AN ABSTRACT OF THE THESIS OF

Joseph T. DeFrancesco for the degree of Master of Science in Horticulture, presented on June 12, 1987.

Title: Effects of Nitrogen and Storage Time on the Quality of Highbush Blueberry Fruit.

Abstract approved: Lloyd W. Martin

To determine the effects of rate of nitrogen application and storage time on fruit quality of highbush blueberries (Vaccinium corymbosum, L.), five rates of ammonium sulfate fertilizer were soil-applied in 1984 and 1985 to cvs. Bluecrop and Jersey. Fruit was harvested up to three times during the 1985 season and held at $0^{o}C$ for up to 40 days. The fruit quality characteristics measured were firmness, percent soluble solids, percent titratable acidity, pH, and percentage of fruit with mold. Leaf mineral analysis was performed in early August.

Increased rates of N application increased berry firmness in both cultivars. A positive correlation existed between rate of N application and firmness for 'Jersey' berries at pick ($r = .3041$, $p < 0.05$, $n = 40$), when averaged over all harvests. Berries from all N treatments were considered to be of acceptable quality for the fresh market. Increased rates of N application also increased

percent titratable acidity, pH, and incidence of mold; influence of N on soluble solids was variable. The results from this study do not support the often-stated premise that high rates of N application result in soft berries.

As length of time in cold storage increased, firmness and pH decreased and incidence of mold, percent soluble solids and percent titratable acidity increased, indicating that berries can be stored for only a certain length of time before an appreciable loss of quality occurs.

EFFECTS OF NITROGEN AND STORAGE TIME ON THE QUALITY OF HIGHBUSH BLUEBERRY FRUIT

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirement for the
degree of

Master of Science

Completed June 12, 1987

Commencement June 1988

APPROVED:

Professor of Horticulture in charge of major

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Date thesis is presented June 12, 1987.

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ACKNOWLEDGEMENTS

Sincere thanks to Dr. Lloyd Martin for his support, encouragement, and advice. Special thanks to Dr. Timothy Righetti for his technical assistance, statistics and computer help, and for always making himself available to answer the many questions that came up along the way. Thanks to Dr. Glenn Klein for his insight into the importance of extension education in agriculture.

Dr. Daryl Richardson provided much-needed laboratory space and Richard Tetley gave freely of his time to answer questions, provide help and give advice in laboratory procedures; their assistance was greatly appreciated. Thanks to Dr. George Varseveld for his helpful information and use of freezer space. Thanks to the Washington Blueberry Commission for their financial support in partially funding this project.

Last, but not least, my thanks go to Steve Erickson and Daryl VanCleave of VanCleave Farms for all their help and cooperation, and for allowing me to put my research plots on their farm.

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REVIEW OF LITERATURE

Influence of Nitrogen

Firmness

There are no published studies that look directly at the effects of nitrogen on the firmness of blueberry fruit. However, when studying the effects of crop load and N application rate on other blueberry fruit qualities, Ballinger et al. (6) showed that N application treatments alone did not have a significant influence on the amount of sound fruit (not decayed, shriveled, soft or leaky) when three different rates of N fertilizer were applied.

When looking at the effects of rate of N application on firmness of fruits other than blueberries, workers have reported variable results. Shoemaker and Greve (47) report that strawberries receiving 250 pounds of nitrate of soda per acre were softer than fruit from the untreated plots. Darrow (23), on the other hand, states that nitrogen fertilizer treatment did not have an effect on strawberry firmness. Though not significant, he noted that plots fertilized with 500 pounds of nitrate of soda showed greater firmness than the control. Degman (24), working with apples and peaches, found that there was no consistent effect of firmness of the fruit from the use of nitrogen fertilizers. A later study by Degman (25), also on apples and peaches, confirmed that nitrogen fertilizer did not cause softer fruit at pick or after storage.

Soluble Solids

The influence of N application on the soluble solids (SS) content of blueberry fruit is variable. Working with the cultivar Wolcott in North Carolina, Ballinger et al. (6) found that fruit from bushes receiving the highest N application rate (130 lbs/A) was lower in SS than from bushes receiving the two lower application rates. This effect was not statistically significant at the first harvest but was for the second and third harvests. In their Michigan study, Ballinger et al. (5) state that a nitrogen-carbohydrate relationship may exist in the blueberry plant. They report that high levels of N in the fruiting-shoot leaves (as % dry wt.) may cause a decrease in the SS content of the blueberry fruit.

In a study of blueberries grown in sand culture, Ballinger and Kushman (3) report that varying the amount of N in the nutrient solution did not consistently influence SS of the berry juice. Uhe (52) found that three rates of nitrogen fertilizer on cv. Jersey in Oregon had no significant influence on the SS content.

Titratable Acidity

In their sand culture experiment, Ballinger and Kushman (3) report that as the amount of N in solution increases, the amount of titratable acidity in the fruit decreases. Ballinger et al. (6) report similar results and state that increased rates of N application are associated with smaller quantities of acid in the fruit. Uhe (52) reported no significant influence of three rates of N fertilizer on titratable acidity in fruit of the cv. Jersey.

pH

Ballinger and Kushman (3) reported that increases of N in the nutrient solution were related to an increase in fruit pH for all harvests of blueberries grown in sand culture. Working with cv. Wolcott blueberries in North Carolina, Ballinger et al. (6) reported a significant increase in fruit pH as rate of N application was increased; the pH increased from 3.15 to 3.30 as N application rate increased from 0 to 130 lbs N/A.

Decay

When studying the influence of cropload and nitrogen application rate on keeping quality (% sound fruit), Ballinger et al. (6) report that after storage at 70^{o}F for six days, no significant effects of N application treatments alone were evident. They did, however, observe that the highest rate of N (130 lbs/A) increased the number of sound fruit early in the season and decreased it later in the season. They noted that the higher N application rate was associated with a lower amount of titratable acidity, causing a higher soluble solids to acidity ratio, which was shown to be negatively correlated to keeping quality. In a later study involving cv. Wolcott blueberries grown in sand culture, Ballinger and Kushman (3) report no effects of nitrogen upon the keeping quality of the fruit.

Influence of Storage Time

Firmness

Bunemann et al. (14) report that ripe berries stored at 32°F in an atmosphere of 11% CO_2 and 10% O_2 were of good, marketable quality (no soft or decayed fruit) after eight weeks. Berries stored at 40°F in normal air, however, developed tough skin and firmer flesh after six weeks in storage and were considered unacceptable for the fresh market.

Soluble Solids

After storing cv. Wolcott blueberries for 10 days at 40°F, Kushman and Ballinger (35) observed a decrease in SS of less than 0.4%, which was not statistically significant.

Titratable Acidity

Kushman and Ballinger (35) observed a change in titratable acidity of up to 0.1% when fruit was held for 10 days at 40°F. They did not present their data so it is difficult to ascertain whether the change was an increase or decrease.

pH

Kushman and Ballinger (35) noted that fruit held for 10 days at 40°F had a range of increase in pH of 0.1 to 0.2 units. They intimate a storage-time by storage-temperature interaction because they observed that fruit held at 70°F for four days had a larger range of increase in pH; 0.2 to 0.4 units.

Decay

Working with the cvs. Bluecrop, Jersey, and Weymouth in New Jersey, Cappellini et al. (17) report that as storage time increased, more mold was found, regardless of storage temperature. Hrushka and Kushman (32) held several blueberry cultivars at 32°F for up to four weeks and report an increase in the incidence of decay as length of time in storage increased; 4.8% mold after one week and 16.4% after four weeks.

Influence of Time of Harvest

Firmness

When studying various factors affecting the firmness of four blueberry cultivars, Ballinger et al. (7) observed that berries are less firm later in the season than berries picked earlier in the season, regardless of cultivar or stage of ripeness. Ballinger et al. (6) reported that fruit from the third harvest did not keep as well (soft, shriveled or decayed berries) as fruit from the first or second harvest. They attribute this to the higher soluble solids to titratable acidity ratio of the fruit at the third harvest. After fruit was held for four days at 70°F, Kushman and Ballinger (35) observed that deterioration was greater for fruit picked later in the season than from earlier harvests.

Deterioration was defined as fruit that was decayed, leaky or soft and splitting upon finger pressure.

Soluble Solids

The effects of time of harvest on SS content are not as well defined as for other aspects of quality and variable results have been reported. Ballinger et al. (6) found that as the season progressed, the SS content increased from 11.7% to 13.6%. When studying various factors associated with ripening of four different cultivars in Rhode Island, Shutak et al. (48) noted that berries in the blue (ripe) stage of development have a slightly lower SS content later in the harvest season than at the beginning. Kushman and Ballinger's (37) study with cv. Wolcott berries reveals that for most of the berry sizes and anthocyanin classes tested, SS content is lowest at the last harvest. They did note, however, that fruits of the middle harvest had the highest SS content.

Ballinger and Kushman (4) reported that in the first year of their study, when averaged across all stages of ripeness, there was a significant increase in SS content, from 6.95% to 8.70%, as the harvest season progressed. Variable results were reported by Kushman and Ballinger (35), with SS content ranging from 11.1% to 13.4% for the several harvests throughout the harvest season, with only a few of the differences between harvest dates being significant. No clear trend was observed as the season progressed.

In Oregon, working with cv. Jersey berries of several different size classes, Uhe (52) observed an increase in SS between the first harvest (12.4%) and the second harvest (14.4%); however, SS decreased by the third harvest (13.4%). He attributes the decreased SS content at the third harvest to slower ripening due to cool weather just prior to that harvest and states he would have expected the third harvest to have the highest SS content.

Titratable Acidity

In an experiment in which berries were harvested three times at weekly intervals, Ballinger et al. (6) reported that titratable acidity drastically decreased as the season progressed; 0.83% at the first harvest and 0.48% at the third harvest. Kushman and Ballinger (35) found that, regardless of harvest interval, titratable acidity decreased as the season progressed. In a later study, Kushman and Ballinger (37) found comparable results and reported that titratable acidity tends to be highest early in the season and lowest later in the season for all berry sizes and anthocyanin classes tested. Uhe (52) reported a significant decrease in titratable acidity as the harvest season progressed, for every berry-size class except the two largest sizes. He related the conflicting results to an observed size by acidity interaction. Ballinger and Kushman (4), reported that titratable acidity, when averaged across all stages of ripeness, significantly increased from 2.28% to 2.80% in the first year of the study but decreased from 2.89% to 2.77% in the following year, as the season progressed.

pH

Ballinger et al. (6) observed an increase in pH, from 3.10 to 3.42, as the season progressed. Uhe (52) reported that berries picked at the end of the season were less acidic (higher pH value) than berries of the first harvest. Kushman and Ballinger (35) also observed an increase in pH with each subsequent harvest, regardless of harvest interval.

Ballinger and Kushman (4) noted that, although there was a significant difference in pH between berries in the various stages of ripeness tested, no clear trend was observed. When all stages of ripeness were averaged together, the pH significantly increased from 2.68 to 2.89 as the 1964 harvest season progressed. In contrast, although not significant, the pH of berries harvested in 1963 was highest at the first harvest and lowest at the last harvest.

Decay

The results from the work Cappellini et al. (17) did in New Jersey on three cultivars indicate that keeping quality deteriorated with each successive harvest. Ballinger et al. (6) report that fruit harvested at the end of the season did not keep as well (greater percentage of unsound fruit) as did fruit harvested earlier in the season.

Other Factors Influencing Fruit Quality

Stage of maturity, berry size, cultivar and berry temperature have all been observed to influence blueberry fruit quality.

As for other fruits (44, 53), the percentage of titratable acidity generally decreases and the SS content increases as the blueberry fruit ripens. Working with cv. Wolcott blueberries in North Carolina, Ballinger and Kushman (4) report that as berries ripen from the green to the overripe stage, pH and soluble solids content increase while the acid content decreases. (They did note that titratable acidity increased during early stages but decreased rapidly during the later stages of development.) Many other workers have reported similar results with regard to pH, titratable acidity and soluble solids (1, 8, 13, 14, 35, 36, 48, 52, 55). Woodruff et al. (55) report a strong correlation between degree of ripeness and shelf-life. They observed that, regardless of storage temperature or length of time in storage, riper berries (as indicated by a higher soluble solids to titratable acidity ratio) have a greater incidence of deterioration and mold. Bowers and Dewey (13) and Ballinger and Kushman (4) report similar results.

