AN ABSTRACT OF THE THESIS OF

ERIC ALAN NELSON for the MASTER OF SCIENCE
(Name) (Degree)

in FOREST MANAGEMENT presented on February 13, 1974
(Major) (Date)

Title: NUTRITIONAL REQUIREMENTS OF THE THIN-LEAVED HUCKLEBERRY (VACCINIUM MEMBRANACEUM DOUGL.)

Abstract approved: ______________________
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Research was conducted on the effect of field fertilization with nitrogen on existing huckleberry fields. Research was also carried out in the greenhouse to ascertain the effects of various levels of nitrogen, phosphorus, and potassium in a nutrient solution and the effect of the pH of the solution on growth of seedlings.

The 1973 berry season provided few berries and no effect of the field fertilization on the berry production could be implied. However, all levels of fertilization (10, 40, and 160 lbs N/ac) yielded better vegetative growth than the control plots. The increases in growth were greatest in the 40 and 160 lbs N/ac treatments and the difference between these two treatments was not significant. It seems that 40 lbs N/ac may provide a response near enough to the maximum possible response that additions of over this amount will cause only slightly better growth.

A bioassay of the field soil and fertilization levels was carried out in the greenhouse using seedlings as a check of the field response. Results were similar to those obtained in the field except that a larger relative response was seen in the bioassay.

The pH study and the nutrient study were carried out in the greenhouse using sterile sand as the growth medium. The pH study showed that huckleberry seedlings grew well if the pH of the nutrient solution was between 4.0 and 6.0, with 5.0 providing the optimum growth. It was found that pH 3.0 caused reduced growth and necrosis of leaf tissue.

All treatment solutions in the nutrient study were derived from Hoagland's solution. Three levels each of nitrogen, phosphorus, and potassium were used. The nitrogen level was the most important factor on the growth of the seedlings, with the high level yielding good growth and the low level yielding little or no growth. High levels of phosphorus and potassium proved to be an asset to good growth only when a high level of nitrogen was also present in the solution. Solutions containing a high level of potassium without a high level of nitrogen yielded little or no growth and caused necrosis of the leaf tissue.

It is concluded that application of a fertilizer containing nitrogen would be the most beneficial type. In addition, applications of fertilizers containing phosphorus or potassium should be avoided unless these elements are limiting factors of growth.

Nutritional Requirements of the Thin-leaved Huckleberry (*Vaccinium membranaceum* Dougl.)

by

Eric Alan Nelson

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed February 13, 1974

Commencement June 1974

APPROVED:

Professor of Forest Physiology
in charge of major

Head of Department of Forest Management

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Date thesis is presented February 13, 1974

Typed by Mary Jo Stratton for Eric Alan Nelson

ACKNOWLEDGEMENT

I wish to express my deep appreciation to Dr. Joe B. Zaerr for his help and encouragement throughout the initiating and conducting of this research. The help of Drs. William W. Chilcote and Don Minore is also gratefully acknowledged.

I wish to thank the U. S. Forest Service for their funding of this research through cooperative research agreement 16 USC 581; 581a-581i. Supplement No. 83.

My special thanks go to Dr. Denis P. Lavender for taking on the responsibilities of major professor during the conclusion of my research and the writing of this thesis.

And finally, I wish to say thank you to my wife, Kathy, for her encouragement and patience throughout my graduate study, for she has helped me in more ways than she will ever know.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NUTRITIONAL REQUIREMENTS OF THE THIN-LEAVED HUCKLEBERRY (VACCINIUM MEMBRANACEUM DOUGL.)

INTRODUCTION

Twelve native species of the genus *Vaccinium* are generally accepted in the Pacific Northwest. These are known by several common names, including huckleberry, blueberry, bilberry, and whortleberry. An identification key to these species may be found in Hitchcock and Cronquist (1973). Of these, the most frequently picked is *V. membranaceum* Dougl., the thin-leaved huckleberry. It grows at moderate to high elevations on both the east and west slopes of the Cascades and Olympic Mountains. In addition, it is found in the Wallowa and Blue Mountains (Hayes and Garrison, 1960). *V. membranaceum* Dougl. has less critical habitat requirements than many of the other northwest species (Camp, 1942). It grows well in dry areas (Darrow, 1960) and is most abundant under partial canopies and in the open (Neiland, 1958), especially in burned-over areas. This species generally requires a soil with abundant pore space for good aeration, good drainage, and a pH of 4.3 to 5.5 (Hall, 1964).

V. membranaceum Dougl. occupies a seral stage ecologically and most of the major fields in the northwest originated after large wildfires which were common in this region. A few years after establishment, the fields will produce a maximum quantity of berries and then gradually decline in production as other shrubs and trees invade the site. The Indians of the area periodically set fire to their huckleberry fields to insure continued production of the fruit (Wermlinger, 1968). Burning every second or third year is still a common management practice in eastern blueberry fields (Black, 1963).

Many times the fields occupy sites which would be classified as marginal for timber production. In these cases, the recreational benefits of the huckleberry fields are far more valuable than the assets of timber production (Bright, 1937; Parke, 1968).

It is estimated that there are 160,000 acres of wild huckleberries in Oregon and Washington (Nelson, 1970). However, due to the current practice of fire prevention, this acreage is declining rapidly. A good example of this is the Twin Buttes Huckleberry Field on the Gifford Pinchot National Forest. The field originally occupied 8,000 acres. In the past 40 years, this field has been reduced to 2,500 acres, and it is estimated that it is losing 100 acres per year (Stamy, 1970). The Twin Buttes field is a popular field and is visited by about 200,000 huckleberry pickers each year. In addition to the recreational benefits, the crop of huckleberries harvested from the field is valued at over $300 per acre per year. While most fields are not this productive or heavily visited, the assets of this species are clearly evident.

Due to the increasing number of people using huckleberry fields, management plans must be devised for the more popular areas in order to insure the continuation of the fields. To date, these plans have been aimed at controlling the number of berrypickers in order to cause minimal deterioration of the site. Little attention has been directed at management of the huckleberries, as until recently little was known about the western species of Vaccinium (Minore, 1972b). In order to insure continuation of the fields, succession must be stopped or reversed. The US Forest Service is currently working on this aspect of management. In addition, the physiological and ecological characteristics of the species must be determined in order to maintain a suitable habitat. My research has been in the area of nutrient requirements of V. membranaceum Dougl. I used two general approaches to this problem, a field fertilization study and greenhouse pot tests. The field study was designed to test the effect of various levels of nitrogen on vegetative growth and berry production. The greenhouse studies were designed to ascertain the minimum nutrient levels necessary to maintain optimum growth in sand culture and the optimum pH level of the nutrient solution. In addition, a study was carried out in the greenhouse using soil from the field and fertilizer levels equal to those used in the field to check the fertilizer effect under controlled growth conditions. Hopefully, the results of this research can be incorporated into a comprehensive management plan for recreationally valuable huckleberry fields.

LITERATURE REVIEW

Very little research has been done on the western huckleberries. The bulk of the research has been done with the eastern species of Vaccinium, specifically the highbush (V. corymbosum L.) and lowbush (V. angustifolium Ait.) blueberries. Complete guides are available to the commercial blueberry grower which provide information on all phases of management (Trevett, 1962; Cain and Eck, 1966).

Soil pH seems to be very important for blueberry growth. While blueberry fields occur on soils of a wide pH range, soils with a pH in the range of 3.5 to 5.5 are the most productive (Townsend, 1969, 1971; Trevett et al., 1971). Hall et al. (1964) found that pH had a significant effect on growth and nutrient uptake, with the range of 4.0 to 5.0 being optimum.

Fertilization has become a general practice in managing eastern blueberries. Trevett (1968a) has suggested using a complete fertilizer to prevent nutrient deficiencies which might develop due to continued use of the fields. Rayment (1965) found that fertilizing with 50 pounds of nitrogen per acre in the form of ammonium nitrate increased yields as much as 50% and that additions of phosphorus and potassium, in the absence of nitrogen, also increased yields. However, he found that applications of a complete fertilizer produced no increases in yields while it stimulated weed growth. The weed stimulation problem due to fertilization of blueberries has been recognized for many years (Chandler and Mason, 1933) and the application of 35 pounds of nitrogen per acre has been suggested as a compromise between increased berry yields and increased weed competition (Trevett, 1968b).

