AN ABSTRACT OF THE THESIS OF

Mohamed Tami for the degree of Master of Science in Horticulture presented on March 8, 1984.

Title: Effect of Nitrogen, Boron, and Rootstocks on Yield, Fruit Quality, and Nutritional Levels in Leaf, Fruit, and Flower Tissue of Starkspur Golden Delicious Apple Trees

Abstract approved: ______________________
Porter B. Lombard

Two levels of N, untreated and 125 g N/tree, were applied in spring of 1982 and 1983, and two levels of B, untreated and 490 ppm sprayed in fall of 1983 to a high density orchard of Starkspur Golden Delicious (*Malus pumila* Borkh.) on four rootstocks: OAR-1, M7, M26, and M106. Leaf, fruit, and flower mineral content, yield components, and fruit quality factors were studied in 1982 and 1983.

High rate of N application increased leaf N, Mg, Mn, and Cu while leaf K and P were decreased. Leaf B and Zn were depressed only in the second season by N application. Soil pH decreased following N applications and therefore increased the availability of Mn. Nitrogen application increased only fruit N in both seasons while in the second season fruit P and B were decreased. Leaf N and fruit N were positively correlated. Fruit set increased only in the first season by N application. Leaf N had

positive correlation with percent bloom in 1982 and yield in 1983. The percent of yellow fruit, soluble solids and bitter pit levels were decreased in one or both seasons due to the negative correlation with leaf and fruit N.

Fall B spray increased only the B content of leaf, fruit, and flower while other mineral contents, yield components, and fruit quality were not influenced by B applications.

Compared to all tested rootstocks, trees on OAR-1 had lower leaf and fruit concentrations of most nutrients in one or both years except for B which was higher. The biennial bearing was greater with OAR-1 because of relative levels of percent of bloom during 1982 and 1983. The lowest percent of bloom in 1982 resulted in lower crop density and consequently in the lowest yield. In one or both seasons, the percent of yellow fruit, bitter pit, soluble solids, and fruit firmness levels were highest and the seed content was lowest in fruit from trees on OAR-1. Trees on M7 had higher levels of leaf K and Cu, fruit N, Fe, Cu, and Zn, and flower Fe, Cu, and Zn in 1983. On M26, leaf P and B were higher on the N treated trees and leaf Mg, Mn, and Zn were lowest on all treatments. However, fruit K was highest in fruit on M26 in the first season and B was lowest in the second season. Flower P and B were higher on trees with M26. Also, trees on M26 had higher crop density in the first year but lower yield in the second year due to lower percent of bloom. Seed content in fruit was highest on M26 in 1982 while fruit diameter was the largest in 1983. Trees on M106 had the highest leaf Ca level and lowest seed content during the first year.

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by

Mohamed Tami

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INTRODUCTION

Apple production in the world has been 14,826,000 metric tons annually (1968-1974) which amounts to the highest tonage among deciduous fruit trees. The United States is a principle apple producing country (Westwood, 1978) with the average of annual production (1968-1974) of 2,797,000 metric tons (Westwood, 1978). Apple production in the U.S. has increased to 3,724,885 metric tons in 1982 (U.S.D.A., 1983). The state of Oregon produces an average (1974-78) of 81,800 metric tons annually. The principle cultivars grown in the U.S. are Red Delicious (29%), Golden Delicious (13%), and McIntosh (12%) representing about 55% of the total production (Westwood, 1978). In Oregon the principle cultivars are Newtown, Red Delicious, and Golden Delicious.

However, several apple varieties of commercial importance such as Golden Delicious are characteristically biennial in their production of fruit. The biennial bearing results in the irregular market supply and in production of fruits of poor quality. The supply of apples is increased significantly in the 'on year' while it is reduced sharply in the 'off year.' The fruit quality is particularly reduced by production of fruit of small size in the 'on year' and very large fruit in the 'off year'. Fortunately, several factors such as pruning and heavy applications of N in the off year (Crow, 1920), thinning out and heading back to wood 3 to 8 years old (Hooker, 1929), and thinning shortly after bloom (Titus, 1960) could control biennial bearing. In fact, immature apple seeds have been found to produce gibberillins such as GA_3, GA_4, and GA_7 (Westwood, 1978). They prevent flower initiation besides working with auxin to prevent abscission of young fruits. Therefore, seed content of apple fruits plays a major role in the alternate bearing. Seed content could be increased by summer application of N which results in the production of "strong flowers" that have stigmas and ovules that remain respectively receptive and capable of fertilization for longer periods than those of normal flowers (Williams, 1965). Carbohydrate/nitrogen ratio affects biennial bearing by controlling flowering and shoot growth (Westwood, 1978). The fertilization program should take into account the nutritional balance status particularly in relation with the 'off' or 'on' year crop.

Considerable literature has indicated that nutritional imbalances in the apple are major causes of many physiological fruit disorders such as internal break-down, lenticel spot, and bitter pit (Al-Ani, 1978). The association of low concentration of calcium in the fruit with many apple disorders is well established (Al-Ani, 1978). The nutritional balance status depends on nutrient uptake which is determined, at least in part, by the rootstock. Also the effect of rootstock on nutrient uptake and other factors such as flower initiation, fruit set, and fruit growth and its ultimate size has influenced the performance of a given apple cultivar. In fact, there can be as much as 50%

difference in yield efficiency, that is, yield per unit of tree size of a given apple cultivar grown on different rootstocks (Westwood, 1978). Rootstocks can also influence components of apple fruit quality such as fruit firmness and soluble solids (Westwood, 1978). However, since apple scions are usually propagated on rootstocks of their own species (Malus pumila), the differences in quality resulting from apple rootstock are less critical compared to other species used as rootstocks (Westwood, 1978).

The response of Starkspur Golden Delicious from excessive nitrogen and fall applied boron on four rootstocks were studied to assess their effect on a) mineral concentration in leaf and fruit tissue; b) cropping and its components, that is, percent of bloom, fruit set, and crop density; c) components of fruit quality, that is, fruit color, fruit size, fruit firmness, bitter pit, soluble solids, and seed content; and d) the linear correlations between all factors studied.

REVIEW OF THE LITERATURE

Nitrogen fertilization of apples

Concentration of minerals in leaves

Magness, et al. (1940), Boynton and Compton (1944), Frear and Anthony (1943), Shear (1947), Weeks (1958), and Boynton and Oberly (1966) reported that the nitrogen content of apple leaves vary directly with nitrogen fertilization. They stated that since the seasonal changes due to growth and senescence are considerable, the use of nitrogen analysis of leaves as a diagnostic criterion is possible only if the sampling is done at a time when the seasonal changes are at a minimum and the samples are properly collected, prepared and analyzed. They concluded that the mid-summer, shortly after the termination of terminal growth, was a period of little change.

In an experiment on Red Delicious apples, Borden and Thompson (1962) found that leaf nitrogen follows a downward trend as the growing season advances. On trees showing no deficiency symptoms, they found that the concentrations of nitrogen were 2.73-2.84% dry weight in May, 2.22-2.37% in August, 1.53-1.59% during harvest in October. Awad and Kenworthy (1963) found similar results. Boynton, et al. (1950) found that apple trees show deficiency symptoms when nitrogen concentrations in leaves are 1.6 to 1.9% dry weight in July. Forshey (1959) suggested 1.4% dry weight in September and later in 1963 found that deficiency symptoms of nitrogen appear in sand culture in August when the concentration in leaves of apples is 1.29 to 1.42% dry weight.

Turner (1962) reported that individual leaves of apples could lose and regain up to 25% of their N during shoot growth. Consequently, he concluded that N levels obtained from leaves during shoot growth may be misleading. Boynton and Oberly (1966) stated that other important factors such as crop load, climatic conditions, age of the trees, severity of pruning and the variety must be taken into account.

In an attempt to optimize the concentration of minerals in apple leaves, the following values are cited as indicative of the range in mineral composition of leaves of Golden Delicious. In other words, at these values no deficiency or toxicity symptoms were observed:

Element	Sampling Date	% Dry Weight	Reference
N	June	2.45	Simons (1960)
K	June	1.75	Simons (1960)
	August	1.93-2.38	Titus and Ghosheh (1963)
	September	1.58-1.87	Titus and Ghosheh (1963)
P	June	0.17	Simons (1960)
Mg	June	0.62	Simons (1960)
Ca	June	1.50	Simons (1960)
B	June	0.003	Simons (1960)
Cu	June	0.0013	Simons (1960)

<u>Leaf content from N applications</u>

Weeks, et al. (1958), Dionne, et al. (1967), Goode and Higgs (1977), and Shear and Faust (1971) reported that the overall effect of nitrogen treatments is raising nitrogen concentration in apple leaves. Shear (1947), Walter (1967), and Goode and Higgs (1977) found that nitrogen fertilization also increases calcium concentration in apple leaves. Cain (1953) obtained 22% increase of leaf Ca by application of 4 lbs/tree of NH_4NO_3.

Shear (1947), Cain (1953), Walter (1967), Goode and Higgs (1977), and Fallahi (1983), concluded that N fertilization decreases leaf K. Cain (1953) suggested that the reduction of potassium in the leaves by increasing nitrogen fertilization might be associated with the metabolic function of potassium and not on a basis of ion competition or antagonism in this tissue.

Cain (1953), Walter (1967), and Goode and Higgs (1977) concluded also that nitrogen fertilization reduced P concentration in apple leaves.

Shear (1947), Cain (1953), and Walter (1967) found that N applications increased Mg concentration in apple leaves. However, Goode and Higgs (1977) found that N fertilization had no effect on leaf Mg.

Shear (1947) found that concentrations of leaf B, Cu, Fe, and Zn were increased by N applications, but Mg was decreased.

Studying the effect of application of different kinds of N fertilizers at different times in the year, Goode and Higgs (1977) applied sulphate of ammonia, calcium nitrate and nitrochalk as a single annual dressing in October, December, February, April, June and August to Cox's Orange Pippin apple trees on M2 rootstock over a 14 year period. They concluded that both the time of application of N and the source of N used affected levels of the nutrients N, P, K, and Mg. Leaf K and Ca were not affected by the source of N and leaf Ca was not affected by timing. Delap (1967) also concluded that time of application and source of N affected the August level of leaf N of Cox's Orange Pippin on M7 grown in sand. Mason (1964) concluded that by applying four levels of NH_4NO_3 (1/2, 1, 2, 4 lbs/tree) on apple trees growing in uncultivated grass sod mown monthly, leaf N concentration increased respectively from 2.12 to 2.34%.

Concentration of Minerals in Apple Fruits

Goode and Higgs (1978) concluded that N fertilization materially affects the nutrition of the fruit, raising N and depressing fruit P, K, and Mg. The level of fruit Ca was not significantly affected.

Attempting to optimize the concentration of minerals in apple fruits at harvest several authors gave the following values at which no symptoms of deficiency or toxicity were observed on Northern Spy and McIntosh.

Variety	Nutrient	Concentration % Dry Weight	Reference
N. Spy	N	0.225	Oberly and Kenworthy (1961)
McIntosh	P	0.09-0.16	Eggert et al (1952)
N. Spy	P	0.30	Oberly and Kenworthy (1961)
N. Spy	K	0.70	Oberly and Kenworthy (1961)
N. Spy	Mg	0.06	Oberly and Kenworthy (1961)
N. Spy	Ca	0.12	Oberly and Kenworthy (1961)

N. Spy	Mn	0.0008	Oberly and Kenworthy (1961)
N. Spy	Fe	0.0037	Oberly and Kenworthy (1961)

Effect of Nitrogen Fertilization on Fruit Set

A great amount of work has been done on the effect of nitrogen fertilization on fruit set of apples. But, the specific physiological basis is not yet understood (Bradford, 1924).

Bradford (1924) found that the percentage of spurs setting fruit in apples increases as a result of spring N treatment. Yogaratnam (1982) working on Discovery and Cox's Orange Pippin apple cultivars found that urea sprays increased fruit set even on trees judged to be of high N status. Magness, et al. (1948) in a study of apple tree responses to nitrogen applied at different seasons found no significant differences in set among the different treatments. However, Knowlton and Hoffman (1932) concluded that trees receiving nitrogen three weeks before bloom have greater set than trees receiving it at bloom. Boynton and Fisher (1949) found that urea sprays starting as late as a week after bloom have as great as an effect on increasing set as have spring ground applications or earlier sprays. Kyungku, et al. (1972) reported that post-harvest urea sprays increased fruit set significantly. Batjer and Westwood (1963) found that fruit set of Delicious apple trees was greater when N was applied to lightly pruned trees, but not when applied to more heavily pruned ones.

Williams (1965) used summer application of N to induce the production of "strong" flowers for comparison with the "normal" flowers produced on trees of Worcester Pearmain given only a spring application of nitrogen. He concluded that the stigmas of "strong" flowers remained receptive for a longer period than those of normal flowers. Egg sac in "strong" flowers continued to enlarge after those of corresponding normal flowers had ceased to grow. The fertilized ovules and embryo sacs of "strong" flowers showed a more rapid acceleration in growth rate than those of normal flowers. Cell division in unfertilized ovules also continued for a longer period in "strong" flowers and appeared to be correlated with the behavior of the egg sac. Ovule longevity provided the most striking difference between the two flower types. The ovules of "strong" flowers remained capable of fertilization for almost twice as long as those of normal flowers.

