The Effect of Varying Levels of Nitrogen, Phosphorus, Potassium, and Calcium on the Quality of the Newburgh Raspberry

Peter B. Enns

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INTRODUCTION

The Newburgh raspberry, ever since its development at the New York State Experiment Station, Geneva, New York, has been noted for its superior vigor and productiveness, and its ability to withstand winter injury even in areas in which a high water table is common. In many districts of the Fraser Valley, in which restricted sub-surface drainage is prevalent, the variety was received enthusiastically largely because of these qualities.

During the period of World War 11 and the immediate postwar years there was an increasing market for sulphur dioxide preserved berries to supply the overseas demand. Since a ready market awaited all the fruit that could be produced, yield became of paramount importance, and quality received little attention.

Under these circumstances the Newburgh became the dominant variety in the new plantings. In some of the newer districts of Sumas Prairie, Yarrow and Chilliwack, this variety accounted for as high as 90% of the total raspberry acreage.

With the termination of the overseas contract in 1945, the market for sulphur dioxide preserved berries was virtually wiped out, leaving the berry industry dependent largely on local and American markets for the fresh and frozen product.

This situation brought the weakness of the Newburgh into the limelight. Its low sugar content, resulting in a rather acid flavor, began to draw increasing criticism. Likewise its adaptability for the quick freeze method of preserving became rather doubtful. A product is said to possess freezing qualities to the extent that it retains, during and after freezing, its natural shape, colour and flavor. Due to its high water content, the Newburgh does not retain its shape very well. Its relatively low sugar content often results in too tart a flavor, or, if acidity also is lacking, gives it a flat taste.

Since the Newburgh possesses characteristics which make it particularly suited to certain areas, the question arose, whether fertilizer treatments could be used to improve its quality. Considerable work has been done in the past on the effect of fertilizer treatment on plant growth, general vigor and yield. Not until quite recently, however, has any attention been given to its effect on the quality of the crop produced.

The purpose of the present experiment was to ascertain the effect of varying amounts of nitrogen, phosphorous and potassium in the fertilizer applied on the quality of the Newburgh raspberry.

Determinations were made on sugar content, vitamin C. content, total solids, soluble solids, proteins, acidity, total minerals, flavor, and freezing quality, all of which are important characteristics of quality.

REVIEW OF LITERATURE

Food quality studies are of relatively recent origin. The characteristics most commonly dealt with in such studies are sugar content, vitamin content and acidity, either total or active. The work done to date on the effect of various fertilizer materials on these characteristics of quality, indicates that the level of nitrogen fertilizer applied is inversely correlated with both sugar and Vitamin Content. Phosphate fertilizers have been shown to have an influence on the flavor of the fruit produced. Thus Darrow (6) found that plants which had received superphosphates together with nitrogen fertilizer produced much sweeter and better flavored berries than plants receiving no phosphates. Similar results were obtained by Vercier (29). Reed (22) observed that the absence of phosphorus greatly impaired the transformation of starch into water-soluble carbohydrates.

The effect of potasium fertilizer on the sugar content of plants has been investigated by numerous workers, but the results are very contradictory and confusing (19). Regarding the effect of potash on flavor Darrow (6) and Vercier (29) found that strawberry plants fertilized with sulphate of potash or muriate of potash produced berries that were sour and lacked flavor in comparison to berries from plants receiving the nitrogen plus superphosphate treatment.

That sugar content and total acidity are closely connected with flavor was demonstrated by Harding and Wadley (10) who found high correlations between palatability and both total acids and solids. Currence and Larson (5) also showed a significant correlation between quality score and refractometer readings. Bartholomew and Sinclair (4) found a high correlation between total soluble solids and total sugars in orange juice. In a later paper (24) the same authors point out that "in fruit-quality studies, the proportion of total sugars to total soluble solids, not the absolute amount of total soluble solids, is the factor which primarily affects the sensation of sweetness". The fact that in most fruits the total sugars make up the major portion of the total soluble solids accounts for the close correlation between total soluble solids and edible quality.

MATERIALS AND METHODS

(a) Location and Layout of Experiment

The location chosen for the experiment was a field of four year old Newburgh raspberry plants at Yarrow, B.C. This district was chosen because of the proportionately large acreage devoted to the Newburgh variety.

A field experiment consisting of four adjacent blocks of ten plots each was laid out according to the randomized block system. The exact layout is illustrated in figure (1) and (2). The rows were 8 feet wide and the plants in the rows 3 feet apart. Each block consisted of five rows. Of these five rows numbers 1,3 and 5 served as buffers. In the even-numbered rows the two plants at each end as well as every tenth plant also acted as buffers. Each plot, therefore, consisted of nine plants and was in area 27 feet by 8 feet - 216 square feet or approximately one-two hundredth of an acre. For fertilizing purposes, however, the size of plot became 30 feet by 16 feet - 480 square feet or approximately one-nintieth of an acre. This difference is due to the fact that the fertilizer was applied broadcast, so that the buffer rows on either side as well as the buffer plants at each end of the plot received an equal share of fertilizer. This difference in plot size is illustrated in figure (3).

