CASTOR BEANS: THEIR NUTRIENT REQUIREMENTS, RESPONSES TO FERTILIZATION TREATMENTS, AND DEFICIENCY SYMPTOMS UNDER CONTROLLED CONDITIONS.

CASTOR BEANS: THEIR NUTRIENT REQUIREMENTS, RESPONSES TO FERTILIZATION TREATMENTS, AND DEFICIENCY SYMPTOMS UNDER CONTROLLED CONDITIONS.

By

BILLY BOB TUCKER

Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1952

Submitted to the Faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE
January, 1953

CASTOR BEANS: THEIR NUTRIENT REQUIREMENTS, RESPONSES TO FERTILIZATION TREATMENTS, AND DEFICIENCY SYMPTOMS UNDER CONTROLLED CONDITIONS.

Thesis Approved:

Charles L. Garlow
Thesis Adviser

A. H. Murphy

A. H. Nielsen
Dean of the Graduate School

ACKNOWLEDGEMENT

The writer wishes to express appreciation to all those who gave assistance in this investigation. He especially wishes to express his appreciation to Doctor Charles L. Sarthou for his advice and constructive criticism during the course of the experiment and for his help in preparation of the manuscript. He wishes to thank Doctor Robert M. Reed who was always willing to give of his time, information, and other assistance most freely.

The author is also sincerely grateful to Doctor Donald L. Van Horn and his staff of the Tobacco, Medicinal, and Special Crops Division, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, for their assistance throughout the investigation, and for supplying the funds which made this work possible.

TABLE OF CONTENTS

Page

I. Introduction - 1

II. Review of the Literature- - - - - - - - - - - - - - - - - - - 3

III. Method of Experimentation- - - - - - - - - - - - - - - - - -5

A. Methods for the Induced Formation of Nutrient Deficiency Symptoms of Castor Bean Plants Under Varying Growth Conditions- - - - - - - - - - - - - -5

1. Nutrient Culture Solutions in the Greenhouse- - --5
2. Soil Pot Cultures in the Greenhouse- - - - - - - -11
3. Field Plants Grown at Three Locations in Oklahoma- -14

IV. Results and Discussion- - - - - - - - - - - - - - - - - - - -17

A. Induced Deficiency Symptoms of Castor Plants Grown in Nutrient Solution Cultures Under Controlled Greenhouse Conditions- - - - - - - - - - - - - - - - - - --17

1. Iron Deficiency Symptoms.- - - - - - - - - - - - - -17
2. Nitrogen Deficiency Symptoms- - - - - - - - - - - --20
3. Magnesium Deficiency Symptoms.- - - - - - - - - - --25
4. Phosphorus Deficiency Symptoms.- - - - - - - - - -29
5. Calcium Deficiency Symptoms.- - - - - - - - - - - --33
6. Potassium Deficiency Symptoms.- - - - - - - - - - --36

B. Chemical Analysis of the Harvested Plant Material Produced in Controlled Nutrient Cultures- - - - - - - -43

C. Induced Deficiency Symptoms of Castor Plants Grown in Soil Pots Containing Three Different Oklahoma Soils.- -45

D. Induced Deficiency Symptoms of Castor Bean Plants Grown on Field Plots at Three Locations in Oklahoma- --47

V. Foliar Testing of the Castor Plant for Nitrogen, Phosphorus and Potassium When Grown- - - - - - - - - - - - - - - - - - --48

A. In Soil Pot Cultures Fertilized With Various Combinations of Nitrogen, Phosphorus and Potassium- - - --48

B. On Soil Plots at Three Locations.- - - - - - - - - - --51

TABLE OF CONTENTS- - -Continued

Page

VI. Summary and Conclusions 54

A. Deficiency Symptoms 54

B. Tissue Tests 57

VII. Bibliography 59

LIST OF TABLES

Page

1. Preparation of the Six Nutrient Solutions in which Castor Bean Plants were Grown in order to Obtain the Deficiency Symptoms under Closely Controlled Greenhouse Conditions. - 7

2. Rates of Application of Nitrogen, Phosphorus, and Potassium Fertilizer Materials in Greenhouse Pot Cultures. - 12

3. Rates of Application of Nitrogen, Phosphorus, and Potassium at the Three Field Locations. - - - - - - - - - 14

4. Growth and Seed Production of Deficient Castor Bean Plants Grown in a Complete Nutrient Solution in Series A Nutrient Culture Experiment. - - - - - - - - - - - - - - - 40

5. Growth and Seed Production of Deficient Castor Bean Plants as Compared to Plants Grown in a Complete Nutrient Culture Experiment. - - - - - - - - - - - - - - - - 40

6. Chemical Analysis of Deficient Castor Bean Plants as Compared with Plants Grown in a Complete Nutrient Solution in Series A Nutrient Culture Experiment. - - - 41

7. Chemical Analysis of Deficient Castor Bean Plants as Compared to Plants Grown in a Complete Nutrient Solution in Series B Nutrient Culture Experiment. - - - 42

8. Key to Nutrient Deficiency Symptoms of Castor Bean Plants. - 39

9. Results of Tissue Tests of Castor Bean Plants Grown in the Greenhouse Pot Cultures . - - - - - - - - - - - - - - 50

10. Results of Tissue Tests of Castor Bean Plants Grown in the Field Plots. - 53

LIST OF ILLUSTRATIONS

Figure		Page
1.	The nutrient solution culture experiment in the greenhouse.	16
2.	Iron deficiency in 4 month old castor bean plants grown in nutrient culture solutions.	18
3.	Iron deficiency in 10 week old castor bean plants grown in nutrient deficiency solutions as compared with plants grown in a complete solution.	19
4.	Nitrogen deficiency in 4 month old castor bean plants grown in nutrient culture solutions.	21
5.	Nitrogen deficiency in 4 month old castor bean plants grown in nutrient culture solutions.	22
6.	Nitrogen deficiency in 10 week old castor bean plants as compared with plants grown in a complete nutrient solution culture.	24
7.	Magnesium deficiency in 4 month old castor bean plants grown in nutrient culture solutions.	26
8.	Magnesium deficiency in 10 week old castor bean plants as compared with plants grown in a complete nutrient solution culture.	28
9.	Phosphorus deficiency in 4 month old castor bean plants grown in nutrient culture solutions.	30
10.	Phosphorus deficiency in 4 month old castor bean plants grown in nutrient culture solutions.	31
11.	Phosphorus deficiency in 10 week old castor bean plants as compared with plants grown in a complete nutrient solution culture.	32
12.	Calcium deficiency in 3 month old castor bean plants grown in nutrient solution cultures.	33
13.	Calcium deficiency in 2 month old castor bean plants as compared with plants grown in a complete nutrient solution culture.	35
14.	Potassium deficiency in 4 month old castor bean plants grown in nutrient culture solutions.	37
15.	Potassium deficiency in 3 month old castor bean plants as compared with plants grown in a complete nutrient solution culture.	38

Introduction

The commercial production of castor beans has become an exceedingly important cash crop for the farmers of the Southwestern United States. This crop is a new addition to their farming program as until recently, practically all castor beans crushed in the United States were imported from either Brazil, Manchuria, Africa, or India (16). The supply from these sources was found to be not only uncertain but also insufficient to meet present and future predicted needs of the United States, insofar as the oil obtained from this plant is used mainly as a raw material in the manufacture of many items vitally needed in military and defense production. The United States should have an adequate and continuous supply of castor beans from domestic sources if some contingency should arise to prevent the importation of the present foreign supplies. Some important uses of castor oil at the present time are: for the lubrication of jet airplane engines, formulation of all-purpose greases, hydraulic and recoil fluids, and the basic constituent of plastic coatings for electrical equipment (22). Other uses are: as a plasticizer in the manfacture of fabrics and explosives (16), artifical leather, soap, printing inks and special low temperature lubricants and flexible coating materials.

Although this crop has been extensively grown since biblical times, very little information has ever been gathered as to its nutrient requirements or ability to respond to varying levels of applied fertility.

Insofar, as castor beans have become an important cash crop, especially in the Southwest, many questions are arising as to the type of soil which is best suited for their growth; and also what fertilization, treatments, if any, will give economically feasible responses under varying

climatic conditions which normally prevail in this extensive area.

It was the purpose of this investigation to lay the preliminary "ground-work" in which it is hoped that sufficient information will be gathered such that future field fertility work will have sufficient scientific basis, not only to predict the behavior of castor plants on nutrient deficient soils, but also to have established definite deficiency symptoms to act as "bench-marks" in evaluating their field responses, if any, from fertilization.

It was felt that these preliminary investigations should include various methods for determining the fertility status of the plant, not only in nutrient culture solutions, but also in pot cultures, using normal Oklahoma soils. With the above points in mind the study of castor beans resolved itself into three phases:

(1) The study of deficiency symptoms in nutrient solution cultures under closely controlled conditions in the greenhouse.

(2) The study of deficiency symptoms and tissue testing in pot cultures using some normal Oklahoma soils under similiar controlled conditions in the greenhouse.

(3) The study of deficiency symptoms and tissue testing under field conditions at various locations within the state of Oklahoma.

Review of the Literature

The castor plant has been grown for the oil content of its seed for centuries, yet it wasn't until 1941 that the first recorded fertilizer trials were conducted in an effort to ascertain the potential crop yield under optinum fertility levels. In that year, Domingo and Crooks (7) in the employ of the United States Department of Agriculture conducted a field fertility experiment in which castor beans were used as the indicator crop, and varying amounts of nitrogen, phosphorus and potassium fertilizer materials were applied in bands at planting time. As a result of these studies, it was concluded by the investigators that castor beans produced no significant response, as reflected in increased bean yields, to any fertilization program attempted in this experiment. In 1943, the same investigators conducted trials using two hundred pounds of a "4-12-8" fertilizer per acre and, in addition, various combinations and amounts of the three plant nutrient elements: nitrogen, phosphorus, and potassium. Phosphorus produced an 8.5 per cent increase of bean yields on plots grown at Princeton, Kentucky; whereas, nitrogen and potassium had no effect on increasing the yield of beans grown on the same plots.

