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A. Boy Pack
University of Massachusetts Amherst

PLANT FAMILY RELATIONSHIPS AND SOIL NITROGEN UPTAKE

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THE INFLUENCE OF FAMILY RELATIONSHIPS UPON THE UPTAKE OF NITROGEN IN THE SOIL BY PLANTS

By
A. Boyd Pack

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INTRODUCTION

Since the early days of plant physiology and soil science as two closely interrelated sciences, investigators have been interested in the chemical composition of plant tissues. After having found certain chemical elements were essential to plant growth, studies of their amounts in plant materials naturally followed. As the scope of these studies broadened, it was observed that the amounts of various elements in plants were goverened by environmental factors, such as the amount of the element in the soil, sunlight, fertilizer practices, and that they varied over wide limits. Volumes of literature are available on the effect of many environmental factors acting individually or together in a group upon the absorption or uptake of any particular element or a combination thereof. Undoubtedly much more will follow and enlarge our knowledge of the close relationship of the plant to the soil.

Nitrogen is one of the very necessary elements in plant growth. Without it a plant will die in a very short time. This element forms the basis for many compounds in plant tissue, the most important ones being the proteins and such lesser ones as amides, amines, alkaloids, and others. The value of plant tissue for the consumption of man and other animals to build up their bodies, comes largely through the nitrogen content in the form of proteins. Therefore, a plant poor in nitrogen content means probably poor foodstuff.

A review of literature follows, which attempts to show the effects of such factors as light, disease, fertilizer practices, kind of plant, etc., on the uptake of nitrogen by a plant, as worked out by numerous investigators.

REVIEW OF LITERATURE

There is an extensive amount of literature on the effect of the many factors of plant growth upon the nitrogen content of plants. The research in the past few decades has entailed a study of such factors as light, climate, soil reaction, fertilizer practices, diseases, and many others on the nitrogen content of all sorts of plants, and we now know fairly well the relationship of a plant to the nitrogen level of the soil. Though this field of research has been well explored and much data accumulated, it is like most other avenues of study, more work can surely be done. Some lines of research on nitrogen absorption need more refinement or a closer check upon present results now on hand, as well as explaining new and untouched fields of experimentation.

The relationship of nitrogen content of a plant and its position in the evolutionary scale of the plant kingdom provides a new and interesting field of research. In the survey of the literature on the subject very little material was found. There are a great number of papers written on the kind of plant and its nitrogen content, but how it compares to other plants of other botanical families either higher or lower in evolutionary tables is lacking.

The plan of this section of the thesis is to summarize the literature reviewed concerning the effect of many factors of plant growth upon the nitrogen content of many kinds of plants. Then the body of the thesis will be presented, which is a report of a study of the relationship between evolutionary and family position of a plant and its nitrogen content.

LIGHT

Let us first examine the nitrogen content as influenced by light. Darkness, short days, or shade, favor a high nitrogen content of plant tissues as compared to the opposite conditions. Hopkins (26) studied soybeans in greenhouse crocks when the long day was sixteen hours, and the short day was seven hours. Plants receiving the long day treatment were low in all forms of nitrogen, such as ammonia, amide, nitrate, as well as total nitrogen. Allison (1) obtained similar results from soybeans. He found also that increased CO2 plus long days, further dropped N_2 content.

Tobacco plant when subjected to eleven days of darkness increased in total nitrogen in stems, and the addition of sodium nitrate helped the increased absorption (12). Not only length of day, but light intensity has an effect upon nitrogen content, as revealed in studies on two varities of wheat. Hurd-Karrer & Dickson (27) found that light intensity of fifty-foot candles gave a wheat of higher nitrogen content than more intense light of one-hundred foot candles.

MATURITY

It is known that as a plant approaches a stage of maturity the amount of lignin, celluose, and other like substances generally increase with the probable result being the dilution of the amount of nitrogen. Thus a plant harvested after bloom will often show a lower percentage of nitrogen than if harvested in early succulent condition. Investigators recognizing the changes taking place in the percentage of nitrogen or protein as a plant becomes older, have to state in their experiment the age of the plant they are investigating if the results are to mean anything. The literature reviewed shows some interesting conclusions regarding the changes in nitrogen content as a plant approaches a mature stage.

Maturity, cont'd.

McHargue & Roy (32) studied the chemical composition of leaves of twenty-three forest trees in Kentucky. With regard to nitrogen content the percentage decreased progressively as the leaves became older.

The changes in N_2 or protein content with maturity becomes of importance in hay crops. In Wales Fagon & Milton (17) investigated the chemical composition of eleven species and strains of grasses at various stages of maturity. Cutting made each month from late April to late July showed a progressive decrease in protein in the common and indigenous cocksfoot, and the common and idigenous meadow foxtail.

Sotola (42) recommended the cutting of alfalfa at about one-half maturity for the greatest protein content. In connection with the age of a plant, Remy (41) made a study of the period of growth in small grains where nitrogen uptake was at its maximum. When the grain is in the period from beginning stalk growth to early blossoming the nitrogen absorption is at its height.

KIND OF NITROGEN FERTILIZER

The nature of the kind of nitrogen fertilizer used to supply the nitrogen affects the nitrogen content of plants, as revealed in studies by Vickery, Pucher, Leavenworth & Wakeman (46), Mussell and Brown (34) and Davidson and LeClerc (8). Nitrogen supplied in the same amounts, but with varying ratio of the element in ammonium or nitrate form affected the nitrogen content of tobacco (46). Ammonium carbonate does not raise the total nitrogen content of grasses significantly, but $Na\ NO_3$, $Ca\ (NO_3)_2$, $NH_4\ Cl$, and $(NH_4)_2\ SO_4$, cyanimid, calnitro, and urea were found to be equally effective, and more so than the carbonate (34). Nitrogen in potassium nitrate was found to be more

Kind of Nitrogen Fertilizer, - cont'd.

valuable for raising the nitrogen content of wheat (8). In a nine year study of fertilizing hay crops in Virginia, Eheart & Ellet (13) came to the conclusion that $Na\ NO_3$ was the most satisfactory fertilizer.

Erdman (16) found that the percentage of nitrogen in tops of soybeans decline up until early fall. An increase follows, and the content is a maximum at maturity.

AMOUNT and FERTILIZER

As the amount of available nitrogen is increased in a soil the percentage of nitrogen in the plant has been shown by many investigators to correspondingly increase. Increasing the amount of fertilizer will not affect the protein content of rye grass as much as it will white clover (24). Batjer & Degman (4) grew one year-old apple trees in sand containing 0 to 168 p.p. of nitrogen, and Gilbert & Hardin (21), working with many plants in general fertilized with 95 to 140 lbs of nitrogen per acre. Both found that their plant materials increased in total nitrogen content.

Eheart & Ellet at New Hampshire made a nine year study of different amounts of fertilizer added to hay and grass plots. Nitrogen in the form of $Na\ NO_3$ was compared to $(NH_4)_2\ SO_4$ and urea in amounts from zero to 200 lbs per acre. Their results led them to conclude that sodium nitrate was the best source of nitrogen, and that 150 lbs per acre gave most satisfactory results. Nitrogen added in amounts of fifty pounds, or less, per acre, did not produce significant changes (13).

Rose shoots grown under high nitrogen, as compared to low nitrogen, have a higher content of nitrogen, ash, and moisture, but less starch (44).