Uhe (52) reported that sugar content increased and acid content decreased as berry size increased. Kushman and Ballinger (37) noted small differences in pH, acidity and soluble solids between berries of different size. Ballinger and Kushman (3) observed that larger fruit tend to have a higher SS content than smaller fruit. In their 1973 firmness study, Ballinger et al. (7) reported that smaller berries were slightly, but significantly, more firm than larger berries.

Differences in fruit composition, firmness and keeping quality between cultivars have been reported by many workers (7, 8, 13, 17, 37, 45, 48, 50, 51, 55). Ballinger et al. (7) reported that fruit firmness of some cultivars was almost double that of others. Woodruff et al. (55) reported that fruit of the cv. Jersey had slightly higher sugar content and considerably lower acid content than fruit of the cv. Rubel. Cappelini et al. (17) reported that certain cultivars were of poorer keeping quality than others; cv. Weymouth had a higher percentage of mold than did either cvs. Bluecrop or Jersey, regardless of storage time or temperature.

The effects of temperature upon firmness and keeping quality of freshly harvested and stored blueberries have been well documented. Many workers have reported that as storage temperature increases, the amount of decay increases and is more rapid than at lower temperatures (4, 8, 13, 17, 29, 34, 49, 54, 55). Ballinger et al. (7) observed a significant decrease in berry firmness as temperature of the fruit increased from 4.4 to 38.0^{o}C. They noted that this physical phenomenon is reversible because berries heated to 38.0^{o}C and then cooled to 4.4^{o}C attained a firmness equivalent to that of berries cooled initially to 4.4^{o}C.

EFFECTS OF NITROGEN AND STORAGE TIME ON THE QUALITY OF HIGHBUSH BLUEBERRY FRUIT

Abstract

To determine the effects of rate of nitrogen application and storage time on fruit quality of highbush blueberries (Vaccinium corymbosum, L.), five rates of ammonium sulfate fertilizer were soil-applied in 1984 and 1985 to cultivars Bluecrop and Jersey. Fruit was harvested up to three times during the 1985 season and held at $0^{o}C$ for up to 40 days. The fruit quality characteristics measured were firmness, percent soluble solids, percent titratable acidity, pH, and percentage of fruit with mold. Leaf mineral analysis was performed in early August.

Increased rates of N application increased berry firmness in both cultivars. A positive correlation existed between rate of N application and firmness for 'Jersey' berries at pick ($r = .3041$, $p < 0.05$, $n = 40$), when averaged over all harvests. Berries from all N treatments were considered to be of acceptable quality for the fresh market. Increased rates of N application also increased percent titratable acidity, pH, and incidence of mold; influence of N on soluble solids was variable. The results of this study do not support the often-stated premise that high rates of N application result in soft berries.

As length of time in cold storage increased, firmness and pH decreased and incidence of mold, percent soluble solids and percent titratable acidity increased, indicating that berries can

be stored for only a certain length of time before an appreciable loss of quality occurs.

Introduction

Commercial highbush blueberry (Vaccinium corymbosum L.) production in the Pacific Northwest is a small but important industry and one that is known for its high-quality fruit.

Due to the large volume of berries on the fresh market, growers need to produce high-quality fruit not only for sale locally but, also, for shipment to distant markets. High production also creates the potential need to keep berries in cold storage for a limited time until market conditions are favorable. Many tons of blueberries can be lost due to decay, which can develop during storage or transportation. The quality of the fruit when it is picked and held in cold storage for a period of time is of concern to both growers and retailers alike.

Blueberries for the fresh market should be firm, sweet and free of contaminants, defects and mold. Optimum fruit firmness is subjective but after years of consumption, consumers have certain expectations when they eat blueberries; if the berries are softer than they expect, repeat purchases are unlikely. The same holds true for sweetness, or flavor, which is generally determined by the amount of sugars and acids in the fruit.

Blueberry plants respond to nitrogen more than any other plant nutrient, and nitrogen fertilization is a key factor in blueberry production. Nitrogen fertilization is generally intended to increase yield and plant vigor rather than to influence the quality of the fruit. Much research has been done to determine the nitrogen requirements of blueberries and the influence nitrogen has on yield (6, 9, 26, 40). Some work has been done which looked at the influence of nitrogen on various quality characteristics of the fruit itself (3, 5, 6, 52).

It has been shown that as application rate of nitrogen increased, fruit acidity (expressed as % citric) decreased and pH increased; the influence upon soluble solids content is variable (3, 6, 52). The relationship between low fruit acidity and poor keeping quality (soft or decayed fruit) has also been well documented (4, 6, 8, 13, 35, 55). Growers may be adding high rates of nitrogen to the soil to increase yield and promote plant vigor but, at the same time, influencing the fruit such that it is of poorer quality for the fresh market.

Commercial blueberry growers have long suggested that high rates of nitrogen application result in berries that are soft and of poor keeping quality. Fruit softening due to nitrogen application has been shown to be true in some cases in some of the other fruit crops, such as strawberries (47), but whether excessive nitrogen causes softer fruit in blueberries has never been fully explored.

The objectives of this study were to determine the effects of nitrogen and storage time on firmness, soluble solids, titratable acidity, pH and incidence of decay. Also of interest was to determine if there is an interaction between nitrogen and storage time with respect to fruit quality, and to identify the range of leaf nitrogen concentration at which acceptable fruit quality occurs.

Materials and Methods

Plots consisting of 25 bushes, replicated four times for each cultivar, were established in a 10-year old, commercial planting of the cultivars Bluecrop and Jersey near Salem, Oregon. The planting had a standard 5x10 foot spacing and a sawdust mulch in the plant row. The treatments (nitrogen and storage time) were factorially arranged and the data from each harvest analyzed as a split block.

Nitrogen, as ammonium sulfate, was applied annually for two consecutive years (1984 and 1985) in a split application (April 1st and May 1st), as is commonly done in the Pacific Northwest. The nitrogen treatments consisted of 0, 126, 252, 378 and 504 kilograms of nitrogen per hectare per year. The fertilizer was applied by hand in a wide band beneath the drip line of the branches.

In 1985, berries at the blue-ripe stage were carefully hand-harvested on three dates for 'Bluecrop' and two dates for 'Jersey'. On each of these harvest dates, all the ripe berries were removed from the plants. A random sample, representing each nitrogen treatment, was taken to the laboratory and field heat removed by placing in $0^{o}C$ storage overnight. Four sub-samples, consisting of 20 berries of uniform size, were taken from each nitrogen treatment sample, at each harvest date, to be later analyzed for firmness, percentage of berries with mold, percent soluble solids, percent titratable acidity and pH. Berries were placed into .3 liter, pressed-paperboard hallocks. The hallocks were put into cardboard flats and loosely covered with cellophane to reduce moisture loss during storage.

Berries were tested for firmness at pick (after field heat had been removed) and after being held in $0^{\circ}C$ storage for 10, 20 and 40 days. Berry firmness, measured as resistance to compression, was determined by using a 1000g, U.C. Firmness Tester penetrometer, onto which was mounted a flat steel plate. A given berry was placed on its side on a wood platform into which a slight depression had been carved, to prevent the berry from rolling. This platform was secured to a small laboratory jack which, when raised, brought the berry into contact with the steel plate of the penetrometer. The berry was then compressed one quarter of its diameter and firmness measured in grams of force.

Decay was determined visually by counting the number of berries that exhibited fungal growth (mold) at pick and after 10, 20 and 40 days in $0^{\circ}C$ storage. The fungal growth on the berries in this study is believed to be <u>Alternaria</u> and <u>Botrytis</u> spp., although a microscope was not used in identification; other fruit-rotting molds may have been present. Researchers elsewhere have shown <u>Alternaria</u> and <u>Botrytis</u> spp. to be the most common post-harvest diseases of blueberries (17, 29, 31).

Once firmness and percentage of berries with mold at pick and after a selected storage time were determined, berries were then placed in plastic bags and frozen at $-23^{o}C$ for further laboratory analysis at a later date. Moldy berries were not included in the frozen samples.

Percent soluble solids, percent titratable acidity and pH were determined for samples at pick and for each thawed and macerated sample after 40 days in $0^{o}C$ storage. Samples were macerated with a Waring commercial laboratory blender. Soluble solids content in the juice of the homogenate, pressed through cheesecloth, was measured with an Atago hand-held refractometer. Citric acid is the dominant acid in blueberries (42) and titratable acid is thus expressed as percent citric acid. Percent titratable acidity was determined by modifying the procedure as outlined by Ruck (43). Five grams of the homogenate was mixed with 50 ml of distilled water and, while stirring constantly, titrated with 0.1N NaOH to an end point of pH 8.1, as indicated by a glass-electrode, Orion Research pH Meter. The pH of the homogenate was measured directly by use of the glass-electrode pH meter.

Leaves were sampled from the mid-portion of the current season's growth during the first week of August and analyzed for mineral content at the Plant Analysis Laboratory at Oregon State University. Nitrogen was determined by the standard micro-Kjeldahl method and all other minerals were analyzed spectrographically.

Fruit yield for the season for each nitrogen treatment was estimated. Actual yield data was collected for the first and second harvests of 'Bluecrop' and second harvest of 'Jersey'. The approximate percentage that each harvest contributes to total yield was known from grower records of previous years; total yield for the season was thus based on those percentage figures.

Results and Discussion

Influence of Nitrogen

Firmness

Nitrogen treatment had a significant ($p < 0.05$) influence on firmness of 'Bluecrop' berries at pick, when averaged over all harvests (Fig. 1). 'Jersey' berries exhibited the same trend with a positive correlation between rate of N application and firmness ($r = .3041$, $p < 0.05$, $n = 40$); firmness generally increased, for either harvest, as rate of N application increased from 0 to 504 kg/ha (Table 1). Fresh-picked berries of every N treatment, however, were considered to be of acceptable quality for the fresh market. After 40 days in storage, there was no significant difference in berry firmness due to N treatment, for either cultivar.

Some blueberry cultivars have firmer fruit than others (7). In this study, 'Bluecrop' berries were consistently more firm than 'Jersey' berries for any given N treatment (Tables 1, 2 and 3).

For the second harvest of 'Bluecrop' berries, a significant correlation ($r = .6084$, $p < 0.01$, $n = 20$) existed between rate of N application and berry firmness at pick. Berry firmness at pick steadily increased, from 391g to 429g, as rate of N application increased from 0 to 504 kg/ha (Table 4). Thirty-seven percent of the variation in firmness of second-harvest 'Bluecrop' berries at pick can be accounted for by N treatment.

When averaged over all harvests and all storage times, N did not have a significant influence on firmness for either cultivar. There was, however, a tendency for a slight increase in firmness, then a decrease, as rate of N application increased (Tables 2 and 3).

Soluble Solids

Nitrogen had a significant influence on the soluble solids content in the fruit of both 'Bluecrop' ($p < 0.01$) and 'Jersey' ($p < 0.05$).

Nitrogen treatment was significantly correlated with soluble solids ($r = .3352$, $p < 0.01$, $n = 60$) for 'Bluecrop' berries at pick, averaged over all harvests; as rate of N application increased from 0 to 504 kg/ha, soluble solids content increased from 14.7% to 15.3%. The same relationship occurred in 'Bluecrop' berries that were stored for 40 days ($r = .4019$, $p < 0.01$, $n = 60$); soluble solids increased from 14.3% to 15.3% as rate of N application increased. When averaged over all harvests and storage times, a similar trend was observed; increased nitrogen treatment significantly increased soluble solids content, from 14.5% to 15.3% (Table 2), and the two factors were significantly correlated ($r = .5527$, $p < 0.05$, $n = 15$). Thirty percent of the variation in soluble solids of 'Bluecrop' berries can be accounted for by N treatment.

'Jersey' berries at pick were significantly ($p < 0.05$) influenced by N treatment although, in contrast to 'Bluecrop' berries, soluble solids decreased from 16.1% to 15.6% as rate of N application increased from 0 to 504 kg/ha ($r = .3691$, $p < 0.01$, $n = 40$). Nitrogen did not significantly influence the soluble solids content in 'Jersey' berries that were stored for 40 days. When averaged over all harvests and storage times, N treatment significantly ($p < 0.05$) decreased soluble solids content in 'Jersey' berries (Table 3).

Rate of N application had a different influence on soluble solids content for 'Bluecrop' and for 'Jersey', but other workers, also, have reported variable results when looking at the relation of N and soluble solids (3, 52).