In 1951, Quinby (18) conducted a factorial fertilizer trial at Chillicothe, Texas, on Miles sandy loam and found a significant difference in yield due to nitrogen alone. Quinby (18) stated: "The addition of thirty pounds of nitrogen at planting time resulted in an increase of three hundred and eighty six pounds of clean beans per acre, and the addition of sixty pounds of nitrogen per acre resulted in an increase of five hundred and forty two pounds of beans."

In 1951, Van Horn (23) at Stillwater, Oklahoma, obtained a sixteen per cent increase in bean yields with the use of fifty pounds of ammonium nitrate per acre and a thirty three per cent increase with the use of one hundred pounds of ammonium nitrate. In addition to these trials, however, Van Horn (24) the same year, conducted other fertilizer experiments at Stillwater, Oklahoma, and experiments under irrigation at Altus, and Blair, Oklahoma, in which quite different results were obtained. Fifty, one hundred, and one hundred and fifty pounds of ammonium nitrate; one hundred pounds of ammophos; and three hundred pounds of a 5-10-5 fertilizer per acre were used at each of these locations. Van Horn found no significant increase in bean yields were obtained, from the applied rates of fertilizer at these specific locations.

III METHODS OF EXPERIMENTATION

A. Methods for the Induced Formation of Nutrient Deficiency Symptoms of Castor Bean Plants Under Widely Varying Growth Conditions:

1. Nutrient Solution Cultures in the Greenhouse

Castor bean plants were grown in a series of four-quart battery jars containing liquid nutrient media with various desired and known concentration of the essential nutrient elements; nitrogen, phosphorus, potassium, magnesium, iron, manganese, boron, zinc, copper, molybedenum and calcium. Aereation was provided by the use of an air-compressor, power being supplied from a 1/6 horse power electric motor. Air was supplied to the nutrient cultures at eighty minute intervals with the intermediate rest period being controlled by means of an automatic electric clock. Artificial lighting was used to give the plants a long and constant day, of a fourteen hour duration. White sodium-vapor florescent lamps were used to produce the artifical extended day and these were connected to a time clock which turned the lights on before sunset and remained on for an adjusted period of time, which extended into the evening. Nutrient combinations and concentrations were used as suggested by Hoagland (12). These solutions were prepared as indicated in table 1 by use of the following stock solutions:

One normal solutions of:

(1) Potassium nitrate (KNO_3)
(2) Calcium nitrate $Ca(NO_3)_2 \cdot 4\ H_2O$
(3) Dihydrogen potassium phosphate KH_2PO_4
(4) Magnesium sulphate $MgSO_4 \cdot H_2O$
(5) Potassium carbonate K_2CO_3
(6) Calcium sulphate $Ca\ SO_4$
(7) Magnesium nitrate $MgNO_3$
(8) Dicalcium phosphate $Ca_2(H_2PO_4)_2$

were prepared and used as basic stock solutions to supply the essential elements to the nutrient cultures.

A minor element solution was prepared by weighing out the following amounts of the various minor element for the compounds which were indicated to be needed for the growth of higher plants by Hoagland (12).

(1) 3.89 grams of manganous choloride $MnCl_2 \cdot 4\ H_2O$?
(2) 6.11 grams of boric acid H_3BO_3 ?
(3) .06 grams of zinc sulphate, $ZnSO_4$
(4) .06 grams of cupuric sulphate $CuSO_4 \cdot 5\ H_2O$
(5) .06 grams of soduim molybdate $Na_2\ MoO_4 \cdot 2\ H_2O$

The above minor elements were then combined, brought into water solution and diluted to one liter. This was then used as a basic stock solution from which allquots were taken to supply the required amounts of the individual elements.

Table 1 - Preparation of The Six Nutrient Solutions in Which Castor Plants were Grown in Order To Obtain The Deficiency Symptoms Under Closely Controlled Greenhouse Conditions.

Complete Solution

Stock solution	Concentration
KNO_3	4 C C per liter
$Ca(NO_3)_2 \cdot 4H_2O$	4 CC per liter
KH_2PO_4	1 CC per liter
$MgSO_4 \cdot H_2O$	2 CC per liter
Minor element	1 CC per liter

Minus Nitrogen Solution

Stock Solution	Concentration
K_2CO_3	4 CC per liter
$CaSO_4$	4 CC per liter
KH_2PO_4	1 CC per liter
$MgSO_4 \cdot 7H_2O$	2 CC per liter
Minor element	1 CC per liter

Minus Phosphorus Solution

Stock Solution	Concentration
KNO_3	4 CC per liter
$Ca(NO_3)_2 \cdot 4H_2O$	4 CC per liter
K_2CO_3	1 CC per liter
$MgSO_4 \cdot 7H_2O$	1 CC per liter
Minor element	1 CC per liter

Minus Potassium Solution

Stock Solution	Concentration
$Mg(NO_3)_2$	4 CC per liter
$Ca(NO_3)_2 \cdot H_2O$	4 CC per liter
$Ca(H_2PO_4)_2$	1 CC per liter
$MgSO_4 \cdot 7H_2O$	2 CC per liter
Minor element	1 CC per liter

Minus Magnesium Solution

Stock Solution	Concentration
KNO_3	4 CC per liter
$Ca(NO_3)_2 \cdot 4H_2O$	4 CC per liter
KH_2PO_4	1 CC per liter
$CaSO_4$	2 CC per liter
Minor element	1 CC per liter

Minus Calcium Solution

Stock Solution	Concentration
KNO_3	8 CC per liter
KH_2PO_4	1 CC per liter
$MgSO_4 \cdot 7H_2O$	2 CC per liter
Minor element	1 CC per liter

Iron was supplied to the nutrient cultures at the rate of 15 milligrams of iron as ferric tartate, per liter of solution. It was found that this rate when applied twice a week for four hours was sufficient to prevent the initiation or recurrence of iron chlorosis in castor plants. Iron was applied for this four hours, in the absence of all other elements to prevent any excessive fixation of the iron, and to insure sufficient uptake so as the plants would absorb an adequate supply for optimum growth. Ferric tartrate was the source of iron used in this investigation to prevent excess fixation of the applied solution phosphate.

Minus Iron Solution

The three replicates in both experimental series which were selected for the minus iron treatment received the complete solution as shown in table 1. However, when the other replicates received iron these minus iron treatments did not receive the ferric tartrate but were supplied with distilled water alone during these periods.

Hoagland (12) and others (10) have suggested that potassium nitrate, dihydrogen potassium phosphate, magnesium sulphate, calcium nitrate and other minor element solution previously described were the most ideal sources of the essential elements needed in plant growth, at least for nutrient solution cultures. As can be seen from above, these compounds are the major sources of the essential elements used in the experiment but by necessity there were substitutions in order that deficient levels of nitrogen, phosphorus, potassium, calcium and magnesium could each be maintained in their respective solution cultures.

The substitutions necessary to maintain neutral solutions lacking in only one nutrient element were as follows:

Minus Nitrogen solution	K_2CO_3 in place of KNO_3 $CaSO_4$ in place of $Ca(NO_3)_2$
Minus Phosphorus solution	K_2CO_3 in place of KH_2PO_4
Minus Magnesium solution	$CaSO_4$ in place of $MgSO_4$
Minus Potassium solution	$MgNO_3$ in place of KNO_3 $Ca(H_2PO_4)_2$ in place of KH_2PO_4
Minus Calcium	$MgNO_3$ in place of $Ca(NO_3)_2$

The solution cultures were checked by means of a mixed indicator and were adjusted to a pH of 6.8 to 7.2 daily by additions of suitable quantities of bases or acids. The solutions were changed weekly to keep their concentration as nearly constant as possible.

Seed of the Cimmaron variety of castor beans were planted and germinated in pure silica sand to obtain uncontaminated seedling castor plants. After germination the seedlings were transplanted to two-quart battery jars and the lower portion of the plant stems were then wrapped in cotton and supported by one-fourth inch hardware cloth. The jars contained distilled water for the first forty-eight hours, after which the various levels of nutrients were added.

Two series of plant nutrient solution cultures were conducted. Both series were replicated in triplicate. Each pot was rotated weekly in order to provide, as nearly as possible, identical light conditions to the entire plant and experiment. In the first series the plants were all given a complete nutrient solution combination from the moment of transplanting and for the first thirty days after which time the deficient treatments were applied. In the second series, the plants were started in the deficient solutions from the moment they were trans-

planted from the silica sand to the nutrient culture and this was continued unto the completion of the experiment.

When the plants exhibited abnormal external symptoms of growth the visual symptoms were observed, recorded and photographed and were regarded as deficiency symptoms under these controlled conditions. After maturity and/or death the plants were harvested as three components (1) Seed (2) Shoot and (3) Root. The dry weight of each component was recorded. The germination percentage of the produced seed was obtained by planting the seed in small flats containing acid-washed sand which had optinum water and temperature conditions necessary to produce good germinating conditions. The shoot and root were tested for total nitrogen, phosphorus and potassium.

Nitrogen was determined by the use of the modified Kjeldahl method (8).

Total phosphorus was obtained by the ammonium-molyhdate-stannous chloride method (11). The intensity of the produced blue color was evaluated by means of an Evelyn colorimeter. Extraction of the total phosphorus was obtained by means of the Nitric-percholoric acid, digestion method (11).

Potash was extracted by the use of a 1:3 nitric-perchloric acid solution and the concentration was determined by means of a Perkins-Elmer flame photometer.

2. Soil Pot Cultures in The Greenhouse

Three soils were selected for this study and these were obtained from three specific areas in Oklahoma where castor beans were extensively planted in 1952. It was thought desirable to select the types of soil on which castor beans are normally grown and these three soils were then typical of the major castor bean production areas occuring in Oklahoma.