The form of nitrogen is important in the eastern species. Ammonium, rather than nitrate, is the most favorable form of nitrogen. Cain (1952) found that NH_4-N was absorbed more readily than NO_3-N and that a higher nitrogen level was present in the leaves of plants receiving NH_4-N. Oertli (1963) suggests that NH_4-N is more readily available than NO_3-N at the low pH values which are present in the soil. Townsend (1966, 1967), using pot tests, found the NH_4-N form of nitrogen to be sufficient to maintain growth. In contrast, plants receiving NO_3-N as the only form died within three weeks. Plants receiving both forms together grew satisfactorily, but at a rate less than that of plants receiving NH_4-N only. Leaves of plants in the NH_4-N treatment had higher levels of nitrogen and phosphorus and lower levels of potassium than those receiving the NO_3-N treatment. The plants receiving both forms had intermediate levels of these three nutrients. Herath and Eaton (1968) found that the nitrogen level of the leaves increased with increasing levels of NH_4-N between 0 and 60 pounds of nitrogen per acre.

Field fertilization to increase production has been used for many years. Doehlert (1940) found that blueberry fields could be fertililized at any time of the year. He also stated that fertilized fields produced twice as many berries as non-fertilized fields. Smith et al. (1946) found that using a complete fertilizer produced more vegetative growth and more and larger berries. Many papers have reported increased yields by using only a nitrogen fertilizer (Trevett, 1965b; Ballinger, 1966; Bailey et al., 1966; Trevett et al., 1966). Trevett (1965a) found that the time of application of the nitrogen fertilizer had an effect on the response. Application pre-emergence caused an increase in stem growth and application at the time of die-back caused an increase in the fruit bud ratio (number of fruit buds per inch of stem) the following season. Boller (1951), working with eastern species in Oregon, found nitrogen to be the only nutrient necessary in fertilization and suggested the use of ammonium sulfate.

Pot tests in the laboratory using nutrient solutions have provided additional information on the nutrition of Vaccinium. Doehlert and Shive (1936) found that a high level of nitrogen and low levels of phosphorus and potassium resulted in the best vegetative growth and the highest fruit yield. They also found that a low level of nitrogen and a high level of phosphorus resulted in the poorest growth. Stene (1939) concluded that nitrogen was the most significant element in maintaining good growth. Amling (1960) found that the leaf content of nitrogen, phosphorus, potassium, and calcium increased as the supply of the elements increased in the nutrient solution. Work has also been done on the other nutrients. It has been found that phosphorus is needed in small amounts (Lockhart and Langille, 1962) and that levels in excess of 8.5 meq/L can cause interveinal chlorosis (Ballinger and Kushman, 1969). Childs (1950, 1952) has suggested a toxic effect of an undetermined element if a strong nutrient solution is applied too often.

Foliar analysis has been used to find normal ranges of the nutrients and as an indicator of the effect of fertilization. Bailey et al. (1949) suggested that satisfactory nutrient levels for Vaccinium are lower than those of other fruit crops. Satisfactory levels have been proposed in many papers (Trevett, 1966; Ballinger and Goldston, 1967; Kocher and Valenzuela, 1971; Trevett, 1972). The generally proposed ranges of these levels are 1.5 to 2.0% for nitrogen, 0.08 to 0.12% for phosphorus, 0.40 to 0.55% for potassium, 0.40 to 0.65% for calcium, and 0.15 to 0.20% for magnesium. Nutrient levels would be expected to change throughout the growing season. This is the case and has been documented in several papers (Bailey et al., 1962; Townsend et al., 1968; Townsend and Hall, 1970). Nitrogen generally declines throughout the season; phosphorus follows the same trend but has a slight increase at the end of the season; potassium declines until the middle of the season and then increases to near the initial level.

The nitrogen level has received the most research. Kocher (1973) found that the foliar content of nitrogen increased with increasing levels of nitrogen fertilization. This increase due to fertilization has been shown in the stems and roots as well (Kocher and Valenzuela, 1973).

METHODS AND MATERIALS

Plant Material

The Sawtooth Huckleberry Field, Mt. Adams Ranger District, Gifford Pinchot National Forest (legal description T. 7N, R. 8E) was the location of the field study. It is over 2,000 acres with gentle topography, but this area is shrinking due to brush and tree encroachment. There are many large areas of relatively uniform huckleberry cover and one of these areas was selected for the fertilizer study.

Propagation by hardwood and softwood cuttings from the field was attempted by Don Minore of the U.S. Forest Service. Hardwood cuttings were gathered and placed in rooting beds during the spring of 1972 following the procedures of Bailey *et al.* (1941) and Doran (1941). Softwood cuttings were gathered and placed in rooting beds during the summer of 1972 following the procedure of Johnston (1935). These procedures have worked well with the eastern blueberries. However, all the cuttings of the thin-leaved huckleberry died without rooting. Apparently these procedures for propagation by cuttings do not work with *V. membranaceum* Dougl.

Blueberry seeds have been shown to germinate readily if light and fluctuating temperature are present (Scott and Draper, 1967; Strushnoff and Hough, 1968). Ripe huckleberries were collected from the field research area during the summer of 1972. Seeds were extracted by mashing the berries in a container of water. The pulp was removed by allowing a gentle stream of water to wash it over the side of the container. The yield from 130 grams of fresh berries by this procedure was 1.57 grams of seeds.

The seeds were then placed on the surface of flats containing 1-1/2" Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) bark which had been soaked in water for 24 hours. These flats were placed in a growth chamber which was set for a 9-hour photoperiod with a $65^{o}F$ day temperature and a $50^{o}F$ night temperature. The flats were watered when necessary to keep the bark moist. The average germination capacity of the seeds was 88% and the maximum germination rate was between 15 and 17 days. The seedlings were allowed to grow in the growth chamber until two true leaves were present. They were then transplanted into 2-1/4" x 2-1/4" x 3-1/2" green plastic pots which were filled with a sand-peat mixture (3:1 by volume). Two seedlings were planted in each pot. These seedlings were then grown in the greenhouse under a 16 hour day regime which was provided by fluorescent light and they were watered three times a week. Nutrients were supplied by hemlock duff which was spread on the surface of the pots at six-week intervals. Analyses by Minore (1972a) show this litter to be very rich in nutrients. The seedlings were allowed to grow under these conditions until they were approximately 5" tall, at which time they were used in the pot test.

Field Methods

Forty plots of 1/100 acre (20' 10-1/2" square) were marked in a relatively uniform area on the Sawtooth Huckleberry Field for use in the fertilizer study. Soil samples of the top 24" were taken from each of the plots and analyzed for total nitrogen by the Kjeldahl method. Total nitrogen content of the soil was between 0. 07 and 0. 12% on most plots. The plots were randomly assigned to four treatment groups, with ten plots in each group. Each group received a different level of nitrogen fertilization. These levels were 0 (control), 10, 40, and 160 pounds of nitrogen per acre. Using ammonium sulfate as the source, the additions were no fertilizer, 217. 8 g per plot, 871. 2 g per plot, and 3484. 8 g per plot, respectively. The fertilizer was spread by hand on October 1, 1972. A table of plots and treatments received is included in Appendix A.

Data from the fertilizer study were gathered between August 23 and August 26, 1973. Two separate sampling methods were used. The first sampling method was to cut the five largest branches on each plot. All new growth was clipped off the branches and dried in an oven at 70^{o}C for five days. The weight of the new growth from the five largest branches on each plot was then recorded. The leaves were then separated from the twigs and used for foliar analysis, which will be described under laboratory methods.

The second sampling method was essentially a random selection of ten individual new growth twigs from each plot. These were selected by running a line with ten knots at random intervals between the opposite corners of each plot. At each knot, the new growth twig nearest the knot was clipped off and saved. The length of each twig was measured and recorded. The material from this sample was then dried in the same manner as the first sample and the dry weight was recorded. Leaves were again separated and saved for foliar analysis.

Results of the two sampling methods were compared to see if a high correlation existed between them. If a high correlation existed between the methods, it would indicate that no significant differences were present due to the sampling methods.

Laboratory Methods

Three growth studies were carried out in the greenhouse at the laboratory. The first of these was a bioassay of the field soil using the seedlings which had been grown in the laboratory. Green plastic pots measuring 4-1/4" x 4-1/4" x 4-1/4" were filled with soil from the field study area and one seedling was planted in each pot. Four treatments, each with ten replications, were set-up in this way.

The average shoot length of the seedlings was 10.2 cm.

Fertilizer treatments of 0, 10, 40, and 160 pounds of nitrogen per acre, in the form of ammonium sulfate, were applied to the seedlings on March 8, 1973. These additions were no fertilizer, 6.27 mg per pot, 25.08 mg per pot, and 100.32 mg per pot, respectively. These quantities were applied by pipetting 0 ml per pot, 0.625 ml per pot, 2.5 ml per pot, and 10.0 ml per pot, respectively, of a solution containing 10.032 grams of ammonium sulfate per liter. The seedlings were watered with tap water twice a week and received only enough to keep the soil damp. The total shoot length of each seedling was measured and recorded at the beginning of the study and at two-week intervals thereafter.