Amount of Fertilizer, - cont'd.

Upon finding tomato plants highest in total nitrogen when soil was richest in the element, Phillips et al (39) observed that low nitrogen meant higher carbohydrate, and vice versa.

Pederson (38) made an interesting study on the effect of increasing the nitrogen level of the soil upon the different forms of nitrogen in mangels. He found that an increase in soil nitrogen produced an increase in total nitrogen and nitrate content, but not of protein in the roots, whereas in the tops increases in total nitrogen and protein were observed, but no change in nitrate unless more than 12 grains of nitrogen were applied to a pot.

In connection with yellow transparent apples, it was found that the fruit and seeds from treated plots (treated with 20 lbs of $Na\ NO_3$ each)contained .68% nitrogen on moist basis, as compared to those from untreated plots which contained .512% (30).

Munsell & Brown (34) working with Rhode Island bent grass and Kentucky blue grass, studied the additions of nitrogen in certain amounts, and measured the comparative effect on total nitrogen content. Calnitro, applied at the rate of 14 pounds in each of six applications, produced an increase equal to three applications of 28 pounds each. Comparing the last rate of application with three applications of 56 pounds each, showed that the heavier application raised the percentage of the element .39% in Kentucky blue grass, and .32% in Rhode Island bent grass.

Intensive fertilization with nitrogenous fertilizers increased the nitrogen content of grazed pasture grasses (23).

TIME OF FERTILIZER APPLICATION

Some observations have revealed that the time of application of nitrogen will produce a desired effect as easily as regulating the amounts applied, and therefore may be more practical. In other words, the time of application is important.

Gericke made a study of this factor on wheat and oats (19 & 20) as it governed their nitrogen compensation. It was suggested that the addition of a little nitrogen just before heading time would raise the nitrogen content of wheat and oats materially. The variety makes some difference, however. Enlow and Coleman (15) made similar recommendations. They advocate frequent light dressings of nitrogenous fertilizer as a means of maintaining or raising somewhat the nitrogen content of grasses.

In nine years study of grass and hay plots, it was revealed that if 200 pounds of nitrogen per acre were to be added, a split of this quantity into two equal additions, one made at April 1st, and the other at July 1st, greater increases in dry matter and percentage of protein occurred (13).

Florell (18) found that nitrogen content of wheat and barley increased from early to late spring.

EFFECT OF OTHER ELEMENTS ON NITROGEN CONTENT

It is true that the uptake of an element by a plant may be seriously effected by the presence or absence of other elements when other conditions are favorable. The one element in particular which seems to have such a relationship to nitrogen is calcium.

Soil to which lime was added brought about increases ih nitrogen content of plants when limed to unlimed plots. Ginsberg and Shive (22) observed that $Ca\ CO_3$ raised the content of nitrogen in soybeans, whereas $Ca\ Cl_2$ and $Ca\ (NO_3)_2$, had a lesser or no effect. Vanderford concluded that lime aided in nitrogen absorption up to the point that it makes the soil p^H neutral (45).

Combinations of lime and phosphate were studied (9) in connection with the nitrogen content of legumes. Lime alone caused an increase 32 percent nitrogen content, as contrasted to no lime added at all. Adding lime with superphosphate increased the nitrogen content 34.3 percent over using superphosphate alone.

Klinghiel & Brown (29) saw that alfalfa had significantly less nitrogen in its tissue where grown on unlimed soil, as compared to limed soils.

Parker and Truog (37) observed the interrelationship of nitrogen uptake and other common soil elements. No consistent relationship between nitrogen and potassium was found, although the better understanding of this interrelationship is not at hand yet. Magnesium and nitrogen behave like nitrogen and potassium, phosphorous shows some degree of regularity, and may be quite important. In connection with calcium some interesting points were revealed. Plants that are heavy feeders of nitrogen required much calcium also, or in other words, high nitrogen content was accompanied by a regular increase in calcium content. Their work was a compilation of literature on the observations of others on thirty-four species of plants.

In connection with phosphorus and nitrogen relationships, phosphorus-starved tomatoes had a higher nitrogen content than those amply supplied (31).

Chandler (6) supplied some additional information on nitrogen and potassium interrelationships in a study of potash fertilizations of Winesap apple trees. Trees receiving heavy additions of sulphate of potash increased their nitrogen content over those lightly fertilized with $K_2 SO_4$.

KIND OF PLANT

As has been stated before in this thesis, the literature on the kind of plant and its nitrogen content, as influenced by the nitrogen fertility level of the soil, is not very extensive. Since this factor more than any other forms the basis of this research, the literature was critically reviewed on this factor especially. The work of Campbell (5) and Fagan and Milton (17) are the most nearly like the work presented in this thesis.

Campbell made a study of the nitrate nitrogen content of about twenty-five different weeds at three stages of maturity. He confined his investigations to three botanical orders, the Chenopodiales, Polygonales, and the Caryophyllales. He found the Chenopodiales highest in nitrate content, particularly just before blooming. The Polygonales followed second, and the Caryophyllales third. He also found that the weed Amaranthus retroflexus was very rich in nitrate content, more than any other weed studied.

Fagan and Milton's work has been cited before in connection with maturity of the plant and its nitrogen content

An interesting paper by Hock (35) on the composition of the woods and the farm fungi, in connection with a research on carbon nitrogen ratio was reviewed. Some facts brough out are as follows:

Fungi from the woods contained from 1.5 to 7.7 percent nitrogen, as compared to the farm fungi, which had 2.6 percent. As the nitrogen content

Kind of Plant, cont'd.

of the media dropped 1 percent, the nitrogen content of Aspergillis Niger drops from 7 to 3 percent. Fungus tissue is high in water soluble nitrogen, particularly the wood-rotting fungi Trichoderma ligrorum.

DISEASES OF NITROGEN CONTENT

The composition of diseased plant tissue, with respect to nitrogen content, has been studied quite a bit and some conclusive results procured. Jodidi (28), True et al (43), and Coon and Klotz (7), working independently, studied the effect of diseases upon the nitrogen content of spinach, celery, and cabbage. Spinach inoculated with a mosaic blight, contained less total nitrogen than healthy leaves (43). Cabbage, infected with mosaic, behaved like the spinach, when compared to uninfected plant (28). Celery leaves, inoculated with Cercospora apii, contained 2.94 percent nitrogen, and healthy leaves had 4.77 percent. Other plants infected with Septoria apii had 4.38 percent, as compared to 5.10 percent in healthy leaves (7).

Extending the study of diseases and nitrogen content of plant tissue, the composition of chlorotic and non-chlorotic leaves was included. A paper by Parberry (36) revealed that chlorotic orange tree leaves are low in nitrogen, as well as magnesium, when compared to non-chlorotic ones.

EFFECT OF SEASON

The nitrogen content of Bartlett Pear shoot was determined as a function of the season (23). A steady rise in nitrogen content was observed from October through December, and a rapid fall from March through July.

EFFECT OF CULTURE

That culture practice may influence the nitrogen content of plants was observed by Olson, working in Washington (35). Increasing the distance apart of wheat seeding in increment of three inches from six to eighteen inches, resulted in an increase in nitrogen in the plant tissue. This change was most noticeable in the fall. Irrigation was found to have little or no effect, as determined by this same experiment. Nursery grown wheat contains 12 percent more of the element than that grown under field conditions, and the distance apart of rows may or may not have any effect (35).

