THE EVALUATION OF A NEW FERTILIZER

DERIVED FROM FISH WASTE

By

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Abstract

Water in three separate applications was allowed to percolate through columns of pots containing different types of soils to which fish proteinate had been added only in the top pot. The volume of water was sufficient to saturate all the soil and to give a small excess for analysis. Plants were subsequently grown in all pots and the increased growth in different pot levels was used as a measure of nitrogen retention.

On the whole the fish proteinate was well retained, particularly in heavy soils, but the retained fertilizer was more efficiently utilized in light soil.

The tendency of the fish proteinate in its present form to absorb moisture from the air and to cause the formation of a hard crust, especially in the light soil, are definite drawbacks, and it is concluded that these undesirable features must be overcome before the product should be put on the market.

THE EVALUATION OF A NEW FERTILIZER DERIVED FROM FISH WASTE

1. INTRODUCTION:

(a) The Fertilizer Material Under Test:

In spite of the urgent demand for nitrogenous material for nutritional, fertilizer, and industrial uses, available sources of nitrogen in the form of fish waste are discarded in tremendous quantities every year. One manufacturer in British Columbia who obtains oil from fish waste by chemical extraction is endeavouring to utilize the nitrogenous residue from this process by converting it to a form suitable for fertilizer. The material is dried to a powder and then mixed with diatomaceous earth in an effort to overcome the tendency to absorb moisture. The final product has a reaction ranging from pH 6 to pH 10 and a nitrogen content of approximately 8%. The nature of the nitrogenous material in the fertilizer has not been ascertained; it is referred to by the manufacturer as "fish proteinate".

(b) The Object of the Experiment:

The experiment was carried out in the greenhouse to supplement a test already made (6) and a field experiment currently in progress (5) to determine the feasibility of using the fish proteinate as a commercial fertilizer. The main purpose of this experiment was to obtain information regarding the retention of the fertilizer in successive soil layers and the availability of the nitrogen in different soil types; and also to observe the degree of leaching of the material, its effect on the physical nature of the soils, and some of the properties of the fertilizer itself.

(c) Review of Literature:

Due to the fact that so little was known about the chemical nature of the material under test, the literature reviewed was necessarily restricted, and dealt only with a method previously used to evaluate the retention of nitrogen in soils.

The procedure used in this experiment is an adaptation of the percolation method used by Conrad (2) to determine the degree of retention by soil of nitrogen from a wide variety of sources. The method gives semi-quantitative results, and provides a very satisfactory means of determining the retention in the soil of nitrogen from complex organic compounds whose reaction with the soil cannot be predicted with any degree of accuracy.

Conrad's method consisted of percolating a solution of the material under test through a column of three pots and subsequently measuring the growth of plants in the top, middle, and bottom pots. By this means he showed that the nitrogen contained in anionic units in compounds was not retained in the soils tested; that nitrogen contained in cationic units of the compounds was completely or almost completely retained in the top pots of their respective columns. Nitrogen in amphoteric or approximately neutral units were unpredictable and their behaviour varied considerably.

Since the exact chemical nature of the nitrogen fraction of the fish proteinate was not known, it was impossible to predict the reaction of the material with the soil and the consequent degree of retention.

2. MATERIALS AND METHODS:

(a) General Remarks:

Conrad's method consisted of percolating a solution of the nitrogenous material through the column of pots, but in the present experiment, due to the nature and composition of the fertilizer mixture, it was deemed advisable to incorporate the fish proteinate with the soil in the top pot in each column and to percolate only water through the series. This method served two purposes: it produced conditions somewhat comparable to those in a field on which fertilizer had been broadcast and harrowed in, and it prevented the accumulation on the surface of the soil of the diatomaceous earth contained in the fertilizer.

A further modification of Conrad's method was made by carrying out the leaching procedure three times instead of once. The soil was thus subjected to very severe leaching, and it was considered that if the fertilizer was retained in spite of such treatment, the degree of retention must be very good. Furthermore, the comparatively long period between the first leaching and the initiation of the growing test allowed time for the breaking down of the fish proteinate into a form available for plant growth. It was hoped that plant response would be an indication of the rate of availability of the nitrogen as well as an indication of the degree of retention in the different soils.

Owing to the large number of percolate samples and to the fact that the object of analysing the percolate was to obtain an indication of ranges rather than exact values, it was decided to make use of a colorimetric method for estimating the total nitrogen and the nitrate nitrogen in the percolate.

Emmert's (3) method of nitrogen determination was tried and numerous tests were made on the first percolate, but consistent results could not be obtained and the method had to be discarded. Due to the failure of this method, bacterial growth was pronounced in all percolate samples from test columns, with the result that no nitrate nitrogen estimations could be made on these samples. The amount of bacterial growth was recorded as being a possible indication of the amount of nitrogen in the percolate.