On August 7, 1973 the four treatments were harvested. The soil was washed off the roots with water and the seedlings were dried in an oven at 70°C for five days. The dry weight of each seedling was recorded and the leaves were then separated from the stems and saved for foliar analysis.

A sterile sand was used as the growth medium for the other two studies carried out in the greenhouse. The methods outlined by Hewitt (1952) for sand preparation were generally followed. The sand was first screened through a wire mesh of 14 strands per inch to remove the coarse particles. A wire mesh of 40 strands per inch was then used to remove the fine particles. The sand was washed in a

3% solution of hydrochloric acid to sterilize it and then leached with distilled water to remove all traces of the acid. The size distribution of the sterilized sand by weight was: 12.6% larger than 1 mm, 52.4% between 0.5 mm and 1.0 mm, 27.2% between 0.25 mm and 0.5 mm, and 7.8% less than 0.25 mm.

Green plastic pots measuring 5-1/2" x 5-1/2" x 6" were used in the two sand culture studies. The drainage holes were covered with sterile cotton and 1" of water-washed gravel was placed in the bottom of each pot to assure good drainage. Approximately 4-1/2" of sterile sand was placed on top of the gravel.

The basic nutrient solution, from which all solutions used in the sand culture studies were derived, was first used by Arnon and Hoagland (1940) and is commonly known as Hoagland's solution. At full strength, it contains 18 meq/L of nitrogen, 6 meq/L of phosphorus, and 10 meq/L of potassium, as well as other necessary nutrients and micronutrients. A complete description of the solution is included in Appendix B. Solutions were prepared by pipetting concentrated stock solutions into a beaker and diluting with distilled water to the appropriate concentration.

The first sand culture study was designed to determine the effect of pH of a nutrient solution on growth. Four treatments, each with ten replications, were planted and the average shoot length of the seedlings was 16.5 cm. The pH of a 1/10 strength Hoagland's solution was adjusted by adding either sulfuric acid or sodium hydroxide until the desired pH was reached. Treatments consisted of watering with nutrient solutions of pH 3.0, 4.0, 5.0, and 6.0 beginning on May 4, 1973. Each seedling was watered with 200 ml of the nutrient solutions on Monday, Wednesday, and Friday and flushed with distilled water on Sunday so that toxic concentrations of the nutrients could not build up in the sand. Stem length of each seedling was measured and recorded at the beginning of the study and at two-week intervals thereafter.

On September 6, 1973 all treatments were harvested. Sand was washed from the roots of the seedlings with water and the seedlings were placed in an oven at 70°C for five days. Dry weights of the seedlings were recorded and the leaves were separated from the stems for use in foliar analysis.

The second sand culture study was designed to determine the effects of various amounts and combinations of the nutrients nitrogen, phosphorus, and potassium. Each nutrient solution treatment contained all three nutrients. The maximum concentration of each nutrient was the concentration of that nutrient in full strength Hoagland's solution. In addition, two other concentrations of 1/10 and 1/100 that of full strength of each of the three nutrients were used. Concentrations of all nutrients other than nitrogen, phosphorus, and potassium were maintained at the levels present in Hoagland's solution. By using the three nutrients together with three concentrations of each nutrient, 27 nutrient solutions were derived. Table I shows the levels present in these treatments. The treatment numbers show the levels of nitrogen, phosphorus, and potassium, respectively, with 1 being the full strength level, 2 being the 1/10 strength level, and 3 being the 1/100 strength level. All solutions were adjusted to pH 5.0 by adding sulfuric acid or sodium hydroxide. Two hundred seventy seedlings (10 replications of 27 treatments) were planted on June 16, 1973 and the average shoot length was 16.4 cm. Each seedling was watered with 200 ml of nutrient solution on Monday, Wednesday, and Friday, and flushed with distilled water on Sunday. The shoot length of each seedling was measured and recorded at the beginning of the study and again at the end. The treatments were rotated around the greenhouse room at two-week intervals during the course of the study to minimize the effect of possible environmental differences throughout the room.

On September 14, 1973, all treatments were harvested and dried following the same procedure as in the pH study. The dry weight of each seedling was recorded and the leaves were separated and saved for foliar analysis.

Foliar analysis was performed on the leaves of the plants of all studies. The leaves were prepared by grinding them through a 40-mesh screen and collecting the ground material in glass vials. Each open vial was placed in an oven at 70^{o}C the afternoon before

Table I. Composition of Nutrient Treatments.

Treatment NPK	N Level[x]	P Level[y]	K Level[z]	Treatment	N Level[x]	P Level[y]	K Level[z]
111	H	H	H	231	M	L	H
112	H	H	M	222	M	L	M
113	H	H	L	233	M	L	L
121	H	M	H	311	L	H	H
122	H	M	M	312	L	H	M
123	H	M	L	313	L	H	L
131	H	L	H	321	L	M	H
132	H	L	M	322	L	M	M
133	H	L	L	323	L	M	L
211	M	H	H	331	L	L	H
212	M	H	M	332	L	L	M
213	M	H	L	333	L	L	L
221	M	M	H				
222	M	M	M				
223	M	M	L				

[x] H - 18.0 meq/L; M - 1. 8 meq/L; L - 0. 18 meq/L

[y] H - 6. 0 meq/L; M - 0. 6 meq/L; L - 0. 06 meq/L

[z] H - 10. 0 meq/L; M - 1. 0 meq/L; L - 0. 1 meq/L

analysis was performed. The micro-Kjeldahl method (A. O. A. C., 1950) was used to determine percent nitrogen in the leaves of all studies. Wet ash digestion for use in cation determination (Fiske and Subbarrow, 1925) was carried out on the leaves of selected treatments of each study. Percent phosphorus was determined colorimetrically and percent potassium and calcium was determined by flame spectroscopy.

RESULTS AND DISCUSSION

Field Fertilization Study

The 1973 huckleberry season was extremely poor. The hypothesis expressed by Dr. Don Minore of the U. S. Forest Service attributes this to two factors. First, an extremely cold week in early December before the bushes were covered with snow killed many of the buds, and second, a freeze in mid-June when the bushes were in bloom caused heavy flower drop. Due to the lack of berries, no data on the effect of the fertilizer treatments on berry production could be gathered.

Oven dry weight of the new growth obtained by the two field sampling methods (see Field Methods section) showed no significant difference between the methods ($r = 0.832$, $N = 40$). Therefore, only the data from the twig sampling method will be reported because it was the less subjective of the two methods. Data from the individual plots are included in Appendix C.

All fertilizer treatments were significantly greater than the control treatment in both new growth length and new growth oven dry weight (Table II). In addition, the 40 and 160 pounds of nitrogen per acre treatments were significantly better than the 10 pounds of nitrogen per acre treatment in both categories. While the 160 pounds of nitrogen per acre treatment showed slightly better growth than the

40 pounds per acre treatment, these treatments were not significantly different.

Table II. Average New Growth Length, Oven Dry Weight, and Foliage Nutrient Content of Field Fertilization Treatments.[x]

Treatment (lbs N/ac)	Twig Length[y] (cm)	Oven Dry Weight[y] (g)	% N[y]	% P[z]	% K[z]
0	32.26a	1.387a	1.755ab	0.170a	0.91a
10	41.49b	1.802b	1.714a	0.167a	1.02a
40	50.20c	2.423c	1.800b	0.160a	0.86a
160	57.74c	2.791c	1.831b	0.183a	0.98a

[x]Comparable means followed by the same letter are not significantly different (0.05 level) according to Duncan's New Multiple Range Test.

[y]Each observation is the average of 10 plots.

[z]Each observation is the average of 2 plots.

Phosphorus, potassium, and calcium levels in the leaves did not vary significantly among the treatments and the averages were 0.17% for phosphorus, 0.94% potassium, and 0.74% for calcium. All these levels are above the levels considered satisfactory for eastern blueberries (Trevett, 1972). This would indicate adequate levels of these nutrients are present in the soil and thus make the addition of a complete fertilizer, which has been recommended for eastern species (Trevett, 1968a), unnecessary. Nitrogen levels in the leaves generally increased as the amount of fertilizer increased. While the foliar nutrient content of the treatments was similar, total nutrient uptake of the higher treatments was greater due to the increased amount of growth of these treatments.

