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Relation of Nitrogen Fertilizer to the Firmness and Composition of Strawberries

J. S. Shoemaker and E. W. Greve

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RELATION OF NITROGEN FERTILIZER TO THE FIRMNESS AND COMPOSITION OF STRAWBERRIES

J. S. SHOEMAKER AND E. W. GREVE

Claims are frequently made that application of nitrogen fertilizer to strawberry plants growing in the field makes the fruit softer and of inferior handling quality. Such claims assume importance in cultural work and in marketing, particularly because increased yields are often possible from timely nitrogen fertilizer applications and because the fruit of the strawberry is, even normally, a highly perishable commodity.

The results of certain physical tests, physiological and chemical determinations, and yield comparisons are presented in this bulletin in relation to the effects of applications of nitrogen fertilizer on the firmness and composition of strawberries.

SOURCE OF SAMPLES

The field plots at the Ohio Experiment Station, from which the samples were taken in 1930, consisted of one bed of strawberries planted in 1929 and bearing its first crop, and another bed planted in 1928 and bearing its second crop. Premier, the leading strawberry variety in Ohio, was used. Both beds received a treatment of a light covering of rather strawy poultry manure during the winter previous to planting, and superphosphate (250 to 300 pounds per acre) and muriate of potash (50 to 100 pounds per acre) when preparing the soil for planting.

The bed bearing its first crop contained 76 rows and that bearing its second crop contained 100 rows of plants. Fifteen plants were set in each row. Each third row was a check and, altho receiving the previously mentioned application of phosphorus and potash fertilizers, did not receive any commercial nitrogen fertilizer. The two rows between each pair of checks in the second fruiting crop bed received in 1928, the year of planting, sulfate of ammonia, which was used as the source of nitrogen, in addition to the bed treatment, applied at different times but usually in the same amount (250 pounds per acre). The bed set in 1929 and bearing its first crop in 1930 was not fertilized with nitrogen the year it was set.

Both beds were fertilized early in the spring of 1930 with nitrate of soda applied at the rate of 250 pounds per acre to each third plot adjacent to a check. The bed bearing its second crop had also previously received, in 1929, an early spring application of sulfate of ammonia at the rate of 250 pounds per acre, applied on the same rows that were fertilized in 1930.

The leaves in the rows fertilized with nitrogen were darker green in the bed bearing its second crop than those in the bed bearing its first crop. This was undoubtedly due in part to a better physical condition of the soil and in part to the previous applications of nitrogen fertilizer.

A marked increase in yield of fruit of the present second-crop bed was obtained in the first fruiting year of that bed from nitrogen fertilizer applied about August 15 of the year the plants were set out (Shoemaker, 30). The early spring applications in fruiting years, on the other hand, did not increase total yield in either 1929 or 1930, as is reported elsewhere in this bulletin. However, even tho an August application in the year of planting is considered much more beneficial than an early spring application in the year of fruiting with respect to increased yield, attention in this bulletin is devoted primarily to the latter.

The chief reason for this decision was that the claims that application of nitrogen fertilizer to strawberries makes the fruit softer are based on spring applications. The August time of application is a new development in strawberry culture and, except when renewing beds, has not been generally practiced thus far by growers in Ohio.

Samples were taken thruout the picking season, with the exception of the first light pickings. The distribution of plots was such that 19 rows in the bed bearing its first crop and 25 rows in the bed bearing its second crop were available for the nitrogen-treated and check samples, respectively. Berries of approximately the same stage of ripeness, size, and general condition were selected from the representative rows at each picking.

PHYSICAL TESTS

Statements that fertilizing with nitrogen in the spring of a fruiting year makes the fruit softer are found in publications by Chandler (5), Brown (4), French (13), Colby (8), Auchter and Knapp (2), Loree (22), and others.

Brown (4), in Oregon, found that with extremely warm weather during a large portion of the picking season the plants which had received heavy applications of nitrogen produced larger berries which tended to be soft. In years when it was cool during the picking season there was no difference in firmness.

Auchter and Knapp (2) stated that an application of quickly available nitrogen fertilizer may cause detrimental results if the application is too heavy, and especially if the season is wet, by causing the berries to be soft and green.

Clark (6, 7) determined the relative firmness of flesh of a number of different varieties of strawberries and ranked them as follows, the softest being listed first: Howard 17 (Premier), Beacon, Pearl, Boquet, Gandy, and Chesapeake. Darrow (9) stated that the Howard 17 (Premier) does not hold up so well in shipment as some other varieties.

