EFFECTS OF CERTAIN MANAGEMENT PRACTICES ON NUTRIENT STATUS OF HIGHBUSH BLUEBERRY PLANTS ON ACID SPHAGNUM PEAT

by

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ABSTRACT

Field experiments designed to reveal the effects of certain management practices and fertilizer applications on the nutritional status of highbush blueberries (Vaccinium corymbosum) were conducted during the summer of 1967. The concentration of N and Ca in the leaf tissue of plants receiving general grower care are similar to Ballinger's estimated deficiency levels while that of Mn was very high. Mn levels were higher in plants growing on the highly decomposed peats. The application of N or NPK increased the concentration of these individual elements. Increases in N appeared to depress the uptake of Mg and encourage the utilization of P. Certain management practices improved nutrient utilization especially under the high fertilizer treatment regime. A negative correlation existed between N and growth ratings in 2 of the 3 experiments. There was no indication that herbicides reduced the uptake of nutrient elements. The leaf levels of the cations Mg, Ca and Mn all declined as the yield increased.

Soil temperature and moisture levels were consistently greater in hoed and herbicide treated plots than in mowed plots.

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INTRODUCTION

The highbush blueberry *Vaccinium corymbosum* is a fruit crop which is growing in importance in British Columbia. In 1959, there were 700 acres of plants of producing age. By 1967, this has increased to well over 1,000 acres. Most of the plantings are situated in Richmond on acid sphagnum peat bogs (pH 3.2 - 3.8) that have had 4 - 6 feet of fibrous peat commercially harvested before planting. The remaining 3 - 4 feet of peat covers a gray clay. The top 12" - 18" of this is usually a fibrous type of peat while that remaining is of a highly decomposed type. Most growers prefer to plant in the layer of fibrous peat, but there are some large plantings on the highly decomposed type. The site of these plantings is usually low and, as a result, poorly drained.

Nutritional problems of plants growing on peat soils are different from those encountered on mineral soils. Most of the research has been done on the mineral type soils (19, 33). Cain (12), and Amling (1) have carried out research in the greenhouse in sand culture. While this research has been done under controlled conditions, their results cannot be applied directly to the field. Black *et al.* (11) found that peat soils varied considerably in their nutrient content and according to Voznyuk (54) in their availability of nitrogen. Therefore, nutrient studies on diversified peat soils are desirable. Childers (14) reported that data on micro nutrients: Fe, Mn, Zn, Cu and B are not adequate to establish critical levels.

The use of leaf analysis as both a research and diagnostic tool in the field of fruit nutrition has become increasingly wide-spread. In evaluating leaf analysis results, many factors affecting nutrient status must be considered. Archibald (3), for example, reported a significant effect of season on nutrient content in the foliage of peach, apple, pear, and sour cherry trees and grape vines. In some blueberry growing areas deficient and desirable ranges of nutrient concentrations within the foliage have been suggested (7). These ranges aid growers in interpreting leaf analyses from their own plantings and provide a basis for efficient use of fertilizer. In order to establish such ranges, several years of data under various management practices and seasonal variation must be recorded. A survey of blueberry plantings by Herath et al. (24) is a beginning for British Columbia.

Beckwith et al. 1939 (10) reported that clean cultivation for the 4-month period starting in mid-April stimulated bush growth and crop production. Archibald and Bradt (2) working on peaches found that hay mulch resulted in similar and highly significant increases in rate of growth, yield and leaf content of N and K.

Dancer (16) recorded that regular close mowing of grass beneath trees in a sod may avoid or minimize the grass-tree competition for N. Control of competition from weeds may release more nutrient for the plant to utilize. According to Klingman (31) weeds commonly found in corn fields contained in their dried tissues an average of twice as much N, 1.6 times as much P, 3.5 times as much K, 7.6 times as much Ca and 3.3 times as much Mg as did corn itself.

A number of researchers have evidence that herbicides themselves contribute to the uptake of nutrients. How this is done is not yet understood. Renney (44) found simazine and diuron increased protein content of wheat. Ries *et al.* (45) postulated that simazine had increased N content of apple and peach leaves. Recent work by Freney (21) showed that by adding 0.06 p.p.m. of simazine to a nutrient solution the concentration of N, P, K and Mg increased by 37, 25, 41, and 24% respectively. Yields of corn leaves were also increased.

Most blueberry plantations in British Columbia are under a sod system. This system is employed to reduce root injury by cultivation on this shallow rooted plant (14) and to enable the movement of equipment. As plantings mature, control of weeds with equipment that moves through the rows at harvest often results in damage to the fruit. For these reasons long residual control of weeds directly under the bush, with herbicides is a fitting management practice. This non-cultivation technique is not only practical in that it allows movement of machinery between the rows on a sod strip for spraying etc., but it has many other worthwhile benefits. The more important of these are: yield increases (49, 53), decreases in water loss (52), increases in water infiltration in some cases (47), labor saving (34), and may contribute to the nutrient concentration in the plant as mentioned above.

Objectives of this study include: (a) An examination of nutrient concentrations in the foliage under conditions in British Columbia compared with other blueberry producing areas, (b) an effort to interpret the results of these tissue analyses based on research findings of other workers, (c) a study of the nutritional and yield responses of the plant under a number of specific management practices, (d) a brief examination of the influence of these management practices on the environmental factors of soil temperature and moisture.

MATERIALS AND METHODS

Field experiments were conducted on commercial plantings of highbush blueberries both in Richmond and at Pitt Meadows, B. C. The experiments were numbered according to location as follows; Experiment I, Northern Peat Co. Ltd., No. 8 Road, Richmond, B. C.; Experiment II, Lulu Island Peat Co. Ltd., No. 7 Road, Richmond, B. C. and Experiment III, Blueboy Blueberry Co. Ltd., Pitt Meadows, B. C. At each location uniform plants of the variety Bluecrop were selected.

Procedures common to all experiments are described below. Those which were specific to experiment I, II, III will be explained under the appropriate heading.

Chemical Analysis: Forty leaves from the middle third of vegetative shoots directly below a fruiting cluster were collected from all sides of the bush. These samples, collected on July 16 or 17, were dried for 72 hours in a 70°C oven in the laboratory, then held at 105°C for 12 hours.

A porcelain mortar grinder made for the Torsion Balance Co. of Clifton, New Jersey by F. Kurt Retsch, Model M62 was employed to grind samples until they were fine enough to pass through a 20 mesh screen. Approximate grinding time for a 40-leaf sample was about eight minutes. The samples were then stored in tightly sealed 2-ounce glass jars with screw-on bakelite tops.

The Mettler, type H 16 balance was used to weigh out portions of the ground sample for chemical analysis. All such portions were weighed to 0.01 Mg.

Total N was determined by the semi-micro kjeldahl procedure, P was determined colorimetrically by the phosphomolybdate method of Dickman and Bray (18). Atomic absorption spectrophotometry was used for the determination of Ca, Mg, Mn, and Fe. The atomic Absorption Spectrophotometer Model 140 EEL was the instrument used. This same machine, with an emission adaptor, was used to determine K by flame emission.

To prepare samples for analysis by the atomic absorption spectrophotometer and for phosphate-molybdate determination, the wet digestion method of Chapman and Pratt (13) was followed. The digestion mixture consisted of 750 ml concentrated nitric acid, 150 ml of concentrated sulphuric acid and 300 ml of 60% perchloric acid. This mixture was diluted by 50% and 40 ml of the diluted digestion mixture was gently added to a 125 ml beaker containing about 1 gm of ground sample. This was slowly heated to boiling on a hot plate under a fume hood. After approximately 10 hours the volume was reduced to a clear liquid, approximately 2 - 4 ml. This was washed with hot distilled water into a 100 ml volumetric flask and made up to 100 ml by adding cool distilled water. This extract was transferred to new nalgene containers with tightly fitting screw-on tops.

<u>Determination of Mineral Element Concentration</u>: The atomic absorption method uses the "ground state" principle in measuring the concentration of mineral elements. Atoms of a particular element at ground state are able to absorb light of their own wave length.

The atomic absorption spectrophotometer is composed of the following principal parts:

1. A source of compressed air and acetylene which provides the flame.
2. An atomizer which sucks up liquid and atomizes it in the flame.
3. A chamber for attaching a hollow cathode source lamp that generates a wave length of light common to the element from which it is made.
4. A meter which measures the amount of light which passes through the flame.
5. A recorder, model PS01WGA, which physically sets down the meter measurements.

When the atomizer sucks up distilled water no light from the hollow cathode lamp is absorbed. The recorder reading is zero or should be adjusted to zero. This constitutes the base line. Any light absorbed by unactivated atoms from a given sample will give readings above the base line. The absorption of light at a specific wavelength for each metal by the unactivated atoms is proportional to its concentration in the sample solution.

For each element, standard solutions were prepared of varying concentrations. These were run before and after every fifty sample extracts. This enabled the computation of a regression line which became the standard curve. Using the standard curve a computer program was written which calculated the PPM of an element in the sample extract. (An example of the computer program can be found in Table 15). It was found that Ca, Mg and Mn did not provide a linear response. Therefore log transformations were used to make a linear standard curve. There was no need to transform the values for P, K, and Fe.

No adjustments were made for interference of one element on another. The concentrations were believed to be too low to cause serious interference. Even for Ca the P interference was believed to be negligible. Heeney et al. (23) suggest that P interference was most pronounced when P levels were greater than 0.3 per cent. The P concentration in these samples averaged about 0.1%.