While no conclusions can be drawn on the effect of the fertilizer treatments on berry production as had been hoped, it is clear that the fertilizer treatments had a beneficial effect on the new vegetative growth of the huckleberry bushes. This increased growth due to nitrogen fertilization has been reported for the eastern species (Boller, 1951; Bailey et al., 1966). The absolute size of the effect, however, seems to be greatest at the lower levels of fertilization and decreases at the higher levels. Additions of over 160 pounds of nitrogen per acre would probably cause only slight increases in the growth effect and the cost-benefit ratio might be reduced. Thus, an application of ammonium sulfate at the rate of between 40 and 160 pounds of nitrogen per acre would seem to be the best practice. This rate is slightly higher than that recommended on eastern blueberry fields (Trevett, 1968b).

Bioassay Study

The bioassay study was carried out to supplement the field study by demonstrating the fertilizer effect on seedlings in a constant, favorable environment. The control and the 10 pounds of nitrogen per acre treatments were not significantly different (Table III). The treatments with higher levels of fertilization, however, had

Table III. Average Shoot Length, Oven Dry Weight, and Foliage Nitrogen Content of Bioassay Treatments.[x]

Treatment (lbs N/ac)	Shoot Length[y] (cm)	Oven Dry Weight[y] (g)	Nitrogen[z] (%)
0	12.20a	0.536a	0.71
10	13.70ab	0.623a	1.03
40	17.75bc	1.064b	1.16
160	23.00c	1.535c	1.43

[x]Comparable means followed by the same letter are not significantly different (0.05 level) according to Duncan's New Multiple Range Test.

[y]Average of 10 observations

[z]Single observations

significantly better growth than these lower levels. The increase in shoot length for the 40 and 160 pounds of nitrogen per acre treatments was more rapid and longer lasting than for the lower levels (Figure 1). The 160 pounds of nitrogen per acre treatment had the greatest growth of all treatments. It also had a significantly higher dry weight than the 40 pounds of nitrogen per acre treatment. Root development of the seedlings was better at the two highest levels of fertilization.

No treatments were harvested until the 160 pounds of nitrogen per acre treatment had stopped growing. Therefore, the nutrient levels in the leaves of the lower fertilizer treatments were reduced before they were harvested. In addition, the greenhouse conditions may have permitted a dilution of the nutrients in the leaves of the

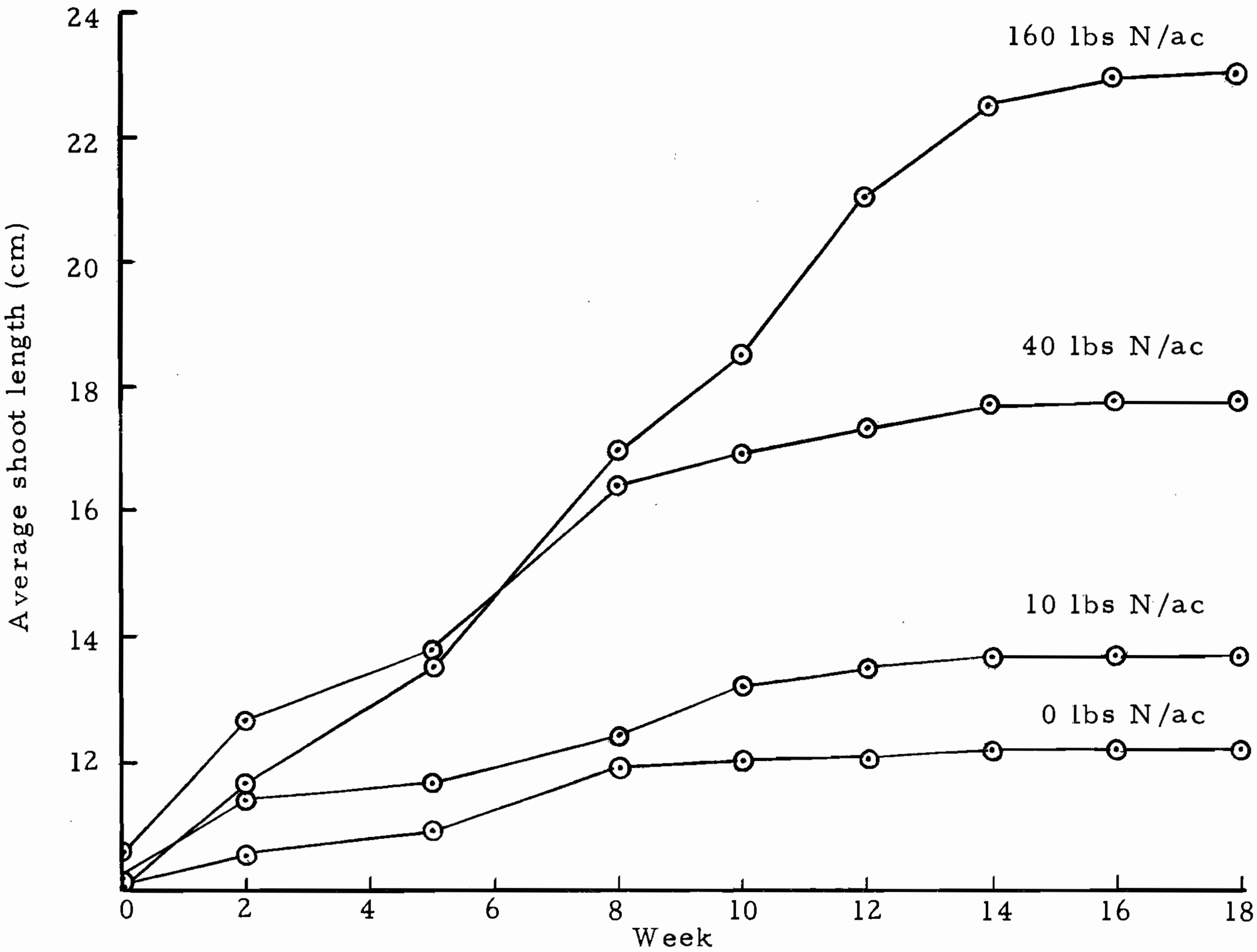

Figure 1. Average shoot length growth of seedlings in the bioassay treatments.

seedlings. Hence, the nitrogen levels, as well as the phosphorus, potassium, and calcium levels, were lower than those found in the field.

The higher levels of fertilization, especially the 160 pounds of nitrogen per acre treatment, appear to have produced a greater percentage increase in vegetative growth in the greenhouse than was apparent in the field study (Figure 2). The more optimum growth conditions were probably largely responsible for this difference. In addition, the fact that seedlings were used in the greenhouse and established plants were used in the field to measure the response to the fertilizer treatments may have had an effect on the relative response.

pH Study

The pH study was used to determine the effect of the pH of nutrient solutions on huckleberry seedling growth. Leaf necrosis occurred in the pH 3.0 treatment and there was less growth than in the other three treatments (Table IV). The pH 5.0 treatment had the best growth of all treatments but was not significantly better than the pH 4.0 or pH 6.0 treatments. Seedlings grown with these three treatments had relatively equal shoot growth (Figure 3) throughout the study and their root development was similar. Nutrient levels in the leaves of seedlings from the three higher pH treatments were also