Degman (12), working with apples and peaches, found that there was no consistent effect on the keeping quality of the fruit from use of nitrogen fer-

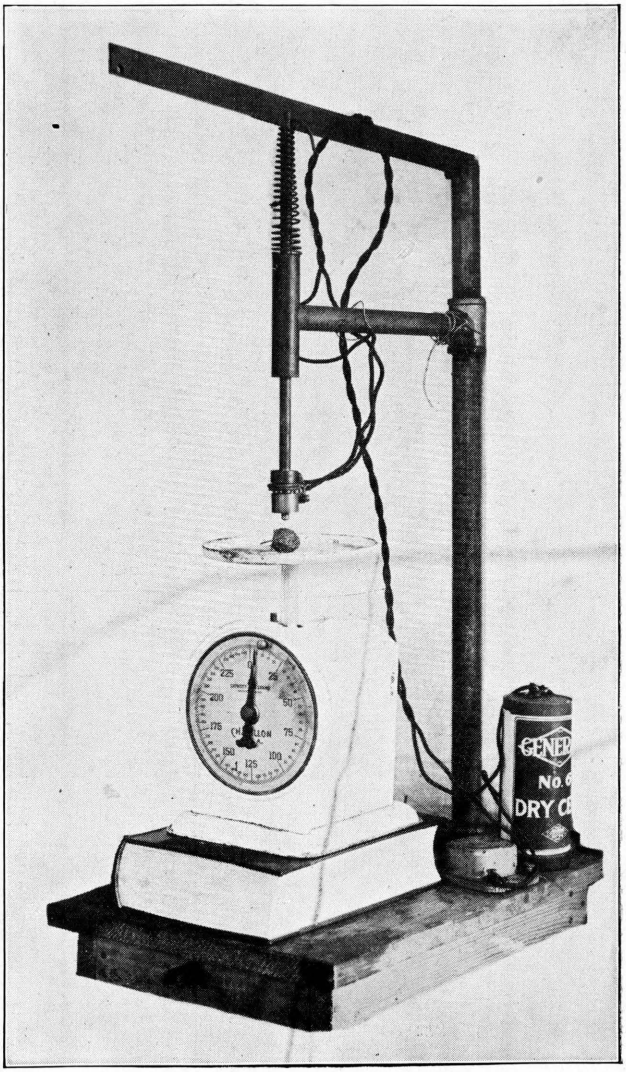

Fig. 1.—Apparatus used for the mechanical pressure tests

tilizers as indicated by pressure tests. In apples picked from five different orchards, he found that in the case of three of them the fruit from the check trees tested harder at the time of picking than the fruit from the trees receiving nitrogen. Only in one case, however, did the fruit from the check trees test significantly higher than the fruit from the nitrogen-fertilized trees.

MECHANICAL PRESSURE

A pressure tester commonly used with apples was modified so as to be adaptable to strawberries, Figure 1. The 7/16-inch plunger was replaced by a plunger ¼ inch in diameter, accompanied by a correspondingly smaller cylinder into which it fitted. The tests were made the same day the berries were picked.

The reading was taken when the ¼-inch plunger had been forced into the strawberry a distance of ⅜ inch, at a point one-third the distance from the calyx to the apical end. Instead of measuring the pressure in pounds, as with apples, the readings were taken in grams. At the instant the plunger had been forced into the berry ⅜ inch, electrical contact was made by the base of the cylinder containing the plunger and another piece of brass above it, completing a circuit thru a small buzzer. The pressure was read from the small gram scales upon which the strawberry rested. The tests were made on 10 berries for each of the plots of the first two pickings and on 100 berries of the last two pickings.

TABLE 1.—Firmness of Berries in Mechanical Pressure Tests

Plot	June 11	June 12	June 13	June 16
	Av. grams	Av. grams	Av. grams	Av. grams
Berries from first-crop bed*				
Nitrogen	170	190	210	214
Check	169	209	235	236
Berries from second-crop bed*				
Nitrogen	193	210	217	211
Check	217	229	233	235

*Thruout this bulletin the data refer to two different beds and not to two different fruiting seasons for the same bed.