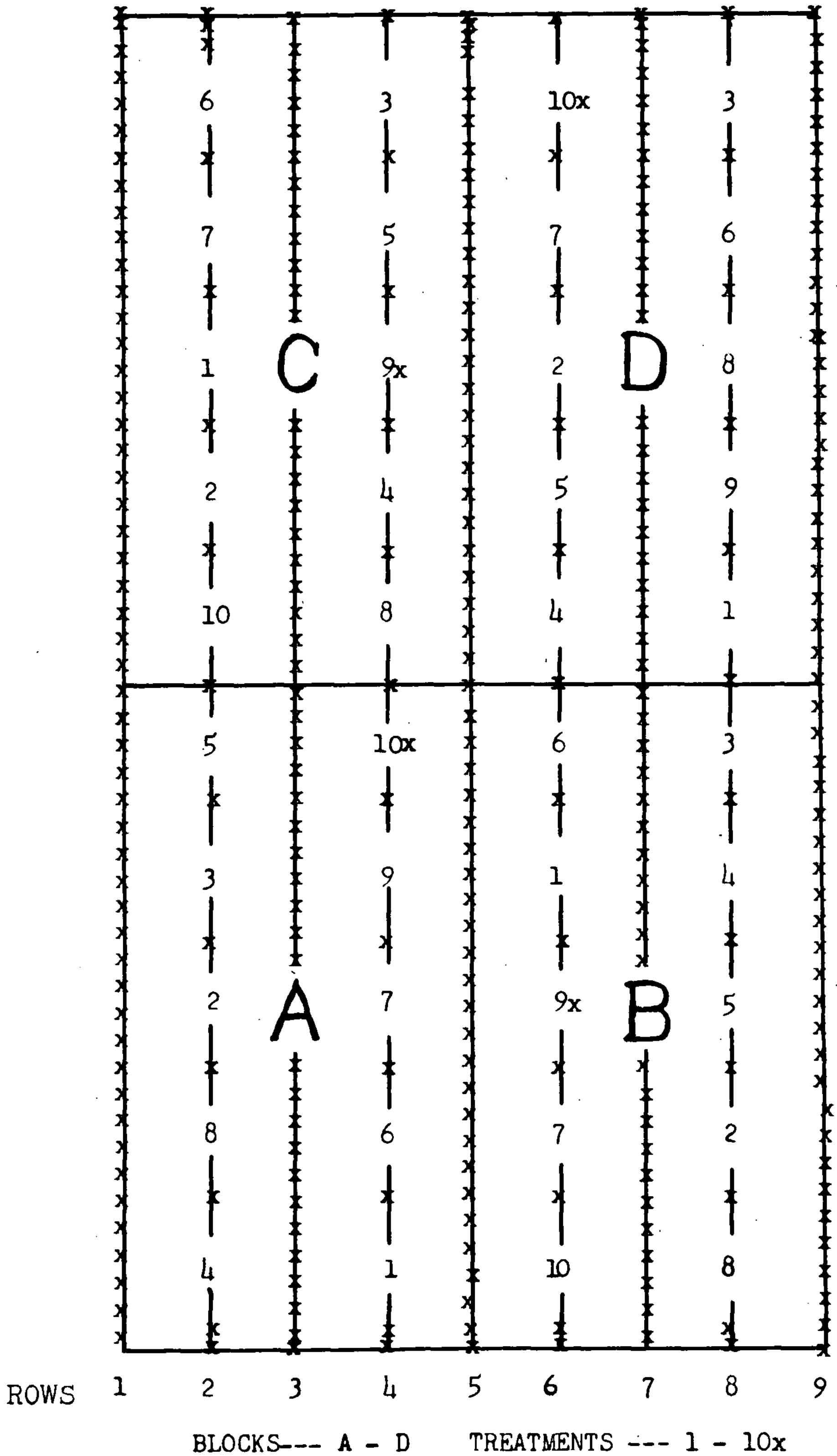


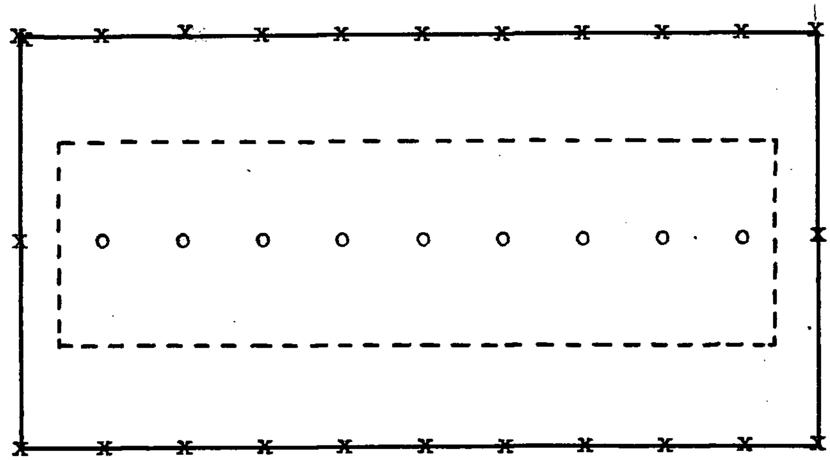
fig. 1. Layout of Blocks and Plots (x--Buffer plants)

6 $N_2 P_2 K_3$	3 $N_2P_2K_1$ + Lime	10X Check	3 $N_2 P_2 K_1$ + Lime
7 $N_2P_2K_3$ + Lime	5 $N_1P_2K_3$ + Lime	7 $N_2P_2K_3$ + Lime	6 $N_2P_2K_3$
1 $N_1P_2K_1$ + Lime	9X Milorganite	2 $N_2 P_2 K_1$	8 $N_3P_2K_3$ + Lime
2 $N_2 P_2 K_1$	4 $N_3P_2K_1$ + Lime	5 $N_1P_2K_3$ + Lime	9 Milorganite + Lime
10 Check + Lime	8 $N_3P_2K_3$ + Lime	4 $N_3P_2K_1$ + Lime	1 $N_1P_2K_1$ + Lime
5 $N_1P_2K_3$ + Lime	10X Check	6 $N_2 P_2 K_3$	3 $N_2P_2K_1$ + Lime
3 $N_2P_2K_1$ + Lime	9 Milorganite + Lime	1 $N_1P_2K_1$ + Lime	4 $N_3P_2K_1$ + Lime
2 $N_2 P_2 K_1$	7 $N_2P_2K_3$ + Lime	9X Milorganite	5 $N_1P_2K_3$ + Lime
8 $N_3 P_2K_3$ + Lime	6 $N_2 P_2 K_3$	7 $N_2P_2K_3$ + Lime	2 $N_2 P_2 K_1$
4 $N_3P_2K_1$ + Lime	1 $N_1P_2K_1$ + Lime	10 Check + Lime	8 $N_3P_2K_3$ + Lime

Randomized plots with respective treatments

Legend: N_1 = 20 lbs/Ac(low) N_2 = 60 lbs/Ac (Med) N_3= 160 lbs/ac.(high)
P_2 = 80 lbs/Ac K_1 = 30 lbs/Ac (Low) K_3= 90 lbs/Ac.(high)
Milorganite: 1 Ton per Acre Lime 1 Ton per Acre

Fig. 2.



Legend: _______________ Boundary of plot for fertilizing purposes. Area: 30 feet by 16 feet equals 480 square feet.

\- - - - - - - - - Boundary of plot for calculating yield. Area: 27 feet by 8 feet equals 216 square feet.

o -------------- Plants from which berries were harvested.

x -------------- Buffer plants.

fig.(3) A representative plot showing buffer plants and plants from which berries were harvested.

Nature of soil and Method of Analysis

The soil on which the experiment was located is classified by the Lower Fraser Valley Soil Survey (25) as a Monroe Clay Loam. It is generally of a highly fertile nature and except for its restricted sub-drainage is well adapted to the growing of cane fruits.

Although a detailed analysis of the soil was not carried out, an attempt was made to determine the relative level of fertility of the soil on which the test plots were located.

Soil samples were taken on February 21, 1948, and analyzed at the Plant Nutrition laboratory, U.B.C., for nitrogen phosphorus, potassium, magnesium, organic matter, and soil reaction. The methods outlined by Morgan (20) were used in making all determinations except that of soil reaction. The latter was determined with a Beckman pH meter, using a glass electrode.

The results of the preliminary soil analysis are given in Table 1, below. They indicate that both nitrogen and potassium content were very low. This is in agreement with the findings of Harris and Woods (12) in

Table (1) Results of Preliminary Soil Analysis

Sample No.	N.	P.	K.	Mg.	Organic Matter	pH
1	very low	low med.	very low	high	high	5.85
2	"	med.	"	"	"	5.25
3	"	low med.	"	"	"	5.1
4	"	low med.	"	"	"	5.35
5	"	med.	"	"	"	5.05
6	"	low med.	"	"	"	5.25
					composite sample	5.35

their work on the seasonal variation of plant nutrients in raspberry plantings of the Fraser Valley. The phosphorus content ranged from low to medium and the magnesium content was high. Organic matter was high in all samples tested. The soil samples varied considerably in acidity with pH values ranging from 5.05 to 5.85. A composite sample comprised of equal amounts of all samples gave a pH reading of 5.35 which is satisfactory for the growing of raspberries on a soil of this type.

However, in order to ascertain whether liming had any effect on the quality of the fruit lime was applied at the rate of 1 ton per acre, or 22 lbs. per plot. As immediate or first-year effects were desired the $Ca(OH)_2$ form, sold commercially as agricultural lime, was used. The amount applied is, theoretically, enough to raise the reaction of a clay loam, high in organic matter, such as was used in this experiment, approximately 7 units. The lime was broadcast by hand on March 19, 1948.

(c) Fertilizers used and method of application

The fertilizer materials used were ammonium sulphate (20-0-0), superphosphate (0-18-0), and muriate of potash (0-0-60). Also included was a treatment using an organic fertilizer, sold commercially as Milorganite. The latter treatment was included since this fertilizer was being used extensively in the Yarrow district.

The rates at which the fertilizers were applied in the various treatments are given in table (2).

The fact that raspberries respond well to luxurious phosphorus feeding was noted by Harris (11) and later confirmed by Hornby (14). In order to keep the number of treatments as low as possible, only one level of phosphorus, 80 lbs. per acre, was used. This is well above the average level usually recommended for raspberries in that district.

TABLE (2) Fertilizer Treatments as applied to Newburgh Raspberry Plots.

TREATMENT NO.		N	P_2O_5	K_2O
		lbs./acre	lbs./acre	lbs./acre
1	$(N_1P_2K_1)$ #	20	80	30
2 X	$(N_2P_2K_1)$	60	80	30
3	$(N_2P_2K_1)$	60	80	30
4	$(N_3P_2K_1)$	160	80	30
5	$(N_1P_2K_3)$	20	80	90
6 X	$(N_2P_2K_3)$	60	80	90
7	$(N_2P_2K_3)$	60	80	90
8	$(N_3P_2K_3)$	160	80	90
(9	(Milorganite)	120	40	0
(9 X	(Milorganite)	120	40	0
(10	(Check)	0	0	0
(10 X	(Check)	0	0	0

- 1 - low; 2 - medium; 3 - high

X - Treatments marked X did not receive any lime. All others received lime at the rate of 1 ton per acre.