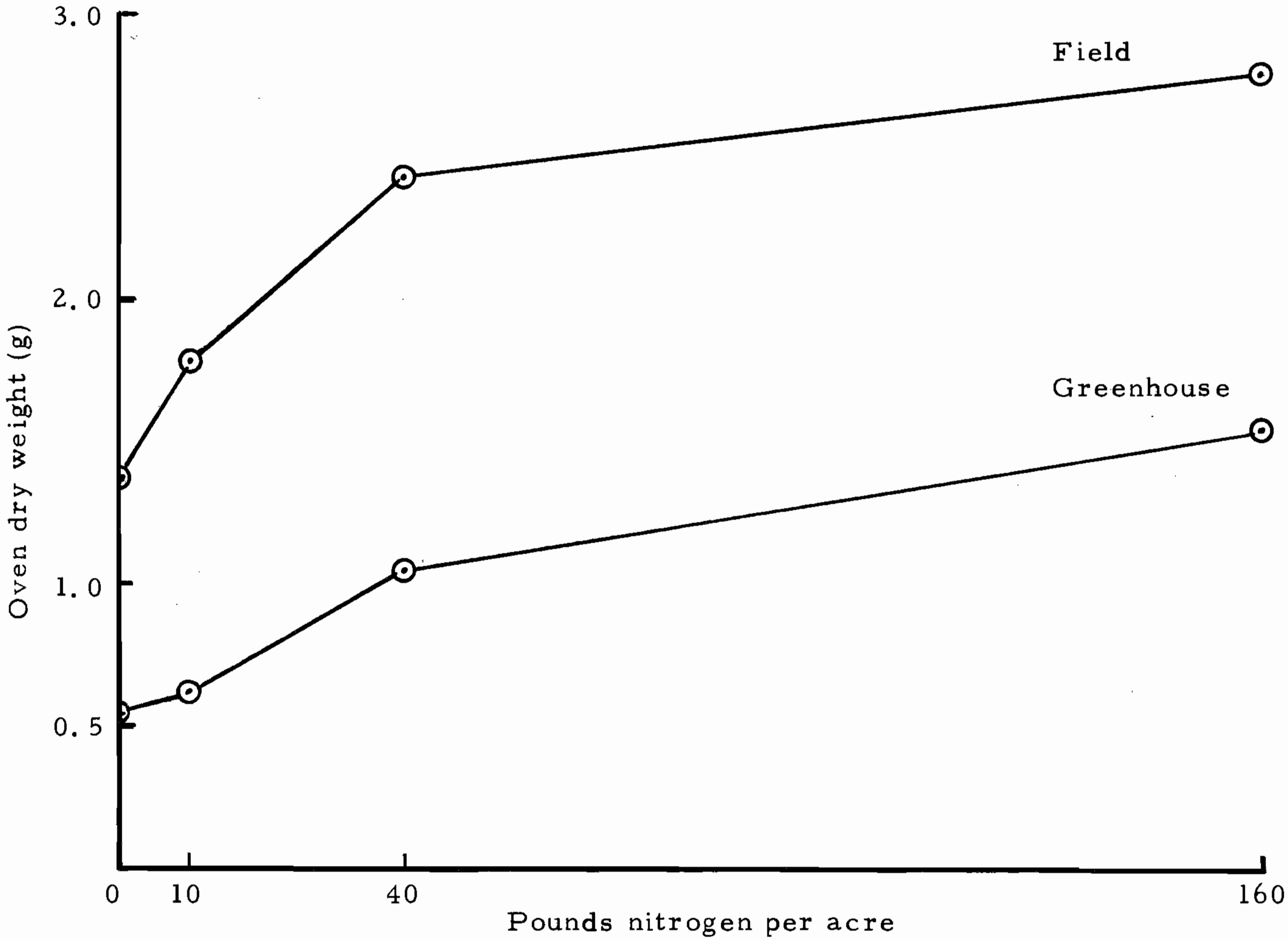

Figure 2. Average oven dry weight of field fertilization and bioassay treatments.

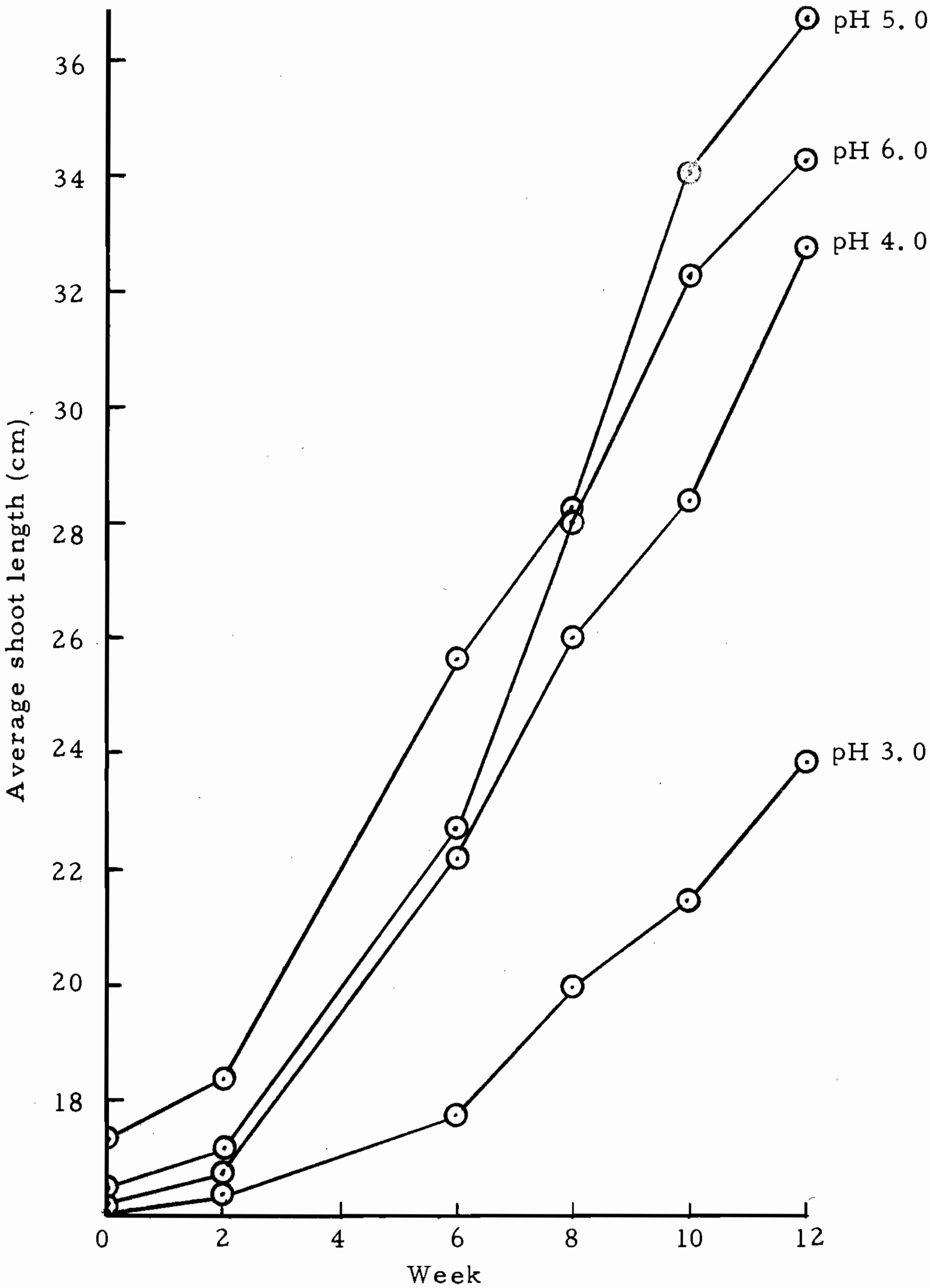

Figure 3. Average shoot length growth of seedlings in the pH treatments.

Table IV. Average Shoot Length, Oven Dry Weight, and Foliage Nitrogen Content of pH Treatments.[x]

Treatment (pH)	Shoot Length[y] (cm)	Oven Dry Weight[y] (g)	Nitrogen[z] (%)
3.0	23.75a	0.626a	1.60
4.0	32.70ab	0.838ab	1.75
5.0	36.70b	1.193b	1.89
6.0	34.25ab	0.952ab	1.91

[x] Comparable means followed by the same letter are not significantly different (0.05 level) according to Duncan's New Multiple Range Test.

[y] Average of 10 observations

[z] Single observations

similar. The nitrogen level of foliage from plants grown with the pH 3.0 treatment was slightly lower than the other three, but its potassium level was over 1/3 higher.

It therefore appears that huckleberry seedlings grow well in sand culture over a range of pH values of the nutrient solution. While 3.0 seems to be too acidic, the range between 4.0 and 6.0 appears to be suitable, with 5.0 being near optimum. This range is in general agreement with the range considered satisfactory for the eastern species of blueberries (Hall *et al.*, 1964; Townsend, 1971).

Nutrient Study

The purpose of the nutrient study was to ascertain the effects of various levels of nitrogen, phosphorus, and potassium on seedling growth in the greenhouse. Tables V and VI show the effects of the nutrient treatments on oven dry weight and shoot length of the seedlings. The nutrient levels (N1, P2, etc.) are the levels that are present in the treatment solutions, with 1 being the high level, 2 the medium level, and 3 the low level (see Laboratory Methods section). These data were then analyzed to ascertain the effects of the individual elements and the possible interactions between them.

The levels of phosphorus and potassium, when analyzed individually, made no significant difference on the weight of the seedlings (Table VII). The level of nitrogen, however, was highly significant, with the highest level of nitrogen yielding the greatest weight. These relationships were also found to be true with regard to average shoot length of the seedlings (Table VIII). It is therefore clear that the nitrogen level of the treatments was the most important single factor. This has been shown to be true for eastern blueberries as well (Stene, 1939; Kocher and Valenzuela, 1973).