The pressure tests, Table 1, indicated that the berries from the plots receiving nitrogen were slightly softer than those from the check plots. With one exception, the pressure required to force the plunger into the berry increased consistently thruout the picking season. The increasing firmness may be due to the fact that the berries decreased in size as the season progressed.

SHIPPING TEST

To determine the effect of nitrogen fertilizer on the shipping quality of the fruit, a 24-quart crate of berries containing boxes from treated and check plots was shipped from Wooster to Columbus[1], a distance of 100 miles. The shipment was made from Wooster on the afternoon of June 9 and arrived in Columbus by express the following day. The berries when picked were somewhat riper than would ordinarily be shipped by the commercial grower to market. Drouth conditions led to considerable scalding of the fruit.

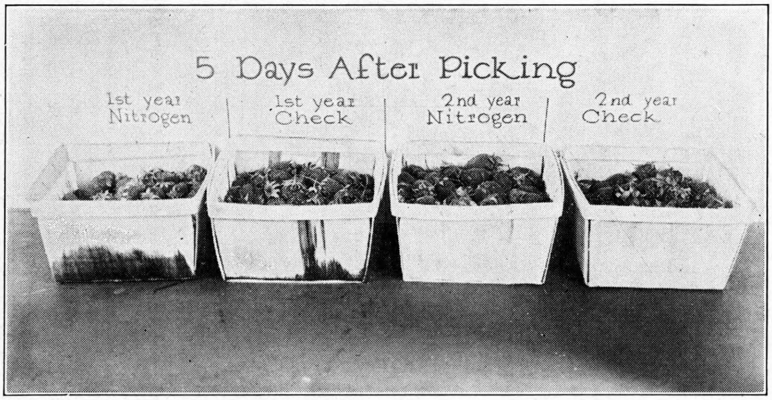

Fig. 2.—Typical boxes of berries selected from a 24-quart crate shipped from Wooster to Columbus, a distance of 100 miles

Classification of typical boxes indicated conflicting results between the treatments and checks for the berries from the first fruiting crop bed and those from the second fruiting crop bed, Table 2. The percentage of berries arriving in sound condition after shipment from the first-year bed was greater with the nitrogen than the check plots; the reverse was the case with the berries from the second fruiting crop bed.

Lloyd and Newell (21) found that the percentage of spoilage in roughly handled lots of strawberries was approximately double that in carefully handled lots. It is possible, therefore, that in shipments of strawberries the method of handling the berries while picking and preparing for market is of more concern than the factor of fertilizing the plants with nitrogen.

Further study is needed before the relation of fertilizing with nitrogen to the handling quality of strawberries, especially for long distance shipment, is conclusively ascertained.

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[1]The authors are indebted to F. H. Beach, Ohio State University, for cooperation in the shipping test.

PHYSIOLOGICAL AND CHEMICAL DETERMINATIONS

NITROGEN CONTENT OF THE FRUIT

Observations of the leaves of the strawberry plants fertilized with nitrogen clearly indicated, by darker green foliage and other appearances, a reaction to nitrogen. Chemical analyses were conducted to determine whether more nitrogen went into the fruit from the fertilized than from the check plots.

TABLE 2.—Condition of Typical Boxes of Berries After a 100-Mile Shipment

Plot	Sound berries		Crushed berries	
	No.	Weight Oz.	No.	Weight Oz.
Berries from first-crop bed				
Nitrogen	78	11	40	6
Check	55	8	59	8
Berries from second-crop bed				
Nitrogen	54	8.5	60	9
Check	61	11	49	7.5

Gourley and Hopkins (16) found that application of nitrogen fertilizer to apple trees resulted in a marked increase in the nitrogen content of the fruit. Differences for young trees in cultivation were not so great as for mature trees in sod. One sample taken in 1928 from young Wealthy trees in cultivation showed an increase of 46 per cent in the nitrogen content of the treated rows over the checks, or, calculated on the basis of total grams of nitrogen per sample, 47.2 per cent. Samples from mature Stayman trees in sod showed, in many cases, increases of more than 100 per cent in the nitrogen content of the fruit. Storage results, however, failed to indicate that internal breakdown followed any treatment employed in the work.

Nightingale, Addoms, and Blake (28) found that the total nitrogen content of the flesh of peaches was over 100 per cent higher with fruit from a high-nitrogen tree than from fruit grown on a high-carbohydrate tree.