Effect of nitrogen on yield

Boynton and Burrell (1944) and Mason (1964, 1969) found that N treatments have very little effect on yield.

Boynton and Burrell (1944) obtained higher yield when leaf nitrogen was 2.1% than when it was 1.8%. Williams and Billinsley (1974) obtained maximum yields of best fruit quality on Golden Delicious when leaf nitrogen levels were in the range of 1.9-2.1% on a whole leaf dry weight. Goode, et al. (1978) obtained maximum cropping by using enough nitrogen to bring the nitrogen status of the trees to a concentration of 2.4% nitrogen in the dry weight of August leaf samples.

Concerning kind and time of application of nitrogenous fertilizers, Hooker (1922), Hofmann (1930), Harlan and Collison (1933), and Magness, et al. (1948) reported that generally, the use of equivalent quantities of readily available forms of nitrogen on orchard trees resulted in no significant differences in fruit production, either in relation to the kind of N fertilizer used or the time at which it was applied.

Effect of nitrogen on biennial bearing

Crow (1920) reported that alternate bearing apple trees show fruiting buds on 60-90 percent of the spurs in their fruiting year. He stated that a full crop required fruiting buds on 30-50 percent of the spurs. He recommended to stimulate new growth of the tree in "the off year" so that a considerable percentage of spurs would not produce fruit buds in the following season. Hooker (1929) worked on York Imperial in Missouri, found that spring application of N enhances biennial bearing by increasing set of fruit in the bearing year and more vegetative growth in the non-bearing year. He stated also that N application in the fall has a considerable residual effect next spring and tends to increase the chances for starch accumulation in non-bearing spurs the following June, during the time of fruit bud differentiation, in Missouri. Hence, he concluded that spring applications of N should be supplemented by fall application in the "off year." But, since biennial bearing was not attributed to N fertilization alone, Hooker (1929) suggested to supplement it with pruning and stated that frost factor plays a role in regulating bearing. Auchter and Schrader (1932) working with the same variety, applied various spring and fall treatments of N, pruning at different soil cultural methods. These treatments were applied alone and in combination. Their results on N treatments were inconclusive, and they stated that irrigation and thinning are to be considered as important factors in regulating bearing. Titus (1960) studied the effect of N fertilization on the biennial bearing in Golden Delicious apple trees. He established a "biennial bearing index" by dividing the difference between two crop yields by the total yields for the two years and multiplying by a hundred. He found that as the level of N applications increased, there was an increase in the biennial bearing index.

Effect of N Fertilization on Fruit Quality

Fruit color: Reuther, et al. (1958) reported that N level in the tree during the 2 or 3 months before harvest seems to be the most influential on apple fruit color development. Also, Magness, et al. (1940), Overholser and Overley (1940), Fisher, et al. (1948), Mori and Yamazuki (1959) found that late spring and mid-summer application of nitrogen fertilizer might be expected to reduce apple fruit color development more than fall or early spring applications.

In comparison of different application levels of N, Mason (1964) found that the highest rate of N (4 lb/tree) reduced the red skin color by 9% compared with the lowest rate (0.5 lb/tree). Baxter (1957) studied the effect of different sources of N. He used complete fertilizer (2:2:1), N only, and no fertilizer. Color was best with no fertilizer and poorest with N only. He concluded also that N applied as urea produced similar reduction in color of Delicious compared with no fertilizer.

The reduction of fruit color due to high N is also evident on trees growing under permanent grass. Thus, Oland (1955) applied nitrogen to Gravenstein trees with grass sod at rates from 37 to 99 lb N/acre (111 kgs N/ha). The crop on trees receiving the highest rate of N consisted almost entirely of green apples, while the lowest rate of N resulted in more than 60% red-colored fruit. Palmiter and Hamilton (1954) compared the effect of soil and foliar applications of various fertilizers particularly urea. He found that fruit color decreased more with soil application than with foliar application of urea.

Timing of application resulted in variable results in fruit color. Dullum and Rasmussen (1952) reported that reduction in apple color was especially marked when nitrogen was applied in the spring. Richard (1963) however, reported that N applied during spring had little effect on fruit color, but applications in July-August delayed coloring. More (1963) obtained poor fruit color with application of high level of nitrogen in May-June. Van Doren (1961) obtained reduction of fruit color on Red Delicious with foliar application of urea starting on May 20. Southwick (1961) and Lalatta and Gorini (1963) reported that high nitrogen reduces the development of yellow color on Golden Delicious.

Thomas Raese and Williams (1974) reported that leaf N is closely related to the percent of yellow color of Golden Delicious apples at a given harvest date. The correlation coefficient r was found equal -0.938 with spur leaves and -0.867 with mid-terminal leaves. Baxter and Dillon (1962) associated the optimum fruit coloring of apples with 1.8 to 2.1% nitrogen in mid-terminal leaves. Raese and Williams (1974) suggested 1.4 to 1.7% nitrogen in spur leaves sampled in September gave the optimum fruit color. Magness, et al. (1940) correlated the amount of red surface color on Rome Beauty apples with the nitrogen content of leaves from the same trees sampled in September. They concluded that an increase of 0.1% nitrogen in the dry weight of the leaf sample was asso-iiated with a decrease of 5% in the surface of the fruit colored. A similar correlation was made by Boynton and Cain (1942) for the variety McIntosh.

Bould and Jarrett (1962) obtained optimum fruit color in Cox apple with a nitrogen concentration of 2.0 to 2.2% in dry matter of leaf samples taken in August. Van Doren (1961) reported that leaf nitrogen level of 2.2 to 2.4% gave optimum fruit color on Red Delicious and Golden Delicious. Similar optimum levels have been reported for McIntosh by Fernand and O'Grady (1958) and O'Grady (1959). White (1957) reported that an increase in leaf nitrogen in July from 1.84% to 2.4% resulted in a gradation from a yellow to a green ground color on Golden Delicious fruits at harvest. Suyama and Mori (1958) reported that high leaf N in mid-June is associated with poor fruit color at harvest.

Magness, et al. (1940) stated that the leaf analysis from their work supported the general conclusion to obtain the best color, N applications should be light and consistent for satisfactory growth and yield.

Oberly and Boynton (1966) reported that Faust (1965) found that color development occurs only when there is a decrease in the protein nitrogen. Protein nitrogen ranges at about 1.0% throughout the growing season and drops to 0.4% or less prior to the development of anthocyanin.

Boynton and Oberly (1966) reported that high nitrogen status of the tree in the early growing season fosters maximum productivity and low nitrogen status in the fall fosters the best color development. The economic importance of the effect of nitrogen on color varies for different varieties, different regions, and varies greatly from year to year in any region. It is more important in regions with low light and warm temperatures at harvest time and least important in regions with cool, bright weather during harvest (Oberly and Boynton, 1966).

Bitter pit: Oberly and Kenworthy (1961), Martin, et al. (1962) showed that fruits affected with bitter pit appear to be higher in nitrogen than unaffected fruits. They showed also that the incidence of bitter pit on Northern Spy increased as the size of the fruit, leaf B, leaf K, fruit B, fruit K, fruit N, and fruit P increased. Conversely, the incidence of bitter pit decreased as leaf Mg, leaf Mn, fruit Ca, and fruit Mn increased.

Goode, et al. (1978) showed that increasing nitrogen reduced the incidence of bitter pit of apples. But, Lewis, et al. (1977) showed that supplying extra N increases bitter pit incidence of apples.

Soluble solids: Mason (1964) and Smock and Broynton (1944) reported that differences in soluble solids following N applications are not always apparent. Where they are, soluble solids decrease with the increase of N. However, Maxon (1969) showed that the percent soluble solids increased from 13.0 at 0.5 lb NH_4NO_3/tree to 13.3 at 1.5 lb NH_4NO_3 level then declined to 13.1% at 2.0 and 3.0 lb NH_4NO_3/tree.

Fruit firmness: Magness and Overley (1930), Gourley and Hopkins (1931), Rasmussen (1935), and Baster (1958) found that the effect of nitrogen fertilization on the firmness of the apple were inconsistent. However, Knowlton and Hoffman (1931), Verner (1934), Smock and Boynton (1944), Boynton, et al. (1950), and Mason (1969) reported that there is strong evidence that fruit firmness at harvest is decreased by nitrogen applications. Thus, there is an inverse correlation between leaf nitrogen and fruit firmness.

Fruit size: Mason (1964) and Williams and Billingley (1974) reported that fruit size at harvest time was not affected by nitrogen treatments. Goode and Higgs (1977) suggested that fruit size was often affected by crop load much more than by nitrogen levels. Goode, et al. (1978) and Boynton and Oberly (1966) stated that decrease of apple fruit size resulted from an increase in fruit number. Finally, Boynton and Oberly (1966) concluded that fruit size of apples is influenced by the relationship between fruit numbers and the amount and efficiency of the leaf surface. Therefore, nitrogen fertilization can influence fruit number by its effect on bloom and set, and amount and efficiency of the leaf surface from its effect on shoot growth and leaf color.

Boron fertilization of apples

Concentration of boron in leaves and fruits of apples

Boron leaf content Oberly (1963) stated that apple leaves showed deficiency symptoms when leaf boron ranges from 18 to 26 ppm. No boron deficiency symptoms were observed when leaf boron content was 30 ppm and above. William and Thompson (1962) found that early-season sprays of boron increase significantly the boron concentration in leaves and fruits. This increase dissipated as the season progressed. At harvest, there was no increase of boron concentration in leaves contrary to the concentration in mature fruits. Data suggested to the authors that the seasonal fluctuation apparently was not influenced by treatments.

To find the optimum leaf concentrations of boron in several apple varieties, Awad and Kenworthy (1963) conducted a survey of 40 apple orchards in August and found that there is no apparent deficiency or toxicity symptoms of B when leaf boron concentrations are in the range between 28 and 34 ppm for Golden Delicious, 30 and 46 ppm for Red Delicious, 16 and 42 ppm for McIntosh, 18 and 46 ppm for Stayman, 26 and 38 ppm for York, 14 and 26 ppm for Cortland, 26 and 38 ppm for Rome Beauty, 30 and 38 ppm for Grimes Golden, and 18 and 34 ppm for Summer Rambo. They concluded that the average for different varieties should be 27 to 35 ppm. Similar results were found by Askew (1935), Askew and Chittenden (1936), McLarty (1936), Walrath and Smith (1952), Smith and Taylor (1952), Burrell (1956), Boynton and Anderson (1956), and Bramlage and Thompson (1962).

Bramlage and Thompson (1962) and Awad and Kenworthy (1963) found that leaf B followed a downward pattern as the season advances. Bramlage and Thompson (1962) found that the concentration levels in leaves were 33 to 228 ppm in May, and 18 to 33 ppm in August.

Boron fruit content In terms of fruit B in apple trees, Askew et al. (1936) found that the rate was relatively uniform during much of the growing season with treated trees of Jonathan apples in New Zealand. However, in terms of concentration, treated trees had 21.5 ppm in dried fruit tissue five weeks after bloom and 17.5 ppm three and a half months later (harvest). The initial level of B in the fruit of untreated trees was 33.0 ppm, but the concentration dropped to 8.9 ppm at the end of the growing season indicating the downward in seasonal trend of boron. Similar results were obtained by McLarty (1936) and Woodbridge (1937). Boynton and Oberly (1966) suggested that there is a fair relationship between boron content of fruit and boron deficiency symptoms adding that this relationship is much more consistent than the relationship existing between soil boron and deficiency symptoms. Oberly (1963) found that fruits with B concentrations of 0.4 to 0.7 ppm fresh weight showed deficiency symptoms; fruits without symptoms had boron contents ranging from 0.6 to 1.0 ppm fresh weight. Boynton and Oberly (1966) stated that apple fruits show deficiency symptoms where the concentration of B in the fruits is in the range of 2 to 10 ppm at harvest. The concentrations of boron in normal fruits at harvest is usually above 8 ppm to more than 30 ppm. With heavy applications of B, Haller and Batjer

(1946) obtained concentrations as high as 86 ppm in the apple fruit.

Boynton and Oberly (1966) suggested that the relationship between tissue analysis and visible deficiency symptoms less than perfect since a temporary shortage of boron can occur resulting in symptom deficiency.

Eaton (1935) reported that toxicity of B could be a serious problem in arid regions. But Boynton and Oberly (1966) stated that no definite upper limits could be set for apple fruit.

Effect of boron on fruit set

Boron applications to improve fruit set Batjer and Thompson (1949) reported that boron increased fruit set in Anjou pear, but later Batjer, et al. (1953) attributed the mechanism to a response to the correction of an incipient boron deficiency. Degman (1953) and Johnson, et al. (1954) confirmed the observations of Batjer. Batjer, Rogers and Thompson (1953) found that the incipient boron deficiency is induced by an inability of roots of pear trees to take up boron from cold soil in early spring and, consequently, causes blossoms to wilt and die or "blast." Kamali and Childers (1970) observed reductions in fruit set in peach when boron was withheld in sand culture experiments. Chaplin, et al. (1977) reported that deficiency of boron in Italian prune causes death of meristematic regions, particularly flowers.