Titratable Acidity

Differences in titratable acidity due to N treatment were small for either cultivar and significant ($p < 0.05$) for 'Jersey' berries only, which showed a slight increase as rate of N application increased (Fig. 2). Rate of nitrogen application and percent titratable acidity of 'Jersey' berries that had been stored for 40 days were positively correlated ($r = .3792$, $p < 0.05$, $n = 4$). 'Bluecrop' berries also exhibited a slight, although not statistically significant, increase in titratable acidity with an increase in rate of N application (Table 2). Other workers report opposite results and indicate that as N increases, titratable acidity in the fruit decreases (3, 6). Uhe (52), on the other hand, reported that N treatment had no significant influence on titratable acidity.

pH

When averaged over all harvests, rate of N application had a significant influence on the pH of 'Jersey' berries at pick ($p < 0.01$) and after 40 days in storage ($p < 0.05$). The pH of berries at pick increased from 3.51 to 3.94 and, after 40 days in storage, increased from 3.48 to 3.71 as rate of N application increased from 0 to 504 kg/ha. This effect occurred, also, at each individual harvest (Table 5).

'Bluecrop' berries also exhibited the same trend as 'Jersey' but it was statistically significant for berries at pick only ($p < 0.01$). When averaged over all harvests, pH of berries at pick increased from 3.26 to 3.45 as rate of N application increased. Increases in pH were also observed at each individual harvest (Table 5).

A significant positive correlation between N treatment and pH of 'Jersey' berries ($r = .7387$, $p < 0.05$, $n = 10$) existed when averaged over all storage times. A positive correlation between N and pH has also been reported by other workers (3, 6).

The influence of N treatment on pH was similar for both cultivars but 'Jersey' berries consistently had higher pH values than did 'Bluecrop' berries (Fig. 3).

Decay

As rate of N application increased, the percentage of berries with mold significantly increased for both 'Bluecrop' ($p < 0.05$) and 'Jersey' ($p < 0.01$) (Tables 2 and 3). A positive correlation existed between N treatment and incidence of mold ('Bluecrop': $r = .4458$; 'Jersey': $r = .6370$) but was significant ($p < 0.05$) for 'Jersey' only. 'Bluecrop' had a lower percentage of mold at all N levels than did 'Jersey' (Fig. 4).

The influence of N on the incidence of mold can be related to pH of the berries. In culture solutions prepared with various acid and sugar levels, Ballinger and Kushman (4) report that growth of two of the most prevalent fruit-rotting fungi affecting blueberries, Alternaria and Botrytis spp., decreased as acid level in the solution increased. In the present study, although titratable acidity actually increased slightly with increased rates of N application, there was a large and significant increase in berry pH with N treatment. This increase in pH indicates that berries were less acid, thus possibly creating a more favorable environment for fungal growth.

Influence of Storage Time

Firmness

Differences in firmness due to length of time in storage, when averaged over all N treatments and all harvests, were significant ($p < 0.01$) for 'Bluecrop' berries only (Table 2). 'Bluecrop' berries stored for 40 days were 23% less firm than berries at pick. Firmness of 'Jersey' berries decreased from 376g to 351g after 40 days in storage (Table 3). Regardless of N treatment or harvest date for either cultivar, the softest berries were those stored for 40 days.

Both cultivars exhibited a similar pattern of softening as length of time in storage increased (Fig. 5). The increase in firmness after 10 days in storage is interesting and can possibly be attributed to a loss of berry moisture. It seems that a higher firmness reading would be obtained on a berry that has incurred some cell-wall breakdown and a certain amount of moisture loss. Bunemann et al. (14) also noted firmer flesh in berries that were stored at 40^{o}F for six weeks, although no explanation is offered for this occurrence.

Soluble Solids

Length of time in storage significantly ($p < 0.05$) influenced the soluble solids content of 'Jersey' berries (Table 3), and a significant correlation existed between these two factors ($r = .9701$, $p < 0.05$, $n = 4$) when averaged over all N levels.

For 'Bluecrop' berries, there was a slight decrease in soluble solids content after 40 days in storage, but this effect was not significant (Table 2). The reason for the difference in trends between the two cultivars can be explained upon closer examination of the relation of soluble solids and storage time within each individual harvest of 'Bluecrop' (Fig. 6). After 40 days in storage, soluble solids significantly increased in berries of the second and third harvests ($p < 0.05$) but drastically decreased ($p < 0.01$) in berries of the first harvest. The low soluble solids content of first-harvest berries after 40 days in storage is an anomaly that cannot be explained.

Titratable Acidity

Titratable acidity in 'Bluecrop' berries significantly ($p < 0.01$) increased, from 0.673% to 0.739%, after 40 days in storage (Table 2). 'Jersey' berries also showed a slight, although not significant, increase with length of time in storage (Table 3). The titratable acidity content of 'Bluecrop' berries was 60 to 70% higher than that of 'Jersey' berries (while soluble solids was fairly similar for both) indicating a difference in fruit composition due to cultivar, which is in agreement with the findings of Woodruff et al. (55).

pH

The pH of 'Bluecrop' berries significantly ($p < 0.01$) decreased after 40 days in storage (Table 2). 'Jersey' berries showed only a slight decrease in pH and this effect was not significant (Table 3). Kushman and Ballinger (35), however, report an increase in pH after berries were in $40^{o}F$ storage for 10 days.

Decay

For both cultivars, incidence of mold significantly ('Bluecrop': $p < 0.05$; 'Jersey': $p < 0.01$) increased as length of time in storage increased (Tables 2 and 3). There was a strong correlation between storage time and incidence of mold ('Bluecrop': r = .7056; 'Jersey': r = .7409); other workers have reported a similar correlation (17, 32).

'Jersey' berries had more mold after 40 days in storage than did 'Bluecrop' berries (Fig. 7). This may be attributed to the fact that 'Jersey' berries had smaller amounts of titratable acids and a higher pH value, which would create a more favorable growing environment for some of the fruit-rotting molds.

Influence of Time of Harvest

Firmness

Berry firmness of both cultivars was significantly ($p < 0.01$) influenced by time of harvest, when averaged over all N levels and all storage time treatments. Berries of the last harvest were less firm than berries of earlier harvests (Tables 2 and 3). A significant negative correlation between harvest date and firmness existed for 'Jersey' berries ($r = -.9857$, $p < 0.01$, $n = 10$), when averaged over all storage times. The correlation between these two factors was strong, though not significant, for 'Bluecrop' ($r = -.7705$).

For 'Bluecrop', the firmest berries were those of the second harvest. This can be attributed to stage of ripeness; berries of the second harvest were less ripe (soluble solids to titratable acidity ratio (SS:Ac) = 16) than berries of the first harvest (SS:Ac = 28) or third harvest (SS:Ac = 27). Most other workers, however, report a steady decrease in firmness as the harvest season progresses (6, 7, 35).

'Jersey' berries of the second harvest were considerably more firm than third-harvest berries but, because berries of the first harvest were not tested, it is difficult to predict whether or not the trend would have been the same as that of 'Bluecrop'.

Soluble Solids

The soluble solids content of 'Bluecrop' berries was significantly ($p < 0.01$) influenced by time of harvest. Soluble solids increased from 14.9% to 15.2% between first and third harvest but was lowest for second harvest (14.1%) (Table 2). The lower soluble solids content of second-harvest berries can be attributed to the less-mature stage of ripeness at that harvest, as indicated by the low soluble solids to titratable acidity ratio (16:1) of those berries. Woodruff (55) and others (4, 13, 36) have shown a strong positive correlation between stage of ripeness and soluble solids content in the fruit.

In contrast to 'Bluecrop' berries, the last harvest of 'Jersey' berries had the lowest soluble solids content, although the difference between harvests was slight and not significant. Other workers have reported variable results when determining the influence of harvest date on soluble solids content in blueberry fruit (4, 6, 35, 37, 48).

Titratable Acidity

Time of harvest had a significant ($p < 0.01$) influence on the titratable acidity content of both cultivars. For 'Bluecrop' berries, titratable acidity increased between the first and second harvest then decreased and was lowest at the third harvest (Table 2). Other workers, also, have reported a decrease in titratable acidity as the season progresses (6, 35, 37). 'Bluecrop' berries of the second harvest had the highest titratable acidity content but this peak can be attributed to stage of ripeness. Berries of the second harvest were less ripe than berries of the other two harvests and, thus, would have a higher amount of acids in the fruit.

'Jersey' berries reacted differently than did 'Bluecrop' berries; titratable acidity increased between the second and third harvest (Table 3). When averaged over all storage times, a positive correlation existed between harvest date and percent titratable acidity ($r = .7068$, $p < 0.05$, $n = 10$). Ballinger and Kushman (4) also report an increase in titratable acidity of cv. Wolcott berries as the harvest season progressed.

pH

Changes in pH due to time of harvest were significant ($p < 0.01$) for both cultivars. The pH of 'Bluecrop' berries decreased between first and second harvest then increased and was the highest at the third harvest (Table 2). This effect was prevalent regardless of how long berries were kept in storage. Other workers report an increase in pH as the season progresses (6, 35). The low pH values of the second harvest of 'Bluecrop' can be attributed to the fact that those berries were less ripe than berries of the first or third harvest. Stage of ripeness has been shown to have an influence on berry pH; immature berries are more acidic and have lower pH values (4).

In contrast to 'Bluecrop' berries, the pH of 'Jersey' berries significantly decreased between second and third harvest (Table 3). Ballinger and Kushman (4) report a similar decrease for one year of their study but the influence was not statistically significant.

Decay

For both cultivars, berries of the last harvest had a higher amount of mold than did berries of earlier harvests, although the differences were not statistically significant (Tables 2 and 3). When averaged over all storage time treatments, the correlation between amount of mold and time of harvest was significant ('Bluecrop': $r = .5400$, $p < 0.05$; 'Jersey': $r = .6439$, $p < 0.05$). The strong positive correlation between these two factors has been reported by others (17, 32).

Interactions

Several significant treatment interactions were observed with both 'Bluecrop' and 'Jersey' berries.

Nitrogen by Storage Time

Nitrogen treatment interacted significantly ($p < 0.05$) with storage time, affecting pH in both cultivars, although no clear trend was observed (Table 5). 'Jersey' berries exhibited the most drastic interaction in that berries receiving 0, 126 or 504 kg N/ha treatment decreased in pH after 40 days in storage, whereas berries receiving 252 or 378 kg N/ha increased in pH after 40 days (Fig. 8).

Nitrogen by Time of Harvest

'Bluecrop' berries had significantly ($p < 0.05$) more mold with the N treatment of 378 kg N/ha at third harvest. The earlier harvests had considerably less mold (Fig. 9). Berries of the first harvest had the highest incidence of mold when no nitrogen was applied but had the lowest amount at the 126, 252 amd 504 kg N/ha treatment rates.

Storage Time by Time of Harvest

A highly significant ($p < 0.01$) interaction between storage time and time of harvest, affecting berry firmness, occurred for both cultivars. At pick, 'Bluecrop' berries of the first harvest were the firmest and berries of the second harvest were the softest. But after 40 days in storage, the reverse was true (Fig. 10). What is of interest is the pattern of softening for each harvest due to length of time in storage. First and third harvests follow a similar pattern of softening but berries of the second harvest reacted very differently in storage (Fig. 10). This difference may be attributed to stage of ripeness; berries of the first and third harvests were more ripe than second-harvest berries. Pectins are rapidly broken down in the later stages of ripening (55) and this may account for some of the softening after 40 days in storage. The less-mature berries of the second harvest possibly did not experience as much pectin breakdown or as much moisture loss, thus maintained a fairly high firmness level in storage. Another reason may be that second-harvest berries had small amounts of sugar at pick, less sugar was available for oxidative breakdown during respiration and thus less softening occurred during storage.

Time of harvest significantly ($p < 0.01$) interacted with storage time, influencing soluble solids content in 'Bluecrop' berries (Fig. 6). The decrease in soluble solids content of first-harvest berries after 40 days in storage is the main reason for the significant interaction, although there is no explanation for such a low reading or why soluble solids decreased when the other harvests showed an increase with storage time.

Titratable acidity of 'Bluecrop' berries was significantly ($p < 0.01$) influenced by an interaction between storage time and time of harvest. Berries of the first harvest had the lowest titratable acidity content at pick but after 40 days in storage, titratable acidity increased drastically and was higher than that of third harvest berries (Fig. 11). The titratable acidity of first-harvest 'Bluecrop' berries after 40 days in storage seems unreasonably high. If first harvest berries were omitted from the statistical analysis, then no interaction between storage time and time of harvest would have been observed.