The addition of a nitrogenous fertilizer after adding a complete fertilizer was found to increase nitrogen content of certain grasses (2).

EFFECT OF p^H

No study of the effect of soil conditions upon the nitrogen content of plants is complete unless the role of hydrogen ion concentration or pH is investigated. Such an investigation was carried out by Emmert in connection with lettuce and tomato plants (14). It was found that the nitrogen content of lettuce and tomatoes did not show a good correlation with soil p^H.

EFFECT OF CLIMATE

Lastly, among the numerous factors influencing the composition of plant tissue, as revealed in this portion of the thesis, the effect of climate is briefly mentioned. Delwiche & Tottingham (10) compared the protein content of corn, barley, and red clover, grown at Ashland, Wisconsin, and Madison, Wisconsin, the former being in the northern part of the State. Corn and barley had higher content when grown in northern Wisconsin, by about 4 percent, Effect of Climate, - cont'd.

but on the other hand, red clover was more rich in protein when grown at Madison, by about 10 percent. Several reasons are given for these findings.

OBJECTIVE OF THE INVESTIGATION

The effect of a plant's environment upon its chemical composition has long been observed. In this investigation an attempt was made to see if the family relationships of plants showed any correlation with their uptake of nitrogen in the soil.

By selecting a number of representatives of several common families and growing them in plot fertilized variously with nitrogenous fertilizers it was thought that a number of questions could be answered. The questions in our minds were as follows:

Will all families insofar as we can study them in this experiment show similar reactions to increased nitrogen fertility levels in the soil?

Will the members of a family show a similar trend?

Will the reaction or response of the families and species be in direct proportion to the amount of nitrogen added?

Which family seems most responsive to heavy applications of nitrogenous material? Which the least? Which plant gained the most, and which the least?

Which family seems most responsive to a light application, and which family the least? Which plants?

How does the behavior of the plants to large amounts of nitrogen correlate with accepted evolutionary scales?

PLAN OF THE INVESTIGATION

For the experiment a plot of land 300 feet long by 42 feet wide was selected on the farm of the Massachusetts Agricultural Experiment Station. The soil lay in an area which was transition zone between the Merrimac series and the Wethersfield series. This area in the past few years had been cropped to corn, but the soil was rather fertile, containing .203% nitrogen.

The plot was divided into three areas, which were to be differently fertilized with respect to nitrogen. Each of the three areas received equal applications of potash, phosphorus and lime, and in all respects were treated similarly, except in the case of nitrogen. To the plot designated as low, no nitrogenous fertilizer was applied; to the plot termed medium, nitrogen at the rate of fifty pounds per acre was introduced; to the high plot an amount of nitrogen equal to 400 pounds was spread. In other words, the rates of nitrogen per acre were none, fifty, and four hundred pounds. In the case of potash, one hundred pounds per acre were applied, and in the case of phosphours as $P_2 O_5$, the application comprised of one hundred twenty pounds per acre. Lime was put on the soil at the rate of one ton per acre.

The source of the potash fertilizer was muriate of potash, for phosphours superphosphate was utilized, and for lime ground limestone was employed. In the case of nitrogen, one-fourth of the nitrogen was derived from nitrate of soda, and the remainder from cottonseed meal. Allowances for the potash and phosphoric acid contained in the cottonseed meal were made in determining the amounts of muriate of potash and superphosphate to apply to each plot. All the fertilizers except lime were broadcasted over the plot, while the lime was spread on with a fertilizer spreader. The fertilizers were then

Plan of the Investigation, - cont'd.

worked thoroughly into the soil by an acme harrow.

About fifty plants were selected for the experiments, and they represented a total of ten families. It was objective of the investigation to select five species in each family when possible. In eight of the families at least, five species were obtained, in one four species were grown, and in one only three could be successfully raised. The number of the families were chosen to represent a variety of crops according to their use. That is, vegetable crops, field crops, ornamental flowers, and weeds were included with one or more representative in the entire group of plants. A list of the plants in their particular family follows:

TABLE I

I. Graminae
   1. Rye
   2. Barley
   3. Corn
   4. Millet
   5. Sudan Grass

II. Solanaceae
   1. Tobacco
   2. Petunia
   3. Eggplant
   4. Peppers
   5. Nicotiana

III. Compositae
   1. Sunflower
   2. Endive
   3. Asters
   4. Ragweed
   5. Chrysanthemums

IV. Leguminosae
   1. Peas
   2. Beans
   3. Crimson Clover
   4. Vetch
   5. Soybeans

V. Circubitaceae
   1. Squash
   2. Cucumbers
   3. Pumpkins
   4. Watermelons

VI. Scrophulariaceae
   1. Snapdragon
   2. Digitalis
   3. Penstemon

VII. Liliaceae
   1. Leek
   2. Hemerocalis
   3. Garlic
   4. Onions
   5. Asparagus

VIII. Umbelliferae
   1. Celery
   2. Parsley
   3. Dill
   4. Parsnips
   5. Carrots

IX. Cruciferae
   1. Cabbage
   2. Cauliflower
   3. Alyssum
   4. Radishes
   5. Turnips
   6. Shepherd's Purse

X. Chenopodiaceae
   1. Spinach
   2. Chard
   3. Lambsquarter
   4. Beets
   5. Mangels

Some plants were grown from seed and others transplanted from materials secured from local greenhouses. All species were grown in each one of the three plots. The members of a similar family were planted together in the same row.

The stage of maturity at which each plant was harvested varied, due to the stage wanted and the lateness of the season. The grasses, for example, were allowed to reach the dough stage, the flowers of ornamental value were in a late blooming period, etc. The prime objective was to obtain a plant which had been subjected to the differences of nitrogen for an adequate time to reveal any changes in composition if they were effected by the different levels of nitrogen fertility. The stage of growth of vegetable crops and field crops was selected where possible at a time when they were usually used for human and animal consumption, therefore giving the thesis some practical value, if possible.

Upon harvesting, the entire above ground portion of each and every plant was taken. That is, the stems, leaves, and flowers and seeds, if they were gathered. The material was washed free of soil and contaminants and dried in an oven at temperatures ranging between fifty and sixty degrees Centigrade. Then each dry plant in each series was ground separately in the Wiley Mill to a fineness that passed a one millimeter sieve, and the material bottled in pint Mason jars well stoppered and kept as dry as possible until ready for analysis.

All of the plant materials from each plot were analyzed for total nitrogen, using the Kjelhahl method to include nitrate nitrogen (3). It was not possible to get sufficient sample from some of the plants grown outside. This was due to a number of things, such as lateness of season, poor seed, etc. These plants which failed outside were grown in the greenhouse in butter boxes, fertilized at the same rates as each of the three replicas in the outside plots on a weight basis. Members of the Lily family comprised the majority of the plants grown in the greenhouse boxes. To be more specific, the following plants were raised under greenhouse conditions: Leek, Garlic, Onions, Asparagus, Dill, and Soybeans.