Samples for Mg determination were diluted by taking a 2 ml aliquot of sample extract and making it up to 50 ml. This enabled the machine to detect Mg levels within the most desirable range. For other elements the extracts were undiluted. Machine parameters for each element are given in Table 16.

As a test on possible contamination each group of samples prepared contained a "blank". When blanks were inserted in the machine zero or very near zero readings were obtained. This enabled sample readings to be taken directly. To examine repeatability of results duplicate readings from the same sample were run periodically. These corresponded very closely in all cases.

N, P, K, Ca and Mg were expressed in percent of oven dry weight. Mn and Fe were expressed in parts per million of oven dry weight.

Soil Temperature: Soil temperature measurements were obtained at various times during the early growing season. Temperatures were obtained with a Thermistemp Model 425L Serial No. 2990 YSI* and a model 418 12-inch metal probe. In taking a measurement the probe was inserted on the south-east side of each bush at about one foot from its base. The probe was inserted first to 3 inches and then to 6 inches, taking a reading after a period of 90 seconds at each depth.

Soil Moisture: This was determined by the gravimetric method. A stainless-steel soil-sampling tube served to remove a 4 x 3/4 inch core of soil which was taken at a

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*Yellow Springs Instrument Company Inc. Yellowspring, Ohio.

point one foot from the base of the plant. The soil was placed in 3-ounce seamless tin boxes, style No. 201 from the Buckeye Stamping Co., Columbus 7, Ohio, then taken directly to the laboratory where the sample was weighed. The samples were then placed in an oven at 105°C. The lids were removed and samples dried to a constant weight then weighed again. The results were expressed as grams of moisture per gram of dry peat.

To test soil pH one composite sample from the whole test area was randomly collected for each experiment. Each individual sample was obtained by inserting the soil sampler to a depth of 3 inches then removing the core of soil. In experiment I and II sampling was done in mid-July, in experiment III it was carried out in September.

Weed Growth Ratings: The treated area under each bush was rated on the basis of competing weeds. The general area was observed closely for weed growth of all sorts. A plot having a high population of a small slow growing weed such as sheep sorrel would not receive as high a rating as one with a high population of a weed such as bracken fern, *Pteridium aquilinum*. The rating then depended on both ground cover and vegetative density. A rating of zero meant no growth, one of ten meant very dense growth.

Statistical Analysis: Analysis of variance was carried out on concentrations of leaf nutrient elements, soil temperature, soil moisture, and yield data from experiment III.

Duncan's New Multiple Range Test as described by Li (36) was used to test differences among means.

Cluster counts provided the covariate for covariance analysis on yield in experiment I.

A regression analysis using nutrient elements and soil moisture as variables was carried out. In experiment II and III fruit size and yield were also included while ripe fruit was used as a variable in experiment I only. These regression analyses are presented as a correlation matrix for each experiment in Tables 19, 20 and 21. The dates July 1, 9, 12 and September 27 refer to the dates on which weed growth ratings were recorded.

In Figures 2, 3, 4, and 5, means of the same element sharing the same letter were not significantly different at the 5 per cent level.

Experiment I: On this site in 1962, two-year-old nursery plants were set out in rows running east and west. The spacing employed was 5 feet in the row and 10 feet between the row. Rows were numbered starting on the south side with number one. Plants varied greatly in the size and number of fruiting shoots and vegetative one-year-old shoots. As uniform plants as possible were selected from rows five and eleven. Compared to other plantings, most of these bushes appeared to lack vigor when examined during the dormant season. During the growing season, however, growth was vigorous and the planting appeared healthy.

The site is very low and poorly drained. At times during the winter many areas of the planting were covered with 3 to 4 inches of water.

The soil is a sphagnum peat soil of a fibrous nature to a depth of 12 to 18 inches and of a highly decomposed type to a depth of about 2 feet. The pH of this soil was 3.15.

The weed population on this site was more dense than on any other field examined. Large populations of sheep sorrel, Rumex acetosella and hardhack, Spiriea douglasii were common around each bush. Coarse grasses common in swamps were also found.

An examination of the grower's past fertilizer practices revealed the following:

Year	Formulation	Rate
1964	4-10-10	200 lb/A
1965	10-20-10	300 lb/A
1966	10-20-10	400 lb/A
1967	2-15-15	1000 lb/A

In early May a 4-foot rotary power hose was used between the rows. The plantation was mowed with a portable power brush cutter early in June and again in mid-July.

Treatments included two applications of paraquat at 2 lb/A. These were applied on May 6th and July 1st by a hand operated sprayer. The second treatment was the mowing treatment carried out by the grower as described above.

The experimental design was a randomized complete block design with 2-plant plots. The subdivision of degrees of freedom, and error mean squares for each nutrient element are included in Tables 17 and 18.

Experiment II: Over a period of years, 4 to 5 feet of fibrous peat had been removed from this site. The remaining 12 to 18 inches of peat was of a highly decomposed type that tends to cake when dried. This peat covered a grey clay. Before planting a land breaking plow was employed to plow the site to a depth of 16 to 18 inches. As a result some areas of the field had a lot of clay mixed with the peat.

This planting was set out in 1964 with rows running north and south. Three adjacent rows approximately forty feet from a drainage ditch were chosen. The planting had grown poorly since its inception. For the first three years weeds were allowed to grow until mid-summer when they were mown once. This year the planting was mown five times.

Growth and general vigour improved this season but many plants still lack vigous (Figure 1). Also evident in Figure 1 is the dense cover of Velvet Grass Holcus lanatus and Sheep Sorrel.

Figure 1. General view of plantation showing close mowing, unselected poor plant, ground cover, and some plots.

During the winter months the site appeared poorly drained as low areas in the field tended to fill with water. As the growing season progressed the planting became very dry compared to experiments I and III. An attempt to sub-irrigate was begun on July 1st. A pump was used to pump water into the ditches in an effort to raise the water table. It took until July 14th to flood the planting. The water was allowed to recede through percolation and evaporation.

Each year the plants received approximately 4 - 5 ounces of 13-16-10/bush or about 310 lbs/A. In 1967 the plants received 4 to 5 ounces of 2-15-15/bush or about 310 lbs/A.

Two by four factorial treatments were arranged in a randomized complete block design. Uniform two-plant-plots were selected.

The first factor included 2 fertilizer regimes. One was the general grower practice of applying approximately 6 pounds of actual N/A. The source of this nitrogen was the ammonium fraction of ammonium phosphate (NH_4PO_5) in the 2-15-15. The other as an application of 120 pounds of actual N/A in addition to the 2-15-15. The nitrogen source for this high nitrogen regime was ammonium sulphate (NH_4SO_4). These were applied May 24th. No additional phosphorus or potassium was applied.

The second factor in the experiment included 4 weed control regimes as follows.

1. About March 14th the plants were hoed. At this time only a one foot radius around the bush was hoed to about a 3 inch depth. Sheep sorrel and some velvet grass was removed at this time. About May 10th the plots were hoed again but this time an area of 2.5 feet in the

row by 2 feet between the row on each side was hoed. This involved an area of about 20 sq. feet/bush or 40 sq. feet/plot.

2. Paraquat was applied on May 20th and June 16th at two pounds active ingredient per acre in 100 gallons of water/A.

3. Paraquat plus simazine was applied on May 20th with a hand sprayer at 2 pounds/A paraquat active ingredient plus 4 pounds/A simazine active ingredient in 100 gallons of water per acre. Herbicide plots were the same size as the hoed plots.

The herbicide was applied at 6 a.m. when there was no spray drift. A one-gallon hand-sprayer was used to apply the material.

4. Mowed plots which served as "checks" received the same care that the grower gave to the rest of his planting. This involved mowing with a "Woods" power take-off rotary mower attached to a tractor. A small "tractor-type" grass mower was used to mow between the bushes. Plots were mown in early May, early June, late June, mid-July and again in mid-August. The mower was set at 1 - 2 inches above the ground.

The subdivision of degrees of freedom and error mean squares for each nutrient element are included in Tables 17 and 18.

The number of flower clusters was small but varied considerably on this young planting, as nutrient concentration of the foliage is believed to be affected by yield this source of variation was eliminated by removing all blossoms and fruit by June 10th. In 1966 the grower removed all fruit as a means of encouraging vegetative growth.

Experiment III: Prior to planting in 1958, about 3 - 4 feet of fibrous peat was removed from this site. About eight feet of peat remains over a white clay. The top 1 to 2 feet is a fibrous type of peat; the remainder is highly decomposed. At this time the planting site was mounded in the center by scraping peat from near the drainage ditches, along the sides, toward the center. The site is well drained but appeared to retain ample moisture during the summer.

Two-year-old plants were set out in rows running north and south with rows 4, 6 and 9 being used, counting from the east side. Row six was on top of the mound and row nine the lowest, being close to the ditch. It was observed that the bushes in row nine lacked vigour compared to bushes in the other two rows.

Pruning was heavy in 1966 because the grower required additional shoots which were used as hardwood cutting for propagation.

General plant growth and yield of the plantation were good.

Weed cover was generally medium in this experiment compared to the others. There was however much more bracken fern in this site. Since the bushes were larger, considerable shading discouraged some grasses and sheep sorrel which made up the rest of the ground cover.

From 1962-66 a 2-15-15 formulation at 6 - 8 oz/plant was applied each year.

Two by four factorial treatments were arranged in a randomized complete block design. Uniform two plant plots were selected.