The soils were: (1) Parson's fine sandy loam, from Pittsburg County near McAlester, Oklahoma, (2) Stidham fine sandy loam from Payne County, near Paradise, Oklahoma and (3) Stidham loamy fine sand near Perkins, Oklahoma in Payne County. The above three soils which were selected were found to be low in their natural fertility. The soil from Paradise, Oklahoma contained 1.253 per cent organic matter, only 16 pounds per acre of easily soluble phosphorus, as determined by the method of Harper's (11), and 168 pounds per acre of available potassium as indicated by neutral ammonium acetate extraction method used in the soils laboratory at Oklahoma A & M College (11). Total calcium was found to be .4956 percent and total magnesium measuring .8119 percent. This soil was moderately acid in reaction as determined by the use of a glass electrode.

The soil from Perkins contained 1.96 per cent organic matter, .142 per cent total phosphorus and 162 pounds per acre of available potassium. Total calcium in this soil being .392 per cent.

The McAlester soil (Parsons) contained 1.96 per cent organic matter, .141 per cent total phosphorus and 98 pounds per acre of available potassium and the soil reaction was moderately acid. The Parsons soil was also found to be poorly drained as it possesses a dense clay pan

at about 13 inches of depth. Air and water relationships are considered to be very poor in this soil under field conditions.

The three soils used in this experiment were screened through a four mesh sieve and weighed into two and one half gallon glazed pots. Each pot of the entire series contained twenty pounds of soil. Acid-washed sand was placed in the bottom of each pot to a depth of one inch, and glass tubing was placed through the soil to the sand in order that excessive applications of water could be removed if present.

Castor beans were planted and fertilized in June, 1952, The various series were replicated in triplicate with the exception of the Parsons fine sandy loam series which was replicated four times.

The fertilizer treatments for the soil pot cultures are listed in table 2, which follows:

Table 2.

Rates of Application of Nitrogen, Phosphorus and Potassium fertilizer Materials in Pounds per acre to Parsons and Stidham Soil Material in Greenhouse Pot Cultures.

Treatment No.	Nitrogen Pounds/ acre	Phosphorus lbs/ acre	Potassium lbs/acre
1	0	50	0
2	0	50	25
3	25	50	25
4	25	0	25
5	25	50	0
6	0	0	25
7	25	0	0
8	0	0	0

The sources of the fertilizer elements used were:

Nitrogen from Ammonium nitrate (33%N.)
Phosphorus from Super Phosphate(20% P_2O_5)
Potassium from Muriate of Potash(60% K_2O)

The fertilizers were applied to the soil in bands at a depth of approximately four inches with the seed being planted at a slightly shallower depth.

At the beginning of the experiment each pot containing the measured soil was weighed to obtain its specific dry weight. The total weight of the pot plus water was determined by first weighing the pot plus the weight of soil, and then the weight of water necessary to bring the soil moisture up to seventy-five percent of field capacity was added and included in this total weight to be considered as normal following watering. At specific intervals throughout the experiment the original normal weight of each pot of soil was restored by the addition of distilled water. The plants required watering every two to three days. Each week the pots were rotated in such a manner as to have all of them subjected to an nearly identical light conditions as possible.

Every pot received an application of "Aerotil" soil conditioner the third month of the experiment in order to produce more favorable air and water relationships.

As deficiency symptoms occured, the symptoms were studied and recorded. The petioles of the older leaves were tested for nitrogen, phosphorus and potassium as the symptoms appeared, in an effort to correlate the deficiency symptoms with the amounts of the various nutrients found in the plant.

3. Field Grown Plants at Three Locations In Oklahoma

Three soils were selected for the field studies, Parson fine sandy loam, on the Jones farm near McAlester in Pittsburg County, Oklahoma, Stidham loamy sand on the Schaffer farm near Perkins, Payne County Oklahoma, and a Miller Clay on the Oklahoma A & M College Experimental farm, Lake Carl Blackwell area, Payne County, Oklahoma.

In fertility plots at McAlester and Perkins the fertilizer was applied as a side dressing when the castor plants were approximately one month old. The various combinations of nitrogen, phosphorus, and potassium were applied at the rate of twenty-five pounds per acre of nitrogen, fifty pounds per acre of phosphorus and twenty-five pounds per acre of potassium. The fertilizer applications are indicated in table 3.

Table 3 - Rates of Application of Nitrogen, Phosphorus, and Potassium at the Three Field Locations.

Treatment No.	Rates of Application in Pound Per Acre		
	N	P	K
1	0	50	0
2	0	50	25
3	25	50	25
4	25	0	25
5	50	50	0
6	0	0	25
7	50	0	0
8	0	0	0

The castor beans at McAlester and Perkins were of the Cimmaron variety. The fertilizer was applied in bands about two inches to the side of and slightly below the seed.

At Lake Blackwell the U.S. 74 variety of castor beans were planted and fertilized at the same time in one continious operation. The fertilizer was placed about two inches to one side and slightly below the

seed. The source of the elements was the same as those previously stated for the greenhouse soil pot studies.

Total chemical analysis were obtained for the three soils previously mentioned and in addition available amounts of phosphorus and potassium in these soils were determined by the use of the methods as practiced in the soils laboratory at Oklahoma A & M College.

Visual abnormalities occuring in the growing plants were noted and recorded approximately once every two weeks.

Plant tissues were collected from each of the treated plots at two stages of growth at the Blackwell and Perkins plots and once at the McAlester plot. These leaf petioles were then analyzed for nitrogen, phosphorus, and potassium, using the LaMotte-Morgan, LaMotte-Troug soil testing kit. Nitrates present in the petioles were also checked using Bray's powder method (3).

Figure 1. - The nutrient solution culture experiment in the greenhouse.

RESULTS AND DISCUSSIONS

A. Induced Deficiency Symptoms of Castor Bean Plants Grown in Nutrient Solution Cultures Under Controlled Greenhouse Conditions.

Iron Deficiency Symptoms

The first visible symptoms of a nutrient deficiency occured in the castor plants grown in culture solutions which had received no further application of iron after the fifth day after transplanting, from silica sand to the liquid nutrient culture.

The plants in series A, which were started off in a complete solution, exhibited similiar symptoms the fifth day after iron was excluded from their media; these plants were four weeks old and were growing in a complete solution, with iron being supplied every three days, when iron was then entirely omitted from the solution. These symptoms were first exhibited in the form of a general chlorotic appearance of the newly emerging leaflets. These new leaflets were very light in color, later turned yellow throughout with only the midrib and the leaf veins retaining their green color. A few of the slightly older leaves became chlorotic shortly afterwards. The new terminal leaflets became lighter and lighter until they were almost white, and appeared to be bleached of all green color. Finally, the newer leaflets became necrotic and died shortly after emergence. The chlorotic leaves curved in a downward direction approximating an involution of the leaf. Some cells of the older chlorotic leaves began to die showing large necrotic (black) dead areas. The iron deficient leaves were smaller in size than normal leaves and were often ragged in appearance because of the tearing of the necrotic interveinal areas. The leaf

Figure 2.- Iron deficiency in 4 month old castor bean plants grown in nutrient culture solutions.

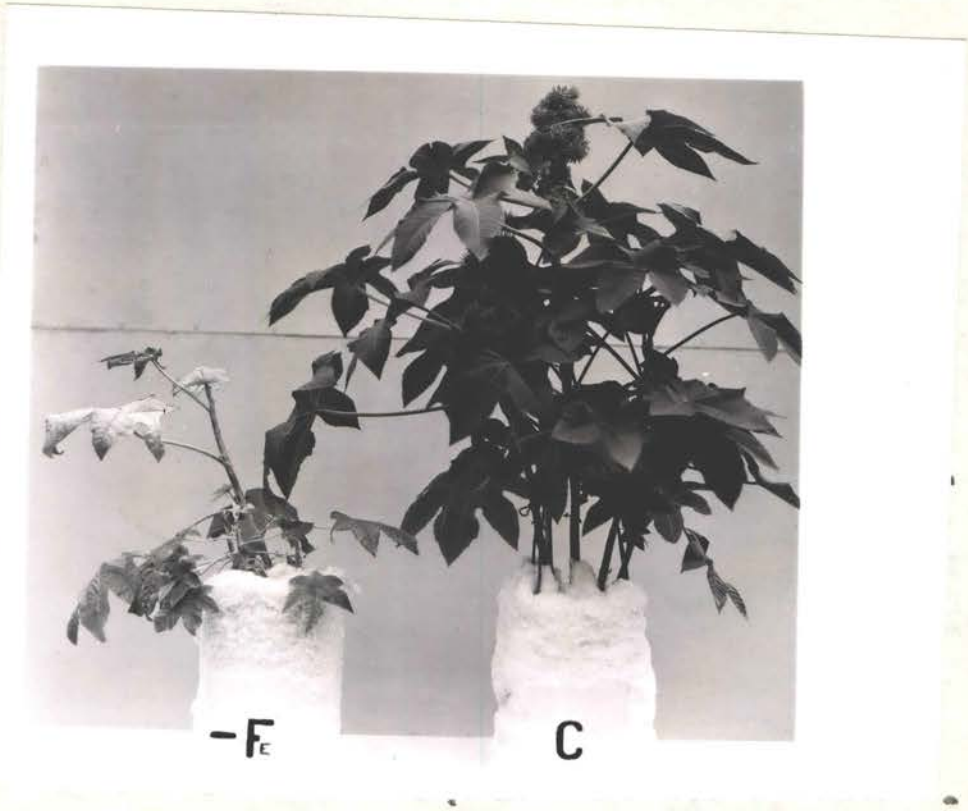

Figure 3.- Iron deficiency in 10 week old castor bean plants as compared with plants grown in a complete nutrient solution culture.

margins also had a tendency to smooth out. The lower leaves that developed before the symptoms appeared retained their normal green color, indicating that iron is not translocated within the plant. The root system, when iron was deficient, retained a very bright, almost white appearance.

In the second series of the nutrient culture experiment the castor bean plants were transplanted directly from silica sand into the nutrient solution and iron was excluded from the very moment of transplanting. It was found, in this series, that the plants without iron could not survive longer than two weeks unless this essential metal was added to the nutrient media. Deficiency symptoms were also the same as previously stated but of a more severe nature. These plants from the second series did not form seed heads or attempt to complete their life cycle and this was in great part due to their reduced and retarded growth.

Nitrogen Deficiency

The second symptom to become visible was that of nitrogen deficiency. This too, was a chlorotic condition of the leaves, but they differed from iron deficient plants in that the lower leaves were first to become chlorotic.