The dried samples obtained in the moisture determinations which are presented later were used for the determination of total nitrogen in the fruit. The modified Gunning method was used so as to include the nitrogen of nitrates if such were present.

Fertilizing with nitrogen in the early spring of fruiting years increased the nitrogen content of the fruit, Table 3. Altho the greatest increase appeared in one of the first fruiting year pickings (88.18 per cent), the increase for the entire season and for most pickings was greater in the bed fruiting the second time than in that fruiting the first time. An explanation for this has been given previously in the bulletin.

There seemed to be no consistent variation in the nitrogen content as the picking season progressed in the first fruiting crop bed, but a tendency toward a consistent decrease occurred in the second-crop bed.

TABLE 3.—Total Nitrogen Content of the Berries

Plot	June 7	June 9	June 11	June 13	June 16	June 18	Season
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct. average
Berries from first-crop bed							
Nitrogen	.1326	.1044	.0970	.1054	.1297	.0981	.1112
Check	.1057	.1032	.0847	.0898	.1044	.0521	.0898
Average increase	25.57	1.09	14.44	17.34	24.19	88.18	23.83
Berries from second-crop bed							
Nitrogen	.1503	.1212 .1206	.1182	.1075	.1035	.1029	.1172
Check	.1037	.0879 .0814	.0914	.1739	.0801	.0902	.0869
Average increase	44.89	42.90	29.17	59.00	29.21	14.07	34.98

The yields during the last few pickings of the season are given later in the bulletin. Analyses during two of these pickings indicated that the increased yield from nitrogen fertilizer was associated in only one instance out of four with an increase in the total nitrogen content of the fruit. The analyses were not extended to include the entire picking season as the berries of the last few pickings were so small in size and unattractive in appearance that they were of little value for commercial shipment.

MOISTURE CONTENT OF THE FRUIT

The season during which the work presented in this bulletin was conducted was exceptionally dry in Ohio. The moisture content of the berries, however, from 89.44 per cent to 91.71 per cent, approximates rather closely that found by other investigators, altho the range is narrower than sometimes reported.

Loree (23) found that the moisture content varied but little with berries picked from plots receiving various fertilizer treatments. In 50 determinations on different varieties of ripe strawberries, the moisture content ranged from 87.9 per cent to 92.8 per cent. The berries from unfertilized plants showed a lower moisture content than those from fertilized plants. Plants which had been fertilized with nitrogen during the summer produced berries with a higher moisture content than those which had been similarly treated only in the spring.

Gerhart (15) found an average moisture content of 89.78 per cent in strawberries analyzed as they arrived on the market. Loss of water seemed to be about the same in dry air as in moist air. With green strawberries an average of 90.52 per cent moisture was found. The water content of the fruit varied but little over the whole of the ripening period.

Gourley and Hopkins (16) stated that there seemed to be a correlation between the nitrate treatment and the moisture content in the fruit of the apple.

Hendrickson and Veihmeyer (19) found a higher moisture content in peaches from irrigated trees than from non-irrigated, but Nichols (27) found no significant differences in condition after shipping, ability to stand up under common storage, and in the canning quality of the peaches from these plots.

The berries used for the moisture determinations were brought to the laboratory immediately after picking. Twenty-four berries were selected from each plot; thin slices were cut from them and placed in a glass evaporating dish which had been previously weighed. Fifty grams of tissue were used for each sample. The samples were then dried in a vacuum oven at 85° C. and under a vacuum of 28 to 29 inches of mercury.

Two samples were prepared on June 9 from each of two different lots of berries from the same plot in order to check the accuracy of the results. In the one sample the percentage of moisture was determined in two cases as 91.25 per cent and 91.25 per cent, or the same in both cases; and, in the other sample as 90.14 and 90.08 per cent, or a variation of .06 per cent.

The determinations on berries of the second fruiting season indicated, except for one instance, that the moisture contents of the berries from the check plots were slightly lower than those from the nitrogen plots, Table 4. This relationship was not evident with berries of the first-crop bed. On the whole, during the exceptionally dry summer of 1930, differences in moisture content were slight in fruit from fertilized and check plants.