Crandall and Woodbridge (1968) found that preharvest, post-harvest and prebloom sprays increased boron levels in Bartlett pear flower bud clusters. Batjer, et al. (1953) and Johnson, et al. (1954) corrected "blossom blast" on pears by both fall and spring boron sprays. Johnson, et al. (1954) reported that fall sprays were most consistent. In studies of fruit set of Anjou pears, Batjer and Thompson (1949) reported that spring applied boron sprays increased fruit set. Horsfall and Shear (1950) concluded similar results on apples. Bramlage and Thompson (1961) sprayed Jonathan, Stayman and Golden Delicious apple varieties with boron in spring and found that fruit set of Stayman was increased but not that of other cultivars. They considered Stayman as an inherently poor setting variety while heavy setting cultivars like Jonathan and Golden Delicious respond only to boron after second spray. They believed that this may be due either to the greater concentration after the second spray or to the time of application. Yogaratnam (1982) also reported such varietal differences in fruit set response of apples to boron. Initial fruit set of Cox's Orange Pippin was increased by boron sprays, whereas Solubor sprays did not help set of Discovery. On grapes, Thompson and Batjer (1950) reported that prebloom boron sprays increased fruit set. Chaplin, et al. (1977) and Chaplin and Westwood (1980) concluded that fall boron sprays applied to Italian prune and sweet cherry trees not deficient in boron, and spring sprays of boron to filbert trees resulted in a significant increase in fruit set and yield the following year. Analysis of mid-shoot leaf tissue the August following treatment showed no differences in boron content for treated and untreated trees. The experiments suggested the following to the authors:

1) There is a demand for boron which is unrelated to and not furnished by the general boron nutrition of the plant as evaluated by the traditional mid-summer leaf tissue analysis.

2) The increase in yields from boron application is not due to correction of an incipient boron deficiency of the kind reported by Batjer and Thompson (1949), and Batjer, et al. (1953) on pears, but rather a direct effect on the reproductive physiology of the plant.

3) Fall boron applications furnish boron in a form and at a location in the plant which can supply the needs for floral development and fruit set. Presumably boron moved into the fruit buds where it is overwintered and metabolized into forms readily available and usable in fruit set processes the following spring.

The work of Callan, et al. (1978) showed that Italian prune responds to boron for higher setting, but the effectiveness depends on time of application. The authors did not get any response from boron sprayed in the prebloom period, but post-harvest foliar application resulted in a significant increase of fruit set. They found that the increase of boron concentration in flower buds from fall sprays resulted in increase of fruit set.

Boron levels may influence the time of bloom. Williams and Veerhoff (1940), Dianes, et al. (1953), Cibes, et al. (1955), Hernandez and Childers (1956), and Kamali and Childers (1970) have shown that excess of boron delays bud break in peach. Hansen (1974) working on apples, concluded similar results. A delay in the time of bloom can increase fruit set under certain conditions since chances of favorable temperatures for fruit set increase as the season progresses. However, Sparks and Payne (1976) reported that the date of pecan bloom is advanced by boron toxicity.

Effect of boron on pollen germination Boron affects fruit set through its effect on pollen germination. Stanley and Linskens (1974) found that boron enhances in vitro pollen germination in most plants. Species such as pear with high endogenous pollen boron levels generally gave a great response to boron in the germination medium. Blaha and Schmidt (1929) working on cherries and pears, Thompson and Batjer (1950) on cherries, apples, and apricots, Stanley and Lichtender (1963) and Okamoto and Kobayashi (1971) on grapes, and Callan (1976) on prune, all found that boron improved in vitro pollen germination. Blaha and Schmidt (1929) found that the addition of boron to the germination medium has no effect on plum pollen. Thompson and Batjer (1950) concluded that boron has a slight effect on plum pollen since it increased pollen germination only by 6% to 10%.

Antles (1951) first obtained stimulation of pollen germination of pear by addition of boron to the germination medium, then observed no effect on pollen taken from pear trees fertilized for four years. He concluded that the response of pollen to boron depends on the supply of B to the plant.

Vasil (1964) showed that while the pollen germination of most plants is enhanced by the addition of optimum amount of boron to the germination medium, an excess of boron in the medium reduces pollen germination in many plants. Kamali and Childers (1970) found the same example with the soil induced boron toxicity in peach. But boron excess has no effect on pollen germination of some species such as apricot, as reported by Eaton, et al. (1941).

Effect of boron on pollen tube growth Visser (1956) and Stanley and Loewus (1964) found that the addition of boron to the germination medium has accelerated the pollen tube growth rate in almost all plant species studied. Zittle (1951) stated that the enhancement of pollen tube growth by boron could be related to the reaction of borate with compounds in the germination medium such as diphenols, preventing them from inhibiting germination or pollen tube growth. Martin (1972) reported caffeic acid to be a diphenol inhibiting germination and pollen tube growth of many plant species.

Effect of boron on yield Heinike, et al. (1942) and Boynton and Oberly (1966) working on McIntosh concluded that boron deficiency resulted in reduction of yield. This reduction was mainly due to heavy preharvest drop in early summer and a decrease in size of fruits because of internal or external corking. Most fruits that were affected early, abscessed and resulted in a reduction of apparent set.

Shorroks and Nichlson (1980) found that spring boron sprays improved the total crop yield by more than 10% by reducing cracking incidence.

Effect of boron on fruit quality

Effect of boron deficiency Boynton and Oberly (1966) reported that boron deficiency results in the decrease of fruit quality because of the appearance of the symptoms, internal and external cork at any time from shortly after bloom until harvest. The external cork results in dwarfed fruit (small), misshaped, and cracked. Boynton and Oberly (1966) reported that the incidence of internal or external cork or both on apples depends on the variety and the date at which symptoms first develop. Faust and Shear (1968) reported that when boron concentration increased in the fruit of apples, Ca concentration also increased, therefore decreasing the incidence of corking. They stated that boron seems to be needed for the transport of Ca into the fully developed tissues of apple trees.

Effect of boron on fruit color Dunlap and Thompson (1959) attempted to determine the effect of boron sprays on apple color and finish of York Imperial apple, but they found that the results were inconclusive. William and Thompson (1962) concluded that early-season boron sprays do not have any significant effect on fruit finish or color of apples. On the other hand, Chittenden and Thomson (1940) and Haller and Batjer (1946) stated that preharvest dropping and change from green to yellow ground color of fruits is hastened on Jonathan apple trees heavily fertilized with boron. Similar results were obtained by Phillips and Johnson (1943) on McIntosh and Latimer and Percival (1943).

Effect of boron on internal fruit condition William and Thompson (1962) and Shorrocks and Nicholson (1980) reported that the early-season sprays increase the development of water core in the fruit. William and Thompson (1962) stated that generally there is no effect of early-season boron sprays on internal breakdown, finish, decay, scald, moisture content, total sugars, and firmness of apples.

Shorrocks and Nicholson (1980) working on Cox's Orange Pippin found that spring boron sprays reduced significantly cracking of the skin of the fruit. They found also that excess amount of boron (1 kg of boron/tree) increased the incidence of flesh breakdown. They concluded that flesh breakdown occurs when the boron content of the fruit is more than 24 ppm (dry weight basis). Also, B had no direct significant effect on the incidence of bitter pit. But, since Ca applications reduced bitter pit (50% reduction at harvest), while B sprays improved fruit calcium levels, boron applications could provide indirectly some measure of control of bitter pit in apples. So, the combination of calcium and boron provided some control of cracking and bitter pit. Then suggested that Ca oxalate deposition could be enhanced by boron deficiency.

<u>Control of boron deficiency</u> Recommendations for control of boron deficiency can be based on the assessment of boron requirements of apple trees. Askew, et al. (1936) estimated the quantity of boron removed by an orchard of bearing apple trees. They concluded that with an orchard of 150 trees per acre (370 trees per ha) producing 14 lbs (6.35 kg) of fresh leaves per tree and 600 bu of fruit per acre (60 MT/ha) removed 44 g of B/tree from the soil with 33 g of these 44 g removed by the fruit.

Benson (1963) recommended spray applications of 5 to 10 lbs/acre (5.6-11.2 kg/ha) of solubor or boro-spray annually on apples. Boynton and Oberly (1966) controlled boron deficiency with 4 lbs/acre (4.5 kg/ha) of sodium pentaborate, solubor or boro-spray on apple and this could be applied with the one or two cover spray every three years, about one to three weeks after petal full or 1/8 to 1 lb (0.14-1.12 kg) of borax/tree annually, depending on tree size. Time of application of B and the method was not critical. Burrell, et al. (1956) reported that fall application of borax to the soil several weeks before deep freezing and early spring application are equally effective in raising the boron content of leaves and fruits of McIntosh and Cortland apple trees. He found that the source of boron supplied to the trees does not affect their boron content.

Studying the effectiveness of different methods of soil application, Burrell, et al. (1956) found no clear differences among the size of ring applications from close to the tree trunks to wider ones extending beyond the outermost branch tips. However, broadcasting the material was less effective than when it is banded around the tree. There was evidence that post-bloom sprays increased the boron content of leaves and fruits during the year of treatment more than do ground applications, but the boron content of trees with soil-application was slightly higher the second and third years.

Boron and nitrogen interactions. Latimer (1930) and Hill and Davis (1936) reported that high nitrogen levels of the trees increased boron deficiency. Burrell, et al. (1956) studied the influence of nitrogen applications on the boron content of the leaves. They found that the boron content decreased as the N supply was increased. Boynton and Oberly (1966) suggested that this may be due to a dilution of a limited boron supply as a consequence of the excessive vegetation growth of high nitrogen trees.

Rootstock effect on leaf and fruit mineral content, fruit quality, and yield

Effect of rootstock on nutrient concentrations in scion leaves

Working on apples, Tukey, et al. (1962) noticed that rootstock affected the concentrations of nutrients in scion leaves. They obtained significant differences with Rome Beauty on M1, M2, M7, and M13 in all tested nutrients. For Jonathan on the same rootstocks, they noticed the difference only in the concentrations of N, P, and Mg. Sistrunk and Campbell (1966) found that Winesap, Rome and Jonathan apple cultivars give higher concentrations of Ca when grafted on Hiberna than when grafted on French Crab.

In a four year greenhouse experiment, Lockard (1976) used Red Delicious apple cultivar and three rootstocks, M111, M106, and M9. He obtained lower levels of Ca in the leaves of plants with M111 rootstock than with those on M106 or M9. The level of K in the leaves was lower on plants with M9 rootstock than with M106. He also observed that M111, M106, and M9 differentially affected the leaf levels of N and Ca over the four year period.

Whitfield (1963) reported that leaves of Jonathan and Cox's Orange Pippin gave higher Ca and Mg levels when grafted on M9 than when they are on M7. Trees on M2 showed higher P, Ca, and Mg levels than those on M16. Trees on M7 rootstock gave very levels of leaf Mg.

Bould and Campbell (1970) analyzed leaves of young apple trees on three clonal rootstocks. They found that rootstock affected the level of leaf K throughout the experiment. They reported that trees on M106 were generally higher in leaf Mg and Ca than trees on the other rootstocks of M104 and M111. Kennedy, et al. (1980) grafted several apple varieties on a number of rootstocks among them M7, M9, M26, and M106. They obtained significant differences in levels of leaf K, Mg, and Ca due to rootstocks.

Woodbridge (1973) obtained higher levels of N, P, K, and Cu but lower Mg with leaves of Bartlett pear trees on seedling roots than those on quince roots. He also found that differences in Ca, S, B, Fe, Mn, and Zn levels were variable.

Fallahi (1983) found that leaves of Starkspur Golden Delicious apple variety on OAR-1 rootstock had significantly lower Ca than on M26. He also concluded that trees on M106 had the highest levels of Ca. B was higher in the scion leaves on OAR-1 compared to the leaves of the trees on several other rootstocks such as M7, M106, M26, M1, and seedling. He stated that Starkspur Golden Delicious apple leaves on M26 had significantly higher Mg than those on M1, M106 and OAR-1. Leaves on M7 had more Cu than other rootstocks.

<u>Effect of rootstock on nutrient concentrations in fruit</u>

Fallahi (1983) compared the concentrations of nutrients in fruits of Starkspur Golden Delicious on six different rootstocks seedling, M1, M7, M26, M106, and OAR-1. He concluded that OAR-1 induced lower concentrations (about 15%) of N, P, K, Mg, Fe, and Cu. But, the concentration of B was about 17% higher with OAR-1 compared to the other rootstocks tested. Fruits from M7 had higher (about 10%) concentrations of N, K, Fe, and Cu than most other rootsotcks. Fruit on M26 induced about 6% lower concentrations of B than most other rootstocks.

Concerning the seasonal trend, Fallahi (1983) found that the concentrations of all minerals declined in fruits on different rootstocks as the season advanced.