The first factor included 2 fertilizer regimes. One was an application of 2-15-15 at 0.6 pounds/bush, the other was 2.6 pounds of 2-15-15 plus 0.3 pounds of ammonium sulphate (NH_4SO_4)/bush. This provided a total of 120 pounds of actual N/A.

The second factor in the experiment included 4 weed control practices as follows.

1. Two applications of paraquat at a rate of two pounds active ingredient/A were applied on May 10th and June 14th. These were applied with a hand sprayer in a mixture of 100 gallons of water/A.

2. Dinoseb was applied with a commercial sprayer on May 25th at a rate of two pounds active ingredient in 100 gallons of water/A.

3. Paraquat was applied as in treatment one plus simazine at a rate of 2 pounds of active ingredient/A.

4. This treatment involved the normal mowing practice carried out by the grower. In early June mowing was done with a power rotary mower. In early July the planting was mowed by hand as too much fruit damage would be incurred if the planting were machine mowed.

All treatments were applied to an area of 2 1/2 feet on either side of the bush in the row and 2 feet on the sides of the bush between the row.

The subdivision of degrees of freedom and error mean squares for each nutrient element are included in Tables 17 and 18.

The total weight in ounces of fruit at each picking was recorded. Size records were obtained by counting the number of berries in a standard sample-cup, a small number of berries per cup indicating large berry size.

RESULTS

Experiment I

Nutritional Studies: Statistical analysis of nutritional concentrations within the foliage indicated that treatments had no significant effect on N, P, K, Ca, Mg, Mn and Fe. Error mean squares for these elements may be found in Table 18.

Table 1. Nutrient Element Concentration in the Foliage

	% oven dry weight					PPM	
	N	P	K	Ca	Mg	Fe	Mn
Paraquat	1.80	.14	.73	.16	.35	.79	632
Mowed	1.74	.14	.69	.16	.36	175	595

Correlation analyses of nutrient elements, weed growth rating, soil moisture, total weight of fruit harvested, weight of ripe fruit and fruit size are presented in a correlation matrix (Table 19).

Yield Studies: It was found that a highly significant correlation (r^2 = .57, 22 degrees of freedom) existed between cluster number and total fruit weight.

To obtain a true picture of the effect of treatment on yields, the yields were adjusted through the use of covariance analysis. Results of this test revealed no significant effect of treatment on total weight of fruit.

Table 2. Effect of Treatment on Yield

	Total Oz./Bush
Paraquat	77.6[a]
Mowed	78.1[a]

The number of clusters varied considerably from one bush to another (Table 3).

Table 3. Number of Clusters in Replication 3

Replication	Bush	Treatment	Number of Clusters
3	1	Paraquat	219
3	2	Paraquat	157
3	1	Mowed	192
3	2	Mowed	311

Soil Temperature Studies: Soil temperatures were obtained on May 9th, May 20th and July 1st. It required approximately 2 hours to take the 24 readings at each depth.

On May 9th treatments had no significant effect on temperature at the 3-, 6- or 12-inch depths. There were, however, significant differences among these levels. A significantly higher temperature was recorded at the

12 inch depth than at the 6 inch, and at the 6 inch depth than at the 3 inch depth.

On May 20th, soil temperatures were significantly higher at each of the three, six and twelve inch depths in the paraquat than in the mowed plots. Similar results were recorded at each of the temperature readings periods which began at 10 a.m., 2 p.m. and 6 p.m. Temperatures were significantly higher at the 6 p.m. period when compared to the other periods.

On July 1st, soil temperatures were significantly warmer in the paraquat plots than in the mowed plots at the 3 and 6 inch depth.

Table 4. Average Soil Temperature at Various Depths and Dates.

	Temperature °C		
Date and Treatment	Depth 3"	Depth 6"	Depth 12"
May 9			
Paraquat	9.88[a]	10.57[b]	10.87[c]
Mowed	9.88[a]	10.63[b]	10.73[c]
May 20			
Paraquat	16.16[a]	14.14[c]	12.47[e]
Mowed	15.08[b]	13.58[d]	12.06[f]
July 1			
Paraquat	21.00[a]	17.80[c]	--
Mowed	18.83[b]	16.51[d]	--

<u>Soil Moisture Study</u>: There was no significant difference between treated and untreated plots on May 20th. The highest level of moisture for any one block was 4.29 grams of water per gram of peat. The lowest was 3.20 grams of water per gram of peat.

On July 1st moisture levels had dropped to a high of 2.69 grams of water per gram of peat compared to a low of 1.99 grams of water per gram of peat. Even though precipitation at the field laboratory, University of British Columbia in June was 1.79 and 0.54 inches in 1966 and 1967 respectively there was no significant difference in moisture levels between treatments.

<u>Experiment II</u>

<u>Nutritional Studies</u>: Concentrations of nutrient elements in plants exposed to the various treatments are graphically presented in Figures 2 and 3.

Under the low fertilizer regime, the concentration of N in the foliage of plants receiving herbicide and hoeing treatments were not significantly higher than in plants receiving the mowing. Under the high fertilizer regime, however, hoed plants contained significantly more N than plants exposed to other treatments. Comparing results under the high and low fertilizer regimes, plants under the hoed and mowed treatments showed significant increases in N under the high fertilizer application.

In both high and low fertilizer regimes, plants receiving the hoed treatment contained significantly higher P in their leaves than plants under other treatments. Under the high fertilizer regime plants receiving the paraquat plus simazine treatment contained significantly more P than did plants treated with paraquat only. Increasing the fertilizer application resulted in no significant increase in P in any treatment.

Under the low fertilizer regime there was no significant effect of treatment on K levels. Under the high fertilizer regime leaf tissue samples from bushes in the hoed plots contained significantly more K than samples from the paraquat plus simazine and mowed treatments but not significantly higher than the paraquat only treatment. Leaf tissue samples from plants treated with paraquat alone under this N regime contained significantly more K than did samples receiving the paraquat plus simazine treatment. Plants exposed to the paraquat plus simazine treatment contained significantly higher levels of K under the low fertilizer regime compared to the high fertilizer regime.

Mg levels were significantly higher in leaf tissue samples from bushes in the mowed plots under the low fertilizer regime than those exposed to any other treatment under either low or high fertilizer regimes.

Among the several weed control treatments, Ca was significantly influenced by fertilizer regime only where paraquat alone was applied. Here high fertilizer application decreased Ca.

Treatments designed to reduce weed competition had no significant effect on concentrations of Mn and Fe in the foliage.

The average concentrations of N and Ca in leaf tissue samples from bushes exposed to weed control treatments were the only elements significantly affected by the fertilizer regimes (Table 5). N was significantly higher in the high fertilizer treatment while Ca was significantly higher in the low fertilizer regime.

Table 5. Effect of Fertilizer Regime on Average Nutrient Concentration

	(Percent oven dry weight)					PPM	
	N	P	K	Ca	Mg	Fe	Mn
High Fertilizer	1.71[a]	.10[a]	.58[a]	.15[b]	.22[a]	210[a]	648[a]
Low Fertilizer	1.49[b]	.10[a]	.61[a]	.16[a]	.23[a]	204[a]	673[a]

Means of the same nutrient element sharing the same letter are not significantly different at the 5 percent level.