(d) Method of Harvesting and Processing of Berries

The samples for analysis were harvested and processed as indicated in Table (3). The berries were picked directly into 20 oz. tins to avoid unnecessary handling. To ensure as representative a sample as possible, four or five berries were picked from both sides of each plant in the plot. The samples for canning were taken into cold storage and canned the same day. Aside from the fact that no syrup or sugar was added, the regular commercial canning procedure for canning raspberries was used. This consisted of a twelve minute exhaust period at 185°F. followed by an 8 minute cook at 210°F. in a continuous rotating cooker. The samples were then cooled in a water bath and stored at room temperature in the Plant Nutrition laboratory, Department of Horticulture, U.B.C. The frozen samples were stored at the Abbotsford cold storage plant until the beginning of November and were then transferred to the freezing unit of the Animal Pathology Department, U.B.C., and held at 0°F. until opened for analyses.

Table (3) Dates of Harvesting, and Methods of Preservation of Newburgh Raspberries

Picking Date #	Method of Preservation	Code No. of Series
July 17, 1948	Canned	C - 1
July 24, 1948	Frozen	F - 1
July 31, 1948	Frozen	F - 2
July 31, 1948	Canned	C - 2

One sample per plot was picked on each picking date

(e) Methods of Analysis of Fruit

The determinations made in the laboratory included, Vitamin C., total solids, total soluble solids, total sugars, total acidity, total minerals, proteins, flavor and freezing quality.

(i) Method of Vitamin C. Determination The method used here was the Indophenol-xylene Extraction Method for Ascorbic Acid used by Robinson and Stotz (23). The modification for interfering substances was found to be unnecessary and therefore the basic method was used.

(ii) Total solids were determined by drying a 25 gm. sample of fresh weight in a drying oven for seventy two to ninety six hours at 60°C. All determinations were made in duplicate.

(iii) Total soluble solids were estimated by use of a Bellingham and Stanley refractometer graduated to read in percentage of sugar.

(iv) Total sugars were determined according to the method of the Association of Official Agricultural Chemists (2), using 20 grams of juice.

(v) Total acidity - This was also determined according to the method of the Association of Official Agricultural Chemists (2).

(vi) Total Minerals- determined on a one gram sample of oven dry material. A muffle furnace was used with a temperature of 600°F. All samples were ashed in triplicate.

(vii) Flavor and freezing quality were determined by a tasting panel comprised of four smokers and four non-smokers. The method used in grading edible quality was used by J.D. Winter (31) in his work on "Strawberry and Raspberry Varieties for Freezing Storage". The scoring system was modified to the extent that color was rated twice as important and flavor three times as important as the other two characteristics, texture and shape. This modification was considered to be more appropriate since only one variety was concerned in which case both color and flavor were deemed more important than either texture or shape.

(viii) Protein Content was determined according to the method of the Association of Official Agriculture Chemists (2).

OBSERVATIONS AND RESULTS

Field Observations on General conditions of Plants as observed on Dates of Harvesting

In spite of the extremely wet growing season and flood conditions only two plots, C_6 and C_7, showed marked effects of excess moisture. The two plots were situated in a slight depression at the extreme end of the field (see fig. 1.). The plants in both plots were stunted badly and the foliage was a greenish yellow as might be found in a case of extreme nit rogen deficiency.

Although no definite symptoms of nitrogen deficiency were noticed except in the two above mentioned cases, every plot conspicuous for its somewhat sparse foliage was found to be of Treatment 1 (low N.) Treatment 5 (low N.) or the Check Plots 10 and 10x, both of which had no Nitrogen. Likewise, the few plots which were outstanding because of their luxuriant growth were invariably of the high Nitrogen treatments.

Plants bearing uniformly large berries were much more prevalent in the plots receiving medium or high nitrogen than in plots to which low nitrogen or none at all had been applied.

Vitamin C

Results of the analyses for vitamin C are given in Table IV, V, and VI. Statistical analyses, Table V., showed that the fruit from unlimed plots had a significantly higher Vitamin C content than fruit from plots that had received lime. Varying nitrogen levels in the fertilizer treatments had no significant effect, although there was a trend for the Vitamin C content to increase with increased nitrogen up to the medium level and then to decrease with the high nitrogen level. The depressing effect of lime on the Vitamin C content tended to be minimized by a high level of potassium (Table Vl). It will be noticed, for instance, that although lime lowered the Vitamin C content in both the low and high potassium treatments, it only lowered it by 31.00 - 29.23 = 1.77 mg. per 100 gm. at the high potassium level as against 31.22 - 27.8 = 3.42 mg. per 100 gm. at the low potassium level.

Figure 4 illustrates graphically the effect of lime on the vitamin C content of raspberries. It also serves to illustrate the fact that in fertilizer treatments high in potash (treatments 7 and 8), the Vitamin C content is not lowered as severely as in treatments low in potash (treatments 1,4 and 10).

Total Sugars

The results from total sugar determinations on the complete F-1 series are given in Table Vll. Analyses of Variance (Table Vlll) indicate a significant difference between treatments. When the high nitrogen fertilizer treatments are compared with the low nitrogen treatments, the difference is found to be highly significant, i.e., the nitrogen level in the fertilizer treatment, and the sugar content of the raspberries produced, appear to be negatively correlated. This negative correlation is illustrated in fig. 5.

Below are the results of the percentage sugar content from the various fertilizer treatments arranged in descending order:

Fertilizer Treatment	% Sugar Content	Fertilizer Treatment	% Sugar Content
$N_2P_2K_3$ + lime	2.92	$N_1P_2K_1$ - Lime	2.62
Check + lime	2.86	$N_3P_2K_1$ + lime	2.60
$N_2P_2K_3$ - lime	2.77	$N_3P_2K_3$ + lime	2.60
Check - lime	2.75	Milorganite-Lime	2.56
$N_1P_2K_1$ + lime	2.72	$N_2P_2K_1$ + Lime	2.52
$N_1P_2K_3$ + lime	2.72	Milorganite+lime	2.47

In order to determine whether any one treatment gave significantly higher results than another, the larger figure must be as great or greater than the sum of the smaller figure plus the significant difference. Thus $N_2P_2K_3$+ lime (2.92) is greater than the $N_1P_2K_1$- lime treatment (2.62) or any treatment below it. Likewise it can be said that the top four treatments are the only treatments which can be considered as giving a significantly higher sugar content than the Milorganite - lime treatment which gave the lowest results.

Total Solids

Table IX gives the percentage dry weights or total solids for both the F-1, (frozen) and C-1 (canned) series. None of the three variables used in the fertilizer treatments i.e., nitrogen, potassium or lime, had a consistent or significant effect on the dry weight of the fruit.

The only noteworthy feature in the table is the fact that plots C_{6x} and C_7, the only two plots which suffered markedly from excess moisture, produced fruit which was highest in total solids in both the frozen and canned series.

Total Soluble Solids

Table X gives the percentage of total soluble solids, as determined by a refractometer, of both F-1 and C-1 series of raspberries. Although the results were not analyzed statistically for significance, they were compared with both edible quality, Table XII, as determined organoleptically by a panel of eight co-workers, and by total acidity (Table XI, F-2 series). The obvious correlation between total soluble solids and edible quality is shown in figure 6. The negative correlation between edible quality and total acidity is also illustrated in figure 6.

Total Acidity

The correlation between total acidity and edible quality has already been mentioned.

Another interesting feature of the total acidity results in Table XI is illustrated in figure 7, where the average total acidity values per treatment, of both F-1 and F-2 series are plotted in ascending order. Possible reasons for the considerably lower values in the F-2 series will be discussed later.

Edible Quality

The results in Table XII were derived by taking the average of the total score allotted to samples from each treatment for color, shape, texture and flavor. The points allotted for color were doubled, those for flavor were tripled, while those for shape and texture were left unaltered. The reason for weighting color and flavor was already mentioned.