The plants were one month old and were very actively growing in a complete nutrient solution when three replicates were selected at random to be used for the nitrogen deficiency study. To these three replicates all essential elements were added periodically to the completion of the experiment with the exception of nitrogen. Within one week after the elemination of the nitrogen application to the cultures, the following symptoms were observed:

Figure 4.- Nitrogen deficiency in 4 month old castor bean plants grown in nutrient culture solutions.

Figure 5.- Nitrogen deficiency in 4 month old castor bean plants grown in nutrient culture solutions.

The lower leaves of the plants began to droop in a downward direction, with the petiole beginning to approximate a curved position. The lower, older leaves appeared to have a light colored margin at first, then the entire leaf bleached to a pale-green color. As the symptom progressed the margins lost their chlorophyll, then faded to a pale yellow and the leaf was shed with a definite abscission layer forming at the base of the petiole. These nitrogen deficient leaves differed from other similar symptoms in that the entire leaf, including the veins and midrib faded along with the rest of the leaf. Nitrogen deficiency symptoms started in the lower leaves and progressed upward, indicating that nitrogen is translocated from the older to the terminal leaves in deficient plants.

While the older leaves were yellowing the next succession of leaves, further up the plant, turned pale green then in turn became yellow and sloughed off. This yellowing and the falling of the leaves continued upward until all leaves of the plant had shed, and the plants were unable to manufacture vital growth materials, therefore, they ceased to grow and reproduce.

The plants grown on a low nitrogen level produced seed even sooner than the plants grown on a complete nutrient solution, but seed were few in number and they had a tendency to shatter before ripening. When nitrogen was absent from the start the plants could only survive for approximately two weeks, however, with only a very small amount of nitrogen added to the nutrient media, the plants remained alive, showing the deficiency symptoms as previously stated, but did not produce seed. The stem of the plant also became very red in color and the root growth

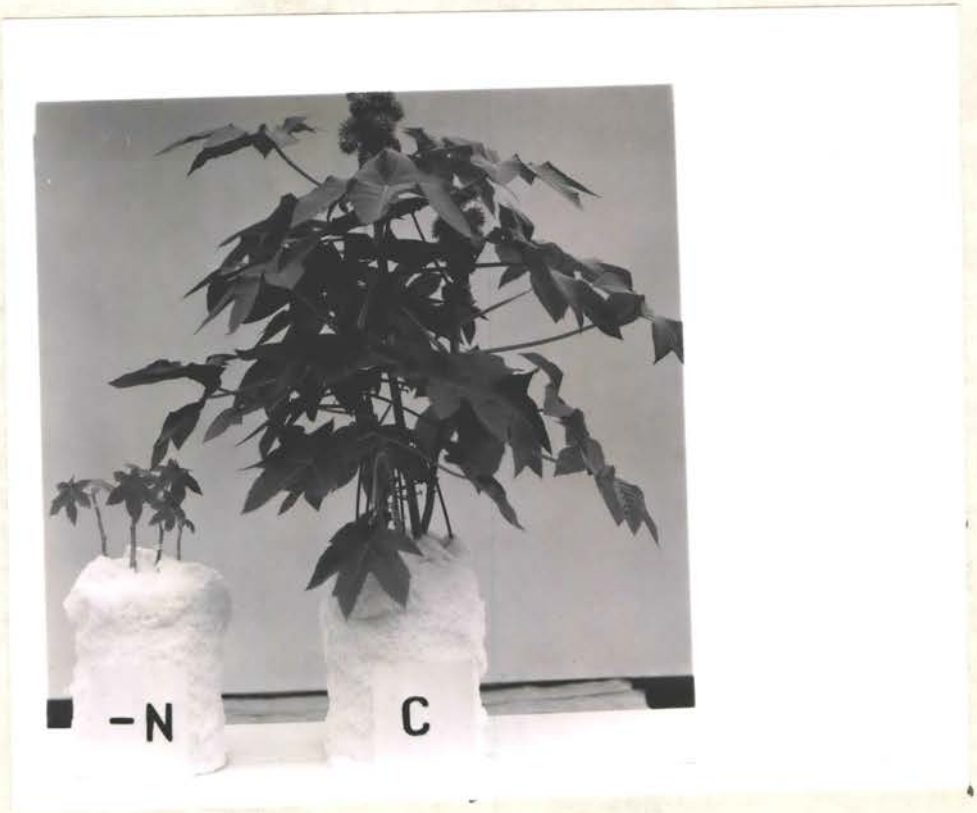

Figure 6.- Nitrogen deficiency in 10 week old castor bean plants as compared with plants grown in a complete nutrient solution culture.

was retarded in the same ratio as the retardation of the shoot growth. Plants of the second series which were deprived of nitrogen, from the beginning, could only survive a few days, unless this element was added.

Magnesium Deficiency

In about one month after depriving castor bean plants, which were actively growing in a complete solution, of magnesium; a deficiency became evident. Magnesium hungry castor plants differ from plants lacking in other essential nutrients, in that they possessed three striking symptoms. At first, the lower leaves lost their normal color at the tips and margins, and between the veins. The color varied from a pale green to a bright yellow. The veins and the tissue close to them tended to retain the normal color long after the rest of the leaf had lost practically all of its green pigment. These leaves faded after a period, dried up and fell off the plant. The same plant may show a very striking uniform mottling of the terminal leaves which consists of a yellow or white strip between the veins. These strips later became larger and the leaves lost this beautiful mottling effect.

Another symptom of magnesium deficient plants was the necrosis of the leaf margins, with the necrosis extending downward, near the petiole. This scorched area is cupped upward and makes the leaf take on a palm-like appearance with the leaf finally slouging off. During high temperatures the latter symptom seems to be prevelant. It appears from these three symptoms, as if magnesium plays an important role in the formation of chlorophyll, over and above, its being a constituent of the chlorophyll molecule.

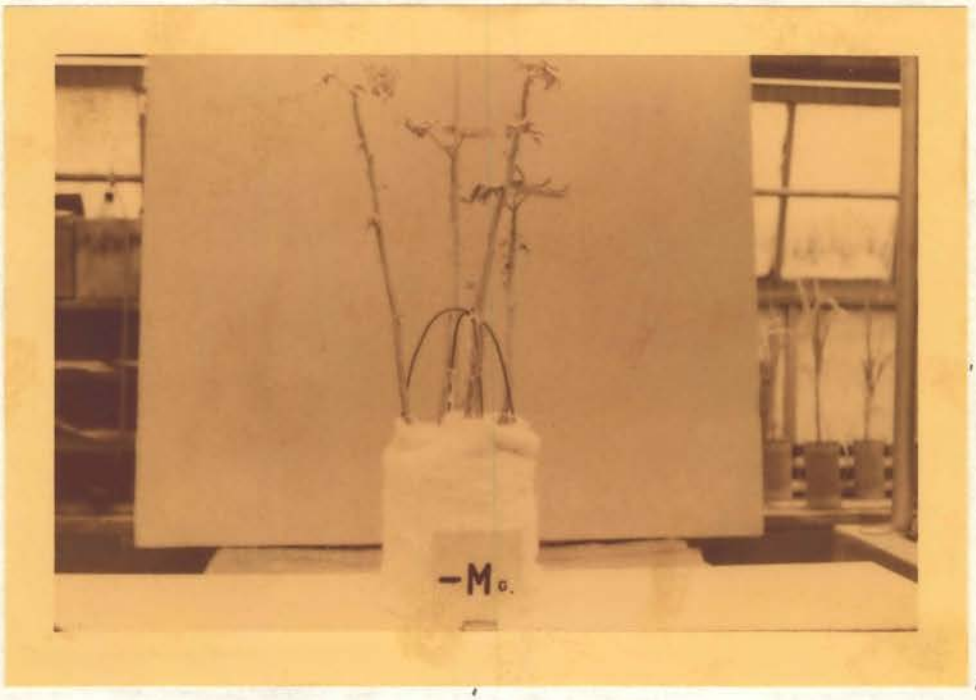

Figure 7.- Magnesium deficiency in 4 month old castor bean plants grown in nutrient culture solutions.

No seed were formed on the low magnesium cultures. In the experiment conducted in the greenhouse,under deficient magnesium conditions, the plants began to flower, but could not set fruit. The male parts of the flower seemed to be normal, but the female parts did not develop and mature. When magnesium was omitted at a very early date, growth was very much reduced, with symptoms occuring in the same manner as was stated previously.

Figure 8.- Magnesium deficiency in 10 week old castor bean plants as compared with plants grown in a complete nutrient solution culture.

Phosphorus Deficiency

Phosphorus deficiency did not occur until nine weeks after phosphorus was excluded from the nutrient solution. As a result of this study, it was concluded, that phosphorus deficiency symptoms depend upon the stage of growth, of the plant, more than on the absolute level or specific presence, or absence of the element in the nutrient culture solution. If phosphorus deficiency symptoms appeared early, there was a marked reduction in growth, of the entire plant. However, when the deficiency occurred later in the growth cycle, the internodes were elongated and the plant was taller than normal, and an appearance of increased, rather than retarded, growth resulted. This then, would lead to erroneous conclusions if growth, in itself, was the only criteria to be used in evaluating phosphorus deficiencies in nutrient cultures.

At the first sign of the phosphorus deficiency, the lower leaves turned downward and became light in color, while the younger leaves appeared abnormally green in that they took on a slightly blue-green cast. The older leaves faded to a dull bronze with irregular round splotches of chlorophyll remaining in the interveinal portions of the entire leaf. The leaves felt very leathery and tough, and the undersides of the leaves often became tinted, with a faint reddish color, which indicated the dominance of pigments other than chlorophyll, one of which was anthe-cyanin. The lower leaves finally faded and turned yellow in color, then brown and they were finally shed or abscissed from the plant. The symptom progressed upwards, which indicated that phosphorus was also readily translocated from the older to the terminal portion of the plant.