EFFECTS OF MANAGEMENT ON % N,P,K,Ca, and Mg

Low Fertilizer

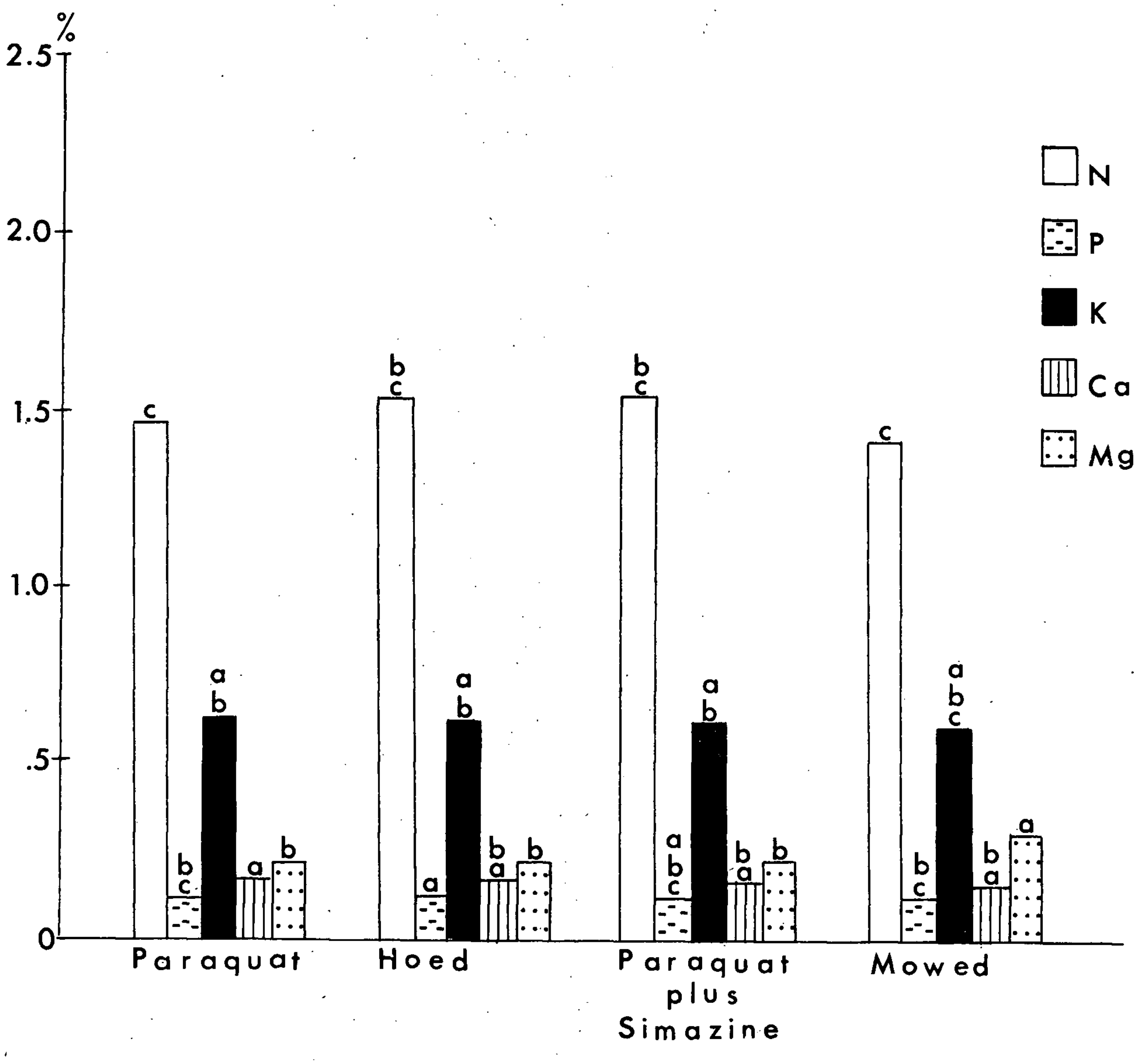

Fig. 2

EFFECTS OF MANAGEMENT ON % N, P, K, Ca, and Mg

High Fertilizer

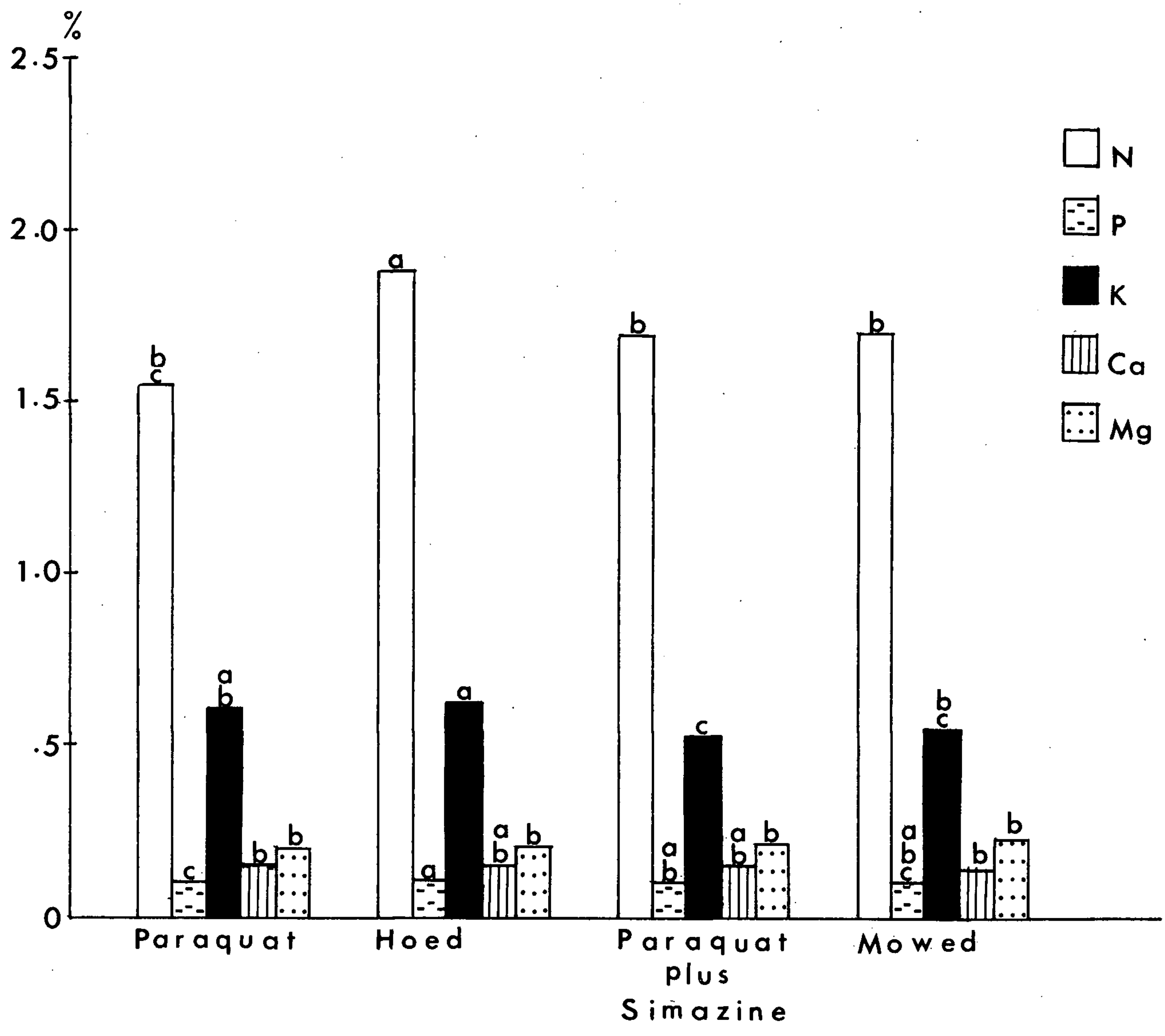

Fig. 3

Correlation analyses on nutrient elements, weed control ratings, and soil moisture are presented in a correlation matrix (Table 20).

Soil Temperature Studies: Plots receiving the herbicide or hoed treatments were significantly warmer on June 3rd at the three inch level than mowed plots (Table 6). Paraquat plus simazine treatments resulted in the highest soil temperature but was significantly warmer than only the paraquat alone and the mowed treatments. Also the treatments exposed to the high fertilizer regime were significantly warmer than treatments under the low fertilizer regime.

Table 6. The Effect of Weed Control Treatments on Average Soil Temperature at the Three Inch Level on June 3rd.

Treatment	Soil Temperature °C
Paraquat	17.0[b]
Hoed	17.2[ab]
Paraquat + simazine	17.3[a]
Mowed	16.4[c]

Means sharing the same letter are not significantly different at the 5 percent level.

Moisture Studies: On May 24th the hoed plots under the low fertilizer regime contained significantly more moisture than the mowed plots (Table 7).

Under the high fertilizer program herbicide and hoed plots contained significantly more moisture than did the mowed plots on June 25th. Under the low fertilizer regime hoed plots contained significantly more moisture than did plots subjected to any other treatment. Applications of fertilizer were associated with moisture levels in the paraquat alone and in the paraquat plus simazine plots. The moisture was significantly higher under the high fertilizer regime.

By July 13th, differences in moisture, with respect to treatment, under the high fertilizer program had not changed. Under the low fertilizer program, the paraquat only and the paraquat and simazine treated plots contained significantly less moisture than plots subjected to the other treatments.

Soil moisture levels under the high fertilizer regime were significantly higher compared to the low fertilizer regime in all but the mowed treatments.

Table 7. Effect of Treatment and Fertilizer Regime on Soil Moisture

Soil moisture in grams water/gram peat

Fertilizer Regime	DATE May 24 High	Low	June 25 High	Low	July 13 High	Low
Treatment						
Paraquat	1.91[a]	1.83[ab]	1.30[a]	0.83[b]	1.13[a]	0.89[c]
Hoed	1.87[a]	2.08[a]	1.31[a]	1.34[a]	1.03[b]	0.88[c]
Paraquat + Simazine	2.00[a]	1.76[ab]	1.30[a]	0.81[b]	1.14[a]	0.68[d]
Mowed	1.64[ab]	1.44[b]	0.83[b]	0.73[b]	0.89[c]	0.90[c]

Means on one date sharing the same letter are not significantly different at the 5 percent level.

Experiment III

Nutritional Studies: Concentrations of nutrient elements in plants exposed to the various treatments are graphically presented in Figures 4 and 5.