TABLE II

PERCENTAGE OF TOTAL NITROGEN
(All analyses are of tops)

Family and Plant	Plot 1 Low Nitrogen	Plot 2 Medium Nitrogen	Plot 3 High Nitrogen
I GRASS FAMILY			
Rye	2.70	3.01	2.62
Barley	2.72	2.96	3.35
Corn	1.53	1.80	1.93
Millet	2.45	2.68	2.95
Sudan Grass	1.80	2.11	1.79
II NIGHTSHADE FAMILY			
Tobacco	2.32	1.91	2.63
Petunia	2.82	2.74	3.26
Peppers	3.80	4.02	3.67
Eggplant	3.31	3.11	3.56
Nicotiana	1.94	2.85	2.67
III COMPOSITE FAMILY			
Sunflower	2.23	2.60	2.72
Ragweed	2.09	2.38	2.59
Endive	3.21	3.04	3.66
Asters	1.74	1.82	1.74
Chrysanthemums	2.43	2.25	2.60
IV MUSTARD FAMILY			
Cauliflower	3.54	3.36	4.08
Cabbage	2.95	3.06	3.69
Alyssum	3.10	2.90	3.19
Turnips	2.97	3.10	4.22
Radishes	3.33	3.06	3.89
Shepherds Purse	4.15	3.72	3.88
V PARSLEY FAMILY			
Celery	2.97	2.34	3.23
Parsley	3.58	3.30	3.86
Parsnips	2.43	3.36	3.38
Carrots	2.08	2.21	2.82
Dill	-	4.40	4.41
VI CUCURBIT FAMILY			
Cucumbers	3.78	3.71	3.82
Squash	3.43	3.27	3.91
Pumpkins	3.27	3.92	3.68
Watermelon	3.14	-	3.87

TABLE II cont'd

Family and Plant	Plot 1 Low Nitrogen	Plot 2 Medium Nitrogen	Plot 3 High Nitrogen
VII GOOSEFOOT FAMILY			
Chard	4.25	4.10	4.66
Spinach	4.47	4.09	4.04
Lambsquarter	2.75	2.82	3.07
Beets	3.91	3.92	3.79
Mangels	3.63	3.52	3.29
VIII LEGUME FAMILY			
Peas	3.00	3.10	4.36
Beans	2.78	3.34	3.78
Crimson Clover	4.09	3.64	4.47
Vetch	4.26	4.34	4.21
Soybeans	2.90	2.91	3.63
IX LILY FAMILY			
Hemerocallis	3.77	3.04	3.76
Asparagus	3.67	3.40	3.33
Garlic	5.80	4.89	5.21
Onions	4.50	4.69	5.28
Leek	3.79	3.97	4.15
X SNAPDRAGON FAMILY			
Snapdragon	2.82	2.63	3.01
Beardtongue	2.64	3.02	3.09
Digitalis	2.43	2.52	2.54

TABLE III

PERCENTAGE DIFFERENCES OF PLOTS

(- = Gain of former over latter and)
(- = Loss " " " ")

Family and Plant	% difference between medium plot and check	% difference between high plot and check
I GRASS FAMILY		
Rye	- 11.5	- 3.00
Barley	- 8.8	-22.5
Corn	- 17.6	-26.1
Millet	- 9.4	-22.4
Sudan Grass	- 16.1	-.5
Family Average	- 12.68	-13.50

TABLE III, cont'd.

Family and Plant	% difference between medium plot and check	% difference betwee high plot and check
II NIGHT SHADE FAMILY		
Tobacco	-17.6	-66.6
Petunia	- 2.8	-15.6
Peppers	- 5.8	- 3.4
Eggplant	- 6.0	- 7.6
Nicotiana	-46.8	-37.6
Family Average	- 5.34	-33.80
III COMPOSITE FAMILY		
Sunflower	-16.6	-22.0
Ragweed	-13.9	-33.9
Endive	- 5.3	-14.0
Asters	- 4.6	- 0.0
Chrysanthemums	- 7.4	- 7.0
Family Average	- 4.48	-13.38

Family and Plant	% difference between plot 2 and 1	% difference between plot 3 and 1
IV MUSTARD FAMILY		
Cauliflower	- 5.1	-15.3
Cabbage	- 3.7	-25.1
Alyssum	- 6.5	- 2.9
Turnip	- 4.4	-42.1
Radish	- 8.1	
Shepherd's Purse	- 8.9	- 6.5
Family Average	- 4.10	-15.95
V CUCURBIT FAMILY		
Cucumbers	- 1.8	- 1.1
Squash	- 4.7	-14.0
Pumpkin	-19.9	-12.5
Watermelon	-	-23.2
Family Average	- 4.46	-12.70
VI GOOSEFOOT FAMILY		
Chard	- 3.5	- 7.3
Lambsquarters	- 4.0	-12.5
Spinach	- 8.5	- 3.8
Beets	- .3	- 2.1
Mangels	- 8.0	- 2.4
Family Average	- 1.54	- 2.22

TABLE III, cont'd.

	% difference between plot 2 and 1	% difference between plot 3 and 1
VII SNAPDRAGON FAMILY		
Snapdragon	- 4.8	- 6.7
Digitalis	- 3.7	-27.2
Phaseleon	-14.4	- 7.8
Family Average	- 4.40	-10.3
VIII LEGUME FAMILY		
Peas	- 3.3	-45.3
Beans	-20.1	-43.2
Crimson Clover	-11.0	- 9.3
Vetch	- .5	-10.3
Soy beans	- 1.4	-19.7
Family Average	- 2.10	-25.56
IX LILY FAMILY		
Hemerocatis	- 2.8	-11.6
Asparagus	- 7.4	- 9.3
Onions	- 4.2	-17.3
Leek	- 4.7	- 9.5
Garlick	-12.7	- 3.8
Family Average	- 4.20	- 6.58
X PARSLEY FAMILY		
Celery	-25.9	- 8.8
Parsley	- 7.8	- 6.4
Parsnips	-34.2	-39.1
Carrots	- 6.3	-35.6
Dill	-	- 1.7
Family Average	- 1.45	-17.64
		Between plots 3 and 2

TABLE IV

RANK OF THE FAMILIES

(the highest family average is rated 100 in each plot)

FAMILY	Medium and Low Plot RATING	High and Low Plot RATING
1. Grass	100	52.8
2. Nightshade	41.3	89.1
3. Composite	35.3	52.4
4. Curcubits	35.2	50.1
5. Snapdragon	34.6	40.3
6. Legume	16.5	100.00
7. Parsley	11.5	69.0
8. Goosefoot	- 1.54	8.7
9. Mustard	- 4.10	62.4
10. Lily	- 4.20	25.8

OUTLINE OF DISCUSSION OF RESULTS

I. General Discussion of Percentages of Nitrogen in the Plants
   1. The number of plants directly affected by fifty pounds per acre additions
   2. The number of plants directly affected by four hundred pounds per acre additions.

II. Discussion of Gains or Losses made by Plants in Medium Plot vs Check Plot.
   1. Element of Chance Involved in these results.
   2. Changes made in members of each family.
   3. Changes made in the families as a whole.
   4. Rank of the families according to their reactions.

III. Discussion of Gains or Losses made by Plants in High Plot vs Check Plot.
   1. Discussion of Changes taking place in the members of each family.
   2. Discussion of changes or Trends in the families as a whole.
   3. Rank of the Families according to their reactions.
   4. Comparison of data in (II) and (III).
   5. Consideration of results from an Evolutionary Standpoint.

DISCUSSION OF RESULTS

Table II gives the percentages of nitrogen found in the above-ground parts of the plant materials analyzed. The plants are listed in their respective family, but otherwise in no special order.