Effect of rootstock on yield

In a high density orchard, Schneider, et al. (1978) obtained higher yield with Goldspur and Redspur on M106 than on seedling rootstock. Fallahi (1983) obtained the highest yield with trees of Starkspur Golden Delicious on M106 compared to those on seedling M1, M7, OAR-1, and M26.

Yield depends also on the type of cultivar used. Hence, in a high density orchard, Westwood, et al. (1976) obtained high yield with Golden Delicious than with Starking on M9 rootstocks. Seely, et al. (1979) reported that spur-type Delicious strain such as Miller spur apple produced more fruit per tree on several rootstocks among than M106, M7 and M26, than the regular type strain such as Red Prince.

Effect of rootstock on fruit quality

Bitter pit Vay Zyl, et al. (1974) obtained less incidence of bitter pit with Golden Delicious apple variety on M7, M106 and M109 apple rootstocks than Merton 793 and M104. They also found that trees on Merton 793 gave fruits with less bitter pit than fruits on M104.

Sharples (1980) concluded that Cox's Orange Pippin apple variety, grown in a low Ca soil orchard, had less bitter pit when grafted on M9 than when it is grafted on M7, M26, or M106. He stated that no significant difference in the effect of rootstock on the incidence of bitter pit was noticed when Ca was supplied. In another study, O'Loughlin and Jotic (1977) found that the incidence of bitter pit on Cox's Orange Pippin was higher on M16 and M115 rootstocks than on M104, M106, M112, or M114. In a high density orchard, Fallahi (1983) observed higher bitter pit on M26 than on other tested rootstocks.

<u>Soluble solids, firmness, and fruit color</u> Fallahi (1983) concluded that fruits on OAR-1 rootstock had greater soluble solids and more yellow color and were firmer at harvest compared to fruits on all other tested rootstocks. He added that fruits on M7 had lower soluble solids than most of other tested rootstocks at several harvest dates.

MATERIALS AND METHODS

A ten-year old, high planting density orchard of Starkspur Golden Delicious apple trees, previously used by Fallahi (1983), at Oregon State University Lewis Brown Research farm near Corvallis, Oregon was chosen for the work outlined below. The plot consisted of trees on four rootstocks: *OAR-1*, *M7*, *M26*, and *M106* planted 0.60 cm inrow-spacing and 2.40 m between rows, resulting in a planting density of 2700 trees/ha. Urea at 125 g N/tree was applied on 96 trees in 6 replicated blocks of 4 different rootstocks and 4 trees/rootstock plot. An equal number of trees were used as control. Urea at 275 g per tree was banded on the ground about 30 cm from each side of the tree trunk. Applications were made in the spring of 1982 and 1983. Solubor at 240 g/100 l of water (490 ppm B) and untreated were imposed on each nitrogen plot as a 2 tree sub-plot or a total of 96 trees for each 3 treatments. Boron was sprayed only in the fall of 1982, November 12, and consequently, the response could only be evaluated in 1983.

The experiment was laid out in a split-split plot design with N as main plot and B as the split-plot for a factorial and then these treatments were imposed on 4 rootstocks as the split-split plot as shown below:

N1				G				N2				G			
Ri	Ri	Ri	Ri	Ri	Ri	Ri	Ri	Ri	Ri	Ri	Ri	Ri	Ri	Ri	Ri
B1		B2						B1		B2					

Symbols	Treatment
Ri	rootstock; i=1, 2, 3, and 4.
N1	untreated: no N applied in 1982 or 1983.
N2	treated: 125 g N/tree applied in spring of 1982 and 1983.
B1	unsprayed: no B applied in 1982 or 1983.
B2	sprayed: 490 ppm B applied in the second year of the experiment (Fall, 1982).
G	guard: for border trees.

Apple plant tissue analysis

The treatment effect on mineral content of apple plant tissue was analyzed on flowers, leaves, and fruits. Samples were composited for each 2 tree plot of 50 whole flower per 2 tree plot taken in spring of 1983 at full bloom (May 12), of 30 mid-shoot leaves taken in mid-August of 1982 and 1983, and 40 fruit slices of 2 cm thick from the 20 fruit sample at 2.5 months after harvest (Dec. 29) in 1982 and 1983. Fruit tissue constituted both flesh and skin. The fruit tissue was freeze-dried. The modified Kjeldahl method (Schuman, Stanley, and Knudsen, 1973) was used for total N analysis and the ICP spectrometry method (Benton Jones, 1977) was used for the analysis of other nutrients, P, K, Ca, Mg, Mn, Cu, Fe, Zn, and B. The NO_3^--N was analyzed in flower tissue using the cadmium reduction method (Armstrong et al, 1967 and Grasshoff, 1969).

Soil analysis

Sixteen samples of soil were taken in July. Eight samples were taken at 0-6 in. depth, 4 samples at 0-18 in. depth and 4 samples at 18-36 in. depth.

One soil sample at 0-18 in. depth, 18-36 in., and two samples 0-6 in. were taken under the trees where the treatments are the following: N plus B, N only, B only, and untreated.

The samples were analyzed for pH, NO_3^--N, NH_4^+-N, P, K, Ca, Mg, Na, B, Zn, Cu, Mn, and CEC.

The methods used for extraction of each element are the following:

a) 1:2 soil to solution ratio and glass electrode pH meter by Jackson (1958) for pH.

b) Steam-distillation method by Bray and Kurtz (1945) for NO_3^-N and NH_4^+-N.

c) Dilute acid-fluoride method by Bray and Kurtz (1945) for P.

d) Ammonium acetate method by Peech, Alexnader, Dean, and Reed (1947) for Ca, Mg, Na and K.

e) Azomethine H method by Wolf (1971) for B.

f) DTPA (diethyltriamine pentacetic acid) method by Lindsay and Norvell (1969) for Zn, Cu, and Mn.

g) Ammonium acetate method by Peech, Alexander, Dean, and Reed (1947) for CEC.

Flowering and fruiting measurements

Two branches, one from each side of the tree, were chosen to determine the influence of the treatments on percent of bloom, fruit set, and crop density.

Percent of bloom: The number of all growing points (T) were counted during the winter from base to apical of the branch and recorded on a tape at the base of the limb. Later during the full bloom, the number of flower clusters (C) were counted in the same way and recorded. Then the level of percent of bloom was obtained by multiplying the number of flower clusters by 100 and dividing it by total number of the growing points (C/T 100).

Fruit set: The number of flower clusters (C) per branch was counted during the full bloom and recorded. Then, the number of fruit (F) per limb was counted after June (or green) drop but before hand thinning. The level of fruit set was evaluated by multiplying the number of fruit by 100 and by dividing by the number of clusters (F/C 100).

Crop density (D): Crop density or cropping level response was obtained by counting the number of fruit (F) produced by the branch before hand thinning and dividing it by the cross-sectional area cm^2 ($D=F/cm^2$).

The reason for measuring crop density is that it integrates both inflorescence and fruit set. A light bloom and heavy fruit set could be equivalent in crop density as a heavy bloom and light set. Crop density can be used to measure the response from different factors. In our research, it is used to measure the crop level response from spring applications of N (urea), full sprays of boron (Solubor), and rootstocks M7, OAR-1, M106, and M26 and its effect on fruit quality.

Yield: Yield was taken in boxes per treatment plot (4 trees in 1982 and 2 trees in 1983) at harvest and then converted to kg/tree.

Fruit quality measurements

To evaluate the effect of nitrogen, boron, and rootstock on the quality of the fruit, 20 fruit were taken randomly from the two trees prior to harvest time on October 13 from each treatment plot. Then, the following observations and measurements were conducted the following December 29.

a) Fruit color: Fruits were separated into two color categories, yellow and green, and the percentage of yellow fruits was calculated.

b) Fruit size: The overall diameter of 20 fruit was taken and then the average per fruit was calculated.

c) Number of seeds in the fruit: Seeds were counted in 20 fruits and the average per fruit was calculated.

d) Fruit firmness: Pressure tests of two sides each of pared fruit were made in kgs using Magness-Taylor pressure tester equipped with an 11 mm plunger (Williams, 1978) and averaged for the 20 fruit.

e) Fruit weight: All 20 fruit were weighed and averaged in g per fruit.

f) Soluble solids: A few drops of juice resulting from the pressure test of each fruit were used for the measurement of soluble solids. The average soluble solids per fruit was calculated from 20 fruit samples.

g) Bitter pit: All sampled fruit were observed for visual symptoms and the percent of bitter pit fruit was calculated. The severity of bitter pit was not taken into account.

Statistical analysis

Data obtained in each year was analyzed separately. The statistical analysis was made for the effect of N treatment, rootstock treatment, and N-rootstock interaction on all data units obtained in 1982. The analysis was also done for all possible linear correlations.

In 1983, the analysis was made for the main effect of N, B, and rootstock treatments and the interactions of N-rootstock, B-rootstock, N-B, and N-B-rootstock. Finally, all possible linear correlations were analyzed.

Means were statistically analyzed using ANOVA at the 5% or 1% levels. When comparing more than two means, Duncan's Multiple Range tests at 5% level was used for mean separation (Steele and Torrie, 1960).

RESULTS AND DISCUSSION

Leaf, fruit, and flower nutrient content

Effect of high N application on nutrient leaf content

The concentration of leaf N in untreated trees was 2.15% in 1982 and 2.06% in 1983 (Table 1). This decline suggests a depletion of N reserve in untreated trees from 1982 to 1983. However, the concentrations are within the optimum range 1.9-2.1% suggested by Boynton and Oberly (1966). In treated trees, the leaf N content was slightly higher in 1983 than in 1982.

The high N application significantly increased the leaf levels of N, Mg, Mn, and Cu in both years (Tables 1, 5, 6, 8) while those of B and Zn were increased only in 1983 (Tables 9 and 10). Potassium and P were decreased in both years (Tables 2 and 3).

The increase of N in leaves with increasing N fertilizer is well documented (Magness et al, 1940; Boynton and Compton, 1944; Fear and Anthony, 1943; Shear, 1947; Weeks, 1958; and Boynton and Oberly, 1966).

The decrease of K by high N application in both years (Table 2) agrees with the results obtained by Shear (1947), Cain (1953), Walter (1967), Goode and Higgs (1977), and Fallahi (1983). However, the K levels of all plots were below the 1.93-2.38 optimum range values suggested by Titus and Ghosheh (1963).

The P decrease associated with high N (Table 3) is similar to responses observed by Cain (1953), Walter (1967), Goode and Higgs (1977), and Fallahi (1983).

Calcium concentration was not significantly decreased by high N application (Table 4) which is in agreement with Fallahi (1983) but contrasts with Goode and Higgs (1977).

The Mg uptake of the leaves was increased significantly by high N application in both seasons (Table 5), and was in agreement with Shear (1947), Cain (1953), Walter (1967), and Fallahi (1983).

Leaf Mn levels were much higher in 1983 from treated plots (Table 6) which could be related to the rapid decline of soil pH from high N application (Table 31). Leaf Mn concentration in treated trees in 1983 was higher than the standard level 13-42 ppm recommended by Boynton (1951).

Although pH decline (Table 31) might be associated with greater Fe availability, the effect of high N application on leaf Fe was not signifiacnt (Table 7), and leaf Fe was within the range 70-315 ppm suggested by Walrath and Smith (1952).

Leaf Cu increased significantly from high N treatments only in 1982 (Table 8). Our results provide some support of Shear's conclusion (1947) that N applications increase Cu in apple leaves. Leaf Cu content was slightly lower than the 13-62 ppm range suggested by Walrath and Smith (1952) but slightly higher than the level 1-4 ppm reported as deficient by Dunne (1938) and Bould (1950).

Nitrogen applications decreased leaf B only in 1983 (Table 9). Boynton and Oberly (1966) attributed a leaf B decrease to the delution effect of N in the plant because of additional growth. Although reduced, B levels were still within the 25-35 ppm range reported by Askew and Chittenden (1936) where no B deficiency or toxicity symptoms were observed.

Leaf Zn was decreased by high N applications in both years but the decrease was significant only in 1983 (Table 10). The leaf levels of Zn which were about 10 ppm in our research were slightly lower than the optimum 14-102 ppm range obtained by Walrath and Smith (1952).

Effect of B sprays on nutrient content of leaves

Fall B spray increased significantly the concentration of leaf B in 1983 (Table 9). The other nutrients tested were not significantly affected. Both treated and untreated plots had B contents in the normal range suggested by Awad and Kenworthy (1968).

Effect of rootstocks on nutrient content of leaves

OAR-1 rootstock Leaves of Starkspur Golden Delicious on OAR-1 had the lowest concentration of N, Ca, and Zn in 1982 and Ca in 1983 (Table 1, 4, 10). Also, OAR-1 produced the lowest leaf Mg and Cu contents (Tables 5 and 8). These results support those of Fallahi (1983) in which OAR-1 had the lowest level of leaf Ca among six rootstocks.

Rootstock differences with regard to leaf P and B in 1982 depended on the rootstock-nitrogen interaction. The highest leaf P level observed in 1982 was from untreated N trees on OAR-1 (Table 3). Nitrogen treated trees on OAR-1 had the highest leaf B in 1982 (Table 9). In 1983, OAR-1 had the highest leaf B regardless of N treatment (Table 9). Fallahi (1983) concluded similar results. He also obtained the highest leaf B and P levels with OAR-1 rootstock. But he obtained no interaction between rootstock and N treatment.