Storage time and time of harvest interacted significantly

($p < 0.01$), affecting pH of 'Bluecrop' berries. Berries of the first harvest had the highest pH at pick but after 40 days in storage, those berries had a pH that was lower than third-harvest berries (Fig. 12). This interaction would not have occurred if first-harvest berries were omitted from the statistical analysis. The reason for such a drastic decrease in pH of first-harvest berries is unexplained.

Conclusion

Five rates of nitrogen were applied to two cultivars of highbush blueberries to determine the effects of nitrogen on fruit quality. Fruit from each nitrogen treatment was collected up to three times during the 1985 harvest season and subjected to tests of quality at pick and after storage at $0^{o}C$ for 10, 20 and 40 days. The fruit quality characteristics measured were firmness, percent soluble solids, percent titratable acidity, pH and percentage of berries with mold.

Nitrogen had the most profound effect on pH and occurrence of mold; as rate of N application increased, both pH and amount of mold increased for 'Bluecrop' and 'Jersey'. As rate of nitrogen application increased, there was a slight increase in percent titratable acidity and a decrease in percent soluble solids of 'Jersey' berries, and an increase in percent soluble solids of 'Bluecrop' berries. Nitrogen significantly increased firmness of 'Bluecrop' berries at pick only; the trend for both cultivars was a slight increase in berry firmness as rate of N application increased. The findings of this study do not support the often stated premise that high rates of N application result in softer berries.

Leaf nitrogen increased as rate of N application increased (Figure 13, Table 6) but the increase was not as great as would be expected for such high application rates. This leads one to question where the soil-applied nitrogen is going and whether the fruit-to-leaf ratio of the plant has a more significant effect on leaf minerals than was previously thought. It appears that without a measurement of plant vigor, leaf-nitrogen concentrations are of little use in helping to define a fertilizer program. To be able to identify the leaf-N level at which optimum fruit quality occurs, fruit-to-leaf ratios and N storage patterns in the plant need to be determined. The exploration of these relationships can be the basis for future research projects.

Length of time in storage had a significant influence on berry firmness and percentage of berries with mold for both cutivars; the softest berries and berries with the most mold were those stored for the longest period of time. As length of time in storage increased, there was an increase in percent soluble solids for 'Jersey'; for 'Bluecrop', there was a decrease in percent titratable acidity and an increase in pH. The findings from this study indicate that blueberries can be stored for only a certain length of time before a serious loss in quality occurs, which eventually translates into an economic loss.

Berries of the last harvest, for either cultivar, were the softest and had the highest incidence of mold. These results indicate that a grower may want to go fresh market with berries of the earlier harvests but designate berries of the later harvests for processing.

The objective of every commercial blueberry grower is to produce berries of the highest quality and to have those berries reach the consumer in an acceptable state of quality. The results of this study indicate that nitrogen alone does not have a great influence on fruit quality.

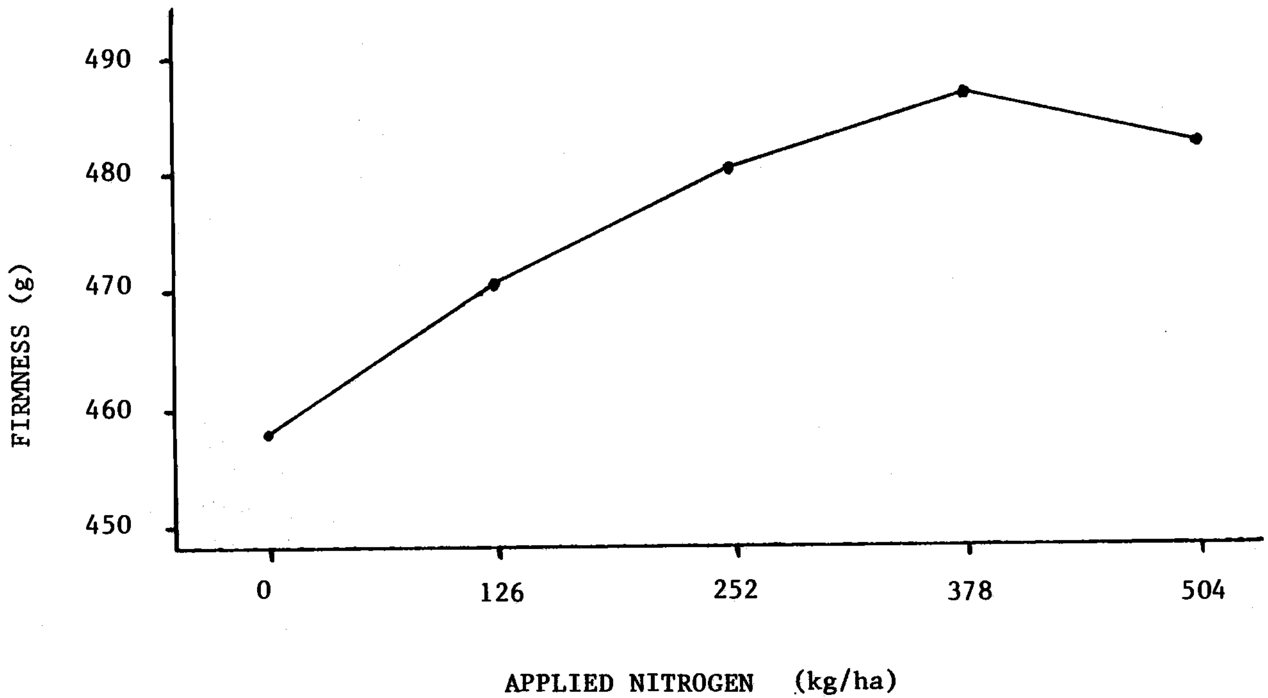

Figure 1. The influence of nitrogen on berry firmness at pick of the cultivar Bluecrop (averaged across all harvests).

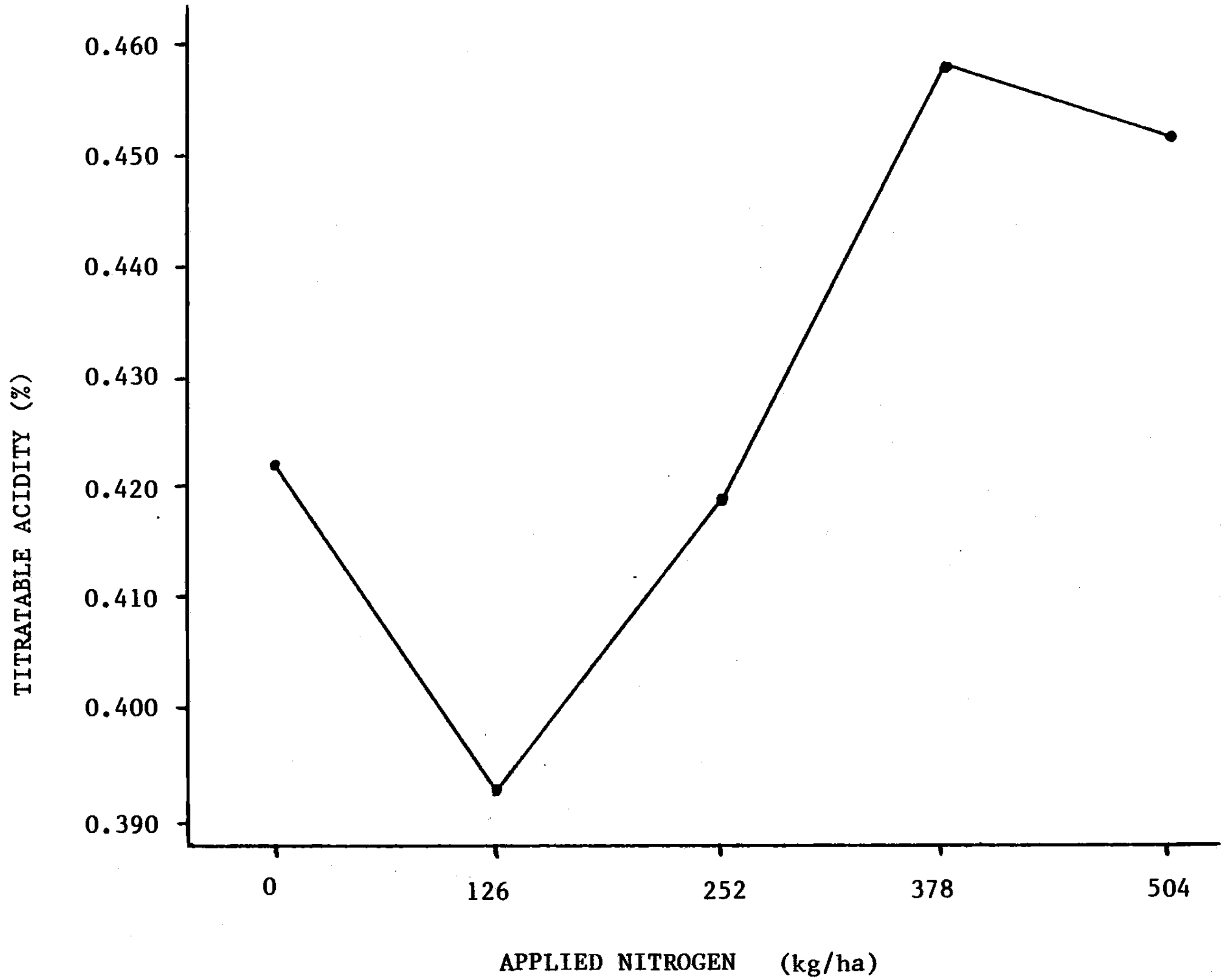

Figure 2. The influence of nitrogen on percent titratable acidity of the cultivar Jersey (averaged across all harvests and storage times).

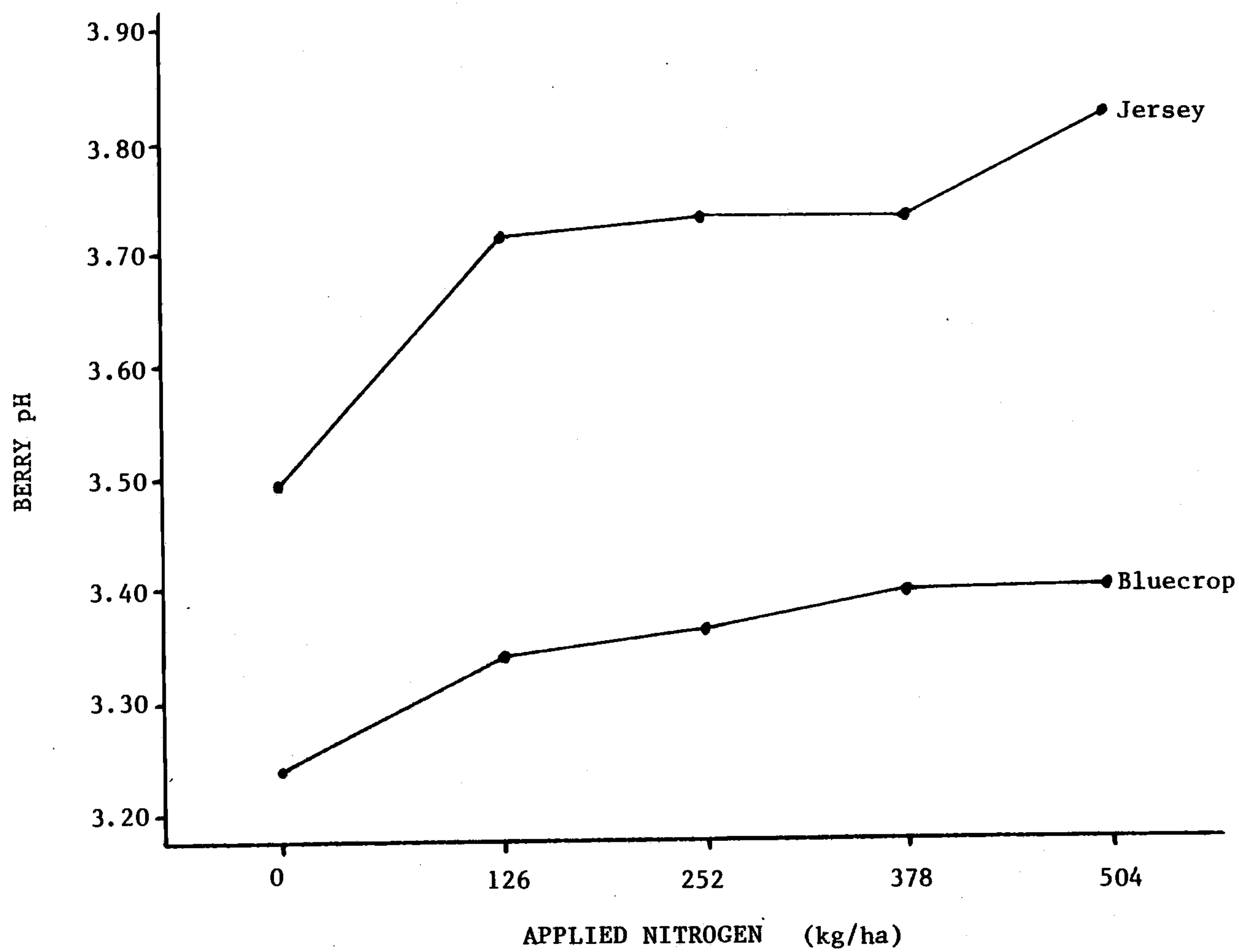

Figure 3. The influence of nitrogen on berry pH of the cultivars Bluecrop and Jersey (averaged across all harvests and storage times).