Total Minerals

The percentage ash weights of fruit from both F-1 and C-1 series are given in Table XIII. The analyses of variance Table XIV show that while there is no significant difference between individual treatments, there is a highly significant difference between the mineral content of raspberries from limed treatments and those receiving no lime. Figure 8 shows that all the limed treatments resulted in fruit which was lower in minerals than fruit from treatments receiving no lime.

Protein Content

Table XVI gives the protein content of the juice from Newburgh raspberries of the F-1 series. Table XVIII shows the protein content of Newburgh raspberries including the seeds. Statistical analyses,Table XVII of the results in Table XVII indicate that the no one fertilizer treatment gave a significantly higher protein content than another treatment.

However, the averages of the high, medium, low Nitrogen treatments in the C-1 series are, 1.149, 1.148 and 1.094 respectively, showing a tendency for Protein content of the fruit to increase with the level of Nitrogen applied in the fertilizer treatments.

Conductivity

The results given in Table XV. showed no consistent trends.

TABLE IV. Vitamin C Content of Newburg Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium and Lime

Fertilizer Treatments	A	B	C	D	Total	Av.
	Mg. per 100 Ml Juice					
1 ($N_1P_2K_1$)	27.95	30.87	26.62	23.04	108.48	27.12
2X ($N_2P_2K_1$)	30.27	28.80	24.53	24.84	108.44	27.11
3 ($N_2P_2K_1$)	25.98	31.95	28.05	29.52	115.50	28.87
4 ($N_3P_2K_1$)	29.00	25.65	24.53	30.24	109.42	27.35
5 ($N_1P_2K_3$)	26.56	29.79	28.38	28.08	112.81	28.2
6X ($N_2P_2K_3$)	29.35	28.26	34.32	32.04	123.97	31.00
7 ($N_2P_2K_3$)	28.65	29.79	32.23	27.72	118.39	29.6
8 ($N_3P_2K_3$)	29.69	29.79	27.28	32.76	119.52	29.88
9 (Milorganite)	25.63	26.64	30.36	31.68	114.31	28.58
9X(Milorganite)	31.09	34.47	27.28	32.49	125.33	31.33
10 (Check)	29.23	23.58	30.14	25.56	108.51	27.13
10X(Check)	34.80	29.97	33.33	30.24	128.34	32.1

X - Treatments without lime.

TABLE V. Analyses of Variance of Vitamin C Content of Juice of Raspberries Receiving Varying Amounts of Fertilizer

Source of Variation	S.S.	Degrees of freedom	Variance	Calculated F.	Tabled F.
Total	400.32	47	8.51		
Total Treatments	136.80	11	12.43	1.56	
Limed vs. Unlimed	(44.31)	(1)	44.31	5.56	4.14($P=.05$)
Block	.26	3	.09		
Error	263.26	33	7.97		

TABLE VI. The Effect of Nitrogen, Potassium, and Lime in Fertilizer Treatments on the Vitamin C Content (in mg. per 100 gm.) of Newburgh Raspberries.

Fertilizer Treatments:		High Nitrogen		Medium Nitrogen		Low or No Nitrogen		Averages	
		+ Lime	- Lime	+ Lime	- Lime	+ Lime	- Lime		
High Potassium	+ Lime	29.88		29.60		28.20		+ Lime 29.23	29.87
	- Lime		0		31.00		0	- Lime 31.00	
Low or No Potassium	+ Lime	27.35 28.58		28.87		27.12 27.13		+ Lime 27.80	28.92
	- Lime		31.33		0		32.10	- Lime 31.22	
Average	+ Lime	28.60		29.23		27.48		+ Lime 28.44	
	- Lime		31.33		31.00		32.10	- Lime 30.83	
		29.28		29.82		28.64			

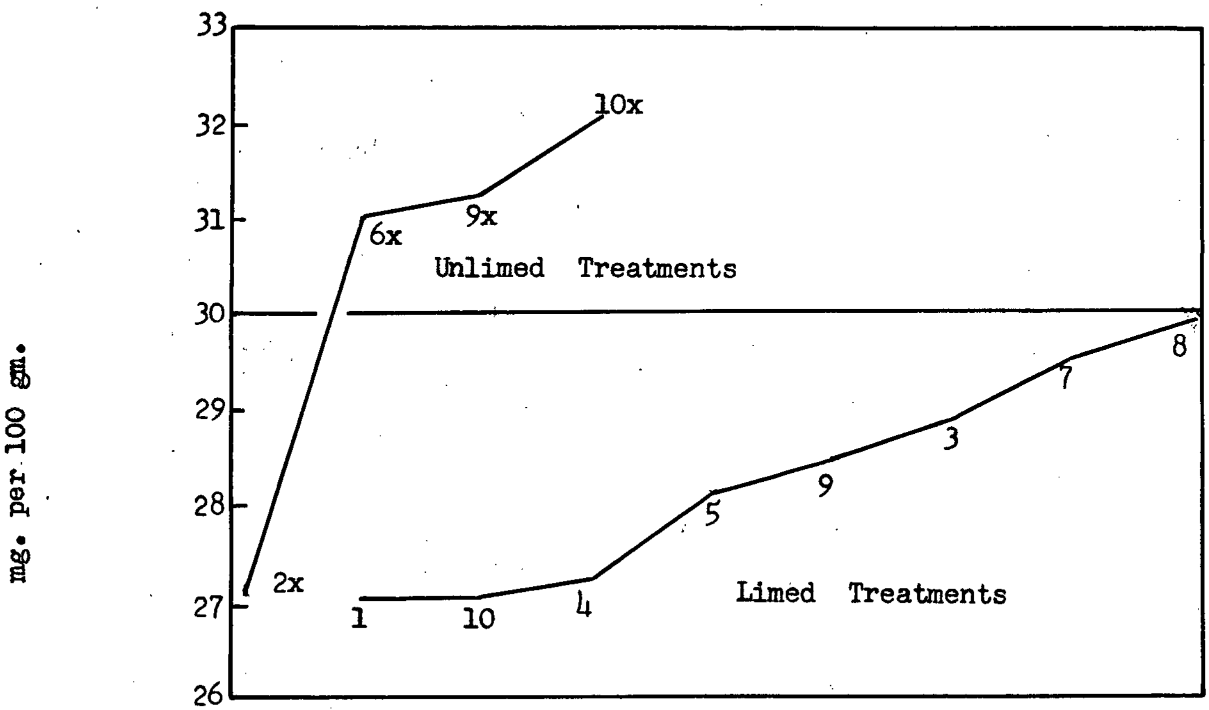


fig. 4. The effect of lime on Vitamin C content

1	(N_1 P_2 K_1)	5	(N_1 P_2 K_3)	9	Milorganite
2x	(N_2 P_2 K_1)	6x	(N_2 P_2 K_3)	9x	Milorganite
3	(N_2 P_2 K_1)	7	(N_2 P_2 K_3)	10	Check
4	(N_3 P_2 K_1)	8	(N_3 P_2 K_3)	10x	Check

x -- treatments without lime

TABLE VII. Total Sugar Content of Newburgh Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium and Lime

Fertilizer Treatments	BLOCKS A	B	C	D	Total	Average
	Percent. of Fresh Weight					*
1 $(N_1P_2K_1)$	2.50	2.82	2.74	2.84	10.90	2.72
2 x $(N_2P_2K_1)$	2.43	2.68	2.58	2.81	10.50	2.62
3 $(N_2P_2K_1)$	2.64	2.52	2.48	2.66	10.30	2.52
4 $(N_3P_2K_1)$	2.45	2.61	2.46	2.90	10.40	2.60
5 $(N_1P_2K_3)$	2.36	2.84	2.86	2.84	10.90	2.72
6x $(N_2P_2K_3)$	2.55	2.78	3.23	2.54	11.10	2.77
7 $(N_2P_2K_3)$	2.76	2.88	3.26	2.80	11.70	2.92
8 $(N_3P_2K_3)$	2.50	2.63	2.60	2.67	10.40	2.60
9 (Milorganite)	2.45	2.50	2.45	2.50	9.90	2.47
9x(Milorganite)	2.50	2.62	2.50	2.62	10.24	2.56
10 (Check)	2.82	2.82	2.90	2.90	11.44	2.86
10x(Check)	2.72	2.78	2.72	2.78	11.00	2.75

x - Treatments without lime

TABLE VIII. Analyses of Variance of Total Sugar Content of Newburgh Raspberries from Plots Receiving Varying Amounts of Fertilizer