<u>M7 rootstock</u> Scion leaves of trees on M7 rootstock had the highest K and Cu content in comparison to the other rootstocks tested (Table 2 and 8). Fallahi (1983) concluded similar results.

<u>M26 rootstock</u> M26 rootstock had the least amount of the scion leaf P and B on the N treated trees (Tables 3 and 9). This rootstock had the highest leaf Mg, Mn, and Zn contents (Tables 5, 6, and 10).

<u>M106 rootsock</u> M106 rootstock had the highest content of the scion leaf Ca in Starkspur Golden Delicious apple trees (Table 4).

<u>Influence of N treatment on fruit nutrient content</u>

Fruit N concentration was the only nutrient significantly affected by N application in 1982 (Table 11). However, several nutrients were affected by N application in 1983. Fruit concentration of N, Mn, Cu, and Zn (Table 11, 16, 18, and 20) were significantly increased, while that of P and B were decreased (Tables 13 and 19). Other minerals were not affected (Tables 12, 14, 15, and 17).

Goode and Higgs (1978) concluded that N application increased fruit N and Ca, but reported that fruit P, K, and Mg were depressed. Fallahi (1983) applying low levels of N concluded that there was no significant effect of N treatment on fruit N content in the first year of the experiment, but increased in the second year. He also found that K and P fruit concentrations were reduced by N applications.

The fact that only the concentration of fruit N was affected in the first year of our experiment and then several nutrients were affected in the second year, suggests that it takes a minimum of two years of high N applications to affect the concentration levels of nutrients in apple fruits.

Influence of B application on mineral fruit content

Fall B spray affected only fruit B level (Table 19), increasing the fruit B concentration. The B levels were between 31 and 35 ppm and no adverse effects were observed. This agrees with results obtained by Boynton and Oberly (1966). They concluded that the concentrations of B in normal fruits at harvest are usually between 8 and above 30 ppm.

Rootstock effect on fruit mineral content

Trees on OAR-1 rootstock had the lowest concentration of N, K, Ca, Mg, Fe, and Cu in the fruit in 1982 (Tables 11, 12, 14, 15, 17, and 18). However, OAR-1 had the highest fruit B in both years (Table 19). Trees on this rootstock had the lowest fruit N and K concentrations in 1983 (Tables 11, 12, and 19). Fallahi (1983) found similar results and attributed these lower concentrations of most fruit minerals of trees on OAR-1 to a high percent dry weight for these fruits which results in a dilution effect, indicating that the high percent dry weight might have been a result of higher scion leaf photosynthesis on this rootstock. The B supply to the fruit must have countered the dry matter dilution.

Trees on M7 had the highest fruit Cu level in 1982 and the highest fruit N, Fe, Cu, and Zn levels in 1983 (Tables 11, 17, 18, and 20). Fallahi (1983) also reported that P and K were highest in fruit of this rootstock.

Trees on M26 had the highest level of fruit K in 1982 and the lowest fruit B level in 1983 (Tables 12 and 19).

The relative positioning of fruit levels for Ca, Mg, and Mn of trees on the four rootstocks depended on the interaction between rootstock and N treatment in 1983 (Tables 14, 15, and 16).

Variation of nutrient fruit content between years

In 1983, N and Ca concentrations in the fruit were 30 to 60 percent lower, respectively, independent of the effect of N application or rootstock. The concentrations of all other nutrients tested were higher in 1983. Depending on the nutrient, the increase varies from 38 to 54 percent. The seasonal difference of nutrient concentrations were much greater in the fruit than in the leaf.

Effect of N and B treatments and rootstocks on nutrient levels of flowers

Minerals in apple flower tissue were evaluated to investigate relationships between N and B concentrations and flowering or fruit set. High N treatments did not affect any of the nutrient concentrations of flowers (Tables 21-30). However, fall B spray increased significantly flower B level and decreased K level (Tables 22 and 29). Among the four rootstocks tested, trees on OAR-1 had the lowest Cu and Zn (Tables 28 and 30). Flowers on M26 had the highest P and B (Tables 23 and 28). Flowers on M106 had the lowest P concentrations (Table 23).

In flower tissue, NO_3-N was found to be less than 2 ppm independently from N, B or rootstock effect. This data suggests that the reading obtained could be due to the color development in the extract solution and the concentration of NO_3-N in the flower tissue is practically nul.

Cropping and fruit quality

Effect of N and B treatments and rootstock on yield and its components

Percent of bloom The N application and fall B spray did not affect significantly percent of bloom while there was rootstock effect (Table 31). Trees on OAR-1 had the lowest level of flower clusters per 100 growing points in 1982 and the highest in 1983. M26 gave the highest bloom level in 1982 but lowest in 1983.

Fruit set Nitrogen application increased fruit set significantly only in 1982 (Table 32).

The increase of fruit set by fall B spray in 1983 was not significant. The increase of fruit set with N and B application could be greater if the variety Starkspur Golden Delicious was not inheritently a heavy setting cultivar. Yogaratnam (1982) obtained fruit set increase with N application on Cox's Orange Pippin. Varietal differences in response of fruit set to B were reported by Bramlage and Thompson (1961) and Yogaratnam (1982). The apple trees sprayed were not deficient in B. However, fall applications of B on cherry and prune trees increased the fruit set even though leaf levels were not in the deficient range (Chaplin, et al. 1977 and Chaplin and Westwood, 1980). Correcting an incipient B deficiency resulted in an increase of fruit set (Batjer, et al., 1953; Degman, 1953; Johnson, et al., 1954).

Rootstocks had no effect on fruit set in 1982, but trees on OAR-1 stock had the lowest set in 1983 (Table 32). This lower level of set in trees on OAR-1 in 1983 may have resulted from a combination of the higher level of bloom initiation (Table 31) and lower B level induced by OAR-1 in the scion flower (Table 29).

Crop density prior to hand thinning Nitrogen and B applications did not affect crop density (Table 33). Rootstocks affected crop density in 1982 but not in 1983. In 1982, trees on OAR-1 had the lowest crop density level and M26 the highest (Table 33). Although bloom initiation was higher in 1983, crop density was not greater (Table 32).

Yield Nitrogen application did not affect the tree yield at harvest (Table 34). This is expected because crop density (Table 33) was not affected and thinning before harvest would aleviate large differences between treated and untreated trees. Boynton and Burrell (1944) and Mason (1964, 1969) also found that N application did not affect yield. Leaf levels of nutrients also indicate that trees are not deficient in N. Similar explanations apply to the lack of a yield response with B applications. The increase of yield from B application is most apparent on B deficient apple trees because B reduced preharvest drop and eliminated the reduction of fruit size due to external corking (Shorroks and Nicholson, 1980).

Trees on OAR-1 had the lowest tree yield in 1982 compared to other tested rootstocks which could be due to the low bloom initiation (Table 31). Trees on M7 and M26 had the lowest yield in 1983 (Table 34).

Alternate bearing Nitrogen fertilization has been one of the factors affecting biennial bearing of apple trees (Titus, 1960). Using the formula of Titus (1960) in which the difference of two successive yields is divided by the total of the two yields and multiplied by 100 to calculate the biennial bearing index (BBI), we found that the BBI of the N treated trees almost doubled that of the untreated N trees (Table 36). The lack of a large BBI must be due to the hand thinning before harvest that reduced large yield differences. Rootstock also had an effect on BBI. The level of BBI was lower with M106 compared to other tested rootstocks (Table 36).

Effect of N and B application and rootstock on fruit quality

Fruit color Nitrogen applications decreased yellow ground color of fruits at harvest in both years (Table 38). These results are similar to those reported by Oland (1955), Fernand and O'Grady (1958), O'Grady (1959), Southwick (1961), Van Doren (1961), Baxter and Dillon (1962), Bould and Jarrett (1962), Lalatta and Gorini (1963), and Mason (1964). There was a close relationship between leaf N, fruit N, and fruit color (Table 46).

The fall B spray of 1982 had no effect on fruit color of the crop following the spray (Table 35) which supports the results of William and Thompson (1962).

In agreement with Fallahi (1983) OAR-1 had the highest percentage of yellow fruits in 1982. However, the difference between rootstocks was not significant in 1983.

Fruit size

Fruit weight and diameter were not affected by the N application in both years (Tables 33 and 36) which agrees with the work of Mason (1964) and Williams and Billingsley (1974). Fruit size depends mainly on fruit number per tree or crop load (Goode and Higgs, 1977, and Goode, et al., 1978).

A fall B spray affected fruit weight in 1983 when applied with N (Table 36). This differs from previous studies where B affected fruit size only when apple trees were deficient (Boynton and Oberly, 1966) and B deficiency caused external corking and small fruit.

Rootstocks did not affect fruit size in 1982 but there was an effect in 1983. Trees on M26 had larger fruit than OAR-1 and M106 (Tables 32 and 33). Crop loads were not significantly different, therefore differences were related to rootstock.

Bitter pit No bitter pit symptoms were observed in 1983, even though fruit Ca contents were considerably lower, this demonstrates the difficulties often encountered in fruit Ca relationships (Table 14). The effect of B could not be evaluated because the disorder did not occur.

Nitrogen application significantly increased the amount of bitter pit (Table 38) in agreement with Goode, et al. (1978) but in contrast with Lewis, et al. (1977).

Bitter pit was affected by rootstocks in 1982 (Table 38). OAR-1 had the highest level of bitter pit and M26 had the lowest. Crop load on OAR-1 was much lower than the other three rootstocks

(Table 34). Fallahi (1983) observed higher bitter pit incidence on fruits from trees grafted on M26 only after six months of storage at 0°C.

Soluble solids Nitrogen application significantly decreased the soluble solids only in 1982 (Table 39). Mason (1964) and Smock and Boynton (1944) also found soluble solids reduction in apples with N application.

Fall B spray did not affect the level of soluble solids in the fruit (Table 39).

Rootstocks affected soluble solids in the fruit in both years. Fruit on OAR-1 rootstock had the highest soluble solids level in both years. Rootstock M26 was comparable to OAR-1 in 1983. The greater fruit soluble solids on OAR-1 could be due to the higher crop load (Table 34). Fallahi (1983) obtained higher percentage of soluble solids from fruits on OAR-1 indicating that the greater soluble solids was due to the direct effect of OAR-1 not from crop load.

Fruit firmness Fruit firmness was not affected by the N application (Table 40). These results agree with those found by Fallahi (1983) but differ with the results reported by Mason (1969).

Fall B spray did not affect fruit firmness (Table 40) in agreement with William and Thompson (1962).

The effect of rootstock on fruit firmness in 1982 was depended on rootstock and N treatment (Table 40). IN 1983, there was no fruit firmness interaction between N and rootstock. Although the 1982 interactions complicate the issue, these results are within general agreement with those of Fallahi (1983). He found that fruit on OAR-1 were firmest and those on M26 were relatively softer.

Seed content Neither N nor B application affected the average number of seed per fruit (Table 41). However, there was a rootstock effect (Table 41). Fruit on M26 had the highest number of seeds per fruit in 1982 but the lowest in 1983. Fruit on M106 had the lowest seed content in 1982 (Table 41).

Concerning the seasonal difference, the average number of seeds per fruit was about one seed higher in 1983 than 1982. However, the relationship between seed number and fruit set was not obtained as expected.

Correlations among all mineral nutrient levels, yield components, and fruit quality factors

Leaf and fruit correlations

Leaf N, P, K, and Mg (Table 44) appeared to be correlated with fruit N. The correlation was positive with leaf N and Mg but negative with leaf P and K. This indicates that as leaf N increased, leaf P and K decreased while fruit N is increased. Leaf Ca was correlated with fruit Cu and B while leaf Zn was correlated with fruit Zn (Table 44). However, only leaf N and fruit N showed a relatively strong and consistent correlation which suggested that leaf and fruit N concentrations increased when a N fertilizer was applied and leaf N analysis could be used to estimate fruit N level. Such weak correlations between fruit and leaf nutrients other than N was reported also by Fallahi

(1983) which would indicate that nutrient content of fruit cannot be predicted from leaf analysis particularly Ca.

Yield and its components as correlated to independent factors

Percent of bloom was correlated positively with yield (Table 45). However, fruit set was correlated negatively with percent of bloom indicating that trees with a heavy bloom had reduced number of fruit per 100 clusters. Crop density had a positive correlation with percent of bloom and yield while yield and percent of bloom in 1983 correlated with leaf N (Table 45).

Fruit quality components as correlated to some other factors

Percent of yellow fruit was found to have a negative correlation with leaf N and fruit N (Table 46). The negative correlation of fruit color with leaf and fruit N explained the greater percentage of colored fruits when no N was applied (Table 37). Also, there was a positive correlation of fruit color with leaf P and K. This positive correlation reflected the high leaf P and K concentrations obtained from untreated N trees.

Fruit diameter was negatively correlated to fruit firmness (Table 46) indicating that larger fruit was less firm.