In general the plant materials contained between two and four percent, or under one percent. Analyses for nitrogen in plant materials reported by others in various experiments fall also in the general range as reported here. The lower limit of percentage nitrogen is shown by corn grown on the low plot with only 1.53%, while the material containing most of the element was vetch grown in the field, and garlic raised in greenhouse boxes fertilized at the rate of four hundred pounds per acre. The members as a whole, of three families, namely, lilies, legumes, and goosefoots, were richer than the members of the other seven families, who as a group were much the same. The fact, however, that certain plants were high in nitrogen did not necessarily correlate with their uptake of the element in large amounts. As a matter of fact, those plants high under unfertilized conditions showed smaller percentages of increase under heavy applications of fertilizer than the plants low in the element on unfertilized areas. This fact will be pointed out throughout the discussion of the results.

An analysis of percentage changes in the plants will be discussed in the subsequent paragraphs, but it should be pointed out that a few things can be gleaned from looking at the percentage of figures. First of all, we can see that only twenty-three out of forty-six plants showed response to the addition of fifty pounds of nitrogen per acre. This amounts to exactly fifty percent of the total. With the addition of four hundred pounds of nitrogen the response was, of course, noted in a far greater percentage of plants than above. Only nine plants out of a total of forty-eight showed a negative trend, and in any case the decrease was not large. In other words, about nineteen percent revealed no ability to put more nitrogen into their tissues when given the opportunity.

As has been cited in the review of literature, plants in general exhibit response toward the additions of nitrogen to the soil, and show it in the amount of the element contained in them. The generally higher percentages found in column three of Table II, bear this out. As stated in the objective, the original problem was to see if members within a family behave in the same general way. The percentage figures answer the question. Within only three families did all species studied increase when the large amount of fertilizer was applied. These families were the legumes, circubits, and composites, while in all others at least one member, and sometimes two, were actually lower in total nitrogen. The family response to adding only fifty pounds was similar to higher addition in that they were not all affected in the same way. Only the grass family showed gains and similar responses throughout the species studied. All other families exhibited wide variation. As will be mentioned in the conclusions to follow, there seem to be no indications in this experiment that members within a family show the same kind of behavior under low medium, or high nitrogen fertility levels. Plants may be grouped into definite families, according to similar and contrasting vegetative and reproductive characters, but a classification of plants into families on these bases will not necessarily encompass plants of like physiological reactions to nutrient uptake.

The writer of this thesis wishes to explain the probable influence of chance in the experiment before delving into a discussion of the data. This will keep the reader's mind aware of such influence, and make the data obtained of better value.

The area used for the experiment, unfortunately, was rich in nitrogen. This undoubtedly hindered a finer distinction of final results than was otherwise obtained. A soil poor in nitrogen would have certainly produced results of a more conclusive character. However, as it was the addition of fifty pounds of nitrogen per acre to the medium plot did not markedly increase the nitrogen level of this plot compared to the section receiving no nitrogenous materials. How are we then to decide whether the differences among the plants in the medium series versus the check series are due to the factor we are attempting to show, i.e., family relationships, or if it is due to the fact that the fifty pound addition may show different results whichever way chance may decide it? We cannot be sure which is the correct reason in these two sets of data, but with the addition of four hundred pounds per acre, conclusions can be made of some merit. This is where the element of chance enters into the picture, and while we cannot and will not entirely dismiss the data of the medium plot, contrasted to the check plot, it will not be used as conclusive evidence in drawing later conclusions.

It seems likely that if this experiment were repeated again under nearly identical conditions that the data from the medium plot might vary quite a bit from that was received at this time. Therefore, we will attempt to draw our answers to our problem from data received where high nitrogen was applied, since in this case the element of chance is considerably smaller, and probably insignificant.

In Table III the percentage changes between plants grown on check plot and the other plots are compiled. Plants grown on the check plot are compared to the other two plots. A positive figure indicates a gain in the percentage of nitrogen in plants of the peculiar series over the check series, and a negative figure depicts a loss. The percentage gain or loss, whichever it might be, was calculated for each plant, and then the average change for the family computed. This allowed the evaluation of each family, as compared to the other nine studied, and the determination of which families responded well and/or which ones poorly to the additions of nitrogenous fertilizers. This table brings out more strikingly the trend of the results from which definite answers and suggestions can be made and prescribed.

Let us first consider the changes among individual plants, in the medium compared to the check plot. As was mentioned previously in this section, fifty percent of the plants showed gains in the nitrogen content of their tissues, when the soil received a relatively small amount of fertilizer.

Of all the plants studied Nicotiana, a beautiful ornamental plant of the nightshade family, increased most. It gained over forty percent. Compare this with a plant of its own genus, tobacco. Tobacco responded negatively, and was second only to celery in this respect. Thus two plants within the same genus and family, behaved decidedly different to the addition of fifty pounds of nitrogen per acre. Another case of behavior between the plants, as has been cited in this instance, was revealed in the calculations of percentage changes. Parsnips made a gain of over thirty percent in their tissues, ranking next to nicotiana, but celery belonging to the same family, shows a large drop.

Some other plants to make gains of fifteen percent, or more, were corn, sudan, pumpkins, sunflower, and beans. Plants showing significant losses of over nine percent included, besides tobacco and celery, crimson clover, garlic, and hemerocallis. These last three plants were of rather high nitrogen content, as compared to the species enumerated above, which gained more, but not less total nitrogen content. This leads us to the apparent conclusion that plants low in nitrogen content will be more affected by small additions of nitrogenous fertilizer than will plants normally rich in this element.

The figures show that with only one exception the top of the root crops reacted favorably to additions of nitrogen. Carrots, parsnips, mangels, beets, and turnips all increased, but radishes suffered a sizeable drop. The root crops of the *umbelliferae* family increased most, followed in order by the *chenopodiaceae* and *cruciferae*.

The least response in one way or another was exhibited by the beet. The change in nitrogen in beet tops was very slightly positive, and so small that it could have been well within the experimental error of the method used. A few other plants, such as vetch, soybeans, and cucumbers, manifested slight response, and every one was in a negative direction.

In comparing the average changes in the families with each other, some interesting figures are presented. The average figure for a family was taken by calculating the algebraic sum of the changes within each species, and the proper sign being fixed.

The grasses upon being the only family in which all species reacted positively to the addition of the fifty pound per acre, showed a gain much higher than any of the others. This can be seen by examining the data in column 2 of Table III, in which the family of greatest gain is called 100, and the others rated on that basis.

The solanaceous family shows a varied trend. Upon taking the average of gains in this family it was found to be second highest, largely on the basis of the great gain exhibited by the ornamental nicotiana. When the grass family was given a rating of one hundred, the nightshade family merited a relative evaluation of about forty-one in comparison.

The composites were a family showing a sizeable increase in the case of two members, with the remaining three making small changes. Endive and chrysanthemums lost about five percent, with sunflowers and ragweed gaining in the neighborhood of fifteen percent.

The mustard family reacted very strongly negative to the addition of fifty pounds of nitrogen per acre. They were only bested in this respect by the lilies. The biggest positive gain in the mustard was made by turnips, which was only 4.4 percent. In conclusion, it appears that the mustard family seems to be strongly affected in the negative direction by small additions of nitrogen.

Pumpkins within the cucurbit family stood out from the other two species examined. Due to the reaction of the pumpkin vine, a favorable increase for the family was the result.