Source of Variation	S.S.	Degrees of freedom	Variance	Calculated F.	Tabled F.
Total	1.99	47	.0423		
Total Treatments	.78	11	.0709	2.46 *	2.11(P=.05) 2.87(P=.01)
Low Nitrogen vs. High Nitrogen	(.35)	(1)	(.35)	12.15 **	
Block	.26	3	.087	3.02 *	
Error	.95	33	.0288		

* Significant Difference between means = .26

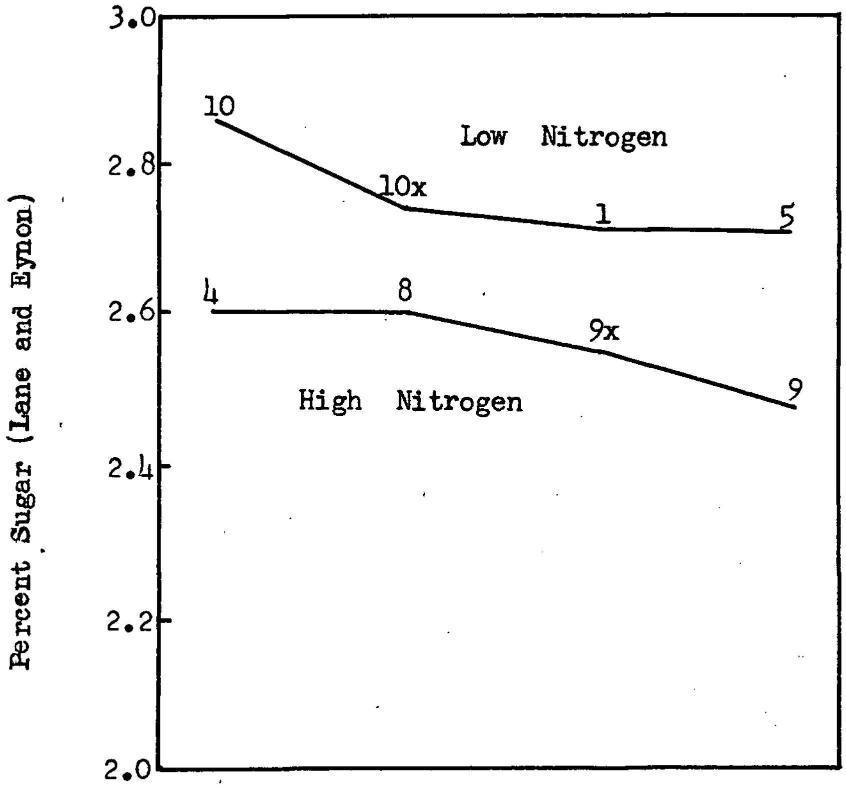


fig.(5) Comparison between the effect of high nitrogen and low nitrogen fertilizer treatments on sugar content.

1 (N_1 P_2 K_1)	5 (N_1 P_2 K_3)	9 Milorganite
2x (N_2 P_2 K_1)	6x (N_2 P_2 K_3)	9x Milorganite
3 (N_2 P_2 K_1)	7 (N_2 P_2 K_3)	10 Check
4 (N_3 P_2 K_1)	8 (N_3 P_2 K_3)	10x Check

x - treatments without lime

TABLE IX. Total Solids of Newburgh Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium and Lime

F-1 Series

Fertilizer Treatments.	A	B	C	D	Average
			Percent of Fresh Weight		
1 ($N_1P_2K_1$)	12.14	12.48	12.48	13.12	12.55
2x ($N_2P_2K_1$)	12.88	13.20	12.64	13.26	13.13
3 ($N_2P_2K_1$)	12.48	12.36	12.68	13.19	12.68
4 ($N_3P_2K_1$)	12.25	12.18	11.68	12.85	12.24
5 ($N_1P_2K_3$)	13.48	12.96	13.02	13.08	13.13
6x ($N_2P_2K_3$)	12.28	12.46	14.28	12.42	12.86
7 ($N_2P_2K_3$)	12.24	12.61	13.04	12.58	12.62
8 ($N_3P_2K_3$)	13.04	13.00	12.12	13.22	12.85
9 (Milorganite)	12.64	12.84	12.65	12.83	12.74
9x(Milorganite)	12.40	12.94	12.30	12.84	12.62
10 (Check)	12.32	12.68	12.36	12.72	12.52
10x(Check)	12.52	12.72	12.93	13.11	12.82

C-1 Series

Fertilizer Treatments.	A	B	C	D	Average
1 ($N_1P_2K_1$)	12.72	12.14	12.22	12.68	12.44
2x ($N_2P_2K_1$)	12.53	13.26	12.38	12.40	12.64
3 ($N_2P_2K_1$)	13.25	12.63	12.89	11.92	12.68
4 ($N_3P_2K_1$))	12.71	12.63	12.30	12.84	12.62
5 ($N_1P_2K_3$)	12.40	11.91	11.92	12.76	12.25
6x ($N_2P_2K_3$)	12.75	12.57	14.60	11.66	12.89
7 ($N_2P_2K_3$)	11.85	12.07	14.08	12.72	12.68
8 ($N_3P_2K_3$)	12.96	11.92	12.28	12.68	12.46
9 (Milorganite)	12.83	12.22	12.30	11.68	12.26
9x (Milorganite)	12.19	12.92	11.76	12.49	12.34
10 (Check)	12.32	12.06	12.76	12.50	12.41
10x(Check)	12.65	12.70	12.81	12.84	12.75

TABLE X. Total Soluble Solids Content of Newburgh Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium, and Lime

F-1 Series

Fertilizer Treatments	BLOCKS A	B	C	Av.
1 ($N_1P_2K_1$)	6.8	6.8	8	7.2
2x ($N_2P_2K_1$)	6.3	8	7.7	7.33
3 ($N_2P_2K_1$)	6.7	7.4	7.5	7.2
4 ($N_3P_2K_1$)	6.8	7.6	7.2	7.2
5 ($N_1P_2K_3$)	6.2	8.5	8.1	7.6
6x ($N_2P_2K_3$)	6.2	6.4	9.1	7.23
7 ($N_2P_2K_3$)	6.7	7.2	8.6	7.5
8 ($N_3P_2K_3$)	6.8	8.4	7.5	7.56
9 (Milorganite)	6.2	-	-	6.2
9x (Milorganite)	-	7.9	7.3	7.6
10 (Check)	-	8.5	8.0	8.25
10x (Check)	6.8	-	-	6.8

C-1 Series

Fertilizer Treatments	B	C	D	Av.
1 ($N_1P_2K_1$)	9.1	-	8.8	8.95
2x ($N_2P_2K_1$)	9.1	-	8.5	8.8
3 ($N_2P_2K_1$)	8.2	-	7.5	7.85
4 ($N_3P_2K_1$)	9.0	-	9.0	9.0
5 ($N_1P_2K_3$)	8.6	9.5	9.5	9.2
6x ($N_2P_2K_3$)	9.0	10.5	7.5	9.0
7 ($N_2P_2K_3$)	9.0	10.0	9.2	9.4
8 ($N_3P_2K_3$)	9.4	7.6	7.7	8.2
9 (Milorganite)	-	-	7.7	7.7
9x (Milorganite)	8.1	7.4	-	7.75
10 (Check)	9.2	9.1	-	9.15
10x (Check)	-	-	9.9	9.9