Total nitrogen determinations were carried out by another method on all the percolate samples from the first leaching, though it was realized that there might be some error due to decomposition of the proteinate. The method of nitrogen analysis finally adopted was a combination of Emmert's (3) digestion procedure and one of Bray's (1) methods for the measurement of nitrate nitrogen.

(b) <u>Soils</u>:

In order that the properties and reactions of the fish proteinate could be studied on a fairly wide basis, soils of various types found in the agricultural areas of the Lower Mainland of British Columbia were used in the experiment. These soils included a heavy clay, a fine loam high in organic matter, muck, and a light sandy soil. No attempt was made to alter the reaction of the soils, nor to add supplementary elements, as it was considered that such changes would create more problems than they solved.

The four soils used in the experiment were designated as follows:

SOIL A: untilled clay soil from Sea Island, classified on the Soil Map of the Lower Fraser Valley (4) as Ladner Clay.

SOIL B: untilled soil from Langley Townsite, classified as Custer Loam.

SOIL C: untilled Black Muck from Lulu Island near Brighouse.

SOIL D: Upland Sandy Loam, previously cultivated, from the Horticulture area of the Campus of The University of British Columbia.

In taking the samples of untilled soils, the cover of weeds and the top two inches of soil were removed and the soil taken to a depth of about eight inches.

The soils were received in field-moist condition and after they had been sifted through a half-inch mesh to remove lumps, stones, roots, etc., they were then spread on a bench in the greenhouse to dry. They were turned and stirred frequently for three weeks, and were then considered to be in an air-dry condition.

(c) Fertilizer:

The fertilizer material used in this experiment has already been described on page 1.

(d) Equipment:

Pots: 60 four-inch pots complete with one-hole corks and "needle-valves" made of glass tubing, served as reservoirs.

180 four-inch pots were used to contain the soil.

All pots were painted on the outside with asphalt paint.

Cans: 180 cannery tins, No. 2½, painted on the inside with asphalt paint, were used to catch the excess drainage from pots containing plants.

Jars: 96 four-ounce jars were used to catch the percolate and to hold samples for analysis.

Racks: 3 wooden racks with removable side bars were designed to hold double rows of pots, as shown in Plate 1.

Chemicals: in addition to the chemicals specified in the analytical procedures, the following reagents were made up:

Reagent 1:

100 gm. $BaSO_4$
1 gm. finely powdered zinc
10 gm. $MnSO_4 \cdot H_2O$

The reagents should be free from nitrate and nitrite and be ground together forming a nearly white powder.

Reagent 2:

10% acetic acid made nitrate-free by the addition of a little powdered zinc.

<u>Reagent 3</u>: To 50 ml. of Reagent 2 add approximately 0.25 gm. of a mixture of equal parts by weight of alpha-naphthylamine and sulphanilic acid.

<u>Plants</u>: "King of Denmark" spinach plants were grown to pricking-out size in a flat and then transplanted to the pots.

(e) <u>Pot Setup for Percolation</u>:

Columns of pots were set up with three pots per column. Each pot contained 300 gm. of air-dry soil, except in the case of SOIL C (Black Muck) when only 200 gm. could be put in each pot. With the soil in the top pot of each column was incorporated 11.2 gm. of fish proteinate (7.5 gm. in SOIL C) so that the nitrogen level of the soil of the top pot was raised by approximately 0.3% on an air-dry basis. The soil and the fertilizer were thoroughly mixed by shaking the two together in a closed can.

Test columns were replicated twelve times for each soil. Similar columns of each soil without added fertilizer were set up to serve as checks.

Check columns were replicated three times for each soil.

Before each pot was filled with soil, a piece of pottery was placed over the drainage hole, and a small handful of washed gravel was dropped in to hold the pottery in place and to provide good drainage and aeration.

From a reservoir pot above each column, tap water was percolated through the soil until an excess of more than 20 ml. had been collected in a jar set below the column. The water was dripped at a sufficiently slow rate to prevent the formation of surface pools, but fast enough so that all percolating was completed within 48 hours. No record was kept of the amount of water required to saturate each type of soil.

20 ml. of percolate was saved from each column for analysis, and the remainder was returned to the top pot. In the case of test columns, the percolate from each group of three columns was made into a composite sample in order to reduce the number of nitrogen estimations to be made. The sample of percolate from each check column was placed in a separate storage jar.

The percolation process was carried out three times, with an interval of 28 days between the first and second, and 8 days between the second and third leachings.

(f) Examination and Analysis of Percolate:

Observations were made on the colour of the percolate at the time it was collected, with the thought in mind that there might be an association between the colour of the percolate and the amount of nitrogen leached out of the soil.

It was remarked above that due to the delay in finding a satisfactory colorimetric test for total nitrogen in the first leachate, bacterial growth was evident in all percolate samples from columns receiving fertilizer. An estimation of the amount of growth was made by visual examination.