Tables IX and X summarize the effects of the possible interaction between pairs of the elements on oven dry weight and shoot length of the seedlings. The effects were the same on both measures of growth. No significant interaction between phosphorus and potassium was found. The interaction of nitrogen and phosphorus was effected almost entirely by the level of nitrogen. The only exception was in the high level of nitrogen. With this level of nitrogen, the low level of

Table V. Average Oven Dry Weight (grams) of Seedlings in Nutrient Treatments.[x]

	N1			N2			N3		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
K1	1.346	1.619	0.972	0.304	0.308	0.334	0.244	0.273	0.272
K2	1.133	0.782	0.669	0.522	0.631	0.598	0.366	0.386	0.389
K3	1.018	0.911	0.692	0.585	0.625	0.651	0.440	0.411	0.385

[x]Each observation is the average of 10 seedlings.

Table VI. Average Shoot Length (cm) of Seedlings in Nutrient Treatments.[x]

	N1			N2			N3		
	P1	P2	P3	P1	P2	P3	P1	P2	P3
K1	35.70	40.05	32.50	19.45	18.05	17.55	16.25	16.65	15.00
K2	34.70	27.25	27.05	24.20	23.80	24.95	16.85	16.80	17.90
K3	35.30	32.55	25.40	23.85	26.05	26.90	18.05	16.20	18.00

[x]Each observation is the average of 10 seedlings.

Table VII. Individual Element Effects on Average Oven Dry Weight of Seedlings in Nutrient Study.[x,y]

N Level	Oven Dry Weight (g)	P Level	Oven Dry Weight (g)	K Level	Oven Dry Weight (g)
1	1.016a	1	0.662a	1	0.630a
2	0.506b	2	0.661a	2	0.608a
3	0.352c	3	0.551a	3	0.635a

[x]Comparable means followed by the same letter are not significantly different (0.05 level) according to Duncan's New Multiple Range Test.

[y]Each observation is the average of 90 seedlings.

Table VIII. Individual Element Effects on Average Shoot Length of Seedlings in Nutrient Study.[x,y]

N Level	Shoot Length (cm)	P Level	Shoot Length (cm)	K Level	Shoot Length (cm)
1	32.28a	1	24.93a	1	23.47a
2	22.76b	2	24.16a	2	23.72a
3	16.86c	3	22.81a	3	24.70a

[x]Comparable means followed by the same letter are not significantly different (0.05 level) according to Duncan's New Multiple Range Test.

[y]Each observation is the average of 90 seedlings.

Table IX. Two Element Interactions on Average Oven Dry Weight (grams) of Seedlings in Nutrient Study. [x][y]

	N1	N2	N3
P1	1.166a	0.470b	0.350c
P2	1.104a	0.521b	0.357c
P3	0.778d	0.528b	0.349c
	N1	N2	N3
K1	1.312a	0.351b	0.263c
K2	0.861d	0.584e	0.380f
K3	0.874d	0.620e	0.412f
	P1	P2	P3
K1	0.631a	0.733a	0.562a
K2	0.674a	0.600a	0.552a
K3	0.681a	0.649a	0.567a

[x] Comparable means followed by the same letter are not significantly different (0.05 level) according to Duncan's New Multiple Range Test.

[y] Each observation is the average of 30 seedlings.

Table X. Two Element Interactions on Average Shoot Length (cm) of Seedlings in Nutrient Study.[x,y]

	N1	N2	N3
P1	35.23a	22.50b	17.05c
P2	33.28a	22.63b	16.55c
P3	28.32d	23.13b	16.97c

	N1	N2	N3
K1	36.08a	18.35b	15.97c
K2	29.67d	24.32e	17.18f
K3	31.08d	25.60e	17.42f

	P1	P2	P3
K1	23.80a	24.92a	21.68a
K2	25.25a	22.62a	23.30a
K3	25.73a	24.93a	23.43a

[x] Comparable means followed by the same letter are not significantly different (0.05 level) according to Duncan's New Multiple Range Test.

[y] Each observation is the average of 30 seedlings.

phosphorus yielded significantly less growth than the medium or high level. Thus, in a soil with a high nitrogen level, a high phosphorus level would produce better growth than a low one, but the phosphorus level will make little difference on the growth if lower nitrogen levels are present.

The interaction between nitrogen and potassium appears to be the most important. Again, the nitrogen level showed its individual effect, but significant interactions with the potassium level were present at all nitrogen levels. At the high nitrogen level, the high potassium level produced significantly more growth than the medium or low levels of potassium. However, at the medium and low levels of nitrogen, the high potassium level produced significantly less growth than the medium or low levels. It thus appears that a high potassium level in the soil would be an asset if a high nitrogen level were present, but it would be detrimental if a low nitrogen level were present.

Each nitrogen level in the nutrient solutions produced a significantly different foliar nitrogen content (Table XI), with the high level having the highest content. The high levels of phosphorus and potassium in the solutions also had significantly higher content of these elements in the leaves of the seedlings. However, the medium and low levels of phosphorus and potassium did not produce significantly different levels of the elements in the leaves. No interaction between the elements was seen in relation to foliar nutrient content.

Table XI. Percentage by Dry Weight of Elements in Foliage of Seedlings.[x,y]

N Level	% N	P Level	% P	K Level	% K
1	2.10a	1	0.206a	1	2.54a
2	1.21b	2	0.156b	2	1.07b
3	0.76c	3	0.144b	3	1.04b

[x]Comparable means followed by the same letter are not significantly different (0.05 level) according to Duncan's New Multiple Range Test.

[y]Each observation is the average of 9 treatments.

Table XII shows the relative total nutrient uptake of the seedlings in the study. The values were obtained by multiplying the average oven dry weight of the seedlings times the content of the nutrients in the foliage. The total uptake of the high level of each nutrient was given the relative value of 100%. The greatest difference in relative uptake was among the nitrogen levels which dropped to an uptake of only 12.5% that of the high level. The relationships among the phosphorus levels and the potassium levels were similar to those seen in the foliar nutrient content of the seedlings.

The seedlings receiving the nutrient solutions with a high level of nitrogen contained 20% more nitrogen in their leaves than the leaves from the field plants. The seedlings receiving the medium and low levels contained less nitrogen than the field plants. The

Table XII. Relative Total Nutrient Uptake of Seedlings in Nutrient Study.

N Level	N Uptake (%)	P Level	P Uptake (%)	K Level	K Uptake (%)
1	100.0	1	100.0	1	100.0
2	28.7	2	75.6	2	40.7
3	12.5	3	58.2	3	41.3

seedlings receiving the high level of phorphorus contained 23.5% more phosphorus in their leaves than did the field plants, and the seedlings receiving the medium and low levels contained about the same level as was present in the field plants. The seedlings receiving the high level of potassium contained 170% more potassium in their leaves than the field plants, while the seedlings receiving the medium and low levels contained slightly more potassium than the field plants.

The high content of potassium in the foliage may have been responsible for the repression of growth in treatments receiving the high level of potassium and medium or low levels of nitrogen. However, the treatments with high foliar levels of both nitrogen and potassium had satisfactory growth. Because of the possible reduction of growth, potassium should not be added as fertilizer to huckleberry fields.

While slight increases in the foliar content of phosphorus were seen in the high level treatments, no substantial growth increases were seen. It would seem that fertilization in the field with phosphorus would not be necessary unless this element was a limiting factor.

The slightly increased content of nitrogen in the foliage and the beneficial effects of higher levels of nitrogen on growth would indicate that nitrogen would be the most productive element to add as fertilizer in the field.

Management Recommendations

Recreation should be the primary use of land currently occupied by wild huckleberries. The results obtained from my studies indicate that fertilization of huckleberry fields can cause increased growth of the bushes. In addition, I believe the berry yield can be increased by fertilization, as is the case in the eastern species (Rayment, 1965). This increase in production would provide a substantial increase in the economical and recreational values of the larger fields. The recreational value, especially, would benefit from the increased production of huckleberries available to the increasing number of visitors to the fields. I believe that it would therefore be advisable to initiate fertilization plans for the larger fields of wild huckleberries.

I would recommend fertilizing with nitrogen. The response from this element was the most pronounced in the nutrient study and, when added to the field in the form of ammonium sulfate, it produced increased growth of the bushes. I would suggest an application of 40 or 50 pounds of nitrogen per acre. This rate showed an increased amount of growth in the field and would be an appropriate starting point. This rate could be adjusted according to the area and the level of nitrogen initially present on the individual sites.

At present, fertilization for other elements does not seem to be indicated. However, shortages of other nutrients may develop after the fields have been under intensive management. A close observation of the nutrient status of the bushes should therefore be maintained in order to monitor nutrient levels for potential shortages. If shortages do develop, fertilization for these other elements may be necessary.

My studies have provided many answers concerning the fertilization aspects of wild huckleberry management. However, there are still areas for possible future research. The time of application of the fertilizer may have an effect on the response of the bushes. Also, the effect of fertilization on the competing vegetation could be studied to ascertain the amount of undesirable stimulation which takes place.