The chenopod group as a family exhibited a slight negative change, which was enhanced by spinach, and which decreased nearly nine percent. It is observed that within this family the large rooted plants, beets and mangels, show an opposite behavior under both medium and high additions of fertilizer to those species not possessing enlarged roots.

The snapdragon group were very similar to the composite and the cucurbits. The three families were separated by only .06 units in the average percentage gains. Penstemon plants gained most, with a rather sizeable gain.

Peas and beans were most alike in their reaction to fifty pounds of nitrogen per acre within the pulse family. These were the only two that exhibited gains. Soybeans were grown in boxes under greenhouse conditions, because they failed to make sufficient growth outside. Their growth was rapid under controlled conditions, but unduly subjected to insects and fungus pests. They were, however, ready for harvest before any noticeable damage could result. Bean plants made one of the largest recorded gains of any plant in this series of data, but due to the loss by crimson clover of over ten percent, the family as a whole rated only sixteen compared to 100 for the grasses.

The other representative family from the monocotyledons (grass being the other) the *liliaceae* experienced the largest negative response to the medium addition of nitrogen of any family studied. With the exception of Hemerocalis, all four of the other members were grown in the greenhouse.

Lastly, the umbelliferae family considered on an average, shows a slight gain. As was mentioned before, celery and parsnips showed widely differing changes, and this was carried over into two other members examined in the family. Parsley resembles celery in appearance, and carrots are quite similar to parsnips, and from an examination of percentage changes data, we see that in these respects parsley behaves like celery, and carrots like parsnips.

However, the range of difference between carrots and parsley was decidedly less. Again, as in the goosefoot group, the crop with enlarged roots of the parsley family show entirely different response to the same addition of nitrogen, except in this family it is confined only to addition of fifty pounds.

In Table III the rating of these families are given with the arbitrary value of one hundred given to the grass family. The order of the families there is again as follows: grasses, night shades, composites, circubits, snapdragons, legumes, parsleys, goosefoots, mustards, and lastly, the lilies. Note that a monocotyledonous family commands the top position, and also the lowest point.

The grasses were well above all the families, probably because everyone of the representatives manifested consistent but not too large increases. Most others fell off in the average, because a member underwent a decided decrease, or else two or more exhibited small but consistent drops. The night shades, composites, snapdragons, and circubits all showed similar trends, with the last three families being very close together. The legumes, parsleys, and goosefoots were most near a zero rating of the families studied. The average change in each group was small, being negative in the case of the goosefoots. The rating given the goosefoots was called negative to keep it separate from families in positive terms. Lastly, mustard and lilies received high negative ratings.

How shall we term these families with respect to their relative behavior to the addition of fifty pounds of nitrogen per acre? It can be said that the grass family reacts strongly; the night shades, composites, circubits and snapdragons show moderate positive response; legumes, parsleys, and goosefoots exhibit indifference and, finally, the lilies and mustards appear to be moderately depressed in their nitrogen content.

In examining the comparative standings of the ten families, there seems to be no definite correlation with the evolutionary scale of plants, as represented by Pool (pg. 122) (40). In Pool's text, he places the composites, scrophulariaceae and circubits very high in development among the dicotyledons, while the legumes and mustards gravitate towards the lower part of the scale:

Pool's Rank of Families: Dicots.	Monocots	Rank According to Nitrogen Intake: Dicots.	Monocots
1. Compositae	Gramineae	1. Solanaceae	Gramineae
2. Scrophulariaceae	Liliaceae	2. Compositae	Lilies
3. Cucurbitaceae		3. Cucurbitaceae	Liliaceae
4. Solanaceae		4. Scrophulariaceae	
5. Chenopodiaceae		5. Leguminosae	
6. Umbelliferae		6. Umbelliferae	
7. Leguminosae		7. Chenopodiaceae	
8. Cruciferae		8. Cruciferae	

With the exception of having the monocotyledons in the same positions relative to nitrogen uptake as in the evolutionary scale, there does not appear to be much correlation in the case. Of course, we see the mustard family at the bottom, and the composites, etc. near the top in both tables, but any similarity beyond these points is lacking.

Now comes the task of discussing the results obtained in the plants grown under four hundred pounds of nitrogen per acre. It is believed that the results received from this treatment when compared to the check plot will be more conclusive.

Elsewhere it was mentioned that slightly over eighty percent of the species studied responded with gains in percentage nitrogen. The general trend in gains was larger for the high plot than in the medium, since the average change in all the plants in the case of the former was + 14.05, and of the latter -2.50. So, therefore, not only the number of plants gaining in nitrogen uptake increased with more of the element added to the soil, but the average amount by which they gained was larger.

As to some peculiar or significant changes among the individual plants, let us cite a few. By far the largest gain exhibited by any plant was the tobacco plant, which increased its nitrogen content ofer fifty percent. It will be remembered that it showed a negative reaction to the addition of a small amount of nitrogenous fertilizer. Nicotiana which was singularly cited in previous discussions, also made a sizeable gain, although less than tobacco.

Peas and beans made gains second only to that achieved by tobacco. These two plants, after showing a different behavior to medium additions, exhibited gains of forty-five percent together. The addition of four hundred pounds seems to have more effect upon the peas than upon the beans.

One interesting reaction to the heavy addition of nitrogen, was the ornamental member of the composite family, the asters. Analyses showed no significant difference between the plants from either plot, and the check and high plot yielded material identical, or nearly so, in composition.

Sudan grass was another specimen to show only slight change. The difference in analytical results for this grass grown on the check plot show only .01 difference, well within experimental error. Other plants manifesting slight changes are cucumbers and dill. Theses species made alterations in nitrogen content of approximately one percent.

It might be well here to say something about the changes occurring in species which showed indifference to the addition of fifty pounds of nitrogen per acre. The reader will notice from the figures in Table III that cucumbers, beets, vetch, and soybeans manifested slight changes. The beets and cucumbers again refused to respond significantly to additions of nitrogen, notwithstanding the heavy application. These two plants, of course, belong to separate families, but the vetch and soybeans, like other members of the legume family, made important response to the four hundred pound application. Beets and cucumbers do not show much reaction to the nitrogen added to our experimental plot.

Plants expressing a strong negative trend after adding four hundred pounds of nitrogen per acre, as shown by the nitrogen content of their tissue, were not many. A decrease of ten percent or over was not encountered, but a few plants dropped about nine percent. These included mangels, asparagus, and shepherd's purse. The asparagus was grown in greenhouse boxes, and the shepherd's purse was taken as a weed found growing here and there on the experimental plot. These two plants also demonstrated a negative trend with the medium fertilization in about the same degree, i.e., 7 to 9 percent. Asparagus was the only member of the lily family behaving as it did, and shepherd's purse was the single Cruciferae reacting as such. As for mangels, they showed a sizeable positive response to the small amount of the element which was approximately equal in magnitude to its positive change. Mangels are an enlarged root crop as contrasted to the two species we considered in this present discussion.

All plants with the exception of asparagus and shepherd's purse which revealed negative response to fifty pounds, gave a positive response when 400 pounds of nitrogen per acre were added. Similarly, all plants showing a negative response to the heavy application of fertilizer, exhibited a positive response to the treatment of the middle plot, with the exception of these two species. In summarizing, we can say, therefore, that all plants showing a negative response to one degree of fertilization, shows a positive response to the other in all cases but two. Some plants can be affected by small additions of nitrogen, and not be large amounts, and vice versa. Plants which have enlarged roots showed different response to a high nitrogen level, and these differences did not vary within the family. The two members of the goosefoot group declined, while both members in each of the mustard and parsley family increased. The umbeliferae were affected to a greater degree than the mustards.