Soluble solids of the fruit had a negative correlation with leaf N, fruit N, P, Ca, Mg, Cu, and Fe, crop density, and yield (Table 46). There was a positive correlation between leaf P and B and fruit B in 1982 (Table 46). This could be due to the early harvest in 1983 (about one week in advance) that reduced the effect of B on sugar assimilation indicating that B may be important during the maturation period for sugar assimilation and translocation.

Fruit firmness was positively correlated with fruit B (Table 46). Therefore, since B applications increase fruit B concentration, we would expect firmer fruit with B applications.

CONCLUSIONS

High N application on Starkspur Golden Delicious apple trees increased leaf and fruit contents. The level of most other nutrients was affected with a decrease in P and K and with an increase of Mg and Mn.

High N application affected partially biennial bearing by increasing yield and some of its components such as the increase of fruit set in 1982. There was a positive correlation between leaf N and percent of bloom. Yield was correlated with percent of bloom, crop density, and leaf N. However, high bloom levels resulted in lower fruit set.

The decrease in fruit quality following high N application was from the delay in fruit color development and the low soluble solids of the fruit. Fruit color and fruit soluble solids correlated negatively with leaf N and fruit N.

Fall B spray increased leaf, fruit, and flower B content without affecting significantly other minerals. Soluble solids correlated positively with leaf and fruit B. Fruit firmness had a negative correlation with leaf Ca and a positive correlation with fruit B.

The four apple rootstocks affected the nutrient content of leaves and fruit, yield efficiency, and effect on fruit quality. M7, M26, and M106 had similar effect on nutrient content of leaves and fruits. However, leaves and fruits from trees on OAR-1 had lower levels of most nutrients with the exception of B which was much greater than those of the other three rootstocks.

Trees on OAR-1 had less yield and crop density but greater variation in percent of bloom from year to year than those on M7, M26, and M106. However, fruits from trees on OAR-1 had higher quality, i.e., fruits had more yellow color and greater firmness.

Table 1

Influence of N and B treatments on mid-August leaf-N content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Leaf-N % dry weight	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	2.51	2.59
	untreated	2.15	2.06
	significance at	0.01	0.01
B fall spray			
	490 ppm	--	2.32
	untreated	--	2.32
	significance at	--	n.s.[y]
Rootstock			
	OAR-1	2.27b[z]	2.39a
	M7	2.31ab	2.39a
	M26	2.37a	2.25b
	M106	2.36a	2.27ab
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.

[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 2

Influence of N and B treatments on mid-August leaf-K content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Leaf-K % dry weight	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	0.92	1.19
	untreated	1.17	1.60
	significance at	0.01	0.05
B fall spray			
	490 ppm	--	1.41
	untreated	--	1.38
	significance at	--	n.s.[y]
Rootstock			
	OAR-1	1.08ab[z]	1.29ab
	M7	1.18a	1.49a
	M26	0.94c	1.66a
	M106	0.99bc	1.13b
	significance at	0.05	0.05
Interactions: not significant			

[y] Not significant.

[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 3

Influence of N and B treatments on mid-August leaf-P content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Leaf-P % dry weight	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	0.17	0.16
	untreated	0.25	0.27
	significance at	0.01	0.01
B fall spray			
	490 ppm	--	0.22
	untreated	--	0.21
	significance at	--	n.s.[y]
Rootstock			
	OAR-1	0.25a[z]	0.21a
	M7	0.22b	0.23a
	M26	0.18c	0.23a
	M106	0.20bc	0.19a
	significance at	0.05	n.s.
Nitrogen - Rootstock interactions			
treated			
	OAR-1	0.18de	
	M7	0.18de	
	M26	0.16e	
	M106	0.17de	
untreated			
	OAR-1	0.32a	
	M7	0.26b	
	M26	0.21cd	
	M106	0.23bc	
	significance at	0.05	n.s.

[y] Not significant.

[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 4

Influence of N and B treatments on mid-August leaf-Ca content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Application	Leaf-Ca % dry weight, Season: 1982	1983
N			
	125 g N/tree	1.26	1.68
	untreated	1.32	1.70
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	1.69
	untreated	--	1.69
	significance at	--	n.s.
Rootstock			
	OAR-1	1.02c[z]	1.27b
	M7	1.29b	1.73a
	M26	1.35b	1.95a
	M106	1.50a	1.81a
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 5

Influence of N and B treatments on mid-August leaf-Mg content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Leaf-Mg % dry weight	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	0.33	0.43
	untreated	0.31	0.32
	significance at	0.05	0.01
B fall spray			
	490 ppm	--	0.38
	untreated	--	0.38
	significance at	--	n.s.[y]
Rootstock			
	OAR-1	0.28c[z]	0.33b
	M7	0.28c	0.35b
	M26	0.39a	0.49a
	M106	0.32b	0.33b
	significance at	0.05	0.05
Interactions: not significant			

[y] Not significant.

[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 6

Influence of N and B treatments on mid-August leaf-Mn content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Leaf-Mn ppm	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	36.91	66.40
	untreated	33.79	36.88
	significance at	0.01	0.01
B fall spray			
	490 ppm	--	51.11
	untreated	--	52.18
	significance at	--	n.s.[y]
Rootstock			
	OAR-1	32.41b[z]	48.65b
	M7	31.16b	46.03b
	M26	44.33a	67.73a
	M106	33.50b	44.16b
	significance at	0.05	0.05
Interactions: not significant			

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 7

Influence of N and B treatments on mid-August leaf-Fe content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Leaf-Fe ppm	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	183.16	188.82
	untreated	192.58	194.19
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	191.89
	untreated	--	191.12
	significance at	--	n.s.
Rootstock			
	OAR-1	190.91a[z]	202.70a
	M7	189.58a	195.75a
	M26	177.00a	196.76a
	M106	194.00a	170.80a
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 8

Influence of N and B treatments on mid-August leaf-Cu content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Leaf-Cu ppm	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	6.04	6.54
	untreated	5.66	6.49
	significance at	0.05	n.s.[y]
B fall spray			
	490 ppm	--	5.94
	untreated	--	7.09
	significance at	--	n.s.
Rootstock			
	OAR-1	4.83c[z]	4.86a
	M7	7.16a	7.20a
	M26	5.25c	8.33a
	M106	6.16b	5.67a
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 9

Influence of N and B treatments on mid-August leaf-B content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Leaf-B ppm	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	33.45	32.50
	untreated	35.50	36.08
	significance at	n.s.[y]	0.05
B fall spray			
	490 ppm	--	36.01
	untreated	--	32.57
	significance at	--	0.05
Rootstock			
	OAR-1	38.16a[z]	39.66a
	M7	35.08ab	33.61b
	M26	31.16c	33.58b
	M106	33.50bc	30.30b
	significance at	0.05	0.05
Nitrogen - Rootstock interactions			
treated			
	OAR-1	40.16a	
	M7	33.66bcd	
	M26	29.00e	
	M106	31.00de	
untreated			
	OAR-1	36.16abc	
	M7	36.50abc	
	M26	33.33cde	
	M106	36.00abc	
	significance at	0.05	n.s.

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 10

Influence of N and B treatments on mid-August leaf-Zn content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Leaf-Zn ppm	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	9.45	9.91
	untreated	9.83	10.08
	significance at	n.s.[y]	0.05
B fall spray			
	490 ppm	--	10.14
	untreated	--	9.86
	significance at	--	n.s.
Rootstock			
	OAR-1	7.58c[z]	9.13b
	M7	10.66ab	10.55ab
	M26	11.41a	12.22a
	M106	8.91bc	8.09b
	significance at	0.05	0.05
Interactions: not significant			

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 11

Influence of N and B treatments on fruit-N
of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Fruit-N % dry weight, Season: 1982	Fruit-N % dry weight, 1983
N			
	125 g N/tree	0.47	0.17
	untreated	0.38	0.07
	significance at	0.01	0.01
B fall spray			
	490 ppm	--	0.12
	untreated	--	0.12
	significance at	--	n.s.[y]
Rootstock			
	OAR-1	0.37b[z]	0.09c
	M7	0.44a	0.16a
	M26	0.44a	0.11b
	M106	0.44a	0.14b
	significance at	0.05	0.05
Interactions: not significant			

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 12

Influence of N and B treatments on fruit-K of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Fruit-K % dry weight	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	0.61	1.14
	untreated	0.60	1.16
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	1.15
	untreated	--	1.16
	significance at	--	n.s.
Rootstock			
	OAR-1	0.55c[z]	1.00b
	M7	0.64ab	1.24a
	M26	0.66a	1.20a
	M106	0.58bc	1.17a
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 13

Influence of N and B treatments on fruit-P of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Fruit-P % dry weight, Season: 1982	Fruit-P % dry weight, 1983
N			
	125 g N/tree	0.063	0.11
	untreated	0.066	0.14
	significance at	n.s.[y]	0.01
B fall spray			
	490 ppm	--	0.13
	untreated	--	0.13
	significance at	--	n.s.
Rootstock			
	OAR-1	0.058a[z]	0.12a
	M7	0.068a	0.14a
	M26	0.068a	0.12a
	M106	0.065a	0.13a
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 14

Influence of N and B treatments on fruit-Ca
of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Application	Fruit-Ca % dry weight Season: 1982	1983
N			
	125 g N/tree	0.058	0.03
	untreated	0.060	0.04
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	0.03
	untreated	--	0.03
	significance at	--	n.s.
Rootstock			
	OAR-1	0.053b[z]	0.04a
	M7	0.062a	0.04a
	M26	0.062a	0.02b
	M106	0.060ab	0.04a
	significance at	0.05	0.05
Rootstock - Nitrogen interactions			
treated			
	OAR-1		0.030b
	M7		0.042a
	M26		0.018c
	M106		0.032b
untreated			
	OAR-1		0.046a
	M7		0.030b
	M26		0.025bc
	M106		0.041a
	significance at	n.s.	0.05

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 15

Influence of N and B treatments on fruit-Mg of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Fruit-Mg % dry weight, Season: 1982	1983
N			
	125 g N/tree	0.030	0.059
	untreated	0.028	0.056
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	0.058
	untreated	--	0.057
	significance at	--	n.s.
Rootstock			
	OAR-1	0.025b[z]	0.061a
	M7	0.032a	0.059ab
	M26	0.031a	0.056b
	M106	0.027ab	0.053b
	significance at	0.05	0.05
Rootstock - Nitrogen interactions			
treated			
	OAR-1		0.054cd
	M7		0.066a
	M26		0.056c
	M106		0.060b
untreated			
	OAR-1		0.052d
	M7		0.057bc
	M26		0.057bc
	M106		0.058bc
	significance at	n.s.	0.05

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 16

Influence of N and B treatments on fruit-Mn of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Fruit-Mn % dry weight, Season: 1982	1983
N			
	125 g N/tree	2.65	6.07
	untreated	2.40	5.08
	significance at	n.s.[y]	0.05
B fall spray			
	490 ppm	--	5.80
	untreated	--	5.35
	significance at	--	n.s.
Rootstock			
	OAR-1	1.95a[z]	5.41a
	M7	2.87a	5.87a
	M26	2.72a	5.34a
	M106	2.55a	5.67a
	significance at	0.05	n.s.
Rootstock - Nitrogen interactions			
treated			
	OAR-1		5.91bc
	M7		6.87a
	M26		5.37c
	M106		6.14b
untreated			
	OAR-1		4.91c
	M7		4.87c
	M26		5.31c
	M106		5.21c
	significance at	n.s.	0.05

[y] Not significant.

[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 17

Influence of N and B treatments on fruit-Fe of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Fruit-Fe ppm, Season: 1982	Fruit-Fe ppm, 1983
N			
	125 g N/tree	25.87	67.16
	untreated	24.25	65.42
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	66.48
	untreated	--	66.10
	significance at	--	n.s.
Rootstock			
	OAR-1	21.41b[z]	55.73b
	M7	26.50a	82.91a
	M26	28.58a	60.50b
	M106	23.75ab	66.03b
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.