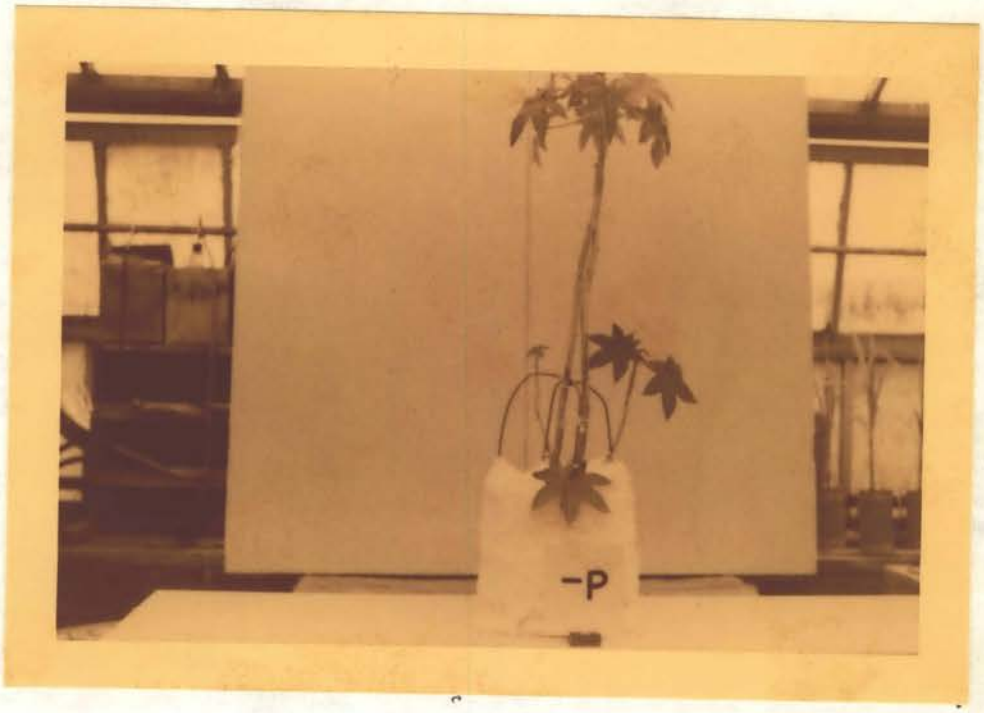

Figure 9.- Phosphorus deficiency in 4 month old castor bean plants grown in nutrient culture solutions.

Figure.10.- Phosphorus deficiency in 4 month old castor bean plants grown in nutrient culture solutions.

Figure 11.- Phosphorus deficiency in 10 week old castor bean plants as compared with plants grown in a complete nutrient solution culture.

As phosphorus deficiency became acute, the plant assumed a spindly appearance with leaves remaining only at the top, and these leaves finally took on a bronze appearance and sloughed off. The maturity date of the plant wasn't affected, very markedly, by low phosphorus levels, but the production of seed was almost nil.

Calcium Deficiency Symptoms

After depriving the castor bean plants of calcium, there was no immediate ill effects, but after approximately four weeks the roots became dull in appearance and finally turned black. Visual above ground portions of the plant, soon followed, with their deficient symptoms. Small lesion-like dots appeared on all the leaves, petioles became weak, bent downward and broke, later resulting in the collapse of the entire petiole. The collapse of the main stem occurred mainly on the younger plants. After the deficiency became very critical, the entire cell wall collapsed, especially near the terminal bud. The roots and shoot both died and decomposed. It took only a few days after the first symptoms appeared until the entire plant was dead.

In the experiment previously described, calcium was supplied after the terminal bud disintegrated, but before the entire cell had collasped and a new growing tip appeared at the highest living node and the plants grew normally to maturity, and produced an excellent seed crop on a complete nutrient media.

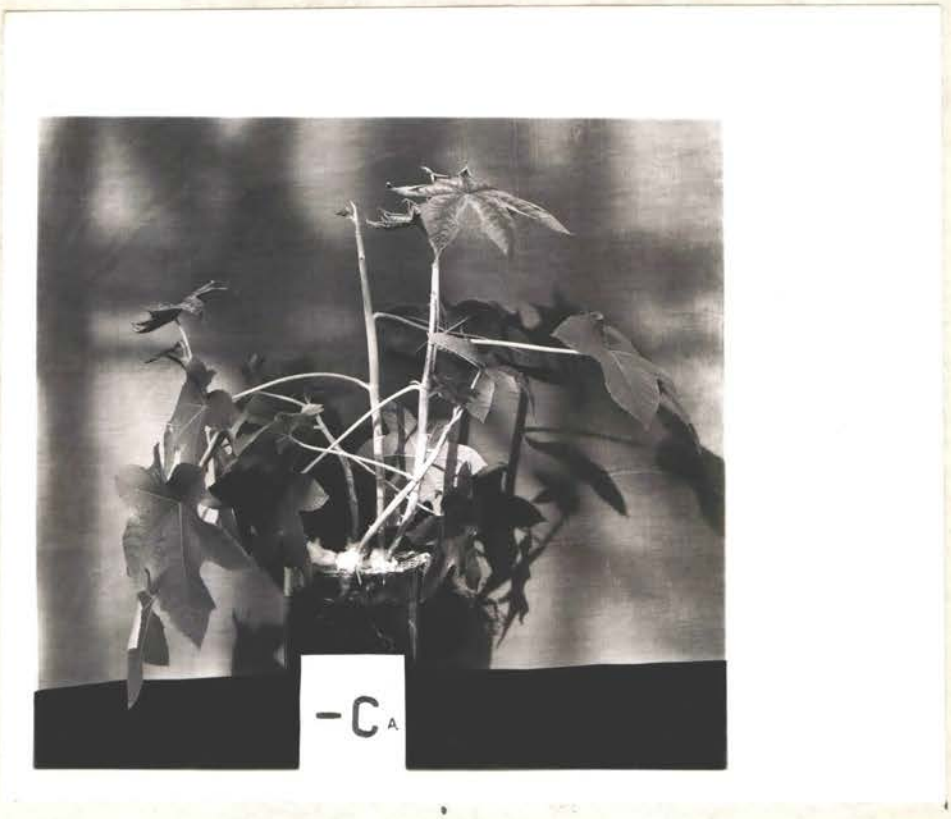

Figure 12.- Calcium deficiency in 3 month old castor bean plants grown in nutrient solution cultures.

Figure 13.- Calcium deficiency in 2 month old castor bean plants as compared with plants grown in a complete nutrient solution cultures.

Potassium Deficiency Symptom

Potassium deficiency was the last to occur. The first symptom was a reduction in growth of the plant. Chlorosis occurred on the lower leaves first; the tips and margins turned light colored, then to yellow, and finally to brown as the chlorosis moved inward. The margins finally curled up, when the marginal tissues died. When the temperature became hot and sunlight intense the light colored margins possessed lesion-like small brown specks near the leaf margins, the margins turned brown and curled up before the yellow color fully developed. Soon after the symptom appeared, the entire leaf faded and sloughed off. Often plants on low potassium wilt quite readily. They also loose rigidity of the flower spike, and the developing seed drooped and curved downward.

Castor plants growing on low potassium levels appeared to have a delayed maturity date as well as reduced bean production.

Figure 14.- Potassium deficiency in 4 month old castor bean plants grown in nutrient culture solutions.

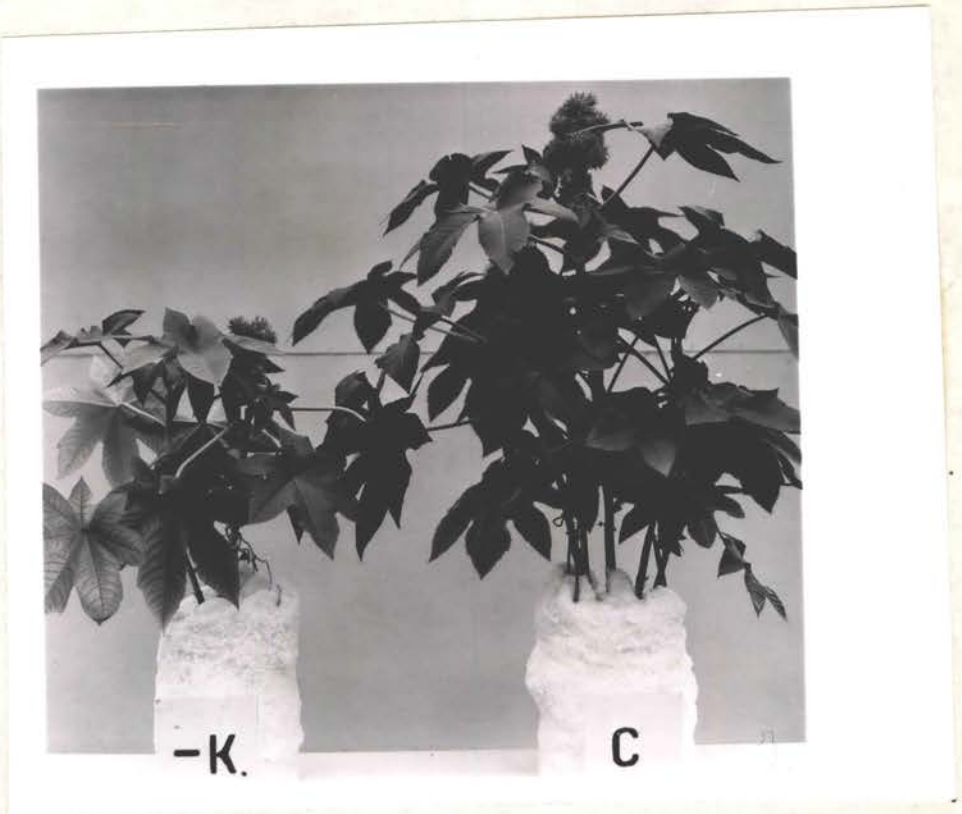

Figure 15.- Potassium deficiency in 3 month castor bean plants as compared with plants grown in a complete nutrient solution cultures.