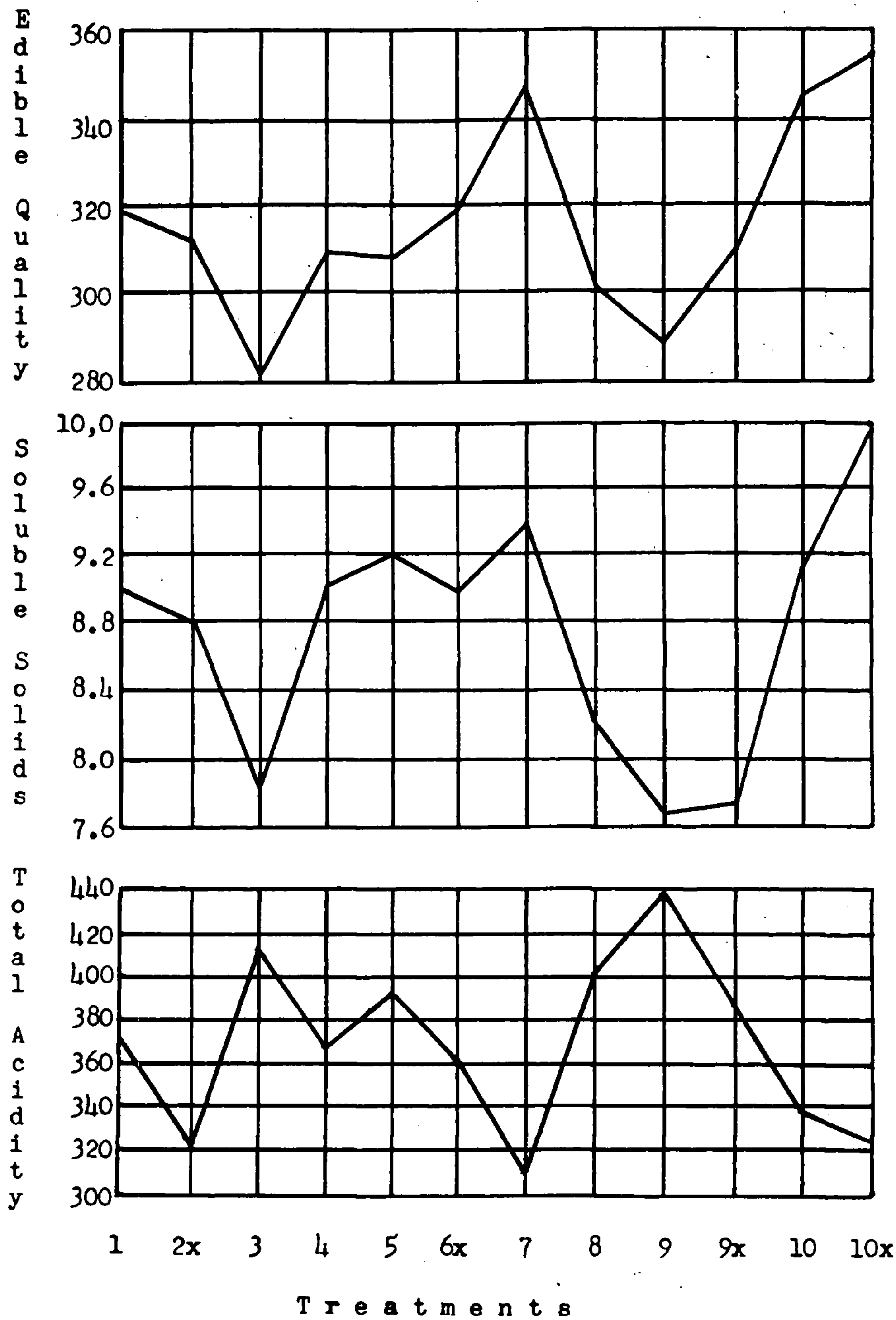


fig. (6) Effect of fertilizer treatments on edible quality as determined by tasting panel, total soluble solids (refractometer), and total acidity in cc. .1 N NaOH per 100 gms. of juice.

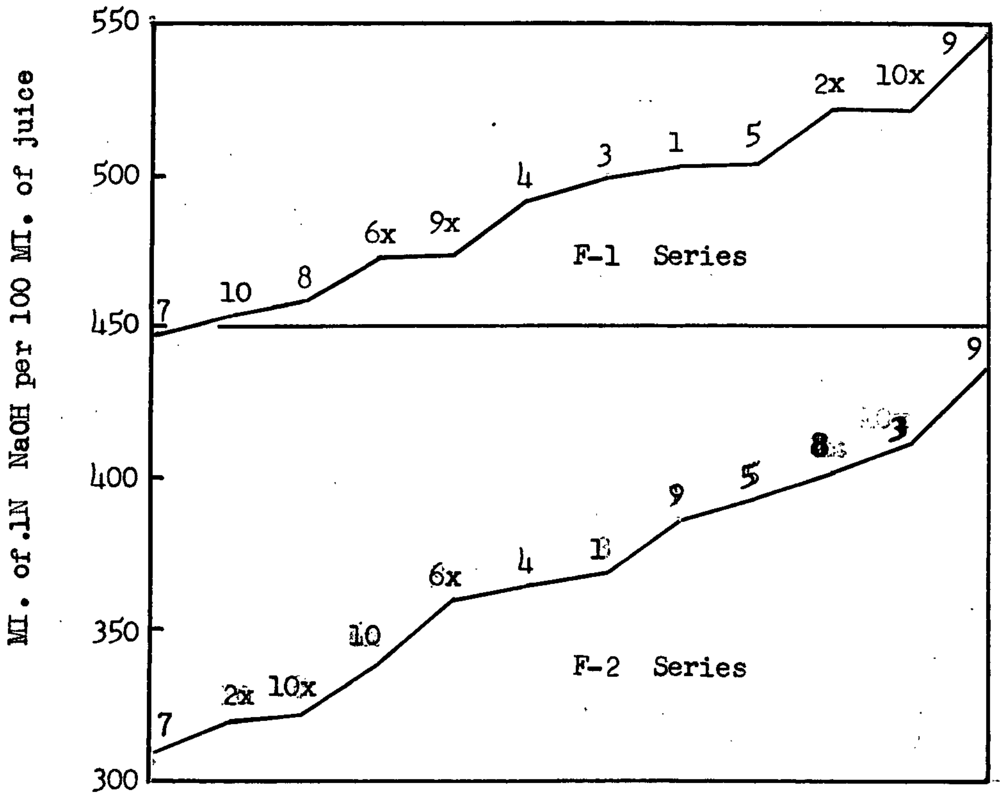


Fig.(7) Total acidity in F-1 series Raspberries harvested on July 24, and F-2 series harvested one week later.

1	$(N_1\ P_2\ K_1)$	5	$(N_1\ P_2\ K_3)$	9	Milorganite
2x	$(N_2\ P_2\ K_1)$	6x	$(N_2\ P_2\ K_3)$	9x	Milorganite
3	$(N_2\ P_2\ K_1)$	7	$(N_2\ P_2\ K_3)$	10	Check
4	$(N_3\ P_2\ K_1)$	8	$(N_3\ P_2\ K_3)$	10x	Check

x = treatments without lime

TABLE XI. Total Acids Content of Newburgh Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium and Lime

F-1 Series

Fertilizer Treatments	BLOCKS A	B	C	D /100	Av
		in Ml. of .I N	NaOH per Ml. of Juice		
1 ($N_1P_2K_1$)	516	466	484	552	505
2x ($N_2P_2K_1$)	604	518	462	514	524
3 ($N_2P_2K_1$)	540	494	444	522	500
4 ($N_3P_2K_1$)	550	510	444	466	492
5 ($N_1P_2K_3$)	516	516	478	518	507
6x ($N_2P_2K_3$)	462	464	462	504	473
7 ($N_2P_2K_3$)	516	462	356	458	448
8 ($N_3P_2K_3$)	532	500	458	552	460
9 (Milorganite)	528	-	-	562	545
9x (Milorganite)	-	484	468	-	476
10 (Check)	-	438	472	-	455
10x (Check)	544	-	-	504	524