TABLE 4.—Moisture Content of the Fruit

Plot	June 7	June 9	June 11	June 13	June 16	June 18
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Berries from first-crop bed						
Nitrogen	90.64	90.51	90.11	89.83	89.44	90.29
Check	91.38	90.18	90.57	90.92	89.71	90.49
Berries from second-crop bed						
Nitrogen	91.71	91.25 91.25	90.30	90.74	90.34	90.70
Check	91.20	90.14 90.08	90.36	90.62	89.60	89.64

CATALASE ACTIVITY

The catalase activity of plant tissue is regarded as an indication of vigor of the plant or plant part. The catalase activity is probably only relative since various conditions, such as the temperature at which the preparation is held, influence the activity of the sample. The results obtained, therefore, on different days are probably not strictly comparable, and the results secured on the same day are more significant in this work.

Heinicke (17, 18) considered catalase activity to be a sensitive indicator of the physiological responses of fruit trees to various fertilizer treatments or conditions of culture. Treatments which caused an increase in the nitrogen content of apple leaves in many cases brought about an increase in catalase activity; whereas conditions causing an increase in the carbohydrate content seemed to cause a decrease in catalase activity.

Knott (20) found that when nitrogen was supplied to the plant thru the roots an increase occurred in catalase activity. Catalase activity decreased when the metabolism of the plant was shifted so that a reproductive growth instead of a vegetative growth was secured.

Auchter (1) found that when nitrate was applied to one side of a tree growing in sod the catalase activity of the leaves on that side of the tree was also increased. In contrast to the case in most woody plants, White (31) stated that, broadly speaking, moisture and nutrients supplied to one side of a row of strawberry plants could be assumed to supply both sides of the plant uniformly.

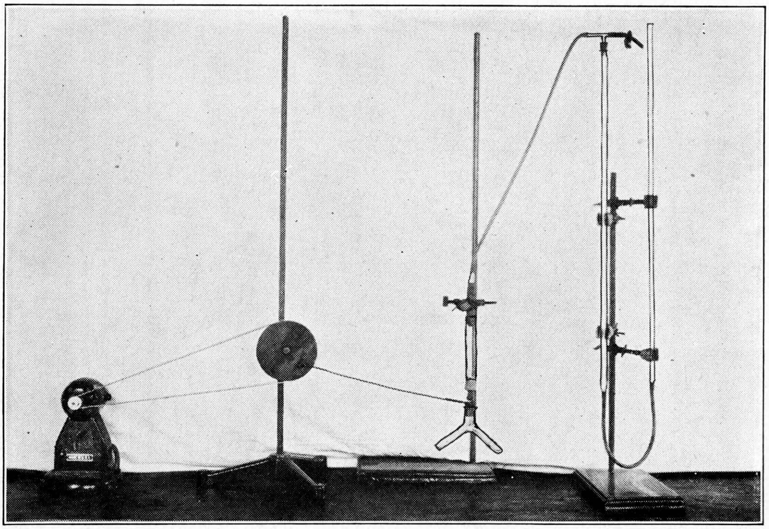

Fig. 3.—Apparatus used for the catalase determinations

Gourley and Hopkins (16) found, in the fruit of the apple, that differences between nitrogen-fertilized and check trees were more marked for catalase than for moisture or nitrogen. A close correlation existed between the catalase activity and the percentage of nitrogen in the fruit. The catalase activity was uniformly lowest in the checks and higher in the treated plots and with few exceptions increased as the nitrogen percentage in the fruit increased. With a decrease in the percentage of nitrogen for the larger nitrate applications there was a corresponding drop in the catalase activity.

Catalase activity of the fruit.—Thin slices were cut from 18 berries until a total of 10 grams per sample was obtained. This was immediately placed in a mortar together with two grams of precipitate chalk and ground finely. Twenty cubic centimeters of water were then added, about 5 or 6 cubic centimeters at a time to ensure good rinsing, and the contents were transferred to a small bottle. The sample was left over night and the catalase determinations made the next day.

The apparatus used was similar to that used and diagrammed by Knott (20). The temperature of the water bath was regulated to 25° C. Two cubic centimeters of the tissue suspension were placed in one arm of the reaction tube, and in the other arm, two cubic centimeters of hydrogen peroxide (12 volume) neutralized with an excess of calcium carbonate. A motor was used for shaking the reaction tube. The rate of shaking was approximately 100 times a minute. The oxygen evolved displaced the water in a burette to which was attached another burette the purpose of which was to serve as a levelling tube so that the reaction could be held at atmospheric pressure. A duplicate determination was made in each case and if the duplicate varied more than 0.20 cubic centimeters the results were discarded.