[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 18

Influence of N and B treatments on fruit-Cu of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Fruit-Cu ppm	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	1.83	4.22
	untreated	1.91	3.57
	significance at	n.s.[y]	0.05
B fall spray			
	490 ppm	--	3.92
	untreated	--	3.87
	significance at	--	n.s.
Rootstock			
	OAR-1	1.33c[z]	2.36c
	M7	2.41a	5.99a
	M26	1.75bc	2.77c
	M106	2.00ab	4.48b
	significance at	0.05	0.05
Interactions: not significant			

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 19

Influence of N and B treatments on fruit-B
of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Fruit-B ppm	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	16.95	31.27
	untreated	19.04	35.01
	significance at	n.s.[y]	0.05
B fall spray			
	490 ppm	--	34.90
	untreated	--	31.38
	significance at	--	0.05
Rootstock			
	OAR-1	25.25a[z]	38.68a
	M7	16.33b	30.93bc
	M26	14.41b	29.13c
	M106	16.00b	33.83b
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 20

Influence of N and B treatments on fruit-Zn
of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Fruit-Zn ppm	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	1.00	2.40
	untreated	0.96	2.26
	significance at	n.s.[y]	0.05
B fall spray			
	490 ppm	--	2.34
	untreated	--	2.33
	significance at	--	n.s.
Rootstock			
	OAR-1	0.78a[z]	2.06b
	M7	0.97a	2.64a
	M26	1.15a	2.33ab
	M106	1.01a	2.30b
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 21

Influence of N and B treatments on flower-N content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Flower-N % dry weight, Season: 1983
N		
	125 g N/tree	3.40
	untreated	3.40
	significance at	n.s.[y]
B fall spray		
	490 ppm	3.41
	untreated	3.39
	significance at	n.s.
Rootstock		
	OAR-1	3.39a[z]
	M7	3.40a
	M26	3.34a
	M106	3.47a
	significance at	0.05
Interactions: not significant		

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 22

Influence of N and B treatments on flower-K content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Flower-K % dry weight, Season: 1983
N		
	125 g N/tree	2.42
	untreated	2.38
	significance at	n.s.[y]
B fall spray		
	490 ppm	2.35
	untreated	2.45
	significance at	0.05
Rootstock		
	OAR-1	2.40a[z]
	M7	2.44a
	M26	2.41a
	M106	2.36a
	significance at	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 23

Influence of N and B treatments on flower-P content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Flower-P % dry weight, Season: 1983
N		
	125 g N/tree	0.59
	untreated	0.56
	significance at	n.s.[y]
B fall spray		
	490 ppm	0.57
	untreated	0.58
	significance at	n.s.
Rootstock		
	OAR-1	0.55b[z]
	M7	0.58b
	M26	0.63a
	M106	0.53c
	significance at	0.05
Interactions: not significant		

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 24

Influence of N and B treatments on flower-Ca content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Flower-Ca % dry weight, Season: 1983
N		
	125 g N/tree	5.43
	untreated	5.44
	significance at	n.s.[y]
B fall spray		
	490 ppm	0.54
	untreated	0.55
	significance at	n.s.
Rootstock		
	OAR-1	0.57a[z]
	M7	0.54ab
	M26	0.55ab
	M106	0.51b
	significance at	0.05
Interactions: not significant		

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 25

Influence of N and B treatments on flower-Mg content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Flower-Mg % dry weight
Main	Application	Season: 1983
N		
	125 g N/tree	0.32
	untreated	0.31
	significance at	n.s.[y]
B fall spray		
	490 ppm	0.31
	untreated	0.32
	significance at	n.s.
Rootstock		
	OAR-1	0.32ab[z]
	M7	0.32ab
	M26	0.35a
	M106	0.29b
	significance at	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 26

Influence of N and B treatments on flower-Mn content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Flower-Mn ppm Season: 1983
N		
	125 g N/tree	31.80
	untreated	30.20
	significance at	n.s.[y]
B fall spray		
	490 ppm	30.41
	untreated	31.59
	significance at	
Rootstock		
	OAR-1	35.44a[z]
	M7	29.55b
	M26	32.27ab
	M106	26.75b
	significance at	0.05
Interactions: not significant		

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 27

Influence of N and B treatments on flower-Fe content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Flower-Fe ppm, Season: 1983
N		
	125 g N/tree	113.57
	untreated	110.47
	significance at	n.s.[y]
B fall spray		
	490 ppm	111.70
	untreated	112.34
	significance at	n.s.
Rootstock		
	OAR-1	108.16b[z]
	M7	123.27a
	M26	111.49b
	M106	105.17b
	significance at	0.05

Interactions: not significant

[y] Not significant.

[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 28

Influence of N and B treatments on flower-Cu content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Flower-Cu ppm, Season: 1983
N		
	125 g N/tree	40.79
	untreated	38.27
	significance at	n.s.[y]
B fall spray		
	490 ppm	39.42
	untreated	39.64
	significance at	n.s.
Rootstock		
	OAR-1	25.54d[z]
	M7	57.46a
	M26	31.65c
	M106	43.46b
	significance at	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 29

Influence of N and B treatments on flower-B content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Flower-B ppm, Season: 1983
N		
	125 g N/tree	89.36
	untreated	92.68
	significance at	n.s.[y]
B fall spray		
	490 ppm	111.00
	untreated	71.03
	significance at	0.01
Rootstock		
	OAR-1	72.36c[z]
	M7	93.26b
	M26	112.24a
	M106	86.22bc
	significance at	0.05
Interactions: not significant		

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 30

Influence of N and B treatments on flower-Zn content of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Flower-Zn ppm
Main	Application	Season: 1983
N		
	125 g N/tree	51.10
	untreated	48.06
	significance at	n.s.[y]
B fall spray		
	490 ppm	50.20
	untreated	48.96
	significance at	n.s.
Rootstock		
	OAR-1	38.88c[z]
	M7	61.04a
	M26	50.79b
	M106	47.60b
	significance at	0.05
Interactions: not significant		

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 31

Analysis of pH, nutrients, and CEC[a] of the soil at different depths and treatments.

Sample Category	Depth (inches)	pH	NH_4^+-N[b] ppm	NO_3^--N[c] ppm	P ppm	K meq/100g soil	Ca meq/100g soil	Na meq/100g soil	Mg meq/100g soil	B ppm	Zn ppm	Cu ppm	Mn ppm	CEC meq/100g soil
Nitrogen + Boron	0-6	4.9	406.0	469.0	34	1.00	11.8	0.18	5.35	1.61	3.26	3.42	66.20	24.5
	0-18	5.5	65.3	153.0	18	0.65	13.5	0.26	0.63	0.93	1.64	3.44	28.00	24.3
	18-36	6.1	27.7	39.7	6	0.27	14.5	0.37	0.76	0.54	0.78	1.52	14.22	24.9
Nitrogen	0-6	4.6	238.0	200.0	30	1.05	9.3	0.16	4.60	0.58	2.34	8.02	71.00	21.4
	0-18	5.1	151.0	185.0	14	0.44	12.1	0.24	0.63	0.56	1.50	14.40	35.02	22.3
	18-36	6.3	16.9	16.1	5	0.17	13.1	0.49	0.65	0.18	0.60	1.48	9.78	21.5
Boron	0-6	6.6	10.3	6.3	24	1.24	14.0	0.16	3.02	1.23	0.68	2.00	8.86	25.0
	0-18	6.6	7.1	2.2	19	0.70	14.6	0.32	0.69	0.81	1.50	9.16	13.20	24.7
	18-36	6.7	4.7	1.4	5	0.19	13.3	0.43	0.71	0.44	2.84	53.20	10.72	23.6
Untreated	0-6	6.8	17.2	1.4	25	0.85	13.7	0.20	3.37	0.90	2.60	8.52	20.06	23.7
	0-18	6.6	6.2	0.5	16	0.52	13.8	0.28	0.70	0.61	1.34	3.66	12.56	23.8
	18-36	6.6	5.7	1.6	6	0.25	14.1	0.33	0.77	0.44	0.70	1.42	8.92	24.3

[a] Cation exchange capacity.
[b] Nitrogen measured as ammonium nitrogen.
[c] Nitrogen measured as nitrate nitrogen.

Table 32

Influence of N and B treatments on percent of bloom of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Percent of bloom (bloom/total growing points)	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	30.00	48.10
	untreated	31.00	47.41
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	48.10
	untreated	--	47.41
	significance at	--	n.s.
Rootstock			
	OAR-1	16.83c[z]	69.95a
	M7	27.83b	41.80b
	M26	47.66a	36.40b
	M106	29.66b	42.87b
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 33

Influence of N and B treatments on fruit set of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Fruit set/100 clusters	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	131.00	104.44
	untreated	120.37	99.68
	significance at	0.05	n.s.[y]
B fall spray			
	490 ppm	--	105.09
	untreated	--	99.04
	significance at	--	n.s.
Rootstock			
	OAR-1	120.58a[z]	65.36b
	M7	115.66a	105.29a
	M26	134.08a	125.89a
	M106	132.41a	111.72
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 34

Influence of N and B treatments on crop density of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Application	Crop density (fruit no/x-sectional area in cm^2) Season: 1982	1983
N			
	125 g N/tree	5.28	4.82
	untreated	5.97	5.15
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	5.40
	untreated	--	4.65
	significance at	--	n.s.
Rootstock			
	OAR-1	3.43c[z]	5.21a
	M7	5.09b	4.44a
	M26	9.46a	5.45a
	M106	5.03b	4.99a
	significance at	0.05	0.04

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 35

Influence of N and B treatments on yield in kgs/tree after hand thinning of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Yield (kgs/tree)	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	14.3	12.0
	untreated	13.2	11.9
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	11.9
	untreated	--	12.0
	significance at	--	n.s.
Rootstock			
	OAR-1	8.7b[z]	12.6ab
	M7	14.7a	10.7b
	M26	15.8a	10.9b
	M106	15.8a	13.4a
	significance at	0.05	0.05
Interactions: not significant			

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 36

Biennial bearing index (BBI)[1]
as influenced by N, B, and rootstock.

Treatment		Yield (kg/tree)		BBI
Main	Application	1982	1983	
N				
	125 g N/tree	14.3	12.0	9
	untreated	13.2	12.0	5
Rootstock				
	OAR-1	8.7	12.6	18
	M7	14.7	10.7	16
	M26	15.8	10.9	18
	M106	15.8	13.4	8

[1] After the procedure of Titus (1960) where BBI=(difference yields/sum yields) X 100.

Table 37

Influence of N and B treatments on fruit color of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		% of fruits with yellow color	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	60.00	57.70
	untreated	84.37	74.06
	significance at	0.05	0.05
B fall spray			
	490 ppm	--	65.52
	untreated	--	66.25
	significance at	--	n.s.[y]
Rootstock			
	OAR-1	88.75a[z]	62.92a
	M7	61.66b	64.58a
	M26	70.41b	65.83a
	M106	67.91b	70.21a
	significance at	0.05	0.05
Interactions: not significant			

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 38

Influence of N and B treatments on fruit weight of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Fruit weight (g/fruit) Season: 1982	1983
N			
	125 g N/tree	148	147
	untreated	136	148
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	144
	untreated	--	151
	significance at	--	0.05
Rootstock			
	OAR-1	131a[z]	128c
	M7	170a	155ab
	M26	135a	164a
	M106	132a	144b
	significance at	n.s.	0.05
Nitrogen - Boron interactions			
N-treated			
	B sprayed		140b
	unsprayed		155a
N-control			
	B sprayed		148ab
	unsprayed		147ab
	significance at	n.s.	0.05

[y] Not significant.

[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 39

Influence of N and B treatments on fruit diameter of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Fruit diameter (cm/fruit)	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	6.72	6.68
	untreated	6.79	6.62
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	6.55
	untreated	--	6.75
	significance at	--	n.s.
Rootstock			
	OAR-1	6.77a[z]	6.36bc
	M7	6.81a	6.81ab
	M26	6.73a	6.90a
	M106	6.71a	6.51b
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 40

Influence of N and B treatments on the percent of Starkspur Golden Delicious fruit showing bitter pit symptoms on four rootstocks.

Treatment		Percentage bitter pit	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	2.08	--
	untreated	5.00	--
	significance at	0.05	--
B fall spray			
	490 ppm	--	--
	untreated	--	--
	significance at	--	--
Rootstock			
	OAR-1	6.25a	--
	M7	2.50ab	--
	M26	1.25b	--
	M106	4.16ab	--
	significance at	0.05	--
Interactions: not significant			

[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 41

Influence of N and B treatments on fruit soluble solids of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Soluble solids (%)	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	10.85	11.57
	untreated	11.39	11.76
	significance at	0.05	n.s.[y]
B fall spray			
	490 ppm	--	11.59
	untreated	--	11.74
	significance at	--	n.s.
Rootstock			
	OAR-1	12.93a[z]	11.98a
	M7	10.51b	10.92b
	M26	10.40b	12.62a
	M106	10.64b	11.14b
	significance at	0.05	0.05

Interactions: not significant

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 42

Influence of N and B treatments on fruit firmness of Starkspur Golden Delicious apple trees on four rootstocks.

Treatment: Main	Treatment: Application	Fruit firmness (kg) Season: 1982	1983
N			
	125 g N/tree	5.74	7.90
	untreated	5.75	7.99
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	7.99
	untreated	--	7.90
	significance at	--	n.s.
Rootstock			
	OAR-1	6.04a[z]	8.23a
	M7	5.56c	7.76b
	M26	5.80b	7.80b
	M106	5.58bc	7.99ab
	significance at	0.05	0.05
Nitrogen - Rootstock interactions			
treated			
	OAR-1	5.85b	
	M7	5.71bc	
	M26	5.79b	
	M106	5.60bc	
untreated			
	OAR-1	6.23a	
	M7	5.40c	
	M26	5.80b	
	M106	5.55bc	
	significance at	0.05	n.s.

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 43

Influence of N and B treatments on seed production/fruit by Starkspur Golden Delicious apple trees on four rootstocks.