F-2 Series

Fertilizer Treatments	B	C	D	Av. /100
		in Ml. of .I N	NaOH per Ml. of Juice	
1 ($N_1P_2K_1$)	332	-	407	369.5
2x ($N_2P_2K_1$)	329	-	314	321.5
3 ($N_2P_2K_1$)	421	-	407	414
4 ($N_3P_2K_1$)	425	-	308	366.5
5 ($N_1P_2K_3$)	407	436	336	393
6x ($N_2P_2K_3$)	336	356	393	361
7 ($N_2P_2K_3$)	343	288	300	310
8 ($N_3P_2K_3$)	407	377	420	401
9 (Milorganite)	-	-	438	438
9x (Milorganite)	400	393	-	386
10 (Check)	329	347	-	338
10x (Check)	-	-	325	325

Table XII. Total points for edible quality allotted by a tasting panel to Newburgh Raspberries from various fertilizer treatments

Treatment	color	shape	texture	flavor	total
1 ($N_1P_2K_1$)	92	42.5	45.5	138	318
2x ($N_2P_2K_1$)	94	48.5	47.5	123	313
3 ($N_2P_2K_1$)	79	45	41.5	117	282.5
4 ($N_3P_2K_1$)	93	46.5	42.5	127.5	309.5
5 ($N_1P_2K_3$)	92	40.3	43.6	132	308
6x ($N_2P_2K_3$)	96	41.3	43.3	138	318.6
7 ($N_2P_2K_3$)	105	42	47.3	151.8	347
8 ($N_3P_2K_3$)	82	48.3	42.6	129	302
9 (Milorganite)	86	41	42	120	289
9x (Milorganite)	87	42.5	48	132	309.5
10 (Check)	101	39	45.5	159	344.5
10x (Check)	108	43	50.	153	354

TABLE XIII. Percent Mineral Content (Fresh Weight Basis) of Newburgh Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium and Lime

Fertilizer Treatments	F-1 Series A	B	C	D	C-1 Series A	B	C	D	Average
1 ($N_1P_2K_1$)	.406	.333	.364	.303	.375	.330	.352	.315	.347
2x($N_2P_2K_1$)	.385	.330	.358	.326	.382	.449	.348	.327	.363
3 ($N_2P_2K_1$)	.388	.296	.372	.361	.309	.345	.317	.403	.349
4 ($N_3P_2K_1$)	.421	.309	.375	.344	.337	.337	.355	.306	.348
5 ($N_1P_2K_3$)	.383	.338	.397	.339	.314	.350	.382	.347	.356
6x($N_2P_2K_3$)	.344	.331	.384	.351	.323	.384	.375	.380	.359
7 ($N_2P_2K_3$)	.357	.356	.351	.328	.341	.343	.357	.312	.343
8 ($N_3P_2K_3$)	.351	.321	.342	.354	.293	.291	.389	.331	.334
9 (Milorganite)	.398	.341	.392	.341	.308	.300	.346	.338	.346
9x(Milorganite)	.447	.313	.447	.313	.380	.368	.383	.370	.378
10 (Check)	.358	.319	.358	.319	.365	.336	.364	.335	.344
10x(Check)	.437	.320	.437	.320	.342	.339	.342	.339	.341

TABLE XIV. Analyses of Variance of Mineral Content of Newburgh Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium and Lime. (using both C-1 and F-1 series

Source of Variation.	SS	Degrees of freedom	Variance	Calculated F.	Tabled F.
Total	117,709	95			
Total Treatments	11,576	11	1,052	1.02	
Limed vs. Unlimed	(7,550)	(1)	7,550	7.31	3.96(P= .05) 6.96(P= .01)
Block	22,556	3	7,519		
Error	83,577	81	1,032		

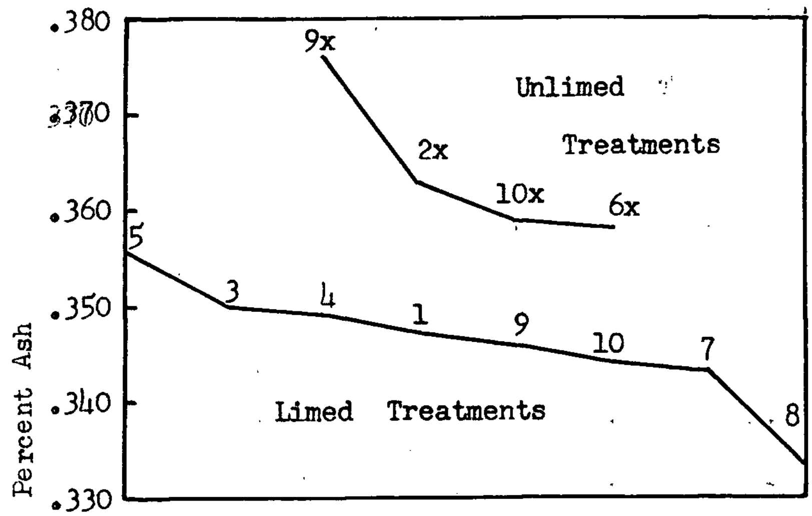


Fig. (8) Percent ash content in Newburgh raspberries showing contrast between limed and unlimed treatments (Based on average of Fl and Cl series.)

1 $(N_1P_2K_1)$	5 $(N_1P_2K_3)$	9 Milorganite
2x $(N_2P_2K_1)$	6x $(N_2P_2K_3)$	9x Milorganite
3 $(N_2P_2K_1)$	7 $(N_2P_2K_3)$	10 Check
4 $(N_3P_2K_1)$	8 $(N_3P_2K_3)$	10x Check

x- treatments without lime.

TABLE XV. Conductivity Readings on the Juice of Newburgh Raspberries as Determined by Soln-Bridge

F-1 Series

Fertilizer Treatments	A	B	C	D	Average
		Percent NaOH			
1 ($N_1P_2K_1$)	.061	.060	.066	.057	.0610
2x ($N_2P_2K_1$)	.060	.063	.065	.056	.0610
3 ($N_2P_2K_1$)	.055	.060	.065	.062	.0605
4 ($N_3P_2K_1$)	.057	.061	.063	.051	.0580
5 ($N_1P_2K_3$)	.060	.062	.067	.057	.0615
6x ($N_2P_2K_3$)	.054	.060	.060	.060	.0585
7 ($N_2P_2K_3$)	.058	.062	.058	.064	.0605
8 ($N_3P_2K_3$)	.056	.060	.060	.058	.0585
9 (Milorganite)	.055	-	-	.058	.0565
9x(Milorganite)	-	.058	.063	-	.0605
10 (Check)	-	.058	.061	-	.0595
10x(Check)	.056	-	-	.053	.0545

C-1-Series

Fertilizer Treatments	BLOCKS A	B	C	D	Average
1 ($N_1P_2K_1$)	.060	.057	.067	.058	.0605
2x ($N_2P_2K_1$)	.067	.064	.067	.060	.0645
3 ($N_2P_2K_1$)	.062	.064	.067	.070	.0660
4 ($N_3P_2K_1$)	.065	.065	.066	.055	.0630
5 ($N_1P_2K_3$)	.065	.060	.069	.063	.0640
6x ($N_2P_2K_3$)	.061	.058	.062	.072	.0630
7 ($N_2P_2K_3$)	.070	.068	.059	.061	.0645
8 ($N_3P_2K_3$)	.062	.059	.067	.064	.0630
9 (Milorganite)	.062	.061	.066	.065	.0635
9x(Milorganite)	.066	.061	.070	.065	.0655
10 (Check)	.062	.062	.064	.064	.0630
10x (Check)	.061	.059	.061	.059	.0600

TABLE XVl. Protein Content of Juice from Newburgh Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium and Lime

F-1 Series

Fertilizer Treatments	BLOCKS A	B	C	D	Average
1 ($N_1P_2K_1$)	.274	.255	.239	.239	.252
2x ($N_2P_2K_1$)	.284	.240	.246	.245	.254
3 ($N_2P_2K_1$)	.289	.250	.246	.253	.241
4 ($N_3P_2K_1$)	.212	.226	.284	.236	.240
5 ($N_1P_2K_3$)	.289	.279	.250	.255	.271
6x ($N_2P_2K_3$)	.308	.255	.219	.232	.253
7 ($N_2P_2K_3$)	.322	.221	.191	.255	.247
8 ($N_3P_2K_3$)	.274	.265	.279	.234	.263
9 (Milorganite)	.332	.312	.312	.294	.312
9x(Milorganite)	.275	.260	.284	.256	.269
10 (Check)	.250	.250	.255	.244	.250
10x (Check)	.318	.300	.219	.212	.262

TABLE XVll. Analyses of Variance of Protein Content of Juice from Newburgh Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium and Lime.