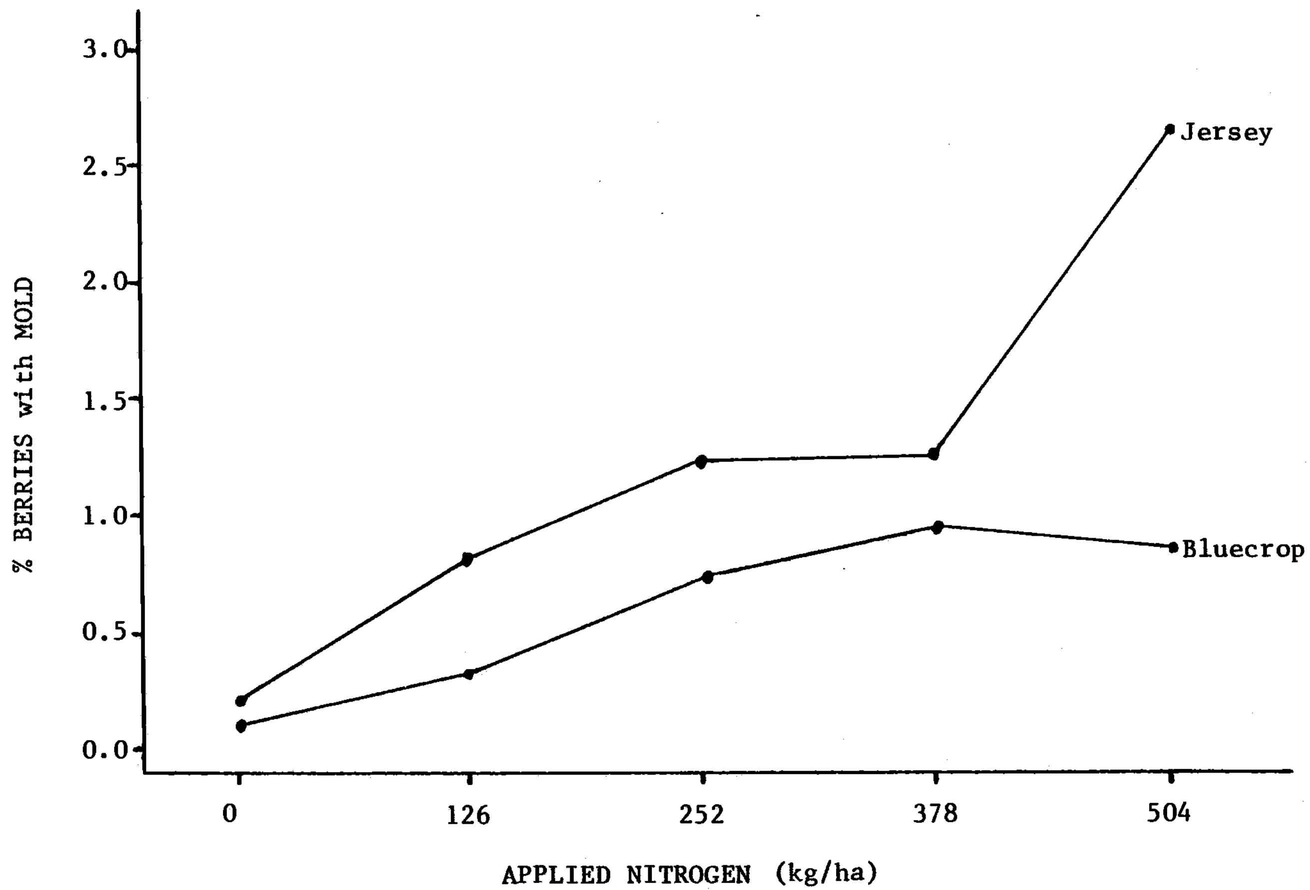

Figure 4. The influence of nitrogen on amount of mold in the cultivars Bluecrop and Jersey (averaged across all harvests and storage times).

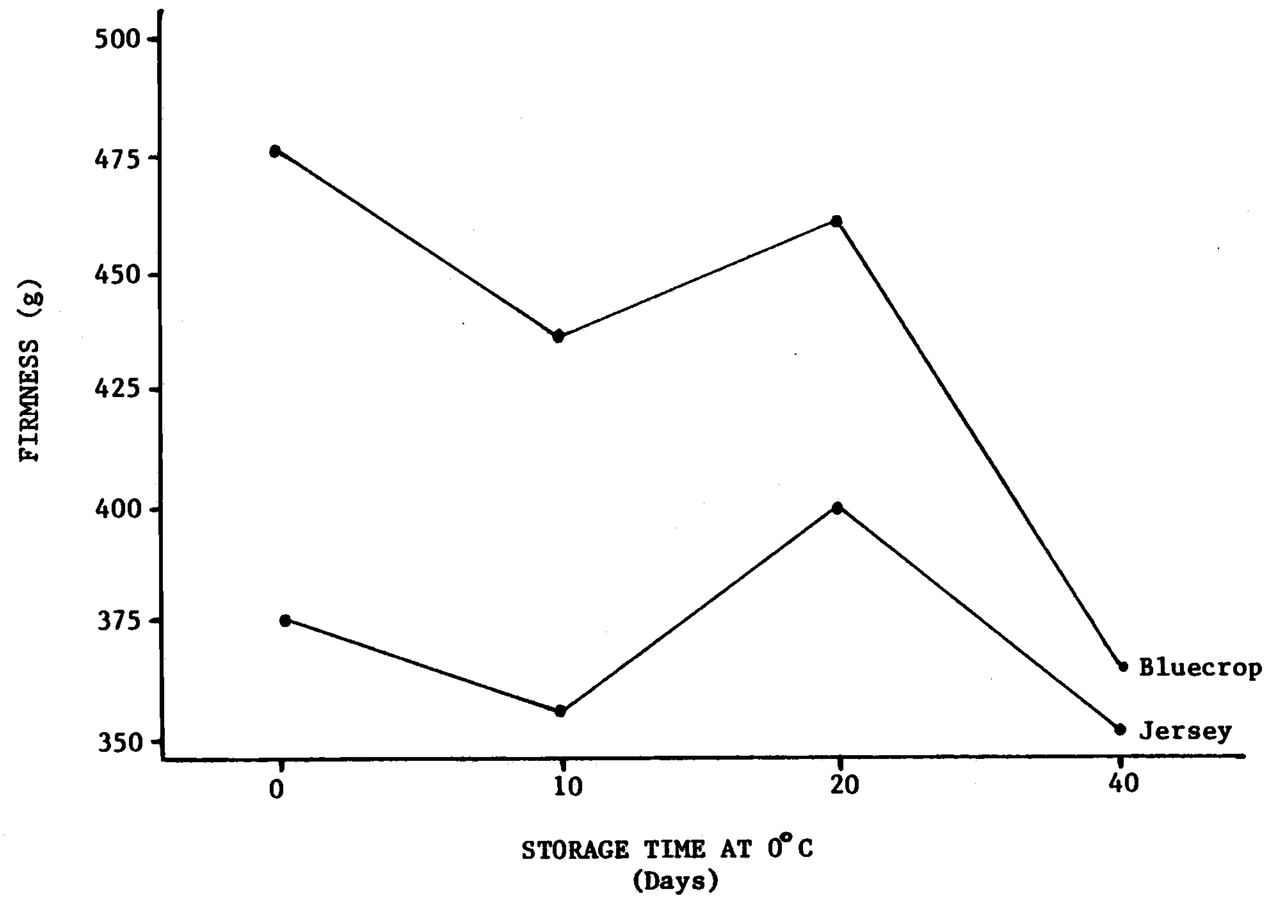

Figure 5. The influence of storage time on berry firmness for the cultivars Bluecrop and Jersey (averaged across all harvests and nitrogen treatments).

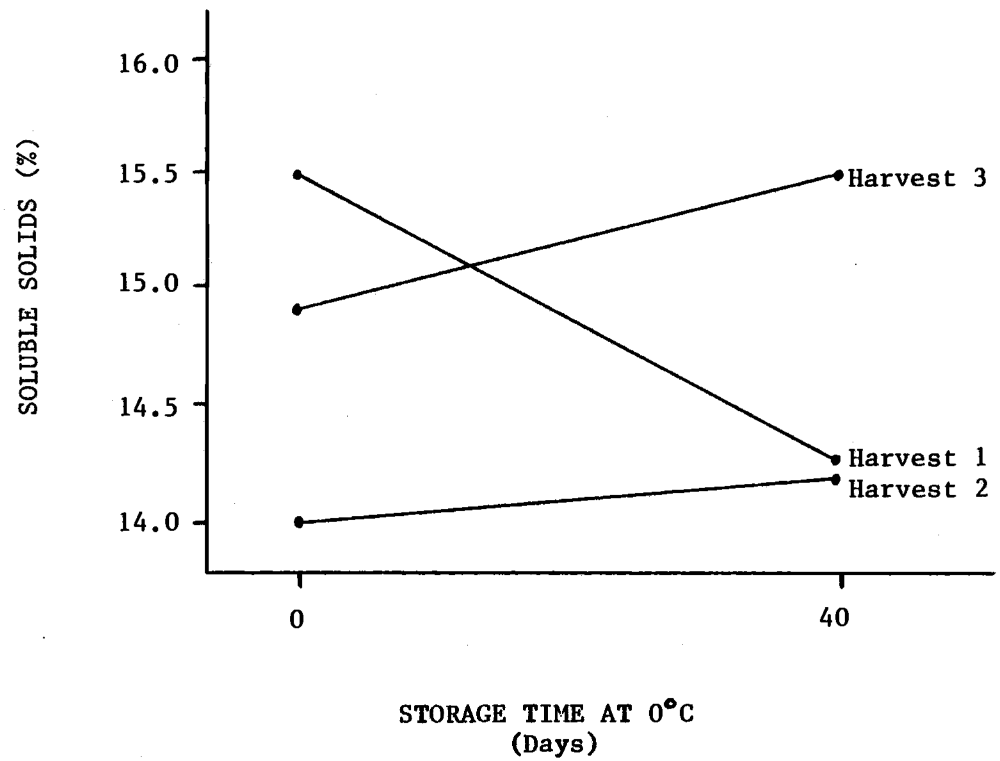

Figure 6. The influence of harvest and storage time on soluble solids content of the cultivar Bluecrop (averaged across all nitrogen treatments).