Fertilization is not the only area which must be included in a management plan for wild huckleberries. Research on the problem of encroachment of shrubs and trees into the huckleberry fields is being conducted by the U.S. Forest Service in an attempt to find a practical way to stop the loss of huckleberry acreage due to natural succession. When this information is available, it will be a valuable addition to a comprehensive management plan.

SUMMARY

It has become evident that workable management plans for heavily used huckleberry fields must be formulated if this recreational resource is to be preserved. These plans must be two-fold in design. First, the natural succession operating on the huckleberry fields must be stopped or reversed in order to insure the continued existence of the acreage which now produces huckleberries. And second, the production of the fields must be increased to supply the demands placed on them by the increasing number of huckleberry pickers who use the fields as a recreational outlet. The emphasis of this research has been directed towards increasing production of the huckleberry fields by means of fertilization.

The sand culture tests run in the greenhouse provided some valuable information which can be applied to the field situation. The pH tests showed that the thin-leaved huckleberry can grow well in soils of pH 4 to pH 6, with the best growth at pH 5. A pH of 3 was found to be too acidic to support good growth.

The most important result of the nutrient study was the beneficial effect on growth which high levels of nitrogen can produce. No detrimental effects were seen in the high nitrogen level treatments. Because of the positive growth effects, nitrogen should be the first element added by fertilization to the huckleberry fields.

The field fertilization study showed that increased growth could be obtained in the field by the application of a nitrogen fertilizer. Response was found to occur in all levels of fertilization (10, 40, and 160 pounds of nitrogen per acre), but the best response occurred in the 40 and 160 pounds of nitrogen per acre treatments. However, the difference between the 40 and 160 pounds of nitrogen per acre treatments was not significant. This indicates that 40 pounds of nitrogen per acre produces a response which is nearly equal to the maximum possible response. At levels higher than 40 pounds of nitrogen per acre, other factors may override the beneficial effect on the growth of the huckleberry bushes. For example, high levels of fertilization might produce an undesirable response from the competing vegetation.

This response to fertilization was also seen in the bioassay test of the field soil and fertilization levels. Because the bioassay was carried out in the more favorable conditions of the greenhouse, the percentage response of the fertilization levels over the control treatments was greater in the bioassay study than in the field study.

Due to the poor crop of berries this year, no results could be gathered on the effect of the fertilizer on berry production, but it seems logical that the berry production would be enhanced by the fertilization. It would be valuable to verify this in the field, however. In addition, it might prove valuable to see if the time of application of the fertilizer has an effect on the type of response, as is the case with the eastern species.

The phosphorus level had little effect on the growth of seedlings in the sand culture tests. It seems that only low levels of phosphorus are necessary to maintain growth of the species. Because of this, additions of fertilizers containing phosphorus would not be necessary unless phosphorus was known to be a limiting factor of growth in that field.

High levels of potassium were found to have an adverse effect on the growth of the seedlings in the sand culture tests. A possible explanation is that the huckleberry plants will take up all the potassium that is available to them. Levels of potassium in the plants may then reach a level that is detrimental to growth. Thus, additions of potassium by fertilization should be avoided unless potassium had been found to be the limiting factor of growth.

In general, then, the best management practice to increase growth of the huckleberry bushes would be to apply nitrogen at a rate between 40 and 160 pounds per acre. Low levels of phosphorus and potassium should be added only if the soil was extremely low in these elements.

BIBLIOGRAPHY

Amling, Harry James. 1960. Influence of nutrient-element supply on leaf composition and growth of highbush blueberry (Vaccinium corymbosum L.) with special reference to importance of sampling date on leaf and fruit composition of field grown blueberries. Dissertation Abstracts 21:1012.

A. O. A. C. 1950. Official methods of analysis of the Association of Official Agricultural Chemists, 7th ed. A. O. A. C., Washington, D. C. p. 745-747.

Arnon, D. I. and D. R. Hoagland. 1940. Crop production in artificial culture solutions and in soils with special reference to factors influencing yields and absorption of inorganic nutrients. Soil Sci. 50:463-483.

Bailey, John S., H. J. Franklin, and J. L. Kelly. 1941. Blueberry culture in Massachusetts. Mass. Ag. Expt. Sta. Bull. No. 358. 20 p.

Bailey, John S., Bertram Gersten, Edward Vlach, and George W. Olanyk. 1966. Response of Rubel blueberry bushes to ammonium sulfate and sulfate of potash-magnesia. Proc. Am. Soc. Hort. Sci. 89:237-242.

Bailey, John S., C. Tyson Smith, and Robert T. Weatherby. 1949. The nutritional status of the cultivated blueberry as revealed by leaf analysis. Proc. Am. Soc. Hort. Sci. 54:205-208.

Bailey, John S., A. F. Spelman, and Bertram Gersten. 1962. Seasonal changes in the nutrients in the leaves of Rubel blueberry bushes. Proc. Am. Soc. Hort. Sci. 80:327-330.

Ballinger, W. E. 1966. Factors affecting the mineral-element content of leaves and fruit of Wolcott blueberries. Proc. Am. Soc. Hort. Sci. 88:325-330.

Ballinger, W. E. and E. F. Goldston. 1967. Nutritional survey of Wolcott and Murphy blueberries (Vaccinium corymbosum L.) in eastern North Carolina. N. C. Ag. Expt. Sta. Tech. Bull. No. 178.

Ballinger, W. E. and L. J. Kushman. 1969. Relationship of nutrition and fruit quality of Wolcott blueberries grown in sand culture. Am. Soc. Hort. Sci. 94:329-335.

Black, W. N. 1963. The effect of frequency of rotational burning on blueberry production. Can. J. Pl. Sci. 43(2):161-165.

Boller, C. A. 1951. Growing blueberries in Oregon. Ore. Ag. Expt. Sta. Bull. 499. 20 p.

Bright, George A. 1937. Huckleberries release from reproduction. Unpublished. On file at Mt. Adams R. D., Trout Lake, Wash.

Cain, John C. 1952. A comparison of ammonium and nitrate nitrogen for blueberries. Proc. Am. Soc. Hort. Sci. 59:161-166.

Cain, John C, and Paul Eck. 1966. Blueberry and cranberry. In: Nutrition of fruit crops. (Norman F. Childer, ed.). Sumerset Press, Inc. Somerville, N. J. p. 101-129.

Camp, W. H. 1942. A survey of the American species of Vaccinium subgenus Euvaccinium. Britonia 4(2):205-247.

Chandler, F. B. and I. C. Mason. 1933. Effects of fertilizer on the native Maine blueberry. Proc. Am. Soc. Hort. Sci. 30:297-298.

Childs, W. H. 1950. Greenhouse fertilization of blueberry hybrids grown in shredded sphagnum. Proc. Am. Soc. Hort. Sci. 56:23-26.

__________________. 1952. Further studies of greenhouse fertilization on blueberry hybrids grown in shredded sphagnum. Proc. Am. Soc. Hort. Sci. 60:141-145.

Darrow, George M. 1960. Blueberry breeding--past, present, future. Am. Hort. Mag. 39(1):14-33.

Doehlert, Charles A. 1940. Dates for applying blueberry fertilizer. Proc. Am. Soc. Hort. Sci. 38:451-454.

Doehlert, Charles A. and John W. Shive. 1936. Nutrition of blueberry (Vaccinium corymbosum L.) in sand cultures. Soil Sci. 41(1):341-350.

Doran, William L. 1941. The propagation of some trees and shrubs by cutting. Mass. Ag. Expt. Sta. Bull. No. 382. 56 p.

Fiske, C. H. and Y. Subbarrow. 1925. The colorimetric determination of phosphorus. J. Biol. Chem. 66:375-400.

Hall, F. C. 1964. Literature review of huckleberry (Vaccinium membranaceum) in the Cascade Range of Oregon. Unpublished. On file at U. S. D. A. For. Serv., Region 6, Portland, Ore.

Hall, Ivan V., Lewis E. Aalders, and Lloyd R. Townsend. 1964. The effect of soil pH on the mineral composition and growth of the lowbush blueberry. Can. J. Pl. Sci. 44(5):433-438.

Hayes, Doris W. and George A. Garrison. 1960. Key to important woody plants of eastern Oregon and Washington. U. S. D. A. Agric. Handbook No. 148. 227 p.

Herath, H. M. E. and G. W. Eaton. 1968. Some effects of water table, pH, and nitrogen fertilization upon growth and nutrient-element content of highbush blueberry plants. Proc. Am. Soc. Hort. Sci. 92:274-283.