Source of Variation.	S.S.	Degree of Freedom.	Variance.	Calculated F.	Tabled F.
Total	47792	47	1,017		
Total Treatments	14979	11	1,362	2.05	2.09
Low Nitrogen vs. High Nitrogen	(1399	(1)	1,399	2.10	
Block	10864	3	3,621	5.44	
Error	21949	33	665		

TABLE XVIII. Protein Content of Newburgh Raspberries from Plots Receiving Varying Amounts of Nitrogen, Phosphorus, Potassium and Lime

C-1 Series

Fertilizer Treatments	BLOCKS A	B	C	D	Average
1 ($N_1P_2K_1$)	1.120	1.087	1.178	1.157	1.135
2x ($N_2P_2K_1$)	1.028	1.203	1.144	1.232	1.152
3 ($N_2P_2K_1$)	1.058	1.146	1.158	1.218	1.145
4 ($N_3P_2K_1$)	1.046	1.150	1.184	1.192	1.148
5 ($N_1P_2K_3$)	1.040	1.013	1.124	1.184	1.090
6x ($N_2P_2K_3$)	1.100	1.113	1.132	1.180	1.131
7 ($N_2P_2K_3$)	1.170	1.120	1.073	1.218	1.145
8 ($N_3P_2K_3$)	1.098	1.100	1.248	1.208	1.163
9 (Milorganite)	1.168	1.121	1.147	1.100	1.134
9x (Milorganite)	1.155	1.191	1.146	1.143	1.149
10 (Check)	1.160	1.198	1.088	1.126	1.143
10x (Check)	1.126	1.117	1.098	1.093	1.108

DISCUSSION

When nitrogen is applied abundantly it tends to produce rank vegetative growth, often at the expense of quality of fruit (19). Das (7) found that increasing the application of nitrogen to sugar cane increased the leaf area but decreased the concentration of sucrose in the expressed sap. Other workers report similar results (31,7,8).

The results in this particular experiment are in accord with the above, that is, the high nitrogen treatments lowered the percentage sugar content in the raspberries and at the same time tended to produce more abundant foliage. The explanation for this lowering of sugar content lies perhaps in the fact that, in the presence of an abundant supply of nitrogen, the carbohydrates are being utilized more rapidly in the formation of organic nitrogenous compounds, thereby decreasing the amount of reserve carbohydrates. It will be remembered that there was a tendency for the protein content of the berries to be higher in the high nitrogen treatments even though the difference did not prove to be significant.

Regarding the results of varying nitrogen levels on the vitamin C content of the fruit there was a tendency for it to increase with increasing nitrogen applications from the low nitrogen level up to the medium level and then to decrease at the high levels. It would appear then, that there is an optimum level of nitrogen beyond which the vitamin C content tends to be lowered.

The more outstanding effect on the vitamin C content was that which resulted from the applications of lime. Either liming interfered directly or indirectly with the synthesis of vitamin C, or, by neutralizing the organic acids in the plant (19), it created a situation whereby vitamin C was rendered less stable. As high nitrogen fertilizer treatments have frequently been reported to interfere with vitamin C production (for example 1,9,) there is the possibility that liming caused the nitrogen to become more available and thus affected the vitamin C content indirectly. Miller (19) cites several examples which indicate that nitrogen, supplied as ammonium sulphate, is more available when the soil reaction is close to neutral, or above, than at a lower pH. Since ammonium sulphate fertilizer was used in this experiment and since the soil reaction is well below neutral, the application of lime could very easily have increased the absorption of nitrogen.

Another interesting feature with respect to the vitamin C content is the apparent regulating effect of potassium on calcium. If we accept the theory that lime lowered the vitamin C content by making more nitrogen available to the plant, it would be reasonable to assume that a high level of potassium minimized this effect by interfering with the calcium intake and consequently, also with the availability of nitrogen. In other words, the addition of potassium might have had a regulatory effect on the nitrogen intake, thereby affecting the vitamin C content.

The real cause for the depressing effect of lime on the mineral content is difficult to determine since only total minerals and not the individual elements were determined. However, in view of the fact that raspberry fruit is high in potash and phosphoric acid (34), it would seem that liming interfered with the absorption of either phosphorus or potassium,or both. Since the lime and fertilizer applications were made only one week apart conditions might easily have been created which facilitated phosphorus fixation, especially as both lime and fertilizer were applied broadcast.

That potassium absorption should be retarded through liming could be accounted for by the retarding effect of one ion on another. Calcium is a slow moving ion and retards the rate of entry of other ions.

Generally speaking, the high nitrogen treatments increased total acidity (fig.6). Since acidity is to a large extent a by-product in the metabolism of nitrogenous compounds, this relationship would be expected.

The drastic decrease in total acids between fruit harvested on July 24, and that harvested on July 31, is perhaps partly due to the somewhat riper condition of the later harvested fruit. According to a report in Technical Bulletin 403, U.S.D.A., (28), both water content and total acidity of raspberry fruit decline during the ripening stage. However, the greater part of the drop in total acids must be attributed to variations in climatic conditions, which have been shown to exert a considerable influence on total acidity. Schupan (25), for instance, found that in strawberries the acidity increased markedly after a rain.

Recognizing the fact that total acidity is so readily influenced by climatic conditions, one can see the difficulty of using individual determinations as a criterian of quality.

The various fertilizer treatments had no consistent effect on total solids, (dry weight). The marked increase in total solids in the fruit from the two plots which suffered from excessive moisture deserves mention even though the treatments had no direct bearing on the results. The plants in these plots were definitely stunted for lack of nutrients. Under such conditions the plant forms small, thick-walled cells which account for the higher percentage of total solids, (dry weight).

In respect to taste panels it is recognized that they have a definite place in the determination of edible quality. The validity of taste panel results, however, depends largely on how much care is exercised in eliminating all human error possible. The general consensus of opinion is that personnel can be trained for greater accuracy in detecting the various sensations that determine flavor. Other workers (5), however, report no difference in results obtained with trained and untrained personnel.

In this particular experiment the organoleptic results are correlated with total soluble solids and total acids.

Of the four most common taste sensations, sweetness, sourness, bitterness and saltiness, it is apparent that the first two were the deciding factors in determining the flavor of the berries. The taste panel showed a preference for the berries with the highest sugar and lowest acid content and, conversely, the least popular berries were those with the lowest sugar and highest acid content. The sweeter berries resulted from the low nitrogen, high potassium treatments, whereas, the more acid berries came from the high nitrogen treatments. No consistent differences were detected in the general appearance of the frozen product as a result of fertilizer treatments.

ABSTRACT

SUMMARY AND CONCLUSIONS

Twelve fertilizer treatments consisting of varying levels of nitrogen, phosphorus, potassium and calcium, were applied to plots of Newburgh raspberries laid out in four randomized blocks. The fruit was analyzed for total sugars, vitamin C, total solids, soluble solids, proteins, total acids, total minerals, flavor and freezing quality in order to ascertain the effect of the various fertilizer treatments on the quality of the fruit.

It was found that:

1. High nitrogen treatments decreased the sugar content, tended to decrease the vitamin C content, and increased the acidity of the berries.

2. Liming decreased both vitamin C and mineral content.

3. An abundant supply of potassium appeared to be beneficial in that it minimized the effects of lime and tended to have a regulatory effect on nitrogen absorption.

4. Quality, as distinguished organoleptically, was correlated with high sugar and low acid content of the berries, and conversely, lack of quality was correlated with low sugar and high acid content. The former resulted from low nitrogen, high potassium treatments, while the latter was produced by high nitrogen fertilizer treatments.

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