.60	2.49	.78			
446	507	2.07	1.61	.50	2.56	.80			
447	508	2.07	1.61	.55	2.56	.75			
448	509	.92	1.40	.30	4.58	.63			
449	510	1.23	1.26	.40	3.50	.70			
450	511	1.46	.70	.90	2.63	.95			
451	512	2.18	1.47	.60	2.34	.83			
452	513	2.16	1.33	.60	2.34	.85			
453	514	2.10	1.26	.65	2.34	.83			
454	515	.98	1.19	.40	4.50	.63			
455	516	1.26	1.05	.45	3.35	.75			
456	517	1.96	.63	.75	3.05	1.30			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks ...

...

RECORD OF SOIL OR PLANT SAMPLES

Soil **Horticulture** (Type and Horizon) Project and Subproject No. **H-152**

Plant **Strawberry** (Specific parts) Project Leader **W. E. Ballinger**

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled **1958** Taken by **WEB** Analyses Desired **N,P,K,Ca, Mg**

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RECORD OF ANALYSES

Sample Number									
Field	*Lab.*	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
457	518	1.48	1.54	.40	3.14	.60			
458	519	1.43	1.26	.45	2.92	.58			
459	520	1.46	1.33	.40	3.30	.58			
460	521	.62	1.33	.30	4.73	.53			
461	522	.78	1.54	.30	3.20	.53			
462	523	1.01	.70	.70	2.49	.55			
463	524	1.68	1.47	.50	2.77	.70			
464	525	1.74	1.40	.45	2.77	.70			
465	526	1.79	1.40	.50	2.77	.73			
466	527	.70	1.26	.35	4.73	.58			
467	528	.90	1.26	.35	3.06	.58			
468	529	.98	.63	.70	3.00	1.00			

Constituent	*Method of Determination*	*Constituent*	*Method of Determination*

Remarks

RECORD OF SOIL OR PLANT SAMPLES

Soil Horticulture (Type and Horizon) Project and Subproject No. H-152

Plant Strawberry (Specific parts) Project Leader W. E. Ballinger

Identification:

Nature of Experiment Serial No.

Method of Sampling

Date Sampled 1958 Taken by WEB Analyses Desired N,P,K,Ca, Mg

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RECORD OF ANALYSES

Sample Number Field	Lab.	N %	CaO %	MgO %	K_2O %	P_2O_5 %			
469	530	2.16	1.82	.55	2.56	.75			
470	531	2.04	1.61	.55	2.49	.78			
471	532	1.90	1.68	.55	2.49	.78			
472	533	.98	1.33	.40	4.50	.60			
473	435	1.26	1.26	.40	3.20	.65			
474	535	1.79	.63	.75	2.70	.95			
475	536	3.64	.63	.45	2.20	.80			
476	537	3.67	.63	.40	2.20	.80			
477	538	3.50	.63	.40	2.20	.80			
478	539	2.72	.70	.35	1.65	.60			
479	540	2.74	.70	.30	1.34	.65			
480	541	2.83	.42	.30	1.34	.65			
Lab Check	542	2.13	.56	.40	1.85	.70			

Constituent	Method of Determination	Constituent	Method of Determination

Remarks