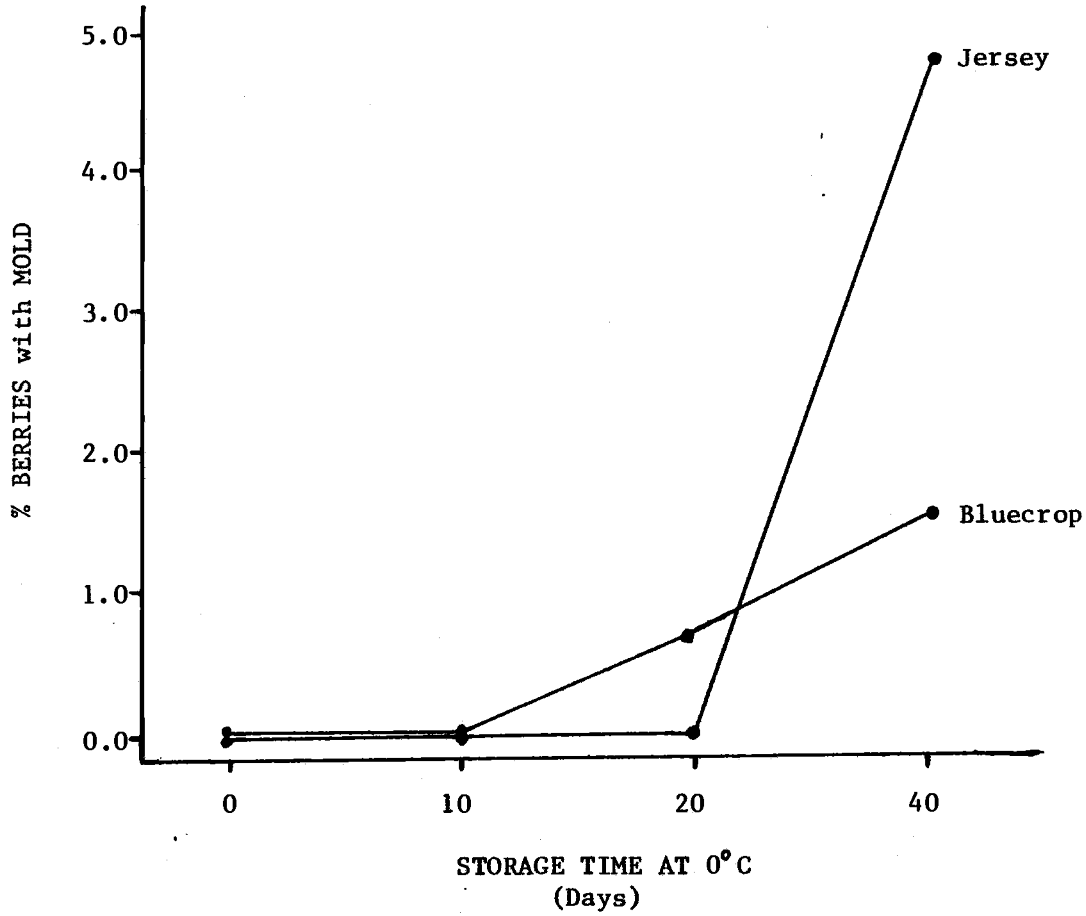

Figure 7. The influence of storage time on amount of mold for the cultivars Bluecrop and Jersey (averaged across all harvests and nitrogen treatments).

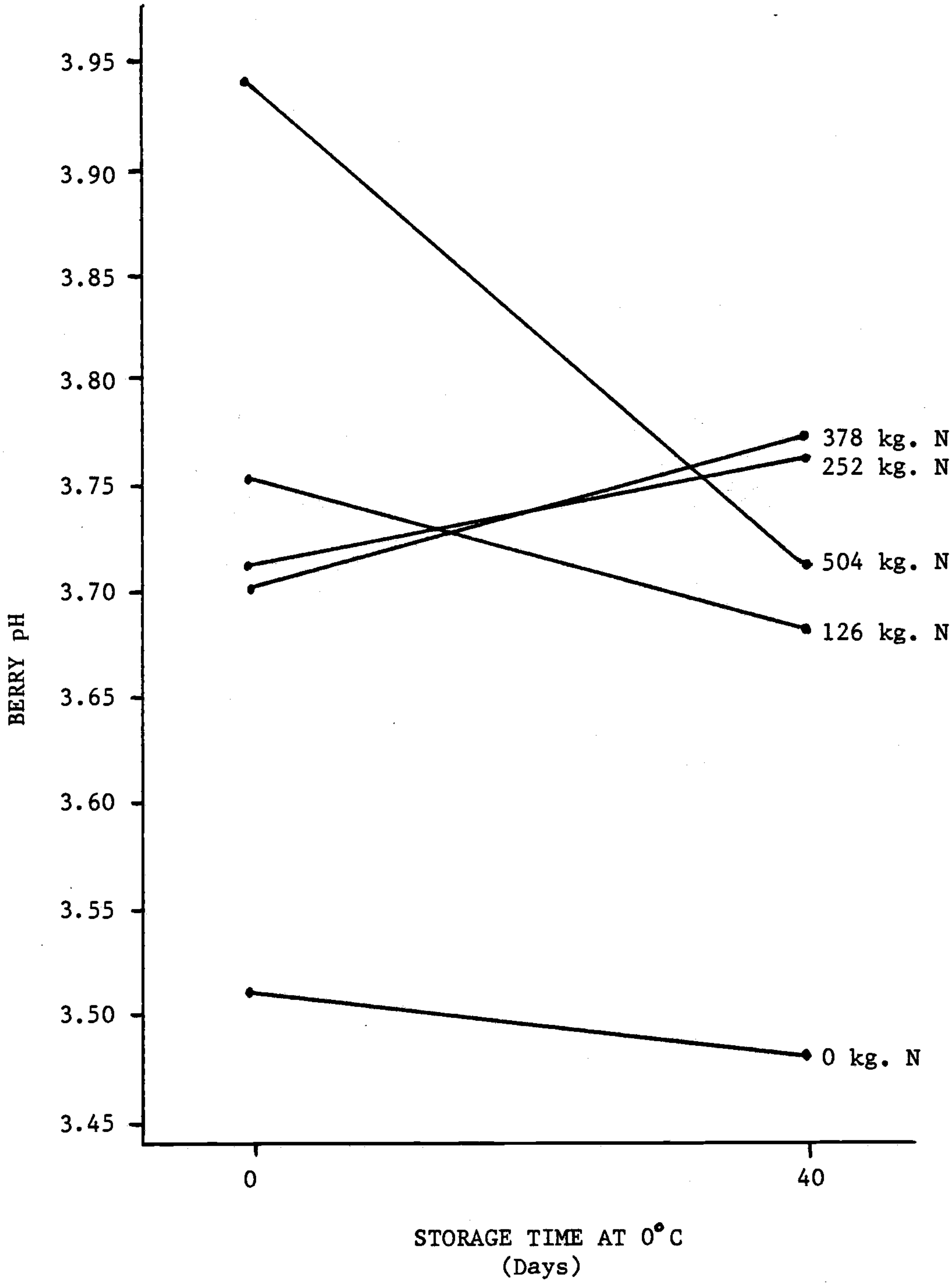

Figure 8. Changes in berry pH of the cultivar Jersey as influenced by storage time and rate of nitrogen application (averaged across all harvests).

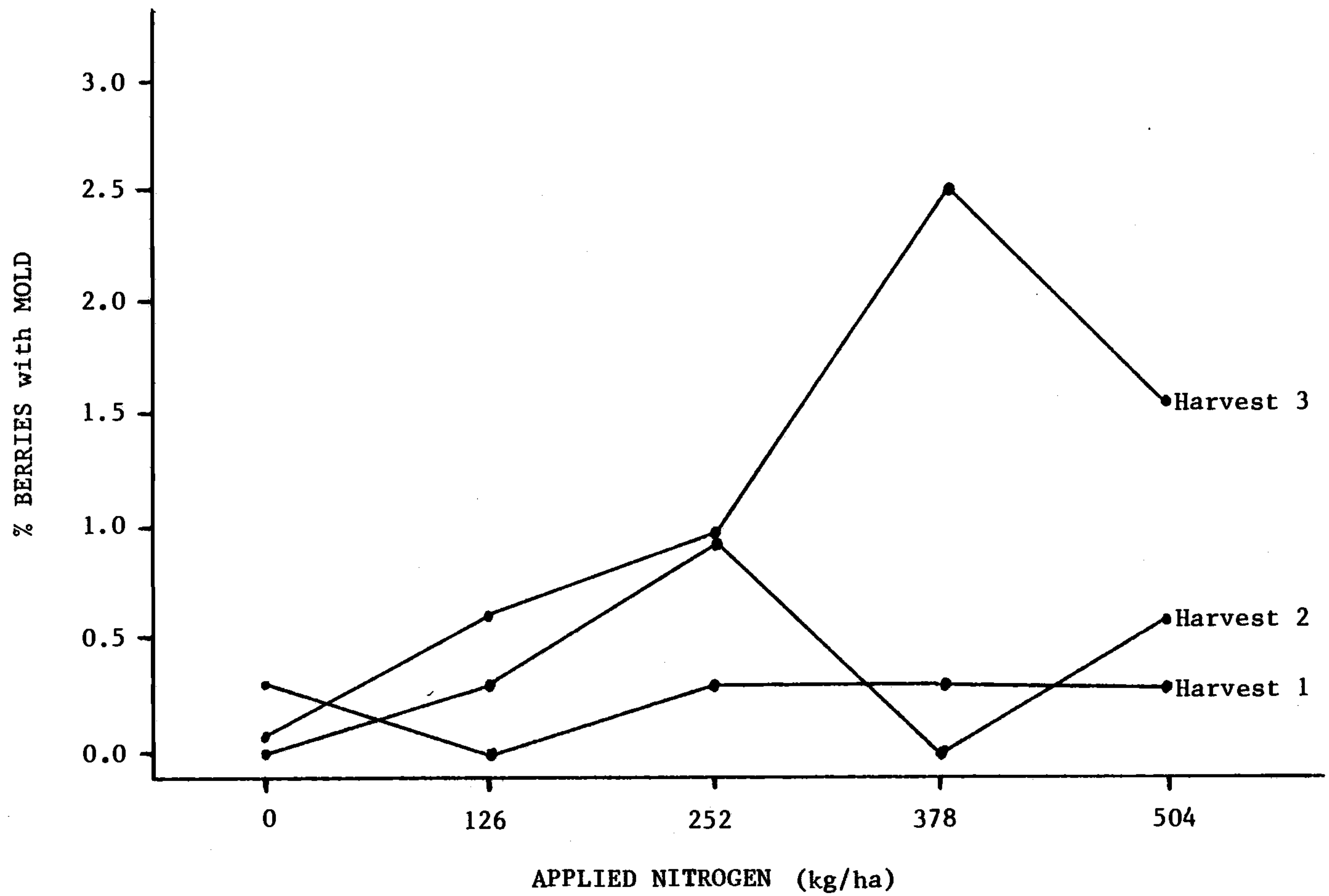

Figure 9. The influence of harvest and rate of nitrogen application on the amount of mold in the cultivar Bluecrop (averaged across all storage times).

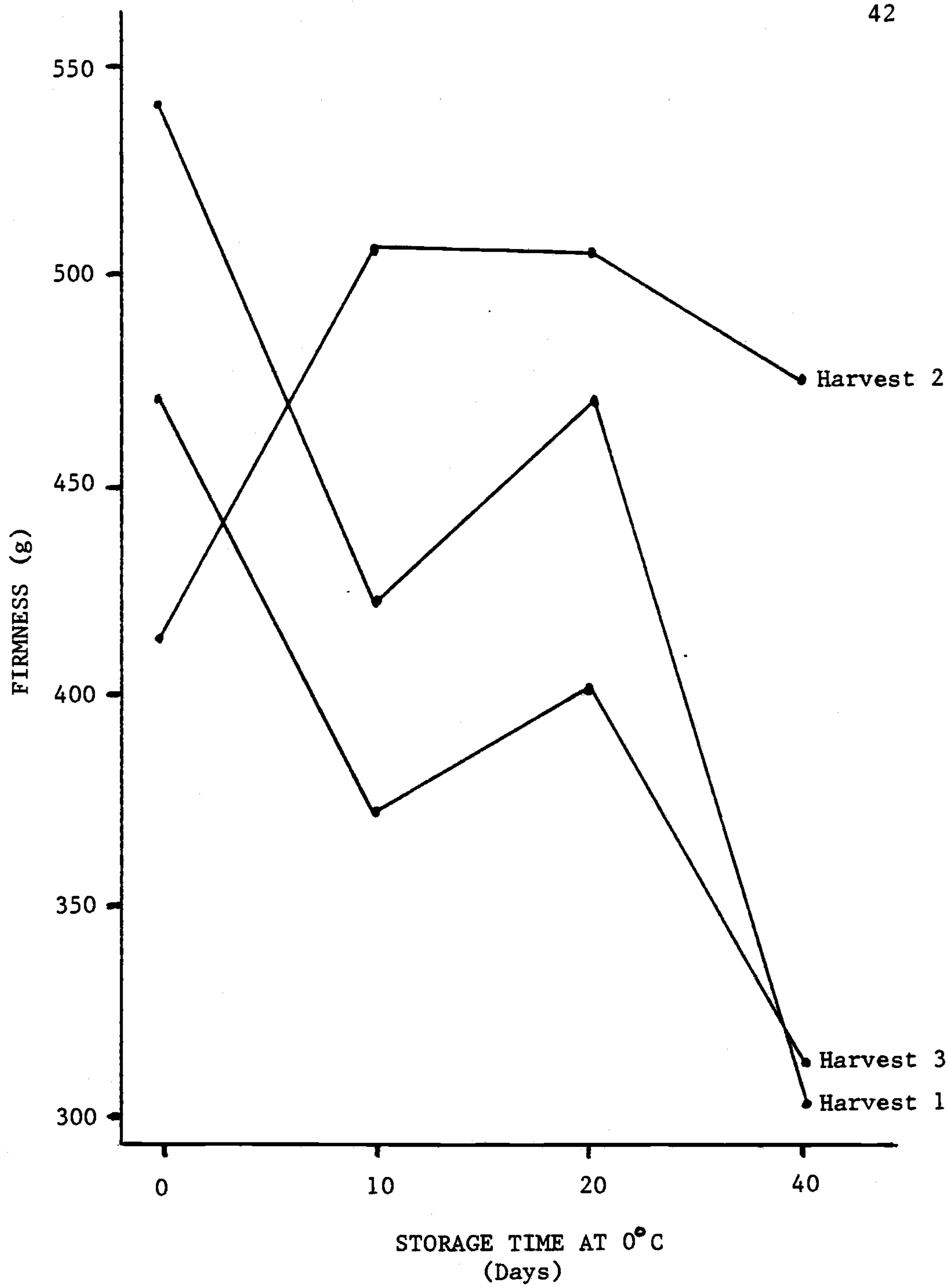

Figure 10. Changes in berry firmness as influenced by storage time and harvest for the cultivar Bluecrop (averaged across all nitrogen treatments).