TABLE 8 - -KEY TO NUTRIENT DEFICIENCY SYMPTOMS OF CASTOR BEANS

A Condensed Description of the Deficiency Symptoms as Obtained From the Nutrient Culture Solutions in the Greenhouse, Classified According to Parts of Plant Affected and Nature of the "Hunger-signs".

I Older or lower leaves of plant affected.

A. Effects mostly generalized over entire plant.

1. Plant light green; lower leaves yellow, drying to light brown color; stalk short and slender, if deficiency occurs in later stage of growth, stalk is often reddish color- - - - - - - - - - - - - - - - -Nitrogen

2. Plant abnormally dark green, elongated internodes, leaves splotched with round spots on chlorophyll, often red and purple colors develop on underside of leaves -Phosphorus

B. Effects mostly localized.

3. Lower leaves mottled or chlorotic, veins remain green, terminal leaves later becoming mottled, margins of leaves cupped upward, stalks slender- - - - - - -Magnesium

4. Lower leaves become chlorotic, tips and margins turned light colored, then yellow, and finally brown. Leaf sometime contains lesion-like spots- - - - - - - - -Potassium

II Newer or terminal leaves affected.

1. Petioles bend and break. Terminal leaves contain lesion-like spots which become larger, stalk finally dies at terminal bud- - - - - - - - - - - - - - - - -Calcium

2. Young leaves become light in color, then yellow, finally white. Older leaves remain green- - - - - - - - - - -Iron

Table 4.-Growth and seed production of castor bean plants deficient in Nitrogen, Phosphorus, Potassium, and Magnesium as compared to plants grown in a complete nutrient solution in Series A* nutrient culture experiment.

Treatment	Total dry weight of the root system in grams.			Total dry weight of the shoots in grams.			Total dry weight of the seed in grams		
	Rep. 1.	Rep. 2.	Rep. 3	Rep. 1.	Rep. 2.	Rep. 3.	Rep. 1.	Rep.2.	Rep. 3.
Complete Solution:	78.00	79.90	67.60	142.80	168.70	73.40	90.50	88.50	47.40
Minus Phosphorus:	10.79	31.50	20.80	30.00	30.60	24.10	33.00	43.00	24.70
Minus Nitrogen:	10.87	35.50	24.50	20.80	50.70	- -	1.00	8.30	- -
Minus Potassium:	53.00	31.50	53.50	40.60	58.00	53.10	21.70	12.50	- -
Minus Magnesium:	20.70	20.30	- -	10.60	10.90	- -	0.0	0.0	0.0

*Series A. - The plants were grown for 2 months in a complete solution before the deficient solutions were applied.

Table 5.-Growth and seed production of castor bean plants deficient in Nitrogen, Phosphorus, Potassium, and Iron as compared to plants grown in a complete nutrient solution in Series B* nutrient culture experiment.

Treatment	Oven dry weight of the root system in grams.			Total weight of the shoot in grams.			Total weight of the seed in grams.		
	Rep. 1.	Rep. 2.	Rep. 3.	Rep. 1.	Rep. 2.	Rep 3.	Rep. 1.	Rep. 2.	Rep. 3.
Complete** Solution	69.00	57.00	- -	50.00	60.00	64.00	70.00	44.00	50.00
Minus Phosphorus:	6.00	10.00	10.00	6.00	4.00	0.00	0.00	0.00	0.00
Minus Nitrogen:	23.00	20.00	11.00	21.00	5.00	3.00	0.00	0.00	0.00
Minus Potassium:**	14.00	30.00	26.00	33.00	16.00	10.00	14.00	7.00	0.00
Minus Iron:	56.00	- -	- -	8.00	- -	- -	0.00	0.00	0.00

*Series B. -Plants started immediately in deficient solutions - enough of the deficient element frequently applied to maintain life.

**In this series only the complete and minus potassium solutions produced seed.

Table 6. -Chemical analysis of castor bean plants deficient in Nitrogen, Phosphorus, Potassium and Magnesium as compared with plants grown in a complete nutrient solution in Series A* nutrient culture experiment.

Treatment	Composition of the roots			Composition of the shoots		
	percent nitrogen	percent phosphorus	percent potassium	percent nitrogen	percent phosphorus	percent potassium
Complete Solution:	2.8140	0.4960	0.0610	1.0480	0.160	0.0960
Complete Solution:	2.609	0.0160	0.1310	2.4130	0.200	0.0870
Complete Solution:	2.8350	0.0640	0.1190	1.1300	0.200	0.1420
Minus Potassium:	2.8240	0.0800	0.0150	0.2362	0.288	0.0140
Minus Potassium:	2.4440	0.0600	0.0200	3.2350	0.160	0.0150
Minus Potassium:	2.4650	- -	0.0150	- -	0.200	0.0110
Minus Phosphorus:	2.4650	0.020	0.0570	0.1440	0.020	0.0800
Minus Phosphorus:	2.3930	0.030	0.0380	0.3080	0.020	0.1225
Minus Phosphorus:	2.5970	0.020	0.0330	0.2670	0.008	0.0940
Minus Magnesium:	3.1730	0.016	0.0770	2.2220	0.188	0.1760
Minus Magnesium:	3.0300	0.092	0.0780	- -	- -	- -
Minus Nitrogen:	0.9590	0.100	0.0990	0.3492	0.300	0.0220
Minus Nitrogen:	1.2220	0.080	0.0750	1.0580	0.260	0.1720
Minus Nitrogen:	0.9040	- -	0.0460	1.2020	0.260	0.1340

* Plants grown in a complete solution for one month before being placed in the deficient solutions

Table 7. -Chemical analysis of castor beans deficient in Nitrogen, Phosphorus, Potassium, Magnesium, and Iron as compared to plants grown in a complete nutrient solution in series B* nutrient culture experiments.

Treatment	Composition of the roots			Composition of the shoots		
	Percent Nitrogen	Percent Phosphorus	Percent Potassium	Percent Nitrogen	Percent Phosphorus	Percent Potassium
Complete Solution:	0.4300	0.060	0.0870	2.1240	0.174	0.1210
Complete Solution:	0.3290	0.092	0.0130	0.6570	0.184	0.1400
Minus Potassium:	0.5340	0.030	0.0065	2.1530	0.450	0.0220
Minus Potassium:	0.4810	0.010	0.0130	2.2120	0.450	0.0230
Minus Potassium:	2.0900	0.090	0.0190	--	--	--
Minus Phosphorus:	2.7990	0.010	0.0540	1.1940	0.054	0.0650
Minus Phosphorus:	2.0910	0.010	0.0110	1.4200	0.079	0.0740
Minus Iron:	1.1930	0.070	0.1340	1.9390	0.090	0.2
Minus Magnesium:	0.1090	0.010	0.0470	0.3400	0.040	0.1000
Minus Nitrogen:	0.2670	0.110	0.1920	--	0.112	0.1920
Minus Nitrogen:	0.1230	0.060	0.1300	0.5570	0.123	--
Minus Nitrogen:	0.0926	0.040	0.1060	--	--	--

*Plants started off in deficient solutions; enough of the deficient elements added merely to substain life.

-- Not enough material available for analysis.

B. Chemical Analysis of the Harvested Plant Material Produced in Controlled Nutrient Solution Cultures.

The results of chemical analysis for nitrogen, phosphorus, and potassium which were conducted on the roots and shoots, of the plants grown in the nutrient culture solutions are given in tables 6 and 7.

In all cases where a specific essential element was omitted from the solution, that particular element was low in both the shoot and roots of the plants as compared to the plants receiving a complete ration. As a result of the study, it was found that there were also various ionic interrelationships present in the nutrient culture solutions, in addition to deficiency symptoms in themselves. These relationships appeared quite interesting and were sufficiently striking, that an attempt will be made to evaluate these, in the following paragraphs.

The series A, which received no magnesium contained higher amounts of nitrogen than the ones growing in a complete solution. In series B plants, the plants growing in potassium deficient solutions contained a much higher nitrogen and phosphorus content in the shoots than plants growing in a complete solution.

It also appears that in the series A plants, the nitrogen content of the root was higher in most cases than in the shoot, yet there seems to be no correlation in this respect with reference to phosphorus and potassium.

The plants were so variable in chemical composition, even between replicates, that it was very difficult to arrive at any definite conclusions as far as this phase of the experiment was concerned, and it is

felt that further work is needed along this line to clarify the situation, if any extensive use of tissue testing is to be undertaken.

C. Induced Deficiency Symptoms of Castor Plants Grown in Soils Pots Containing Three Different Oklahoma Soils.

Deficiency symptoms were definitely produced in the greenhouse, in pots filled with Parson fine sandy loam, Stidham loamy sand and Stidham sandy loam, and receiving the various fertilizer treatments as indicated by table 2.

The most common symptom produced in these soil pots was that of reduced growth. The plants grown in pots receiving no fertilizer, in all cases, were very greatly reduced in growth, however, no definite deficiency symptoms appeared on the leaves of these plants, except in the case of the Stidham sandy loam pots, which produced symptoms similiar to the nitrogen deficiency symptoms produced, in the nutrient solution cultures. The symptoms were, however, slower to appear and the effects were not as severe as in the nutrient solution cultures. The lower leaves drooped in a downward direction followed by the lower leaves taking on a light pale green appearance, which soon became completely yellow and finally sloughed off. In all three series the plants not receiving nitrogen turned a bright red at the base of the stalk. All soils produced nitrogen deficiency, when the pot was not fertilized with nitrogen.

Symptoms similiar to potassium deficiency were noted on the plants of Parsons fine sandy loam pots, which did not receive potassium fertilizer. These symptoms were identical to those produced in potassium free solutions, in the nutrient solution cultures. Potassium deficiency symptoms appeared also in the pots filled with Stidham sandy loam, which received fifty pounds of nitrogen and fifty pounds of phosphorus per acre. Potassium deficiency was not noted in the pots filled with Stidham loamy sand.

Phosphorus deficiency symptoms were observed on plants grown on all three soil types where the pots were fertilized with nitrogen alone or nitrogen and potassium. The internode of these plants were elongated and the plants were taller than normal. The leaves were light in color with "splotches" of dark green color remaining.