Hewitt, E. J. 1952. Sand and water culture methods used in the study of plant nutrition. Commonwealth Bur. Hort. and Plantation Crops Tech. Communication No. 22. 241 p.

Hitchcock, C. Leo and Arthur Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Wash. Press, Seattle, Wash. 730 p.

Johnston, Stanley. 1935. Propagating low- and high-bush blueberry plants by means of small side shoots. Proc. Am. Soc. Hort. Sci. 33:372-375.

Kocher, Frederico. 1973. The nitroten nutrition of the lowbush blueberry. 3. Leaf analysis in the assessment of nitrogen responses in field plants. Res. Life Sci. 20(8):8-11.

Kocher, Frederico and Jorge Valenzuela. 1971. Nitrogenous constituents in tissues of growing and dormant lowbuch blueberry plants. Hort. Sci. 6(4):411-413.

________________. 1973. The nitrogen nutrition of the lowbuch blueberry. 2. Relationships among nitrogen supply, vegetative growth, and tissue composition. Res. Life Sci. 20(8):1-7.

Lockhart, C. L. and W. M. Langille. 1962. The mineral content of the lowbush blueberry. Can. Pl. Dis. Survey 42(3):124-128.

Minore, Don. 1972a. Germination and early growth of coastal tree species on organic seed beds. Pac. N. W. For. and Range Expt. Sta. Res. Paper No. 135. 18 p.

__________. 1972b. The wild huckleberries of Oregon and Washington--a dwindling resource. Pac. N. W. For. and Range Expt. Sta. Res. Paper No. 143. 20 p.

Neiland, Bonita J. 1958. Forest and adjacent burn in the Tillamook burn area of northwest Oregon. Ecology 39(4):660-671.

Nelson, Gerhart H. 1970. Huckleberry management. Unpublished. On file at U. S. D. A. For. Ser., Region 6, Portland, Ore.

Oertli, J. J. 1963. Effect of form of nitrogen and pH on growth of blueberry plants. Agron. J. 55(3):305-307.

Parke, W. N. 1968. Recreation considerations for a managed stand. In: Alan B. Berg (ed.). Management of young growth Douglas-fir and western hemlock symp. proc. 1968:59-63.

Rayment, A. F. 1965. The response of native stands of lowbush blueberry in Newfoundland to nitrogen, phosphorus, and potassium fertilizers. Can. J. Pl. Sci. 45(2):145-152.

Scott, D. H. and A. D. Draper. 1967. Light in relation to seed germination of blueberries, strawberries, and Rubus. Hort. Sci. 2:107-108.

Smith, W. W., Russel Eggert, A. R. Hodgdon, and A. F. Yeager. 1946. Response ob lowbush blueberries to fertilizers. Proc. Am. Soc. Hort. Sci. 48:263-268.

Stamy, Roger S. 1970. Action plan for controlling public use in the Sawtooth huckleberry fields. Unpublished. On file at Mt. Adams R. D., Trout Lake, Wash.

Stene, A. E. 1939. Some observations on blueberry nutrition based on greenhouse culture. Proc. Am. Soc. Hort. Sci. 37:620-622.

Strushnoff, Cecil and L. Fredric Hough. 1968. Response of blueberry seed germination to temperature, light, potassium nitrate and corimarin. Proc. Am. Soc. Hort. Sci. 93:260-266.

Townsend, L. R. 1966. Effect of nitrate and ammonium nitrogen on the growth of the lowbush blueberry. Can. J. Pl. Sci. 46(2):209-210.

_________________. 1967. Effect of ammonium nitrogen and nitrate nitrogen, separately and in combination, on the growth of the high bush blueberry. Can. J. Pl. Sci. 47(5):555-562.

_________________. 1969. Influence of form of nitrogen and pH on growth and nutrient levels in the leaves and roots of the lowbush blueberry. Can. J. Pl. Sci. 49(3):333-338.

_________________. 1971. Effect of acidity on growth and nutrient composition of the highbush blueberry. Can. J. Pl. Sci. 51(5):385-390.

Townsend, L. R. and I. V. Hall. 1970. Trends in nutrient levels of lowbush blueberry leaves during four consecutive years of sampling. Nat. Can. 97(4):461-466.

Townsend, L. R., I. V. Hall, and L. E. Aalders. 1968. Chemical composition of rhizomes and associated leaves of the lowbush blueberry. Proc. Am. Soc. Hort. Sci. 93:248-253.

Trevett, M. F. 1962. Nutrition and growth of the lowbush blueberry. Maine Ag. Expt. Sta. Bull. 605. 151 p.

_________________. 1965a. Fertilizing lowbush blueberries is tricky. Maine Farm Res. 12(4):35-42.

_________________. 1965b. Spring or fall fertilization for lowbush blueberries. Maine Farm Res. 13(3):11.

_________________. 1966. Leaves tell how to fertilize lowbush blueberry. Maine Farm Res. 14(2):25-30.

_________________. 1968a. What fertilizer besides nitrogen for lowbush blueberries. Res. Life Sci. 15(4):20-27.

_________________. 1968b. How much fertilizer does it take to change lowbush blueberry. Res. Life Sci. 16(2):7-15.

_________________. 1972. A second approximation of leaf analysis standards for lowbush blueberry. Res. Life Sci. 19(15):15-16.

Trevett, M. F., P. N. Carpenter, and R. E. Durgin. 1971. Soil acidity and lowbush blueberries. Res. Life Sci. 18(4):43-57.

Trevett, M. F., M. T. Hilborn, and L. W. Boulanger. 1966. Keep lowbush blueberry leaves green. Maine Farm Res. 14(1):12-14.

Wermlinger, Donald E. 1968. Twin Buttes huckleberry management plan. Unpublished. On file at Mt. Adams R. D., Trout Lake, Wash.

APPENDICES

APPENDIX A

FIELD PLOT TREATMENTS

Plot No.	Treatment (lbs N/ac)	Plot No.	Treatment (lbs N/ac)
1	10	21	40
2	0	22	10
3	160	23	160
4	10	24	0
5	0	25	0
6	40	26	40
7	40	27	160
8	10	28	0
9	160	29	40
10	0	30	10
11	40	31	160
12	160	32	10
13	160	33	10
14	10	34	160
15	10	35	40
16	40	36	160
17	40	37	40
18	0	38	0
19	0	39	10
20	160	40	0

APPENDIX B

STANDARD HOAGLAND'S SOLUTION

O. P. 0.6-0.7 pH 4.5-6.0

Nutrient	meq/L	ppm
N as NH_4	2	28
N as NO_3	16	224
P as PO_4	6	62
K	10	390
S as SO_4	4	64
Ca	6	120
Mg	4	48
Fe		0.6
Mn		0.5
B		0.5

APPENDIX C

FIELD PLOT RESULTS

Plot No.	Twig Length (cm)	O. D. Wt. (g)	Nitrogen (%)	Plot No.	Twig Length (cm)	O. D. Wt. (g)	Nitrogen (%)
1	60. 2	3. 03	1. 70	21	50. 6	2. 17	1. 80
2	41. 2	1. 96	1. 80	22	36. 8	1. 47	1. 72
3	68. 7	3. 60	1. 87	23	51. 3	2. 50	1. 90
4	61. 7	2. 27	1. 74	24	34. 3	1. 53	1. 73
5	32. 8	1. 49	1. 80	25	27. 2	1. 00	1. 74
6	49. 2	4. 19	1. 69	26	55. 2	2. 36	1. 79
7	50. 9	2. 81	1. 84	27	50. 7	1. 90	1. 87
8	47. 9	1. 80	1. 61	28	27. 4	1. 22	1. 72
9	47. 5	3. 20	1. 85	29	56. 4	2. 65	1. 80
10	30. 3	0. 95	1. 90	30	35. 8	1. 58	1. 74
11	50. 6	2. 70	1. 88	31	41. 8	1. 32	1. 82
12	74. 3	3. 68	1. 72	32	40. 2	1. 25	1. 75
13	70. 7	3. 72	1. 91	33	33. 1	1. 52	1. 63
14	27. 3	1. 56	1. 80	34	55. 1	2. 37	1. 79
15	37. 9	1. 86	1. 81	35	49. 5	1. 76	1. 98
16	51. 1	2. 18	1. 74	36	49. 8	2. 18	1. 69
17	47. 1	1. 99	1. 63	37	41. 4	1. 42	1. 85
18	26. 4	1. 26	1. 71	38	30. 1	1. 56	1. 60
19	41. 9	1. 69	1. 95	39	34. 0	1. 68	1. 64
20	67. 5	3. 44	1. 89	40	31. 0	1. 21	1. 60