Under the low fertilizer regime leaves from bushes in the paraquat plots contained significantly more N than those mowed by the grower. The other herbicide treatments did not differ significantly from the mowed plots. Plants growing in the paraquat treated plots under high fertilizer contained the highest concentrations

EFFECTS OF MANAGEMENT ON % N, P, K, Ca, and Mg

Low Fertilizer

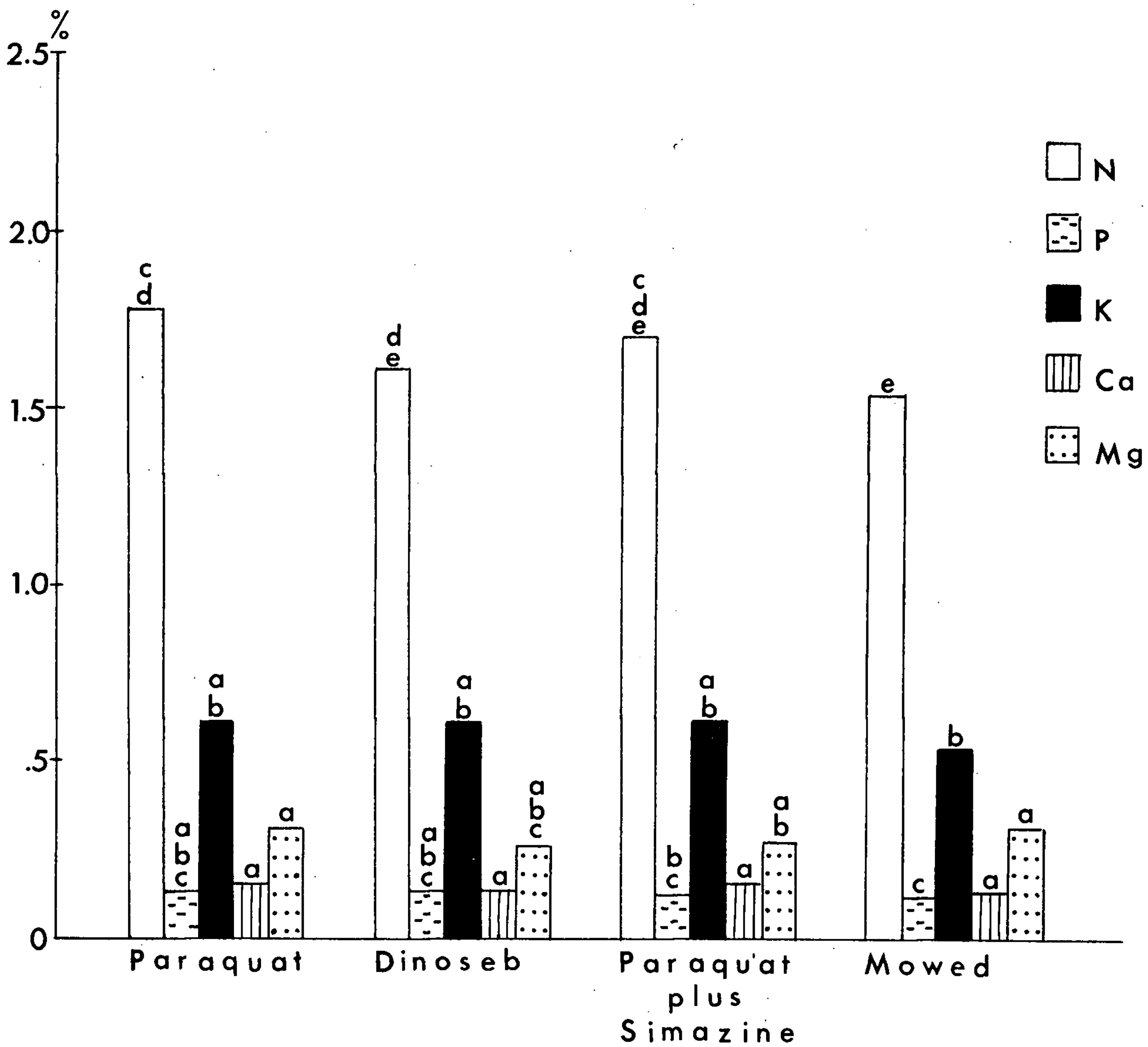

Fig. 4

EFFECTS OF MANAGEMENT ON % N, P, K, Ca, and Mg

High Fertilizer

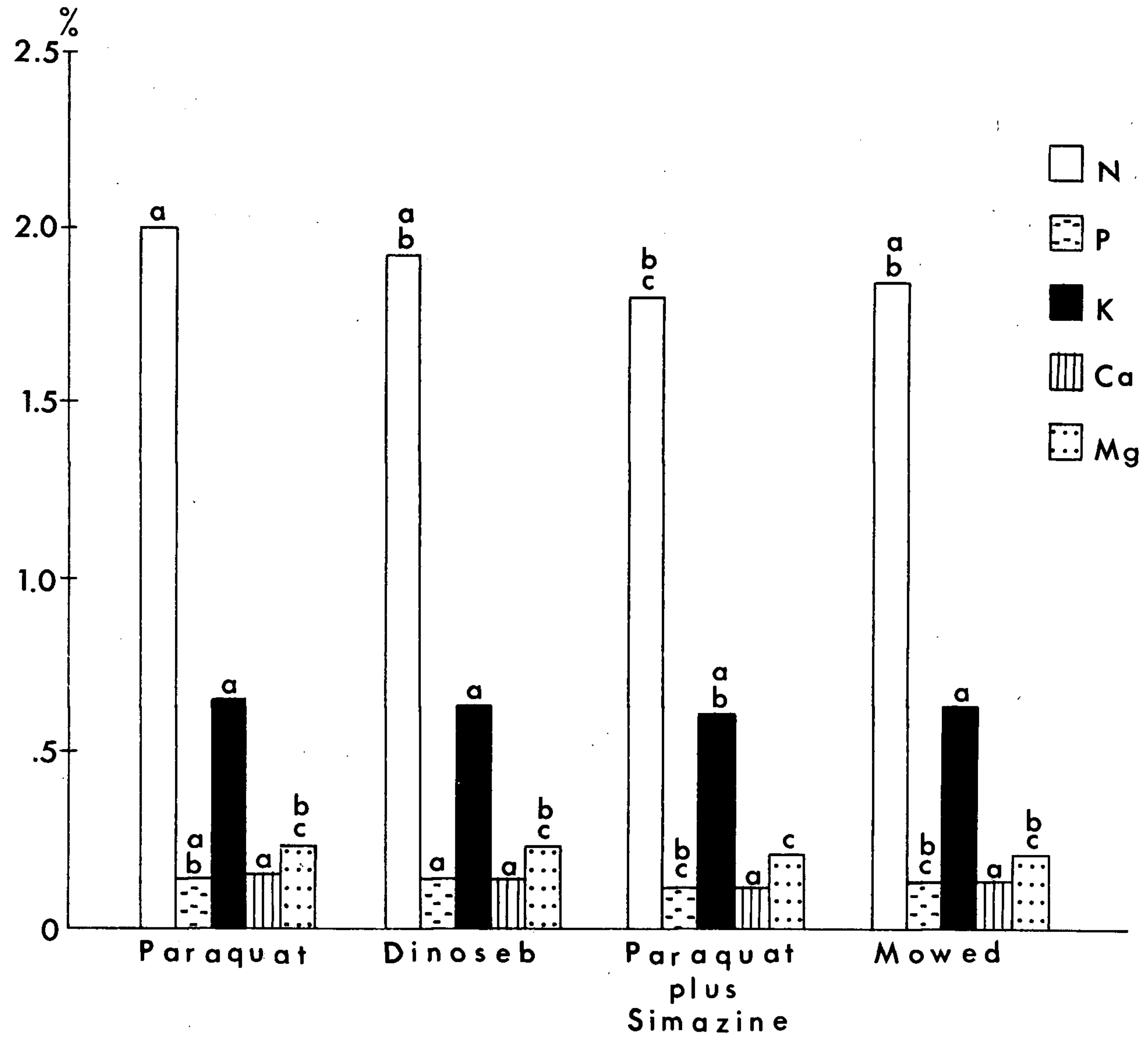

Fig. 5

of N but this was only significantly more than plants exposed to the paraquat plus simazine treatment. Comparing the treatments according to fertilizer regimes, it was observed that the concentrations of N increased significantly under the high fertilizer regime in all treatments except that of paraquat plus simazine.

K levels in the foliage of plants exposed to any treatment under the low fertilizer regime were not significantly different. Treatments also failed to significantly affect the levels of K in the foliage under the high fertilizer regime. Comparing effects under different fertilizer regimes, the plants in the mowed plots only under the high fertilizer program showed significantly more K in their foliage than did those plants exposed to the same treatment under the low fertilizer regime.

Mg levels in plants exposed to the various treatments under either fertilizer regime did not differ significantly. However, the concentration of Mg in the foliage of plants exposed to paraquat, paraquat and simazine and mowing under the low fertilizer program were all higher when compared to the high fertilizer regime.

Treatments under the two fertilizer regimes when compared, failed to produce significant differences in the concentration in the foliage of P, Ca, Mn or Fe.

The average concentration of N, P, K (Table 8) in plants under the high fertilizer regime was significantly higher than under the low regime. Mg was significantly lower while Ca, Mn and Fe were not significantly different.

Table 8. Effect of Fertilizer Regime on Nutrient Content

Fertilizer Regime	Percent oven dry weight					PPM	
	N	P	K	Ca	Mg	Fe	Mn
High	1.90[a]	.13[a]	.63[a]	.13[a]	.23[b]	129[a]	363[a]
Low	1.66[b]	.12[b]	.59[b]	.14[a]	.29[a]	130[a]	415[a]

Means of the same element sharing the same letter are not significantly different at the 5 percent level.

Correlation analyses on nutrient element, ~~competition ratings~~, yield, fruit size and soil moisture are presented in Table 9.

<u>Yield Studies</u>: An examination of plants in the field lead one to conclude that replication II or row 6 was the most uniform in growth and crop load. This was varified in the statistical analysis of yield data (Table 9). For this reason each replication was analysed separately as a 2 x 4 factorial with two plant plots.