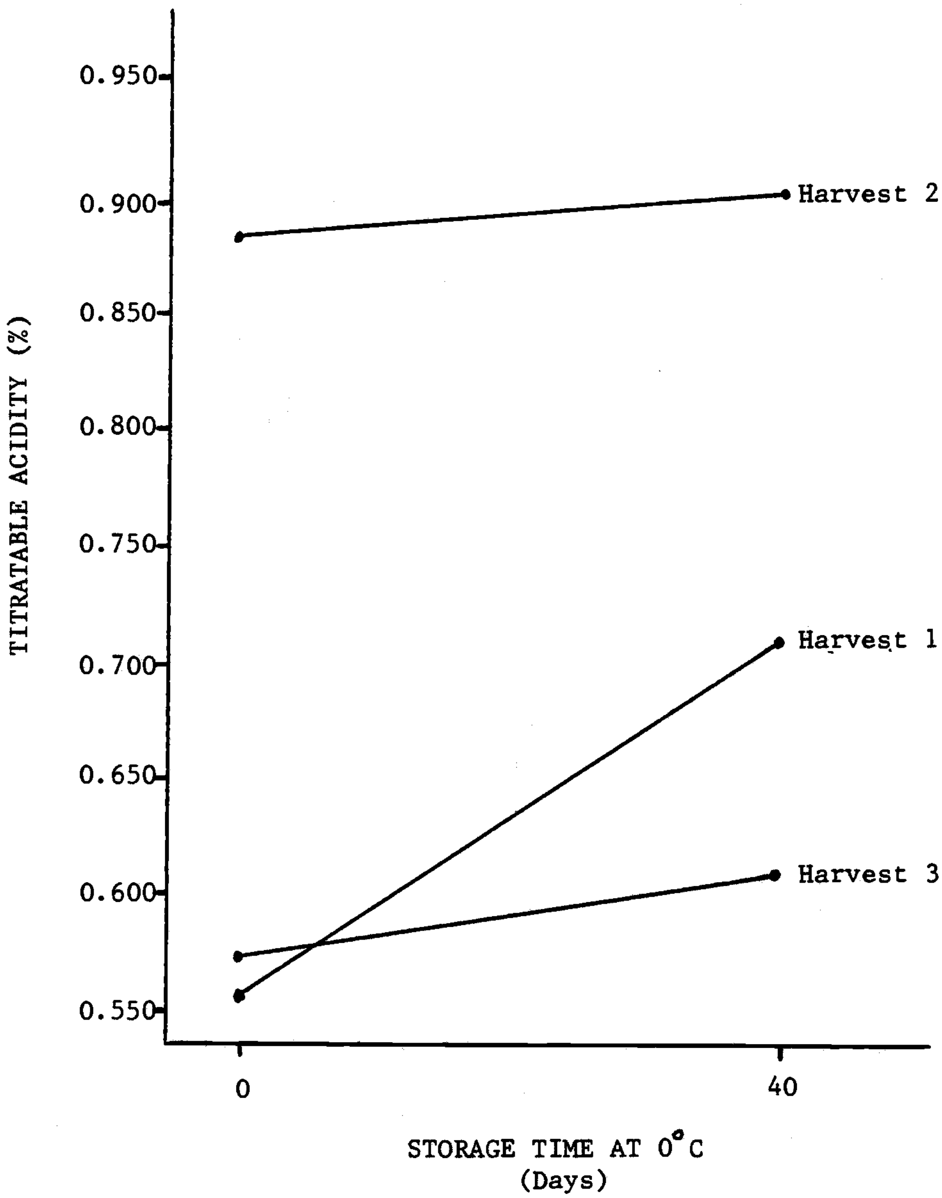

Figure 11. The influence of storage time and harvest on percent titratable acidity for the cultivar Bluecrop (averaged across all nitrogen treatments).

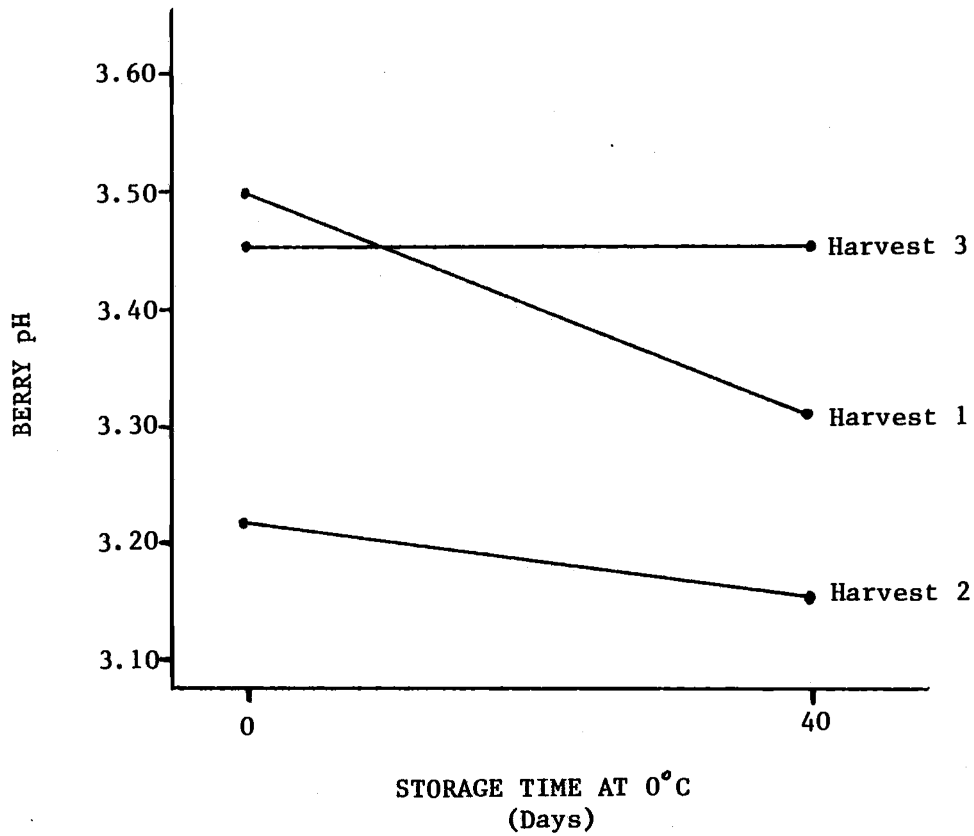

Figure 12. The influence of storage time and harvest on berry pH for the cultivar Bluecrop (averaged across all nitrogen treatments).

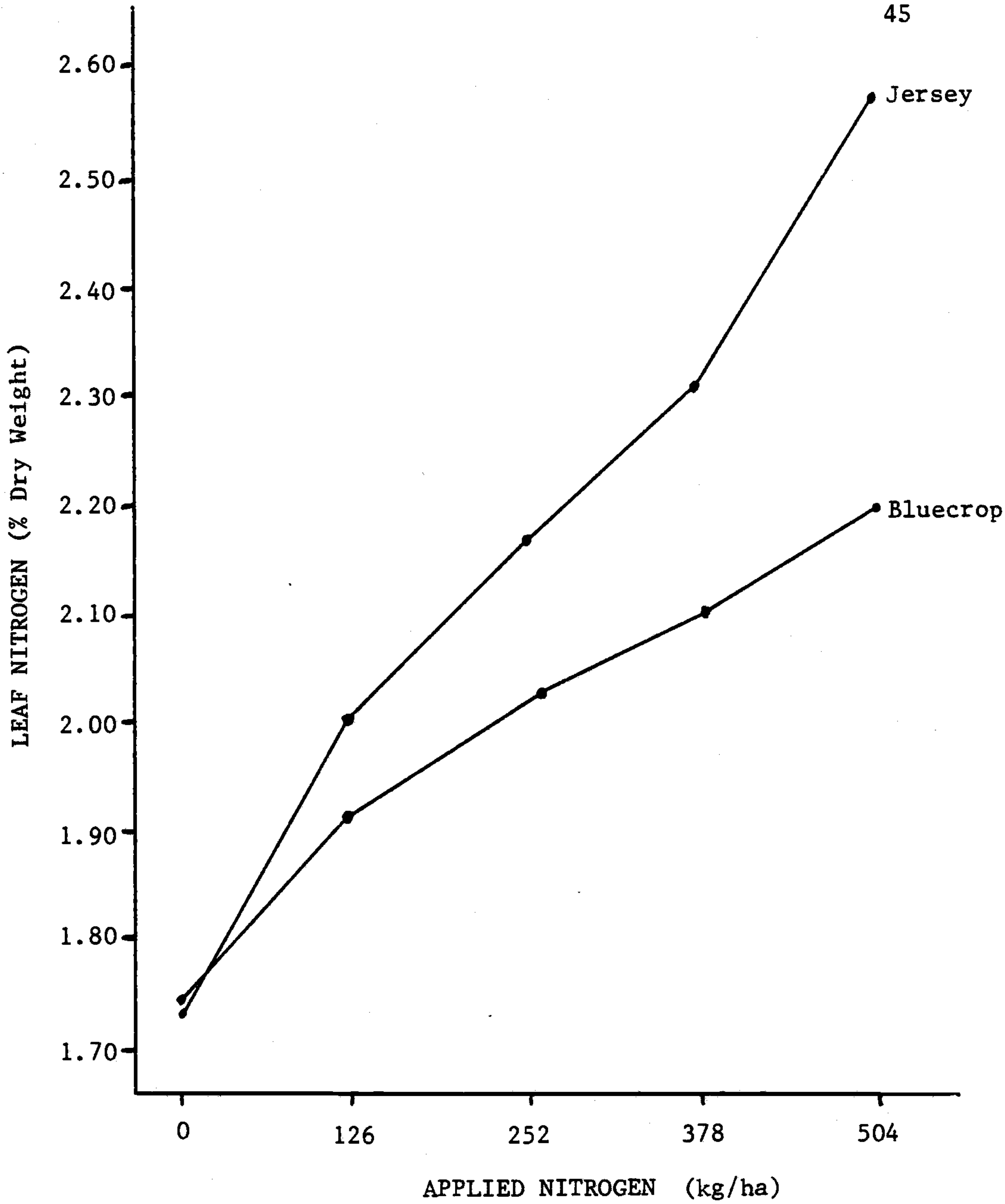

Figure 13. Relation of nitrogen treatment and leaf-nitrogen for the cultivars Bluecrop and Jersey.

Table 1. Interaction of rate of nitrogen application and storage time on firmness of 'Bluecrop' and 'Jersey' berries.