The nitrogen fertilizer treatment increased catalase activity of the fruit in both the first- and second-crop beds, Table 5.

TABLE 5.—Catalase Activity of the Fruit

Plot	Oxygen released at end of 4 minutes		
	June 11	June 13	June 16
	cc.	cc.	cc.
Berries from first-crop bed			
Nitrogen	5.10	5.50	5.95
Check	2.95	3.20	3.10
Berries from second-crop bed			
Nitrogen	4.95	4.75	....
Check	3.60	3.60	....

Catalase activity of the leaves.—Leaves were taken from the plots in the field and immediately brought into the laboratory where the samples for the determinations were prepared. Fifteen leaves were then selected from each lot. Discs, one centimeter in diameter, were cut from each of the three leaflets, thus making a total of 45 discs for each lot. The discs were then weighed and enough water added to them to give a dilution of one part leaf tissue to 50 parts of water. An amount of precipitate chalk equal to the weight of the discs was then added and the whole macerated finely in a mortar. The water was added a few cubic centimeters at a time so that the discs could be macerated better than if all had been added at once. The suspension was then transferred to a small bottle and the determinations made the following day.

The nitrogen treatments increased the catalase activity in the leaves, Table 6. The difference was greatest with leaves from the first-crop bed. Even tho the early spring nitrogen treatment resulted in an increased amount of darker green foliage in the second-crop bed as compared with the first-crop bed, release of 10 cubic centimeters of oxygen required 51 seconds for the former and only 39 seconds for the latter.

TABLE 6.—Catalase Activity of the Leaves

Plot	Time required to release 10 cc. oxygen*
Leaves from first-crop bed	
Nitrogen	39
Check	92
Leaves from second-crop bed	
Nitrogen	51
Check	89

*This manner of expressing the results is used here because of the greater catalase activity in the leaves than in the fruit.

ACIDITY OF THE FRUIT

Gourley and Hopkins (16) found that the pH of the juice of the apple was very constant, not varying more than a few hundredths of a pH irrespective of whether the sample was from fertilized or unfertilized trees.

Nightingale, Addoms, and Blake (28) mentioned that peaches from a high-nitrogen tree increased tremendously in acidity during the period of softening off the tree when picked before the hard ripe stage; whereas peaches from the high-carbohydrate tree showed little change in acidity even when harvested before they were hard ripe.

The acidity of the fruit was determined in terms of the hydrogen-ion concentration. This determination was made electrometrically, a small potentiometer being used. A quinhydrone electrode with a quinhydrone reference cell was used.

The juice was expressed from 18 berries for each sample. The determinations were made on the undiluted juice the same day the berries were picked.

The pH of the juice of the berries from the check plots was consistently lower than from the nitrogen plots, Table 7. In other words, the berries from plants fertilized with nitrogen were somewhat less acid thruout the entire picking season than were the berries from the plots not receiving nitrogen.

TABLE 7.—Acidity of Expressed Juice

Plot	June 7	June 9	June 11	June 13	June 16	June 18
	pH	pH	pH	pH	pH	pH
Berries from first-crop bed						
Nitrogen	3.47	3.43	3.36	3.32	3.53	3.50
Check	3.41	3.35	3.25	3.25	3.45	3.44
Berries from second-crop bed						
Nitrogen	3.55	3.50	3.49	3.47	3.55	3.67
Check	3.48	3.41	3.37	3.38	3.47	3.61

SUGAR CONTENT OF THE FRUIT

Loree (23) stated that one of the effects of the fertilizer treatment on strawberries was an increase in sugars and a decrease in polysaccharides. Spring-treated plants contained more free reducing sugars and less sucrose than the summer-treated plants. The amount of sugar in the plants appeared to be closely associated with the potash content.

Gourley and Hopkins (16) seemed to find that the total sugar was highest with apples in the check and low nitrate trees.

Hendrickson (19) found peaches from plots lacking in readily available moisture (non-irrigated) contained a slightly higher percentage of sugars, calculated on a fresh weight basis, than those grown on continuously irrigated plots.