Treatment		Seed content (no. seeds/fruit)	
Main	Application	Season: 1982	1983
N			
	125 g N/tree	3.33	4.30
	untreated	3.61	4.40
	significance at	n.s.[y]	n.s.
B fall spray			
	490 ppm	--	4.30
	untreated	--	4.40
	significance at	--	n.s.
Rootstock			
	OAR-1	3.55ab[z]	4.57a
	M7	3.35ab	4.63a
	M26	3.77a	3.90b
	M106	3.21b	4.32ab
	significance at	0.05	0.05
Interactions: not significant			

[y] Not significant.
[z] Rootstock means followed by the same letter are not significantly different by Duncan's multiple range tests (Steele and Torrie, 1960).

Table 44

Significant linear correlation coefficients between mid-August leaf nutrients and October harvested Starkspur Golden Delicious apple fruits.

Correlated factors		r value	
Leaf nutrients	Fruit nutrients	1982	1983
N	N	0.60[z]	0.60[y]
P	N	-0.60	-0.46
K	N	-0.36	-0.26
Mg	N	0.31	0.30
Ca	Cu	0.29	0.23
Ca	B	-0.46	-0.21
Zn	Zn	0.48	0.42

[y] In 1983 n=96; r 0.28 or r -0.28 significant at 5% and r 0.36 or r 0.36 significant at 1%.

[z] In 1982 n=48; r 0.2 or r -0.2 significant at 5% and r 0.24 or r 0.36 significant at 1%.

Table 45

Linear correlation coefficients of yield and its components to other independent factors

Dependent factors	Independent factors	r value	
		1982	1983
yield	percent of bloom	0.62[z]	0.43[y]
yield	crop density	0.41	0.41
fruit set	percent of bloom	-0.31	-0.62
crop density	percent of bloom	0.83	0.39
yield	leaf N	0.32	0.23
percent of bloom	leaf N	0.12	0.30

[y] In 1983 n=96; r 0.28 or r -0.28 significant at 5% and r 0.36 or r -0.36 significant at 1%.

[z] In 1982 n=48; r 0.2 or r -0.2 significant at 5% and r 0.24 or r -0.24 significant at 1%.

Table 46

Linear correlation coefficients of fruit quality components as related to several factors

Fruit quality components	Independent factors	r value 1982	1983
Percent of yellow fruit	Leaf N	-.54[z]	-.40[y]
	Leaf P	.32	.21
	Leaf K	.46	.35
	Fruit N	-.41	-.21
Fruit weight	Fruit firmness	-.29	-.34
Fruit soluble solids	Leaf N	-.41	-.29
	Leaf P	.58	.25
	Leaf B	.35	.15
	Fruit N	-.54	-.36
	Fruit Ca	-.30	-.47
	Fruit P	-.33	-.22
	Fruit Mg	-.29	-.48
	Fruit Cu	-.40	-.44
	Fruit fe	-.34	-.30
	Fruit B	.59	.13
	Crop density	-.47	-.31
	Yield	-.73	-.27
Fruit firmness	Leaf Ca	-.51	-.41
	Fruit B	.50	.24
	Fruit Cu	-.32	-.24

[y] In 1983 n=96; r 0.28 or r -0.28 significant at 5% and r 0.36 or r -0.36 significant at 1%.

[z] In 1982 n=48; r 0.2 or r -0.2 significant at 5% and r 0.24 or r -0.24 significant at 1%.

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APPENDICES

Table 47

Linear correlations between leaf nutrients and yield components and fruit quality factors in 1982.

Leaf nutrients	% of bloom	Fruit set	Crop density	Yield kg/tree	% yellow fruit	Bitter pit	Fruit diameter (cm)	Fruit weight (g)	Soluble solids (%)	Seed content
N	.12[z]	.15	.02	.32	-.54	-.34	-.07	.09	-.41	-.29
P	-.18	-.38	-.12	-.30	.46	.41	.17	-.09	.58	.09
K	-.22	-.27	-.13	-.04	.32	.34	.33	0.0	.26	-.09
Ca	.44	.02	.35	.56	-.06	-.12	.04	-.07	-.49	-.10
Mg	.52	.18	.40	.25	-.23	-.39	-.04	.07	-.37	.20
Mn	.67	-.14	.57	.33	.06	-.12	-.12	.02	-.33	.11
Fe	.15	-.33	0.0	.09	.02	-.01	.04	.16	.13	-.08
Cu	-.06	-.08	-.08	.41	-.64	-.17	.04	.17	-.49	-.46
B	-.23	-.27	-.25	-.25	.35	.22	.06	-.01	.35	-.03
Zn	.48	-.13	.44	.58	-.22	-.21	0.0	-.06	-.48	-.10

[z] n=48; $r > 0.2$ or $r < -0.2$ significant at 5% and $r > 0.24$ or $r < -0.24$ significant at 1%.

Table 48

Linear correlations between fruit nutrients and yield components and fruit quality factors in 1982

Leaf nutrients	% of bloom	Fruit set	Crop density	Yield kg/tree	% yellow fruit	Bitter pit	Fruit diameter (cm)	Fruit weight (g)	Soluble solids (%)	Seed content
N	.19[z]	.10	.17	.42	-.42	-.42	-.03	-.02	-.54	-.15
P	.17	-.29	.28	.21	0.0	-.01	.05	-.18	-.33	.01
K	.36	-.32	.40	.44	-.15	-.17	-.17	-.09	-.44	.04
Ca	.22	-.06	.36	.16	.23	-.01	.12	-.13	-.30	.07
Mg	.26	-.13	.31	.33	-.20	-.15	.16	.04	-.29	.07
Mn	.13	-.06	0.0	.19	-.05	-.12	.01	-.05	-.18	.03
Fe	.18	0.0	.26	.25	-.10	0.0	.18	.06	-.34	.08
Cu	.03	-.14	0.0	.34	-.11	-.14	.07	.02	-.40	-.09
B	-.44	-.14	-.33	-.59	.27	.07	-.05	-.05	.59	.09
Zn	.15	-.02	.11	.22	-.20	-.13	0.0	-.17	-.28	-.10

[z] $n=48$; $r > 0.2$ or $r < -0.2$ significant at 5% and $r > 0.24$ or $r < -0.24$ significant at 1%.

Table 49

Linear correlations between leaf nutrients and yield components and fruit quality factors in 1983.

Leaf nutrients	% of bloom	Fruit set	Crop density	Yield kg/tree	% yellow fruit	Fruit diameter (cm)	Fruit weight (g)	Soluble solids (%)	Fruit firmness (kg)	Seed content
N	.30[z]	-.12	.24	.23	-.40	-.05	-.14	-.29	-.04	.10
K	-.30	.05	-.27	-.31	.21	.27	.39	.34	-.23	-.05
P	-.14	-.02	-.13	-.20	.35	.12	.25	.25	-.06	.03
Ca	-.33	.16	-.02	-.14	.09	.20	.47	.13	-.41	-.08
Mg	-.16	.08	0.0	-.19	-.13	.27	.36	.27	-.36	-.15
Mn	-.16	.11	.04	-.19	-.25	.20	.24	.24	-.23	-.14
Fe	-.09	-.03	-.16	.03	-.04	.32	.05	.04	.09	-.05
Cu	-.14	.13	-.03	-.10	.11	.17	.27	.15	-.03	-.04
B	0.0	-.18	-.15	-.17	.01	.02	0.0	.15	-.14	.10
Zn	-.08	0.0	-0.5	-.13	.03	.19	.27	.16	-.27	-.06

[z] n=96; $r > 0.28$ or $r < -0.28$ significant at 5% and $r > 0.36$ or $r < -0.36$ significant at 1%.

Table 50

Linear correlations between fruit nutrients and yield components and fruit quality factors in 1983.

Leaf nutrients	% of bloom	Fruit set	Crop density	Yield kg/tree	% yellow fruit	Fruit diameter (cm)	Fruit weight (g)	Soluble solids (%)	Fruit firmness (kg)	Seed content
N	-.09	.13	.04	-.05	-.21	.16	.10	-.36	-.20	.10
K	-.57	.41	-.25	-.22	-.05	.33	.46	0.0	-.24	-.13
P	-.16	-.02	-.15	-.02	.07	.12	.12	-.22	-.13	.05
Ca	.46	-.32	.14	.29	0.0	-.31	-.46	-.45	.10	.32
Mg	-.04	.04	.12	.02	-.17	.08	.07	-.48	-.22	.04
Mn	.17	-.11	.22	.05	-.22	-.08	-.15	-.39	-.04	.01
Fe	.19	.02	-.02	0.0	-.02	.65	.02	-.30	-.04	.09
Cu	-.31	.16	-.06	-.03	-.14	.16	.20	-.44	-.24	.08
B	-.01	-.03	-.23	-.17	.05	-.13	-.24	.13	.24	.07
Zn	-.08	0.0	-.16	.02	-.93	.06	.14	-.17	-.15	.11

z n=96; $r > 0.28$ or $r < -0.28$ significant at 5% and $r > 0.36$ or $r < -0.36$ significant at 1%.

Table 51

Linear correlations between flower nutrients and yield components and fruit quality factors in 1983.

Leaf nutrients	% of bloom	Fruit set	Crop density	Yield kg/tree	% yellow fruit	Fruit diameter (cm)	Fruit weight (g)	Soluble solids (%)	Fruit firmness (kg)	Seed content
N	-.26[z]	.09	-.17	-.22	.13	.05	.12	.13	-.08	-.05
K	.05	.05	0.0	.05	.06	.38	.13	.08	.05	.04
P	-0.3	.10	-.11	.01	0.0	.25	.15	.05	.19	-.27
Ca	.08	-0.8	-.20	-.01	.09	.31	0.0	.22	.21	-.14
Mg	.16	-.05	-.06	.11	.06	.33	.13	.16	.08	-.11
Mn	.47	-.29	.06	.20	-.01	.07	-.18	.14	.17	0.0
Fe	.03	0.0	-.13	.03	.10	.39	.12	0.0	.11	-.01
Cu	-.29	.18	-.13	0.0	.05	.31	.30	-.31	-.18	.06
B	-.32	.31	-.17	-.19	.04	.25	.28	.24	.07	-.20
Zn	-.13	.18	-.06	.04	-.02	.25	.14	-.15	.04	-.06

[z] n=96; $r > 0.28$ or $r < -0.28$ significant at 5% and $r > 0.36$ or $r < -0.36$ significant at 1%.

Table 52

Linear correlations between the same nutrients of leaf, fruit, and flower of Starkspur Golden Delicious apple trees in 1982 and 1983.

Nutrients	Leaf-fruit (1982)	Leaf-fruit (1983)	Leaf-flower (1983)	Fruit-flower (1983)
N	.60[z]	.60[y]	.15[y]	.05[y]
P	0.0	.22	-.05	-.09
K	.09	.25	-0.8	-.02
Ca	.31	-.15	-.07	-.08
Mg	.22	.16	.26	-.06
Mn	.05	.28	.13	-.03
Fe	-.01	.60	.31	.03
Cu	.34	.46	.76	.82
B	.15	.38	.05	.15
Zn	.48	.42	-.28	-.01

[y] n=96; $r > 0.28$ or $r < -0.28$ siginficant at 5% and $r > 0.36$ or $r < -0.36$ significant at 1%.

[z] n=48; $r > 0.2$ or $r < -0.2$ significant at 5% and $r > 0.24$ or $r < -0.24$ significant at 1%.

Table 53

Linear correlations between yield components and fruit quality factors in 1982.

	% of bloom	Fruit set	Crop density	Yield kg/tree	% yellow fruit	Fruit diameter (cm)	Fruit weight (g)	Soluble solids (%)	Fruit firmness (kg)	Seed content	Bitter pit
% of bloom	--	-.31	.83	.62	-.02	-.07	-.19	-.54	-.23	.21	-.28
Fruit set		--	-.17	-.20	-.13	-.08	.23	.07	.01	-.02	-.12
Crop density			--	.41	.01	-.17	-.19	-.47	-.22	.18	-.25
Yield				--	-.37	.02	-.15	-.73	-.49	-.20	-.32
% yellow fruit					--	.18	-.38	.44	.12	.29	.19
Fruit diameter						--	.08	.17	-.29	.11	.14
Fruit weight							--	.01	.03	-.01	-.09
Soluble solids								--	.46	.03	.41
Fruit firmness									--	.06	.02
Seed content										--	-.08
Bitter pit											--

Table 54

Linear correlations between yield components and fruit quality factors in 1983.

	% of bloom	Fruit set	Crop density	Yield kg/tree	% yellow fruit	Fruit diameter (cm)	Fruit weight (g)	Soluble solids (%)	Fruit firmness (kg)	Seed content
% of bloom	--	-.62	.39	.43	-.02	-.34	-.55	-.32	.19	.32
Fruit set		--	0	-.14	.06	.07	.20	.14	-.04	-.19
Crop density			--	.41	.02	-.37	-.35	-.31	.11	.12
Yield				--	.10	-.21	-.37	-.27	.07	.23
% yellow fruit					--	.01	-.10	.09	-.04	0
Fruit diameter						--	.64	.10	-.34	-.01
Fruit weight							--	.38	-.41	-.25
Soluble solids								--	-.08	-.37
Fruit firmness									--	.03
Seed content										--