			Firmness (g)					
		Storage Time	Rate of N application (kg/ha)					LSD
Cultivar	Harvest	(Days)	0	126	252	378	504	(.05)
Bluecrop	1 (7/20)	0	510	549	550	552	546	38
		40	280	301	322	324	303	31
	2 (7/29)	0	391	414	415	427	429	16
		40	479	472	477	473	480	27
	3 (8/15)	0	473	450	478	482	476	26
		40	339	298	318	293	312	19
Jersey	2 (8/4)	0	377	370	398	392	396	38
		40	435	435	449	432	418	28
	3 (8/17)	0	350	363	368	382	369	32
		40	290	258	261	261	273	30

Table 2. Influence of rate of nitrogen application, storage time and harvest date on fruit characteristics of the cultivar Bluecrop.

Variable	Fruit Characteristic				
	Firmness (g)	Soluble Solids (%)	Titratable Acidity (%)[a]	pH	Mold (%)[b]
N Rate (kg/ha)[d]					
0	423	14.5	0.704	3.24	0.1
126	433	14.1	0.676	3.34	0.3
252	439	14.4	0.724	3.36	0.7
378	437	15.3	0.699	3.40	0.9
504	437	15.3	0.726	3.41	0.8
LSD (.05)	N.S.	0.67	N.S.	0.09	0.6
Storage Time (Days)[e]					
0	476	14.8	0.673	3.39	0.0
10[c]	435	--	--	--	0.0
20[c]	461	--	--	--	0.7
40	365	14.6	0.739	3.31	1.6
LSD (.05)	16.0	N.S.	0.035	0.04	1.05
Harvest Date[f]					
7/20	435	14.9	0.634	3.41	0.2
7/29	476	14.1	0.893	3.19	0.4
8/15	390	15.2	0.591	3.45	1.1
LSD (.05)	29.0	0.40	0.078	0.06	N.S.

a Expressed as citric on a percent fresh-weight basis.
b Percentage of berries showing fungal growth (mold).
c Measurement of percent soluble solids, percent titratable acidity, and pH not made at this storage time.
d Averaged over all harvests and storage times.
e Averaged over all N treatments and harvests.
f Averaged over all N treatments and storage times.

Table 3. Influence of rate of nitrogen application, storage time and harvest date on fruit characteristics of the cultivar Jersey.

Variable	Firmness (g)	Soluble Solids (%)	Titratable Acidity (%)[a]	pH	Mold (%)[b]
N Rate (kg/ha)[d]					
0	364	16.0	0.422	3.49	0.2
126	370	16.4	0.392	3.72	0.8
252	376	15.8	0.419	3.73	1.3
378	377	15.3	0.458	3.74	1.3
504	368	15.8	0.452	3.83	2.7
LSD (.05)	N.S.	0.66	0.042	0.13	0.79
Storage Time (Days)[e]					
0	376	15.7	0.423	3.73	0.0
10[c]	356	--	--	--	0.0
20[c]	400	--	--	--	0.0
40	351	16.1	0.434	3.68	4.9
LSD (.05)	N.S.	0.34	N.S.	N.S.	1.27
Harvest Date[f]					
8/4	410	15.9	0.404	3.76	0.4
8/17	332	15.8	0.452	3.64	2.0
LSD (.05)	21.0	N.S.	0.025	0.06	1.3

a Expressed as citric on a percent fresh-weight basis.
b Percentage of berries showing fungal growth (mold).
c Measurement of percent soluble solids, percent titratable acidity, and pH not made at this storage time.
d Averaged over all harvests and storage times.
e Averaged over all N treatments and harvests.
f Averaged over all N treatments and storage times.

Table 4. Interaction of rate of nitrogen application and storage time on fruit characteristics for the second harvest of 'Bluecrop' berries.

		Fruit Characteristic				
Storage Time (Days)	N rate (kg/ha)	Firmness (g)	Soluble Solids (%)	Titratable Acidity (%)	pH	Mold (%)
0	0	391	14.0	0.885	3.09	0.0
	126	414	13.3	0.864	3.18	0.0
	252	415	13.8	0.900	3.24	0.0
	378	427	14.8	0.887	3.30	0.0
	504	429	14.2	0.872	3.29	0.0
10	0	495	13.8	0.900	3.08	0.0
	126	508	13.6	0.889	3.19	0.0
	252	517	13.7	0.931	3.18	0.0
	378	505	14.0	0.872	3.20	0.0
	504	510	14.0	0.914	3.24	0.0
20	0	499	13.8	0.920	3.06	0.0
	126	510	13.3	0.840	3.16	0.0
	252	493	13.8	0.882	3.22	0.0
	378	507	14.3	0.928	3.24	0.0
	504	521	14.4	0.889	3.31	0.0
40	0	479	13.8	0.952	3.12	0.0
	126	472	14.0	0.864	3.18	1.2
	252	477	13.8	0.959	3.10	3.8
	378	473	14.9	0.844	3.18	0.0
	504	480	14.6	0.903	3.24	2.5

Table 5. Interaction of rate of nitrogen application and storage time on pH of 'Bluecrop' and 'Jersey' berries.

Cultivar	Harvest	Storage Time (Days)	pH Rate of N application (kg/ha) 0	126	252	378	504	LSD (.05)
Bluecrop	1 (7/20)	0	3.40	3.48	3.68	3.56	3.41	0.18
		40	3.18	3.37	3.30	3.35	3.35	0.26
	2 (7/29)	0	3.09	3.18	3.24	3.30	3.29	0.13
		40	3.12	3.18	3.10	3.18	3.24	0.10
	3 (8/15)	0	3.30	3.35	3.46	3.50	3.66	0.13
		40	3.36	3.46	3.41	3.53	3.49	0.16
Jersey	2 (8/4)	0	3.68	3.85	3.74	3.82	3.86	0.24
		40	3.50	3.77	3.83	3.78	3.75	0.19
	3 (8/17)	0	3.33	3.66	3.69	3.60	4.03	0.28
		40	3.44	3.58	3.68	3.75	3.66	0.11

Table 6. The influence of nitrogen treatment on leaf nitrogen, yield and firmness of the cultivars Bluecrop and Jersey.

Cultivar	Nitrogen Treatment (kg/ha)	Leaf Nitrogen (% dry wt.)	Yield (kg/plant)	Firmness[a] at pick (g)	Firmness[a] after 40 days (g)
Bluecrop	0	1.74	8.35	458	366
	126	1.91	7.62	471	357
	252	2.02	7.62	481	372
	378	2.10	6.80	487	363
	504	2.20	5.72	483	365
Jersey	0	1.73	8.71	364	363
	126	2.00	7.62	366	346
	252	2.17	9.43	382	355
	378	2.31	8.26	387	347
	504	2.58	7.26	383	345

a Averaged over all harvests.

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APPENDIX

Appendix

As expected, a strong positive correlation between applied nitrogen and leaf nitrogen existed for both 'Bluecrop' and 'Jersey' (Fig. 13).

Most blueberry growers are now basing their fertilizer program on results from leaf mineral analysis. It has been shown that optimum yield occurs when leaf nitrogen is between 2.00% and 2.10% (dry weight); a reduction in yield occurs when leaf-N values are above 2.10% (9, 40). Growers are altering their fertilizer program to attain this level of nitrogen in the leaves.

At what level of leaf-N does optimum firmness occur and does that level coincide with the level for optimum yield? Optimum firmness for fresh-picked, cooled 'Bluecrop' berries, averaged over all harvests, occurred at a leaf-N of 2.10%. After 40 days in storage, optimum firmness ocurred at a leaf-N level of 2.02% (Table 6). These results are encouraging in that if growers strive to obtain maximum yield through fertilization they are, at the same time, obtaining optimum berry firmness.

For 'Jersey' berries tested at pick, however, optimum firmness occurred at a leaf-N level of 2.31%; after 40 days in storage, optimum firmness was attained when leaf-N level was 2.17% (Table 6). Even though optimum berry firmness at pick occurred at a leaf-N of 2.30%, fruit from all levels of nitrogen were considered to be acceptable for the fresh market. Fruit-to-leaf ratio and nitrogen storage patterns in the plant need to be determined before a leaf-N level at which optimum firmness occurs can be determined.

Yield was not a main component of this study, but an estimate of yield was made based on collecting yield data from one or two harvests and then extrapolating total yield from those figures. Table 6 reveals the relation of yield and nitrogen.

Table 7. Interaction of rate of nitrogen application and storage time on fruit characteristics for the second harvest of 'Jersey' berries.

		Fruit Characteristic				
Storage Time (Days)	N rate (kg/ha)	Firmness (g)	Soluble Solids (%)	Titratable Acidity (%)	pH	Mold (%)
0	0	377	16.3	0.368	3.68	0.0
	126	370	16.0	0.360	3.85	0.0
	252	398	15.6	0.412	3.74	0.0
	378	396	15.2	0.424	3.82	0.0
	504	396	15.4	0.427	3.86	0.0
10	0	390	15.8	0.410	3.48	0.0
	126	408	16.5	0.343	3.86	0.0
	252	416	15.8	0.378	3.84	0.0
	378	413	15.2	0.885	3.90	0.0
	504	406	15.8	0.392	3.94	0.0
20	0	392	16.0	0.382	3.55	0.0
	126	425	16.0	0.402	3.69	0.0
	252	432	15.9	0.385	3.70	0.0
	378	428	15.6	0.305	3.86	0.0
	504	398	16.4	0.396	3.89	0.0
40	0	435	16.0	0.424	3.50	1.2
	126	435	16.7	0.354	3.77	5.0
	252	449	16.0	0.399	3.83	8.8
	378	432	15.8	0.441	3.78	8.8
	504	418	16.2	0.427	3.75	16.2

Table 8. Interaction of rate of nitrogen application and storage time on the soluble solids content of 'Bluecrop' and 'Jersey' berries.

			Soluble Solids (%)					
		Storage Time	Rate of N application (kg/ha)					LSD
Cultivar	Harvest	(Days)	0	126	252	378	504	(.05)
Bluecrop	1 (7/20)	0	15.2	15.1	15.4	16.0	15.7	0.56
		40	14.4	14.0	13.8	14.3	14.8	1.62
	2 (7/29)	0	14.0	13.3	13.8	14.8	14.2	1.09
		40	13.8	14.0	13.8	14.9	14.6	0.98
	3 (8/15)	0	14.8	14.0	14.4	15.4	15.9	1.65
		40	14.8	14.4	15.1	16.5	16.6	1.22
Jersey	2 (8/4)	0	16.3	16.0	15.6	15.2	15.4	0.87
		40	16.0	16.7	16.0	15.8	16.2	1.26
	3 (8/17)	0	16.0	16.3	15.6	14.4	15.9	1.39
		40	16.0	16.6	16.1	15.7	15.6	1.15

Table 9. Interaction of rate of nitrogen application and storage time on percent titratable acidity of 'Bluecrop' and 'Jersey' berries.

			Titratable Acidity (%)					
		Storage Time	Rate of N application (kg/ha)					LSD
Cultivar	Harvest	(Days)	0	126	252	378	504	(.05)
Bluecrop	1 (7/20)	0	0.542	0.490	0.553	0.588	0.640	0.113
		40	0.756	0.634	0.717	0.686	0.735	0.196
	2 (7/29)	0	0.886	0.864	0.900	0.887	0.872	0.171
		40	0.952	0.864	0.959	0.844	0.903	0.159
	3 (8/15)	0	0.542	0.595	0.578	0.567	0.588	0.092
		40	0.546	0.609	0.640	0.623	0.620	0.126
Jersey	2 (8/4)	0	0.368	0.360	0.412	0.424	0.427	0.098
		40	0.424	0.354	0.399	0.441	0.427	0.072
	3 (8/17)	0	0.448	0.434	0.420	0.518	0.417	0.134
		40	0.448	0.420	0.444	0.448	0.536	0.055

Table 10. Interaction of rate of nitrogen application and storage time on amount of mold in 'Bluecrop' and 'Jersey' berries.

			Mold (%)				
		Storage Time	Rate of N application (kg/ha)				
Cultivar	Harvest	(Days)	0	126	252	378	504
Bluecrop	1 (7/20)	0	0.0	0.0	0.0	0.0	0.0
		40	1.2	0.0	0.0	0.0	0.0
	2 (7/29)	0	0.0	0.0	0.0	0.0	0.0
		40	0.0	1.2	3.8	0.0	2.5
	3 (8/15)	0	0.0	0.0	0.0	0.0	0.0
		40	0.0	2.5	3.8	5.0	3.8
Jersey	2 (8/4)	0	0.0	0.0	0.0	0.0	0.0
		40	0.0	1.2	1.2	1.2	5.0
	3 (8/17)	0	0.0	0.0	0.0	0.0	0.0
		40	1.2	5.0	8.8	8.8	16.2