Some leaf discolorations were noticed on the plants in which the soil received potassium alone. It was thought that this discoloration might be a compound deficiency of both phosphorus and nitrogen. Usually the leaf became yellow, on an entire leaf lobe, which extended down the leaf toward the petiole until the leaf would finally fall. This discoloration contained characteristics of both nitrogen and phosphorus deficiencies.

D. Induced Deficiency Symptoms of Castor Plants Grown on Field Plots at Three Location in Oklahoma.

The field plots which were located at three different localities in Oklahoma and which were fertilized with the various combinations of nitrogen, phosphorus, and potassium, as indicated in table 3, did not at any time throughout the experiment possess deficiency symptoms similiar to those produced in the nutrient solution cultures for nitrogen, phosphorus, and potassium. There were, however, some response to the fertilizer applications of these macro-elements. Early in the growing season the increased growth due to fertilization was great but as the season progressed these differences dissipated. This loss of differences may have been due to the 1952 growing season, which was extremely dry at each locality; rainfall being far below normal throughout the state.

At the McAlester location a discoloration of the leaves appeared on all plots irrespective of fertilizer treatment. This abnormal appearance was very similiar to that identified as magnesium deficiency from the nutrient solution culture study. Insofar, as the field plots did not contain magnesium fertilization treatments, the writer could only offer a theory as to a magnesium deficiency being present, but it is felt that in any future field fertility trial, magnesium should be included as one of the applied fertility elements.

V Foliar Testing of the Castor Plant for Levels of Nitrogen, Phosphorus and Potassium When Grown:

A. In Soil Pot Cultures Fertilized With Various Combinations of Nitrogen, Phosphorus and Potassium.

The results of the tissue tests on the plants produced in greenhouse pots filled with Parsons fine sandy loam, Stidham loamy sand, and Stidham sandy loam and receiving different fertilizer treatments are given in table 9.

Because the plant food elements must be transported through the petiole on their journey to the leaf it was felt that the petiole would be the proper portion of the plant to test for available nutrients.

Nutrients often accumulate in the leaf even though the total supply of a element may be approaching the level limiting for normal growth and reproduction for the entire plant. The amount of nutrients in the stem may be a good index but this necessitates a large number of plants, which often times were not available.

The petioles were selected from the lower part of the plant. It was planned to take the third leaf from the botton, but the plants began losing their lower leaves thus interrupting this method of obtaining testing material. A more accurate method of selecting petioles would have been of great benefit to the study. Perhaps selecting a petiole , by counting from the terminal point would be accurate or else counting from a predetermined node may have been a solution to the problem,of obtaining testing material.

As can be seen from table 9, the results obtained from tissue testing appear very promising,as far as nitrogen is concerned. There is almost a direct correlation with the application of nitrogen ferti-

lizer and the amount of nitrates in the petiole, throughout the growing season.

In contrast to results obtained from the nitrate test, the results from testing phosphorus and potassium were erratic. There appears to be no correlation what-so-ever with the amount of these two elements applied and the amount found in the petiole. However, the author found that in the case of phosphorus there was a correlation between the difference in the amount of phosphorus in the lower petioles, and that found in the terminal petioles to phosphorus deficiency symptoms. That is; if more phosphorus was found in the terminal petioles than was present in the lower petioles phosphorus deficiency symptoms soon occured. This suggests that perhaps this might be used as a practical method for determining when phosphorus is becoming limited.

It would appear as a result of this study, that as phosphorus becomes limiting the castor bean plant translocates this element from the older, lower leaves to the terminal younger leaves, in an effort to perpetuate its terminal growth.

Table 9. – Results of tissue tests for nitrogen, phosphorus, and potassium at two stages* of growth of castor bean plants grown in pots in the greenhouse fertilized with nitrogen, phosphorus, and potassium at the rates indicated in table (2).

Treatments				Stidham fine sandy loam						Stidham loamy sand						Parsons sandy loam		
Pounds per Acre.				Stage 1.			Stage 2.			Stage 1.			Stage 2.			Stage 2.		
No.	N.	P.	K.	N.	P.	K.	N.	P.	K.	N.	P.	K.	N.	P.	K	N.	P.	K.
1.	0	50	0	M	M	H	M	M	M	M	M	M	H	H	M	L	H	M
2.	0	50	25	L	M	H	L	M	M	L	H	H	M	H	M	L	M	M
3.	25	50	25	M	M	H	M	M	M	H	H	H	H	M	M	M	M	H
4.	25	0	25	L	M	M	[illegible]	M	M	M	M	M	H	M	M	M	M	M
5.	25	50	0	L	M	H	M	M	M	H	M	[illegible]	H	M	M	M	M	M
6.	0	0	25	L	M	H	L	M	M	M	L	M	M	M	H	M	M	M
7.	25	0	0	M	H	H	M	L	M	H	L	H	H	M	L	H	M	H
8.	0	0	0	L	M	H	L	M	M	H	H	M	M	L	H	L	M	H

Nitrates

L – Low – Deficient
M – Medium – Adequate Supply
H – High – Abundant Supply

Phosphates

L – Low – Deficient
M – Medium – Moderate
H – High – Abundant

Potash

L – Low – Deficient
M – Medium – Doubtful
H – High – Sufficient to Abundant

*Stage 1 – [illegible] weeks after planting.
*Stage 2 – 3 months after planting.

B. On Soil Plots at Three Locations

The results of the tissue tests, on the plants produced on soil plots, at three locations, in Oklahoma and receiving different fertilizer treatments are given in table 10.

The selection of the material was the same as stated above for the soil pot cultures. The petioles were selected at two stages of growth: (1) The early bloom stage (8 weeks after planting). (2) The prematuring stage (3 months after planting.). The leaf petioles were gathered at 9 O'Clock at the Perkins and the Blackwell plots, but at the McAlester plots, the petioles were gathered at 12 O'Clock noon.

The results from the tissue testing on the plants grown, on the soil plots, were directly correlated with the results obtained from tissue testing on the plants grown in the soil pot cultures. It appears from the results listed in table 10, that the amount of nitrogen in the petiole can, in most cases, be directly correlated with the amount of applied nitrogenous fertilizer material. However, entirely different results were obtained when the petioles were tested for phosphorus and potassium, in which case the results seem to indicate that there is no correlation present between the amount of phosphorus and potassium in the petioles and that applied to the soil.

These erratic results with phosphorus and potassium, perhaps, can be explained or traced to the extreme adverse climatic conditions that prevailed in the 1952 growing season, at each of the three locations. Rainfall was well below normal in all portions of the state. Droughty conditions occurred early in June, and were followed by prolonged periods

of high temperatures and hot southwesterly winds during July and August, and those conditions resulted in reduced growth, and lowered yields for the entire castor bean crop throughout the state. As a result of this over-all reduction in plant growth, it was felt that insufficient plant material was produced, such that the diluting effects in the production of normal fast growing plants were absent, and as a result deficiency levels of both phosphorus and potassium were never approximated.

Table 10.- Results of Tissue Tests for Nitrogen, Phosphorus, and Potassium at two stages of growth of castor bean plants grown in the field at three locations fertilized at the rates indicated on table (3).

Treatments				Paradise						Perkins						McAllester			
Pounds per acre.				Stage 1			Stage 2.			Stage 1			Stage 2			Stage 2.			
No.	N.	P.	K.	N.	P.	K.	N.	P.	K.	N.	P.	K.	N.	P.	K.	N.	P.	K.	
1.	0	50	0	L	M	M	L	M	M	L	M	L	L	M	M	L	M	M	
2.	0	50	25	L	M	M	M	M	M	L	M	L	L	M	M	L	M	M	
3.	25	50	25	M	M	L	M	M	M	M	M	M	M	M	L	M	M	L	
4.	25	0	25	M	L	M	M	L	M	M	L	M	M	L	M	M	L	M	
5.	25	50	0	M	M	L	M	M	L	M	M	L	M	M	L	M	M	L	
6.	0	0	25	L	M	M	L	L	M	L	L	M	L	L	M	L	L	M	
7.	25	0	0	M	M	L	M	M	L	M	M	L	M	L	L	M	M	L	
8.	0	0	0	M	L	M	L	L	M	L	L	M	L	L	M	L	L	M	

Nitrates

I-Low-Deficient
M-Medium-Adequate
H-High-Abundant

Phosphates

L-Low-Deficient
M-Medium-Moderate
H-High-Abundant

Potash

L-Low-Deficient
M-Medium-Doubtful
H-High-Sufficient to Abundant

*Stage 1 - 8 weeks after planting.
*Stage 2 - 3 months after planting.

VI Summary and Conclusions

A. Deficiency Symptoms

Plants, although lacking the power to speak, have a means of telling us when their nutrient media is lacking in proper nourishment, but just how do they go about letting us know when they are suffering from the lack of certain essential elements? The plants in themselves do not speak but can tell of their difficulties in the production of certain visual abnormalites in their leaf and stem color, and growth habits, which we call "hunger-signs". It is not their fault that we do not always interpret these symptoms correctly. At times, it is very difficult to interpret correctly the symptoms of plant food deficiencies in the field due to the many environmental factors, which are also constantly affecting the plants. Prolonged periods of adverse weather, insects, and diseases may cause symptoms very similiar to plant food deficiencies (13), but when there is a question concerning these deficiencies, chemical tissue test can be made for nitrogen, phosphate, and potash, the three elements most likely to be deficient and the correlation if any, can be used as a further check. These symptoms and tests can then be used as a guide to the fertilizer applications needed.

Each specie of plants possess somewhat different "hunger-signs" under the same enviromental conditions. It is therefore necessary to study each plant in question under specifically controlled conditions. Therefore, castor beans were grown in nutrient solution cultures under controlled conditions in the greenhouse, in an effort

to obtain deficiency symptoms when each specific element was lacking from the nutrient media. Symptoms were obtained when nitrogen, phosphorus, potassium, iron, calcium, and magnesium were not supplied to the nutrient media in adequate amounts.

Deficiency symptoms for nitrogen, phosphorus, and potassium were also obtained on plants growing in soil pots filled with soils low in fertility. Three soils were fertilized with the various combinations of nitrogen, phosphorus, and potassium as indicated by table (2). The soils fertilized with two elements at the rates indicated in table (3), and the third being omitted, almost invariably produced plants possessing "hunger-signs" which in most cases were very similiar to those produced in the nutrient solution cultures.