Nightingale, Addoms, and Blake (28) found, in the peach, that sucrose increases as the fruits develop but there is also an increase in percentage of reducing sugars, particularly in the flesh of the fruits from the high-carbohydrate (low-nitrogen) tree. It seemed quite apparent that sucrose was the storage form, whereas reducing sugars were a comparatively temporary translocation product. This conclusion was indicated by the almost analogous results of Bigelow and Gore (3) and was further substantiated by the fact that reducing sugars were lower and sucrose was higher at the soft-ripe stage (at the time of the last analysis of the two lots of fruits) than at any other period. Nightingale et al. stated that the sugar content reflected the carbohydrate condition of the vegetative organs of the trees. Fruits from the high-carbohydrate (low-nitrogen) tree were very much higher in reducing sugars, but particularly in sucrose, than fruits from the high-nitrogen tree.

A hundred-gram sample of well mixed pulp was transferred to a Mason fruit jar with enough 95 per cent alcohol so that the final concentration of the mixture would be 80 per cent. Two grams of precipitate chalk were also added. The sample was then heated to boiling and stored away for future analysis.

The sugars were determined by evaporating the alcoholic extract and clarifying with lead acetate. The Munson and Walker method was employed for making the determinations. Inversion was secured by acid hydrolysis at room temperature over night.

Fertilizing with nitrogen resulted in a consistently lower percentage of reducing sugars, a lower percentage of total sugars in most cases, and fluctuating values for sucrose when analyses of berries from the treated plots were compared with the checks, Table 8. The percentages of reducing sugars, sucrose, and total sugars, furthermore, increased with successive pickings.

TABLE 8.—Sugar Contents of Fruit. Second-Crop Bed

Date	Plot	Reducing sugars	Sucrose	Total sugars
		Pct.	*Pct.*	*Pct.*
June 9	Nitrogen	3.445	0.934	4.483
	Check	3.825	0.862	4.783
June 11	Nitrogen	3.890	0.864	4.850
	Check	4.110	0.906	5.117
June 13	Nitrogen	3.925	0.996	5.032
	Check	4.305	1.106	5.534
June 16	Nitrogen	4.725	1.130	5.981
	Check	5.620	1.202	6.955
June 18	Nitrogen	4.575	1.694	6.357
	Check	4.730	1.459	6.351

EFFECT OF YIELD

Experiments in 1929 indicated that sulfate of ammonia applied at the rate of 250 pounds per acre, early in the spring of the first fruiting year, resulted in a lower yield during the first half of the picking season, but in a higher yield during the later pickings in the treated than in the untreated rows. Furthermore, the total yield of the spring fertilized rows was lower than that of the untreated rows.

The studies in 1930, using nitrate of soda instead of sulfate of ammonia, also indicated a lower total yield from spring fertilized rows than from untreated rows, Table 9.

As a rule, a plantation bearing its first crop is more productive than one bearing its second crop. However, the second-crop bed has been very successfully renewed by the grape-hoe method outlined in Ohio Agricultural Experiment Station Bulletin 444 (30). Furthermore, the general physical condition of the soil was much better in the second-year bed than it was in the first-year bed. The second-year bed produced about 50 per cent more berries than did the first-year bed. The difference between the fertilized and unfertilized rows in the second-year bed is not nearly so great as it is in the first-year bed.

TABLE 9.—Effect on Yield of Nitrogen Fertilizer Applied in Early Spring of Fruiting Years

Plot	June										
	2	4	6	9	11	13	16	18	20	23	Total
	Qt.	Qt.	Qt.	Qt.	Qt.	Qt.	Qt.	Qt.	Qt.	Qt.	Qt.
Berries from first-crop bed											
Nitrogen..	1.85	10.6	18.5	16.5	11.1	12.6	10.3	5.93	3.68	2.83	93.89
Check.....	2.65	12.4	21.9	19.8	16.4	14.0	12.5	4.25	2.26	2.34	108.50
Berries from second-crop bed											
Nitrogen..	2.91	10.1	26.3	26.3	20.2	23.0	19.3	13.0	7.20	3.98	152.29
Check......	2.67	11.6	28.3	27.7	19.0	24.1	21.3	11.2	5.70	3.91	155.48

Investigations of Gardner (14) showed that when moisture and temperature are not limiting factors, number of flower clusters, number of flowers, and size of berries are dependent on nutritive conditions within the plant the preceding fall and winter, and they are practically independent of soil fertility conditions during the spring and at the time of fruiting. Treatment that would increase production thru modifying fertility, therefore, according to him, should be given during the summer and fall months.