Table 9. A Comparison of Error Mean Squares in Each Replication where Yield and Size were Analysed

	Error Mean Square (each with 15 degrees of freedom	
Replication	Ounces/Bush	Berries/Cup
1	442.2	214.1
2	193.0	27.3
3	213.4	43.5

The average yield in the dinoseb treated plots in replication 2 was significantly higher than yields from other treatments. In other replication treatments failed to significantly influence yield (Table 10). Treatments also failed to influence fruit size.

Table 10. Effect of Weed Control Treatment on Yield and Fruit Size

	Ounces/Bush Replication			Berries/Cup Replication		
Treatment	I	II	III	I	II	III
Paraquat	64.9[a]	62.8[b]	25.0[a]	79.3[a]	82.6[a]	101.8[a]
Dinoseb	79.9[a]	97.1[a]	36.1[a]	81.7[a]	88.6[a]	97.9[a]
Paraquat + Simazine	67.2[a]	68.3[b]	41.9[a]	82.8[a]	88.1[a]	86.4[a]
Mowed	90.5[a]	43.3[b]	28.7[a]	82.0[a]	90.0[a]	81.1[a]

Means in the same replication sharing the same letter are not significantly different at the 5 percent level.

Fertilizer application failed to influence yield significantly but fruit size was significantly larger under the low fertilizer regime in replication 3 (Table 11).

Table 11. Effect of Fertilizer Application on Fruit Yield and Size

Fertilizer Regime	Ounces/Bush Replication			Berries/Cup Replication		
	1	2	3	1	2	3
High	72.8^{a}	71.5^{a}	38.4^{a}	81.3^{a}	88.0^{a}	97.8^{a}
Low	78.4^{a}	64.2^{a}	27.5^{a}	81.8^{a}	86.6^{a}	85.8^{b}

Means within the same replication sharing the same letter were not significantly different at the 5 percent level.

Temperature Studies: All plots receiving a weed control treatment were significantly warmer at the 3 and 6 inch depth than the mowed plots (Table 12). The average soil temperature of plots receiving the high fertilizer were not significantly warmer than those under the low fertilizer regime.

Table 12. Effect of Treatment on Soil Temperature

Treatment	Temperature °C at 3 inches	Temperature °C at 6 inches
Paraquat	18.3^{a}	16.9^{c}
Dinoseb	18.3^{a}	16.8^{cd}
Paraquat + Simazine	18.2^{a}	16.6^{d}
Mowed	17.6^{b}	16.2^{e}

Means sharing the same letter are not significantly different at the 5 percent level.

Moisture Studies: The average soil moisture content was significantly higher in the paraquat, paraquat plus simazine and mowed plots than the dinoseb treated plots (Table 13). Soil moixture levels under the fertilizer regimes did not differ significantly.

Table 13. Effects of Treatment on Soil Moisture

Treatment	Soil Moisture (grams of water per gram of peat
Paraquat	3.4[a]
Dinoseb	2.8[c]
Paraquat + Simazine	3.4[ab]
Mowed	3.2[ab]

DISCUSSION

Chemical analysis of plant tissue is now being widely used as a research tool in examining problems associated with plant nutrition (8) and in commercial agriculture as a basis for fertilizer practice (30). Many areas now have established critical nutrient ranges for a wide variety of crops. No such ranges have been established for blueberries in British Columbia to date. When the concentration of nutrient elements in samples from mowed plots in Experiment II and III were compared with the estimated deficiency range (Table 14) N and Ca were found to have similar values. Nutrient concentrations of these same plots compared with concentrations found in samples from normal fields in Michigan (Table 14) indicated that P is lower in British Columbia while Mn is much higher. It should be noted here, however, that soils differed greatly, being a coarse sand in Michigan and a sphagnum acid peat in British Columbia.

Peat soils are considered high in N according to Davies _et al_. (17), a fact which may account for the low N fertilizer, 2-15-15, often used for blueberries on peat soils by growers in British Columbia. However, N availability depends on many factors such as pH, carbon-nitrogen ratio and microbial activity. Lucas & Davis (38) suggested that, in organic soils, maximum N availability is achieved at a pH of approximately 5.2. Experiments I, II and III were at pH 3.2, 3.8 and 3.2 respectively. In order to obtain maximum N availability in these soils pH must be raised.

Table 14. Comparative Nutrient Concentrations

Experiment and Description	N	P	K	Ca	Mg	Fe	Mn
II Mowed Low Fertilizer	1.40[c]	0.10[c]	0.59[b]	0.15[b]	0.29[a]	203[b]	625[b]
III Mowed Low Fertilizer	1.54[e]	0.12[c]	0.54[b]	0.13[a]	0.30[a]	126[a]	433[a]
Ballinger Normal Field	2.00	0.16	0.53	0.74	0.28	150	170
Ballinger Est. Defic.	1.50	0.07	0.40	0.30	0.09	60	170
II Mowed High Fertilizer	1.70[b]	0.10[c]	0.55[b]	0.14[b]	0.23[b]	205[b]	657[b]
III Mowed High Fertilizer	1.85[a]	0.13[b]	0.64[a]	0.13[a]	0.22[b]	135[a]	320[a]
I Mowed High Fertilizer	1.74	0.14	0.69	0.16	0.36	176	596

Means of the same element in the same experiment sharing the same letter are not significantly different at the 5 percent level.

Voznyuk (54) found that N availability varies according to the stage of decomposition of peat. Plants growing on highly-humified peat, as in Experiment II, utilized 2 to 3% of the N compared to 18% in low humified peat, such as that in Experiment III. Even though the plants differed in age, fertilizer practice in the past, and location, there was an indication of higher concentrations of N in the plants growing on the less humified peat (Table 14).

Plants growing on organic soils can utilize P most efficiently at a pH of 4.5 or 5.0 unless the soil contains a lot of Al or Fe (38). These elements can combine with P forming unavailable precipitates. The levels found in this experiment are not within the deficient range but are lower than those found in normal fields in Michigan (Table 14). The reasons may be three fold:

1. The pH is below the level for maximum availability.
2. The commercial fertilizer normally applied contains a high proportion of P. Increases in rates of fertilizer application were found to increase P levels in experiment III (Table 14).
3. P uptake is believed to be correlated with ammonium nitrogen which is the most common

form of N in acid peats. This is a recent finding by Leonce and Miller (35) who postulate that ammonium ions had a specific effect on movement of phosphate into the xylem, but the effect seemed to be exerted outside the xylem. They assume that the phosphate ion combines with a metabolically-produced carrier at the outer boundary of the absorption barrier, and that ammonium increased the rate at which the phosphate carrier complex released the phosphate into the xylem. A highly significant correlation between N and P in both experiment I and II support these findings. Herath and Eaton (25) also found a highly significant correlation between blueberry leaf N and P in a greenhouse experiment with peat.

It may be expected that K would be low in peat soils as they are very acid and subject to leaching. According to Lucas & Davis (38) organic soils require liberal rates of K fertilizer and soil pH has less influence on K than on P. The fertilizer, 2-15-15, presently being used by many growers is high in K and appears to satisfy the need for this element. The requirement of the highbush blueberry for cations is reported to be low by Kramer and Shrader (32). On peat soils in British Columbia, however, leaf levels of plants under heavy applications of this element are greater than those found in normal fields in Michigan (Table 14). Possibly this is a compensatory action to the lesser amounts of other cations such as the ammonium ion. There is also the possibility that the requirement for cations is greater on peat soils. It may be of interest to conduct further research on this point.

Calcium levels in all experiments were well below Ballinger's estimated deficiency ranges (Table 14). Under the highly acidic conditions found in experiments I, II and III the hydrogen ion concentration can only be very high. Under high hydrogen ion concentration, Hoagland and Broyer (26) reported a loss of Ca from the plant. It would be expected that Ca levels would be improved by increasing the pH through the addition of lime. However, Herath & Eaton (25) reported an increase in Ca levels in the foliage under increased pH only at the highest level of ammonium N added. In that work N and Ca had an antagonistic effect on Mg. The work considered in this thesis shows that also under field conditions (experiments II and III) increases in N resulted in significant decreases in Mg. Again Amling (1) found that low Ca levels in the nutrient solution promoted the accumulation of heavy metals and Mg and K in the leaf. At the pH levels examined by Eaton & Herath (25) it seems that Mg may have had an antagonistic effect on Ca uptake. From this, it can be postulated that very high levels of available N force the Mg levels down allowing the Ca to rise. Since Mg levels are well above Ballinger's (7) deficiency levels, a moderate increase in pH with a corresponding increase in Ca should not lead to Mg deficiency. It is noted at this point, that leaf analysis could provide a means for a grower to follow the actual change in the balance of these nutrients as the pH is altered.

Fe levels were higher in British Columbia than those found under normal field conditions in Michigan. Applications of N in experiment II and N, P and K in experiment III had no significant effect on Fe levels but levels in experiment II appeared higher than those in experiment III (Table 14). Amling (1) reported that Fe strongly affected the uptake of Mn but high levels of Mn did not reduce Fe levels. These results support Amling's (1) finding and perhaps the high levels of Mn may have caused the increase in Fe. There is no evidence in this work to suggest that Fe antagonized the uptake of Mn but the high levels of Fe may have been required by the plant to balance the high Mn levels.

Amling (1) also reported that a low level of any macro-nutrient resulted in high leaf contents of Mn. This finding is in agreement with the negative correlation between Mn and N in experiment II (Table 20). The highest level of Mn for highbush blueberries found in the literature was 357 ppm, reported by Cain (12). The levels of macro-nutrients are not believed to be low enough (Table 14) to account for almost double this level found in British Columbia. Lockhart and Langille (37) reported 1993 ppm of Mn for lowbush blueberries. Whether anything could be drawn from this would be merely speculation.