Soils low in fertility were fertilized with the same combinations of fertilizers as used in the soil pot cultures at three locations in Oklahoma. These soils were: Stidham loamy sand in Payne County, Oklahoma; Stidham sandy loam in Payne County, Oklahoma; and Parson sandy loam found in Pittsburg County, Oklahoma. These were soils on which castor beans are frequently grown in each specific locality. There were no visual chlorotic conditions developed on any of the plants grown at these locations which were similiar to the nitrogen, phosphorus, or potassium deficiency symptoms produced in the greenhouse. However, at the McAlester plots, a chlorotic condition developed on the leaves of the castor plants which was very similiar to the magnesium deficiency produced in the nutrient culture experiment.

The deficiency symptoms produced in this investigation were very striking and it is believed that the symptoms as reported will become a valuable diagnostic technique in determining the nutritional status of castor beans growing under field conditions.

It must be pointed out, however, that these "hunger-signs" are merely another tool which may help us in accomplishing our work and in determining the correct management practices to follow. They by themselves are never conclusive because, as stated earlier, many factors such as adverse weather, insects, and diseases may cause symptoms very similiar to plant food deficiency symptoms. It is believed that these interfering factors may actually cause certain plant food deficiencies in the plant even though the media upon which the plant is feeding may contain an abundant supply of all the essential elements in a supposedly readily available form.

If we proceed with caution and understand the limitations inherent in any evaluation of the fertility status of soils with the aid of these "hunger-signs", they can be a very valuable asset not only to the trained agronomist but to the farmer as well.

B. Tissue Tests

As previously stated, "deficiency-symptoms" alone are not conclusive enough in most cases to be used entirely alone. It was therefore felt that if we could establish by use of tissue tests when nitrogen, phosphorus, and potassium were becoming limited in the castor plant, that these two techniques used together might be increasingly useful. The procedure involved in making tissue tests is in itself simple. Selection of the tissue to be tested in various plants and the interpretation of the analysis are very complex.

The petioles from the castor bean plants from each treatment of both the soil pots and the field plots were collected and tested for nitrates, phosphates, and potash. The tests were made by use of the LaMotte-Morgan, LaMotte-Troug soil testing kit. Nitrates were also tested by Bray's powder method. The lower petioles were obtained for testing and the petioles were always gathered at the same time of day. All were selected at 9:00 A.M. except those at the McAlester location which were sampled at noon.

The number of tissue tests made in this experiment were by far too small in number to be conclusive. It appears that the nitrate status of the castor bean plant found by the tissues test can be accurately correlated, not only with the amount available nitrates in the soil, but also with nitrogen deficiency symptoms.

Unfortunately, for phosphorus and potassium it is not as easy. Although more work is needed in order to establish definite conclusions, the author believes that the phosphate status of the plant can definitely be established. If a substantial amount of phosphorus was found in the top leaf and much less in the lower leaf, phosphorus

deficiency symptoms usually occured shortly afterwards. It appears that perhaps the plant begins to translocate phosphates from the older leaves to the newer terminal leaves when the supply is insufficient for terminal production.

Since the plant is a dynamic system growing in a dynamic soil system and subject to other ecological influences, many factors will influence the level of the soluble or unassimilated nutrients in a given plant at any given time. Some of the most important factors to consider are: general health and growing condition of the plant; level of other nutrients in the plant; occurance of insect damage or disease; climatic conditions at the time of testing, and the time of day at which tests are made. As stated by Krantz et. al.(27), "The plant diagnostician must be well acquainted with the physiology of the plant if he is to make most effective use of plant-tissue tests."

It is believed that tissue tests as a supplement to "hunger-signs" and other diagnostic techniques can be very valuable as a practical method for determining the nutritive status of the castor bean plant.

The data presented in this paper represents the results obtained from one years study only, therefore, no definite conclusions can be stated. It is recommended that these investigations be continued, especially the work on tissue testing for phosphorus and potassium of which the first years results are definitely inconclusive.

Bibliography

1. Beaumont, A. B., and Snell, M. E. The Effect of Magnesium Deficiency on Crop Plants. Journ. Agr. Res. 50: 5.53-562.

2. Boyton, D. and Compton, O. C., Leaf Analysis in Estimating The Potassium, Magnesium, and Nitrogen Needs of Fruit Trees. Soil Science 59: 339-351, 1945.

3. Bray, Roger H. Nitrate Tests for Soils and Plant Tissues. Soil Science 60: 219-221 (1945).

4. Burke, E., Chlorosis of Trees', Plant Physiology 7: 329-334.

5. DeTurk, E. C., Learn Hunger Signs of Crops, Reprint from Better Crop With Plant Food, American Potash Institute, Washington, D.C.

6. Drake, M., Nutrient Balance in Corn Growing in the Southern States as Revealed by Prudue Plant Tissue Test., Journal American Society of Agronomy 36: 1-9, 1944.

7. Domingo, W.E. and Crooks, D. M., Investigations With The Castor Bean Plant: III Fertilizers, Clipping, Method of Planting, and Time of Harvest. Journal of American Society of Agronomy, Vol. 37, No. 11, Nov. 1945.

8. Fisher, H. J. et. al., Official and Tentative Methods of Analysis of The Association of Official Agricultural Chemists, Sixth Edition Association of Official Agricultural Chemists, P.O. Box 540, Benjamin Franklin Station, Washington 4, D. C. (1945).

9. Hall, A. D., The Analysis of the Soil by Means of the Plant. Journ. Agri. Sci. 1:65:68, 1905.

10. Ginsburg, J. M., Composition and Appearance of Soybean Plants Grown in Culture Solutions Each Lacking a Different Essential Element. Soil Science 20: 1-3 (1925).

11. Harper, H. J., Tenative Methods for the Analysis of Soil and Plant Material. A Mineographed Publication for Use in the Soils Laboratory at Oklahoma A & M College. (June, 1948).

12. Hoagland, O. R., and Snyder, W. C., Nutrition of The Strawberry Plant Under Controlled Conditions, Amer. Soc. Hort. Sci. Proc. (1933) 30:288-294.

13. Hoffer, G. N., Testing Corn Stalks Chemically in Determining Their Plant Food Needs. Purdue Univ. Agri. Exp. Sta. Bull. 298 (Revised) 1930.

14. Hotter, Geo. L. and Fields, John, Okla. Agri. Exper. Sta. Bull. No. 32 (March, 1898).

15. Jones, J. P., The Diagnostic Value of Plant Symptoms in Determining Nutrient Deficiencies of Soils. Journ. Amer. Soc. Agron. 23: 352-356.

16. Miller, et. al., Castor Beans in Texas, Texas Agri. Extension Service, B-195.

17. Morgan, M. F., Tobacco As An Indicator Plant in Studying Nutritional Deficiencies of Soils Under Greenhouse Conditions. Journ. Amer. Soc. Agron. 21: 130-136.

18. Quinby, J. R., Van Horn, D. L. and Brooks, B. E., Progress Report 1455, The Texas Agri. Exp. Sta., April 19, 1952.

19. Scarseth, G. W., Plant-tissue testing in Diagnosis of the Nutrient Status of Growing Plants. Soil Science, 55: 113-120 (1943).

20. Dyner, E. H., The Relation of Corn Yields to Leaf Nitrogen, Phosphorus and Potassium Content. Soil Science of American Proceedings, Vol. 11., p p 317-323 (1946).

21. Ulrich, Albert, Plant Analysis as a Diagnostic Procedure. Soil Science 55: 101-112 (1943).

22. Van Horn, D. L., Castor Bean Production, U. S. D. A. Farmers Bul. No. 2041 (1952).

23. Van Horn, D. L., DR-61 U.S.D.A. Agri. Research Adm. BPI. Soils and Agri. Engr. and the Okla. Agri. Exp. Station.

24. Van Horn, D. L., DR-62 U. S. D. A. Agri. Research Adm. BPI., Soils and Agri. Engr. and The Okla. Agri. Exp. Sta.

25. - - - - - - - -
Present Status of Diagnosis of Mineral Requirements of Plants By Means of Leaf Analysis. Soil Science 59: 353-374. (1945).

26. - - - - - - - -
If They Could Speak, Chilean Nitrate Educational Bureau Inc. 120 Broadway, New York.

27. - - - - - - - -
Diagnostic Techniques for Soils and Crops. Their Value and Use In Estimating the Fertility Status of Soils and Nutritional Requirements of Crops. Published by, The American Potash Institute, Washington, D. C. (1948).

VITA

Billy Bob Tucker
candidate for the degree of
Master of Science

Thesis: CASTOR BEANS: THEIR NUTRIENT REQUIREMENTS, RESPONSES TO FERTILIZATION TREATMENTS, AND DEFICIENCY SYMPTOMS UNDER CONTROLLED CONDITIONS.

Major: Soils

Biographical and Other Items:

Born: January 13, 1928 at Grimes, Roger Mills County, Oklahoma.

Undergraduate Study: O. A. M. C. , 1949-1952

Graduate Study: O. A. M. C., 1952-1953

Experiences: Farm reared., U. S. Coast Guard 1945-1948. U.S.C.G.C. "INGHAM", North Atlantic Weather Patrol 1946-1948., Employed as a laboratory technician in the Soils Laboratory, O.A.M.C., 1950-1953.

Member of Agronomy Club and Alpha Zeta.

Date of Final Examination: January 10, 1953.

THESIS TITLE: CASTOR BEANS: THEIR NUTRIENT REQUIREMENTS, RESPONSES TO FERTILIZATION TREATMENTS, AND DEFICIENCY SYMPTOMS UNDER CONTROLLED CONDITIONS.

AUTHOR: BILLY BOB TUCKER

THESIS ADVISER: DR. CHARLES L. SARTHOU

The content and form have been checked and approved by the author and thesis adviser. Changes or corrections in the thesis are not made by the Graduate School office or by any committee. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

TYPIST: BONITA CHRISTINE TUCKER