Family averages were calculated on this series of data as before, and the same method of ascertaining these values was used. The averages, of course, were higher for every family than under light additions of nitrogen. The average figure for the ten families was a plus 35.56 as against a plus of 2.22 on the medium series.

The grass family was just below the average value, and as a family showed only slightly greater reaction to the four hundred pound addition, than to the fifty pound. Corn was the most responsive member of the grass family to both additions of nitrogen, with barley and millet being nearly identical in both cases.

Passing to the night shade family we see good evidence of comparatively strong tendencies to consume nitrogen in luxury amounts. Within this family two species showed some of the very largest gains found in the experiment. The night shades studied comprised two popular market garden vegetables, egg plants and peppers. These two species responded least to the heavy application of nitrogen, especially the peppers. The peppers are another example of many plants in this experiment which contained high amounts of nitrogen in their tissues on the check and/or medium plot, and exhibited weak or negative responses to the heavy treatment. This experiment seems to show that those plants high in nitrogen under low fertilization respond little to further additions. This fact is of significance.

The composites studied behaved on the average very much like the grasses did. The unresponsive reaction of the asters make it somewhat incorrect to label this family as one of the few studied which showed gains in all members examined. Since the four species made sizable gains, we shall include this family along with two others in the category of families exhibiting increases in all cases studied.

Endive and chrysanthemums both failed to increase their nitrogen content under the light application, the latter changing the most. As four hundred pounds of the element were incorporated in the soil, both plants increased their uptake of nitrogen, and again it was the leafy endive which made the most favorable response. It might be mentioned here, however, that these two plants are entirely different in growth habits, and the source of experimental plant material was not the same. Chrysanthemums, like asters, are a stock ornamental and the materials used were transplants, having started to bloom in the middle of July. Endive is a leafy vegetable, much like lettuce, and was grown from seed.

The mustard family, it will be remembered, responded strongly negative to the additions of fifty pounds of nitrogen per acre. On the other hand, it revealed an average gain of high proportions when the high plot was compared to the check. It was above the average figure for all the families. This family made the most significant response to the addition of three hundred and fifty pounds more to the soil than any other. If we could disregard the shepherd's purse, this family could also be termed a luxury consumer of nitrogen insofar as our data shows; but like several other families examined, one or more members exhibit slight negative changes.

The circubit group contained four members, all of which increased the nitrogen content of their tissues. We have mentioned before, however, that cucumbers were one of the most indifferent plants to nitrogen additions encountered. It was also the species in the circubit family which possessed the most nitrogen where grown on the non-fertilized section. Sufficient material was not obtained on the middle area in the case of watermelons to be analyzed, but it made the greatest gain over the check plot, and had the least amount of nitrogen of any of the circubit group raised on the check area.

The goosefoot family seems to be a group not markedly affected by the nitrogen levels set up in our experiment. Of course, the average for the family was raised by additions of four hundred, as should be expected, but still the increase by applying three hundred and fifty pounds more was the smallest of any of the families examined. The goosefoot studied showed varied but usually small changes under the conditions of the experiment. It will be noted that the crops with enlarged roots reacted oppositely to the other three plants, just as they did under light fertilizations. This leads us to believe that the enlarged root plays an important part in the plant's relationship to the nitrogen level of the soil.

In the snapdragon family very little consistency among the three species examined was noted. While two out of the three gained in nitrogen content, they were in no way comparable. The snapdragons gained a small amount this time, which if compared to the equally small loss under the fifty pound addition makes this species appear somewhat indifferent to nitrogen content of the soil. The digitalis plant responded very well to the application of the 400 pounds of nitrogen per acre after having managed to make a small gain under the light addition of fertilizer. The Penstemon plant, which has been cited before as having accomplished only a small amount of grotth in the late summer season of experimentation, made a slight loss on the high plot. Whether this change is due to normal relationship to the level of soil nitrogen or to its rather static growth habits during the experiment, was not determined. It is felt, therefore, that the investigation should in this case, and in other plants studied, refrain from trying to convince the reader that the differences in reaction to the nitrogen can be attributed solely to their natural relationships to this element as a soil-borne nutrient. The growth habits and stages of growth, as well as other things, will condition their nitrogen uptake and content, but it was impossible during the short time allotted to field experimentation to reduce the variation of some of these factors to a minimum. The reader is referred to page 18 in the procedure which also points out that the investigation recognizes the uncontrolability of certain vital factors. To continue with a discussion of the snapdragon family, it is pointed out that the family average is quite high and it again closely follows the composites and circubits, two families which are also recognized as highly developed.

The legume family showed great response to the heavy treatment, and showed the highest of family averages. The members especially low in nitrogen on the check plot, such as beans and peas, made large increases as contarsted with crimson clover and vetch which, although making positive response, were high in the element on unfertilized land. The legumes made the largest jump in units from the average for the light application to the average for the heavy one, but earlier it was pointed out that the mustard group exhibited the most radical change, that is, from a sizable negative average to a figure of a positive sixteen. We can see that upon closer scrutiny of percentage difference figures that the plants making the most unfavorable response to the small addition of nitrogen revealed the smallest percentage gains also under the heavy treatment.

The lily family, even under the additions of four hundred pounds, still showed one of the lowest family averages. It, along with the goosefoots, seemed to be a family not prone to load up on great amounts of nitrogen when presented with the opportunity. The bulk of the lily family, (excepting hemerocales) were grown in the greenhouse and, therefore, inserts a new factor which may or may not detract from the true position they assume relative to those families grown in the open. These plants were rather high in nitrogen which were raised in the greenhouse, and it is noted that they do not help to support our proposition to a very great extent. Garlic, with a very high nitrogen content did, of course, respond meagerly to the heavy addition; but onions, also with a high figure, was determined as having a very sizable change. The lily family presents interesting trends toward nitrogen levels in the soil, and undoubtedly would make a fascinating and valuable avenue for more exact study.

Lastly, the umbelliferae family is one showing great response to our treatments. Notwithstanding the slight loss revealed by dill (which was grown in the greenhouse) the umbel group made quite significant positive gains, especially the enlarged root crops. In the parsley family, as in the goosefoot, these crops with enlarged roots behaved somewhat unlike those with without them. Of course with the parsleys the response of the enlarged rooted crops was in a different direction than in the chenopods, but the point is the enlarged root of a plant seems to play an important role in the relation of a plant to the nitrogen level of the soil.

As was done with the families in the check-to-medium series, the various families have been arranged in the order of decreasing family averages. These are shown in Table IV. Certain interesting positions are taken by the families especially when compared to the other list. The order for the families this time is - legumes, night shades, parsleys, mustards, grasses, composites, circubits, snapdragons, lilies, and goosefoots. Note that some families which are low in family averagesin the check-to-medium series, and are comparatively low in Pool'sevolutionary scale have in the present series taken positions near the top of the average scale. Also, families which are high in the first place have now dropped down in the second series. Mustards, legumes and umbels moved up, while the grasses, composites, circubits and snapdragons came down. Upon coming to new positions the same order was maintained by those families as was determined in the first series; i.e., legumes, parsleys, and mustards lined up in that order in the first groupings and likewise they did in the second series, etc. The three highly developed families, composites, circubits, and snapdragons, were very similar to each other in the check-to-high series as before indicating a possible tie-up between evolutionary position and relationship to nitrogen in the soil. The three families - night shades, lilies, and goosefoots - remained in their same positions as previous, especially the night shades.