Lucas and Davis (38) report maximum availability for Mn on organic soils occurs at pH levels between 4.0 - 5.5 and 5.0 - 6.5 for mineral soils.

An increase in soil pH and leaf levels of certain cations such as Ca may reduce the concentration of Mn. This may not affect growth as the blueberry, according to Cain (12) is not affected by wide variations in Mn. Hodges and Peterson (27) found that blueberry fruit contained more Mn than did any other food in their test except wheat bran. The whole question of Mn and its effects on other elements requires more research as it is apparent that in large crops, large quantities of Mn will be removed. Further research on the importance of this element in relation to plant growth, yield and balance with other nutrients appears warranted.

Management and Nutrition: The control of weed competition in blueberry plantations is a widely recommended practice (15, 10, 50). Although much has been said about the shallow rooting character of the highbush blueberry, very little has been reported regarding the magnitude of effect on the nutritional levels within the plant. Johnston (29) has reported large increases in yields on plants under clean cultivation compared to plants growing in a grass and weed sod culture. Bailey and Franklin (4) state that tillage of the soil apparently stimulate blueberry plant growth. These observations record the response of the plant to reduce weed competition but why this response occurs is rarely discussed.

To study the effect of management practices on N, it is necessary to compare the effect of fertilizer practices with the treatments. Trevett (51) in comparing lowbush blueberries using a constant amount of fertilizer under high weed population and low weed population, found N higher in the plants in the field with low weed population. No effort was made to mow or reduce the high weed population in any way. In experiments II and III, under the low fertilizer regime, the only treatment to significantly improve N over the mowed plots was the paraquat treatment in experiment III (Fig. 2, 4). Under high fertilizer, hoeing in experiment II was the only treatment to significantly improve N (Fig. 3). There was fairly heavy fertilizer in experiment I, providing no N improvement over the check or mowed plots. This would indicate that the grower's mowing practices under high fertilizer did not reduce the N significantly. The reasons for the N increase under hoeing would probably be the mixing of the fertilizer with the soil, putting it in closer proximity with the roots, and the improved aeration of the soil, allowing a quicker breakdown of the organic matter, thus a release of mineral elements. Also reducing the weed competition for N should improve N levels as indicated by the negative correlation between N and weed growth rating (Table 20).

The contribution of nutrient elements by the herbicides such as simazine has been postulated (44, 45, 21). Although this experiment was not designed to study the effect of simazine in itself upon nutrient status, it does show that this herbicide in combination with paraquat did not reduce levels. It cannot be postulated easily why treatments containing simazine did not increase nutrient concentrations of especially N, but recent findings on this subject may help. Ries *et al*. (46) reported that when ammonium N was used as the source of N instead of nitrate N, the nitrogen concentration in corn plants was not increased by simazine. Since the sources of N used in these experiments were ammonium phosphate and ammonium sulphate, the results recorded in this thesis tend to support the findings by Ries *et al*. (46). It is admitted that more research on this subject is needed before substantial conclusions can be drawn.

The weed control treatment most effective in increasing P levels was hoeing. P, a very insoluble element, may have been moved near the root surface by the hoeing process. N in the ammonium form as outlined above, may contribute to the uptake of P.

There was not a negative correlation in any of the experiments between weed growth rating and P, thus we can expect the weed control by herbicide to contribute little to P uptake under the conditions of these experiments. Hohne (28) reports that grasses utilize 1 1/2 - 2 times as much P as do broad leaf weeds. A hoeing treatment that incorporates the grass into the soil may be expected to contribute to the P content of the soil through grass breakdown. Velvet grass made up a large portion of the total ground cover in experiment II and therefore could conceivably contribute to the uptake of available P.

Since the present weed control practices used by blueberry growers supplied sufficient K in these experiments, little increases in K can be gained through the use of more extensive weed control practices such as hoeing or applying herbicides. A crop of weeds in a potato field, according to Neeman (40) can remove 86 - 117 lbs of K/A. Even though there is no specific effect of weed control treatment on K uptake, the negative correlations in experiments I and III between weed growth ratings and K agree with Neeman's (40) findings. This is particularly true of experiment I which contained the most abundant weed growth and in which the only significant negative correlation between nutrient element and weed growth rating was found for K.

The interpretation of the effect of weed control on Ca and Mg levels is somewhat complicated by the fact that weed growth ratings were correlated negatively with N and positively with Mg. Also a negative correlation was found between N and Mg (Table 20) while a positive correlation existed between Mg and Ca (Table 21) in experiment III. Therefore management practices which tend to depress N levels such as mowing (Fig. 2) result in high Mg levels. It is conceivable then that heavy applications of a N fertilizer could lead to high levels of N in the foliage resulting in a depressive effect on Mg and Ca. On the other hand, practices which improve the Ca levels only, may lead to even higher Mg levels. The reason for levels of Mg increasing may be due to the blueberry having a higher requirement for Mg than Ca according to Kramer *et al.* (32) who carried out their work on a peat soil.

Yield: Yield studies of one year in duration seldom contribute substantial findings for many reasons. Highbush blueberries produce fruit from buds on one year-old wood initiated during the summer prior to blossom (20). Therefore treatments during the year of harvest have no effect on fruit bud numbers that year but may the following year. Weather conditions from year to year may greatly influence yield. For example 80% of the blossoms must be pollinated to produce a commercial crop (20) and consequently poor pollination can result in crop failure. Only under long term experiments can the true effect of treatments be clearly observed. For example in experiment III dinoseb treatments significantly increased yields but in replication 2 only. This gives only scant evidence on which to claim that this treatment will improve yields. It may be that cluster numbers in the bushes treated this way happened to be much greater giving a greater yield. As cluster counts were not obtained here no decision can be made. In experiment I the cluster count made it possible to carry out a covariance analysis on means adjusted according to cluster number but here there was also no significant effect upon yield.

The nutrient influence on yield and growth of blueberry has been correlated mainly with the element N (20). Ballinger (6) reported in one study that he found yields directly proportional to the N content of the leaves up to 2.1% N, above which yields decreased.

Although no correlation between N and yield was found in the present work, the negative correlations between yield and Mg, Ca and Mn (Table 21) indicate that heavy crops of fruit removed considerable quantities of these cations.

<u>Temperature</u>: Both Russell (48) and Pletser (43) have concluded that shading due to plant growth would lower the maximum soil temperature. Findings in this thesis (Table 6) agree with those conclusions.

It is not within the scope of this thesis to include a detailed examination of the effect of soil temperature on nutrient uptake but it is noted that Bailey and Jones (5) recorded increases in growth while Nielsen working with oats (41) reported increased uptake of N, P, and K at higher soil temperatures. Batjer <u>et al</u>. (9) found growth and N increased as root temperature increased.

<u>Moisture</u>: According to Childers (14) the highbush blueberry, because of the fine fibrous nature of the roots, cannot withstand draught. Certainly one reason for growing this plant on peat soils is the high water holding capacity of the soil.

The highbush blueberry according to Ballinger, recorded by Eck (20) is so well adapted to these soils that it is only on these deep moist peat soils that roots meet and interlace in the middle of the row. Even though one may not expect water stress on these moist peat soils, problems of drying out can occur especially on sites that have been drained and/or if the peat is of the highly decomposed type which cakes and cracks when dry. Experiment II is a good example of this for in mid summer the moisture levels at this site were less than half those found on other sites.

Michelson and Lord (39) reported that available moisture declined to 43% of field capacity on herbicide treated plots and to 10% of field capacity on grassed plots. Results in experiment II agree with these findings in that moisture and weed growth ratings at both dates were negatively correlated with moisture levels in the soil (Table 20).

A positive correlation between P and moisture was found in experiment III (Table 21). Gore's (22) report of P being seldom found deficient on soils subject to waterlogging lends support to this finding. Again Olsen (42) reported improved uptake of P under improved water supply.

Economic Aspects: The importance of making wise economic decisions in modern agriculture is frequently stressed. For this reason a brief discussion on the economic significance of this work is included.

In experiment I (Table 22) it is evident that the present management practice is the cheaper.

Experiment II poses a more complex problem. Hoeing, the treatment that provided the highest leaf levels of N, P, and K, does not appear economically feasible (Table 23) when much less expensive treatments such as paraquat and simazine provide nutrient levels that may produce comparable growth and yields. If weed competition is kept to a minimum by frequent mowing, an improved pH, coupled with ample fertilizer application it may be the most economical practice on this young planting.

The addition of fertilizer in experiment III has improved the nutrient status in the less expensive management techniques namely dinoseb and mowing to the point where there appears to be no advantage in using the more expensive treatments.

The dinoseb treatment is of particular interest because it is the least expensive treatment (Table 24) and is also recommended (20) as a control measure for mummy berry, a serious fungus disease of the blueberry in British Columbia. To make it even more effective, one could suggest the addition of simazine or some other material that would provide long residual control of weeds. If this were possible it could still be the least expensive method of controlling competition.

While there is some evidence in experiment III that paraquat and dinoseb increase the efficiency of N and P utilization, further information on these interactions is required to determine the optimum combination of fertilizers and herbicides that will most cheaply provide any desired level of leaf nutrient content.

SUMMARY

A study of the nutritional response of highbush blueberry variety "Bluecrop" to various management practices was conducted in the field on established commercial planting.