Macoun and Davis (11, 24, 25, 26) concluded that there are at least three ways in which applications of a nitrogen fertilizer may affect the yield of strawberries: (a) by causing an actual increase in the number of fruit buds formed; (b) by causing an increase in the size of the individual fruits; and (c) by increasing the set of the bloom. The first factor was considered as probably the most important.

Loree (23) stated that the total number of flowers per plant as modified by fertilizer treatments was determined chiefly by the number of clusters, and to a very limited extent by the number of flowers per cluster. Fertilizers containing nitrogen increased the number of flower clusters per plant. The summer-treated plants produced nearly twice as many clusters as the spring-treated plants. A slightly larger number of clusters was borne by the spring- and summer-treated plants. Applications of fertilizers in the spring of the fruiting year had no effect on the number of clusters or the number of flowers per cluster. Summer-treated plants, which contained more nitrogen at the termination of growth in the fall, set a larger percentage of blossoms than the spring-fertilized plants which were low in nitrogen. Applications of nitrogen in the spring of the fruiting year caused a better setting of blossoms and an increase in the size of the berries. Nitrogen alone, or in combination with phosphoric acid and potash, in every instance increased the total yield. The yield of the summer-treated plants was larger than that of the spring-fertilized plants.

It is unlikely that early spring applications of nitrogen fertilizer in fruiting years can increase the number of fruit buds formed in strawberry plants in Ohio because fruit buds are formed in the fall preceding the fruiting year. Varieties of strawberries grown in the important districts of southern states, however, do not have the "rest period" that occurs in varieties grown farther north (Darrow and Waldo, 10). Furthermore, since Ruef and Richey (29) have pointed out that fruit-bud differentiation might continue uninterrupted until blossoming time in localities where weather conditions permit, it is conceivable that the effects of early spring applications of nitrogen fertilizer may be different in sections with milder winters than in Ohio.

The Ohio work indicates a slight increase in size of berries, most noticeable during the last half of the picking season, from fertilizing with nitrogen in early spring of fruiting years. Increased size of berry may be associated, to some extent, with lower handling quality. The fact should not be overlooked, however, that the last few pickings in which the increase in size of berries was most noticeable were much lighter pickings than the earlier ones and did not represent the bulk of the crop. Also, even tho in the latter part of the season the berries from the nitrogen plots were larger than those from the check plots they were smaller and less attractive than the berries picked earlier.

It was hoped to compare the effects resulting from fertilizing with nitrogen with those resulting from heavy rains but the continuous drouth precluded this. The response obtained in a wet season may be more pronounced than that which occurred in the exceptionally dry year when this study was in progress.

SUMMARY

1. Studies consisting of mechanical pressure and shipping tests, nitrogen, moisture, catalase activity, acidity, and sugar determinations, and yield comparisons were conducted with strawberries from nitrogen-fertilized and unfertilized plants. The season of trial was excessively dry.

2. Slightly softer berries, according to mechanical pressure tests, resulted from spring applications of nitrogen.

3. Differences in moisture content were slight and not consistent between berries from the fertilized and untreated plants.

4. The percentages of berries arriving in sound condition after shipment from Wooster to Columbus, a distance of 100 miles, did not indicate significant differences between the fruit from the fertilized and check plots.

5. The nitrogen content of the fruit was increased by fertilizing with nitrogen in early spring of the fruiting years.

6. The catalase activity of both the fruit and the foliage was increased by the nitrogen treatment.

7. A consistently lower percentage of reducing sugars, a lower percentage of total sugars in most cases, and fluctuating relative values for sucrose resulted from fertilizing with nitrogen. The percentages of reducing sugars, sucrose, and total sugars increased with successive pickings.

8. The pH of the juice of the berries from the check plots was consistently lower than that from the nitrogen plots. In other words, less acid berries thruout the entire picking season occurred in the plots receiving nitrogen.

9. The total yield of berries was not increased by fertilizing with nitrogen in the early spring of fruiting years. The yield was markedly increased by the fertilizer treatments in August of the season previous to fruiting.

10. The results indicate that early spring applications of nitrogen fertilizer in fruiting years tend to make the fruit softer. The results do not seem to indicate, however, that the fruit is so soft or of such inferior handling quality as to preclude the spring use of nitrogen if such treatment would otherwise improve the crop. The greater yield resulting from treatment in late summer or early fall rather than early spring is the important factor in determining the time of application of the nitrogen fertilizer.

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