It can be observed also from the relative ratings that the families are more nearly uniform in their behavior towards heavy applications. For example, notice the wide gap between the grasses and night shades in the first series as compared with the smaller gap between the legumes and night shades where 400 pounds are used. Notice further the difference between successive families in column 3 are not abrupt and unevenly spaced, but on the other hand seem to show definite reactions toward soil nitrogen. That is, as the soil increases in nitrogen content the plant reacts to it by raising the nitrogen content of its tissues and it is the general tendency among our seed plants of agricultural importance. When only fifty pounds of nitrogen is applied to one acre of ground, the chances are that the tendency for the same plants to increase nitrogen content over those grown on unfertilized will be erratic and non-conclusive. However, upon heavy treatments one can look at figures and see the luxury consumption process underlying them in more instances than one.

THE DATA FROM EVOLUTIONARY STANDPOINT

As was stated in the objective, one of the purposes of the investigation was to see if there was any correlation between the position of a family in accepted evolutionary scales and its begavior toward nitrogen in the soil. It was realized that since the families which were selected contain many scores of species, only could we draw conclusions from our data that was obtained in an experiment where all factors were controlled except family relationships, and just because five members of a group reacted positively it is not justifiable to say without further qualification that our results fully characterize the family.

It is thought that plants will tend to 'load up' on elements abundant in sea water. That is, the halogens will enter a plant in far greater abundance than the plant will require, as will certain cations. This thought seems to be borne out in unpublished (to date) data ascertained by the Massachusetts Experiment Station laboratories, as well as in the theoretical aspects. We know that plants like animals, first lived in a water environment, and in subsequent geologic time commenced to exist on land. As a result we consider those plants (or animals) which have cast off their life in the sea for one primarily on land, as the more highly evolved. Yet even in these higher evolved groups we see vestiges of a sea environment in the form of anatomical structures, ecological relationships or physiological functions. This suggestion of luxury consumption has come about and seems to be supported through these evolutionary steps as we most generally accept the today. We can also resort to an examination of present day flora to try and reconstruct these changes taking place in plants as they become more adapted to a land environment, in the later eras of geological time.

Nitrogen is an element of great abundance in the earth's atmosphere and of slight solubility in water in elemental form. Dittmars (11) reporting on the composition of sea water, does not even mention the nitrogen content as being more than in very small quantities. At least the soil must contain much more available nitrogen than the sea and, therefore, those plants which have been on the land for the most extended time might be expected to be heavier feeders upon soil nitrogen than the plants of a later time. This present investigation has attempted to see if in the case of nitrogen, the plants showed any remnants of past existence in the sea, and to throw more light upon the interesting behavior of plants as reflections of their ancient past.

In trying to superimpose the data in Table IV over the order of families with respect to evolution, we do not find a high degree of correlation or reasonable agreement. Again let us try to draw our correlations more from the heavily treated plot for reasons mentioned before. Let us again look over Pool's (40) ranking of the families used in the experiment, and compare with the order of family average on the check - high series.

<u>Pool</u>

1. Compositae 1. Gramineae
2. Circubitaceae 2. Liliaceae
3. Scrophulariaceae
4. Solanaceae
5. Chenopodiaceae
6. Umbelliferae
7. Leguminosae
8. Cruciferae

<u>Pack</u>

1. Leguminosae 1. Gramineae
2. Solanaceae 2. Liliaceae
3. Umbelliferae
4. Cruciferae
5. Compositae
6. Circubitaceae
7. Scrophulariaceae
8. Chenopodiaceae

Families low in the evolutionary scale, that is Umbels, Legumes and Mustards, are more strongly affected by an increase in the nitrogen content of their environment. They seem to be most sensitive to larger additions of nitrogen to their feeding sphere. Those families, i.e., composites, circubits, and snapdragons, which are high in development, conversely are not as sensitive to extending of the nitrogen content of the soil. Furthermore, two families, such as chenopods and nightshades, lying approximately in the middle of the evolutionary scale, were not markedly changed in their position with respect to the other six dicotyledon families when either fifty pounds or four hundred pounds of nitrogen were incorporated into the soil. Summing up, then, our data reveals that if Pool's evolutionary order of the dicotyledon families studied in his investigation are tipped upside down, allowing the nightshades and goosefoots to be the pivot for the half-spin, we have nearly the same order of these families as is submitted as the result of the average reaction of each family to the addition of four hundred pounds of nitrogen per acre. Especially is this true with the families on the ends of the scale. With the two cotyledon families studied, our order of reaction to the nitrogen on the high plot is the same as the evolutionary order, but with only two such families we will not attempt to suggest any reason for it without knowing the reaction of other monocotyledon families.

SUMMARY AND CONCLUSIONS

To summarize briefly: An attempt was made to see if there was any correlation between the uptake of nitrogen and family relationship among plants. A number of species from ten common families were grown on plots containing varying amounts of nitrogen. The tops were analyzed for total nitrogen and the results obtained used to answer the questions of the investigation.

In the experiment there seemed to be no similarity among the families studied in their uptake of nitrogen. Some responded well to additions of heavy amounts of fertilizer, such as legumes and nightshades, while others did not. Also, there was a negative response among such families as the mustards, lilies, and goosefoots under light nitrogen applications.

Members of the families studied did not show always the same trend within the family itself. Only the Leguminosae, Circubitaceae, and Compositae showed the same trend throughout the species studied when large amounts of nitrogenous fertilizer were used. The Graminae members exhibited the same response when a light application was made. In general where large quantities of fertilizer were used, the members within a family manifested a more common response. Under light applications the trend was more irregular.

Where the four hundred pound rate was used, the plants studied showed, in general, a much higher nitrogen content than where the fifty pound rate was used. The average gains made by the species on the high plot was 14.02 as compared to 2.9 on the lightly treated plot.

The Leguminosae family was the most responsive to the heavy quantities used. This family was considerably more affected than the second ranking family, the Solanaceae. As for the plant making the maximum response, tobacco over-shadowed the others by an increase of over fifty per cent. Several plants made gains of between twenty-five and fifty per cent. The family least responsive to the large fertilizations was the Chenopodiaceae and they were well below the Liliaceae which was the next poorest. There were two individual plants that were about equal in slight reaction to a high nitrogen fertility level. These were mangels and asparagus, both of which were even higher in nitrogen content on the untreated plot.

The Gramineae was well above the other nine families under the conditions of a light application. While tobacco made the largest gain on heavily treated plot, its ally, nicotiana made the most impressive gain on the medium plot. The Cruciferae and Liliaceae, followed closely by the Chenopodiaceae, showed the least response; in fact, all these exhibited a negative trend. Celery, a member of the Umbelliferae, was by far the poorest in reaction. As a matter of fact, its nitrogen content was 26% less on the lightly treated plot than on the untreated one.

Our data does not show any good correlation between the uptake of nitrogen by a botanical family and the family's position in standard evolutionary scales.

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Walter S. Eisenmenger

A.H. Sieling.

W. H. Davis