1. Concentrations of N, P, Ca were lower while Mn was higher in the test plants compared to results from other blueberry producing areas.
2. N and Ca were deficient in plants receiving present grower care.
3. Heavy applications of N in experiment II and N, P, and K in experiment III increased foliage levels of these elements accompanied by a depressed Mg level in each case.
4. N and P levels were found to be significantly correlated.
5. Mn levels were believed to be the highest recorded for highbush blueberry.
6. Highly decomposed peats appear to increase the availability of Mn compared to more fibrous types.
7. Certain management practices such as hoeing and paraquat application have improved the uptake of nutrients compared to the present system of mowing.
8. Growth ratings were good estimates of competition for the nutrient element N.

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5. Mn levels were believed to be the highest recorded for highbush blueberry.
6. Highly decomposed peats appear to increase the availability of Mn compared to more fibrous types.
7. Certain management practices may improve the uptake of nutrients compared to the present system of mowing.
8. Growth ratings were good estimates of competition for the nutrient element N in experiments II and III on certain dates.

9. There was little consistent evidence to suggest that weed control treatments or fertilizer application increased yield.
10. Plants producing large crops had greater demand for Mn, Mg and Ca.
11. Soil temperature and moisture were greater under management practices that reduce the weed population.

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APPENDIX

Table 15. Example Computer Program Used to Calculate PPM Mn

```
$IBFTC AACE
C    EMBREE - MN, FOR B--67-N
        DIMENSIØN  I(3), Y(3), X(1)
        REWIND 20
1       READ (5,2) I, Y
2       FØRMAT (3I2, 7X, 2F12.4, 10X, F6.2)
        ASSIGN 30 TØ N
        CALL EØF (5,N)
C        CALCULATIØN  ØF  PPM  MN     B-67-N
        X(1)=(10.**(0.012280+(Y(3)* 0.016452)))*100./(Y(1)-Y(2))
        WRITE (20) I, X
        PRINT 3330, I,X
3330    FØRMAT (1X, 3I2, 7X, F9.3)
        GØ TØ 1
30      END FILE 20
        STØP
        END
$ENTRY
        DATA
$END
$IBSYS
$MFAV
```

Table 16. Atomic Absorption Spectrophotometer Instrument Settings

Element	Lamp Current Range	Monochrometer (Wavelength)	Slit Width	Fuel Acetylene lb/in^2	Fuel Air lb/in^2
K*	-	766.5 mμ	0.50	4.5	11.8
Mg	1	285.0 mμ	0.05	8.0	15.0
Ca	3	421.0 mμ	0.2	7.2	14.6
Fe	5	248.0 mμ	0.08	8.0	15.0
Mn	3	279.0 mμ	0.05	8.0	15.0

* Curves were small for K so the scale was expanded by adjusting the appropriate electrical connection within the machine.

Table 17. Subdivision of Degrees of Freedom

Experiment I

Source of Variation	Degrees of Freedom	
Replications	r-1	5
Treatments	t-1	1
Replications x treatments	(r-1)(t-1)	5
Bushes within treatments x replications	rt(b-1)	12
Bushes x treatments x replications	rtb-1	23

Experiment II

Source of Variation	Degrees of Freedom	
Replications	(r-1)	5
Weed control	(w-1)	3
Fertilizers	(f-1)	1
Weed control x fertilizers	(w-1)(f-1)	3
Replications x weed control x fertilizers	(r-1)(wf-1)	35
Bushes within weed control x fertilizers x replications	rwf(b-1)	48
Bushes x weed control x fertilizers x replications	rwfb-1	95

Experiment III

Source of Variation	Degrees of Freedom	
Replications	(r-1)	2
Weed control	(w-1)	3
Fertilizer	(f-1)	1
Weed control - Fertilizer	(w-1)(f-1)	3
Replications x weed control x fertilizers	(fw-1)(r-1)	14
Bushes within weed control x fertilizers x replications	rwf(b-1)	24
Bushes x weed control x fertilizers x replications	rwfb-1	47

Table 18. Error Mean Square Comparisons of Nutrient Elements for N, P, K, Ca and Mg in Percent and Fe and Mn in PPM.

Experiment	Degrees of Freedom	N	P	K	Ca	Mg	Fe	Mn
I	12	.07	.0004	.002	.0001	.005	289.8	3709
II	48	.02	.0001	.005	.0003	.002	963.9	57355
III	24	.02	.0001	.003	.0007	.002	241.6	9965

Table 19. Correlation Matrix of Variables, Total Weight of Fruit, Grams of Ripe Fruit, Competition Ratings, Nutrient Elements, Fruit Size and Soil Moisture.[1]

	Tot.Wt.	Ripe	July 1	N	P	K	Mg	Ca	Mn	Fe	Size	Moist
Tot.wt.												
Ripe	.95											
July 1												
N												
P	.90	.91										
K			.47	.41								
Mg												
Ca							.55					
Mn												
Fe	.51				.42							
Size												
Moist												

[1]Only significant correlations are presented

Critical r at 5% = .40

Critical r at 1% = .52

Table 20. Correlation Matrix of Variables, Competition Ratings, Nutrient Elements and Soil Moixture.[1]

	July 1	July 9	N	P	K	Mg	Ca	Mn	Fe	Moist
July 1										
July 9	.69									
N	-.26									
P			.50							
K	.70	.99								
Mg	.28	.38	-.26		.42					
Ca										
Mn			-.27				.34			
Fe				-.22						
Moist	.51	-.38	.21	-.39					.21	

[1]Only significant correlations are presented

Critical r at 5% = .21

Critical r at 1% = .27

Table 21. Correlation Matrix of Variables, Soil Moisture, Ground Cover Ratings, Nutrient Elements, Fruit Size and Total Yield.[1]

	Moist	July 12	Sept. 27	N	P	K	Mg	Ca	Mn	Fe	Size	Tot. Wt.
Moist												
July 12												
Sept. 27		.69										
N		-.29										
P	.29			.41								
K		-.31	-.33	.34	.33							
Mg												
Ca							.52					
Mn			.38									
Fe												
Size												
Tot. Wt.			-.43		-.33		-.33	-.31	-.33			

[1]Only significant correlations are presented

critical r at 5% = .29

critical r at 1% = .38

Table 22. Estimated Costs of Each Treatment on an Acre* Basis

EXPERIMENT I

Treatment:

Mowing

1 mowing @ 4.50 hr./A.	4.50
1 hand mowing (power mower) 2 hr. @ 2.00/hr.	4.00
	$8.50

Paraquat

Materials: 2 lb. @ 16.00/lb	16.00
Application: 1 hr. @ 4.50/hr. 2 applications	9.00
	$25.00

* Cost estimates are based on discussion with management. A sod strip is left untreated between each row thus only half the acre is treated with herbicides.

Table 23. Estimated Costs of Each Treatment on an Acre* Basis

EXPERIMENT II

Treatment:

Paraquat

Materials: 2 lb. @ 16.00/lb.	32.00
2 applications 1 hr. @ 4.50/hr.	4.50
3 mowings between the rows 1 1/2 hr. @ 4.50/hr.	6.75
	$43.25

Hoeing

2 hoeings 2.5 min./bush x 1,000 bushes/A @ 1.00/hr.	82.43
3 mowings between the rows 1 1/2 hr. @ 4.50/hr.	6.75
	$89.18

Paraquat + Simazine

Materials: Paraquat 1 lb. @ 16.00/lb.	16.00
Simazine 2 lb. product (50%W) @ 1.90/lb.	3.90
1 application 1/2 hr. @ 4.50/hr.	2.25
3 mowings between rows 1 1/2 hr. @ 4.50/hr.	6.75
	$28.90

Mowing

5 mowings @ 4.50/hr./A.	$22.50

* Cost estimates are based on discussion with management. A sod strip is left untreated between each row thus only half the acre is treated with herbicides.

Table 24. Estimated Costs of Each Treatment on an Acre* Basis

EXPERIMENT III

Treatment

Treatment	Cost
Paraquat	
Materials: 1 lb./A. @ 32.00/2 lb. 2 applications	32.00
Application: 1 hr @ 4.50/hr. 2 applications	4.50
Mowing between rows: 2 at 4.50/hr.	9.00
	$45.50
Dinoseb	
Materials: 1 gal./A. at 2 lb./gal.	2.85
Applications: 1 @ 4.50/hr.	4.50
Mowing between rows: 2 @ 4.50/hr.	9.00
	$16.35
Paraquat + Simazine	
Materials: Paraquat 1 lb./A. @ 16.00/lb.	16.00
Simazine 2 lb/A. @ 1.90/lb.	3.80
Application: 1 @ 1/2 hr. @ 4.50/hr.	2.25
Mowing between rows: 2 @ 4.50/hr.	9.00
	$31.05
Mowing	
Materials: Tractor + Man @ 4.50/hr. 2 mowings	9.00
Hand cutting 4 hr./A. @ 1.50/hr.	6.00
Hand removal of weeds from base of bush 6 hr. @ 1.50/hr.	9.00
	$24.00

* Cost estimates are based on discussion with management. A sod strip is left untreated between each row thus only half the acre is treated with herbicides.

Table 25. Chemical Names of Herbicides

Paraquat	-	1,1'-dimethyl-4,4'-dipyridylium
Simazine	-	2 chloro-4,6-bis(ethylamino)-s-triazine
Dinoseb or DNBP	-	4,6-dinitro-o-sec-butylphenol