The reaction of the last percolate was recorded to show the cumulative effect of leaching on the acidity of test and check soils and to establish the pH of the soils at the time the growing test was begun. The approximate acidity was determined by the use of Hydrion paper. A small piece of the paper was placed in the depression of a spot plate and just moistened with percolate. The colour developed was then compared with the standards provided.

Digestion prior to the determination of total nitrogen was carried out by Emmert's (3) method as follows:

5 ml. of the percolate were placed in a test tube and evaporated to dryness in a water bath. To the dried material was added 1 ml. of 40% sodium chlorate solution without wetting the sides of the tube. The tube was then slanted and 1 ml. of fuming sulphuric acid (15% SO_3) was allowed to run slowly down the side of the tube with constant shaking of the tube to prevent spattering. When the reaction had ceased 3 ml. of distilled water were added.

1 ml. of the digest solution was then placed in a clean test tube with 2 drops of phenolphthalein and the solution was neutralized with 40% sodium hydroxide. Sufficient 10% acetic acid was added to dispel the red colour, and then 10 drops more. The volume was made up to 5 ml. with distilled water.

Using the neutralized digest solution for total nitrogen and the percolate for nitrate nitrogen, a colorimetric estimation of the nitrogen content was made by Bray's (1) method as follows:

To duplicate 1 ml. samples in a test tube were added 7 ml. of Reagent 2, and then ½ ml. of Reagent 1. The tube was shaken immediately for exactly 20 seconds and then 1 ml. of Reagent 3 was added and the tube shaken once more. The tubes were allowed to stand for several hours or overnight before comparison was made with a series of standards prepared by the same method.

(g) <u>Pot Setup for Plant Growth</u>:

The columns of pots were taken down and each pot was placed in a tin can as shown in PLATES II-IV. One spinach plant was set in each pot. The pots were randomized on the greenhouse bench and watered as necessary. Excess water collected in the tin cans was returned to the pots. After about eight weeks of growth, when the lower leaves were beginning to show chlorosis, the plants were harvested.

(h) <u>Weighing of Plant Material</u>:

The tops of plants were weighed immediately after harvesting.

3. <u>OBSERVATIONS AND RESULTS</u>:

(a) <u>Properties of the Fertilizer Material</u>:

In spite of the addition of diatomaceous earth to the dried fish proteinate, it still exhibited pronounced deliquescence, and was difficult to handle after short exposure to the air. Thus even weighing the fertilizer in a beaker presented difficulties, as the material absorbed moisture fast enough to stick to the sides of the glass.

The weighed material could not be used immediately and was stored in glass jars with tight screw caps; at the end of two months the original powder had become a hard, unmanageable mass, and new portions of fertilizer had to be weighed out.

(b) Effect of the Fertilizer on the Soil:

At the time of the second leaching it was observed that all soils in columns which had received fertilizer were considerably caked on the surface. In the case of SOIL D (Upland Sandy Loam) the soil was quite impervious to water until the crust had been broken.

This severe caking effect in SOIL D was still evident at the time of transplanting seedlings; in the other soils the effect had been eliminated almost entirely by successive leachings.

(c) Percolate:

Colour: The results of these observations are tabulated in TABLE I.

Bacterial Growth: TABLE II records an estimation of the amount of growth in percolates from the different soils following the first leaching.

pH: The results of the acidity estimations on the third percolate are shown in TABLE III.

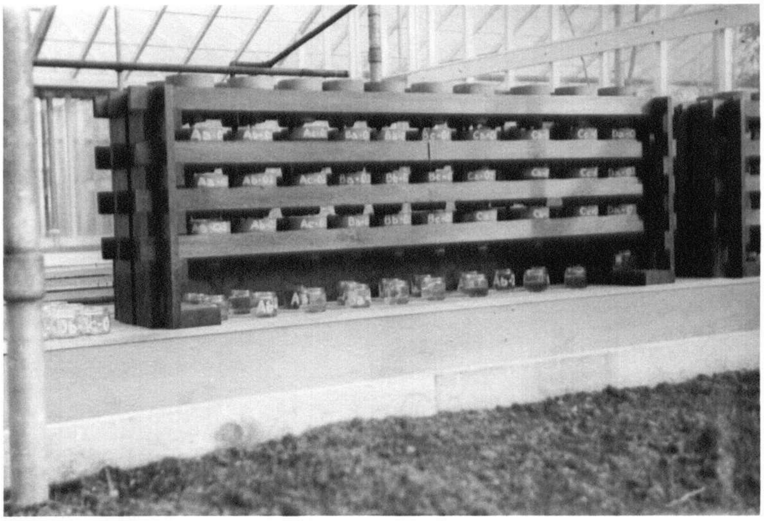
Nitrogen Content: In TABLE IV is shown a summary of the estimations of total nitrogen and nitrate nitrogen in the percolate collected from all columns of pots, and the increase in the total nitrogen leached from the soils as a result of the addition of fertilizer.

<u>Growth</u>: The comparative sizes of plants in the check, top, middle, and bottom pots are shown in the photographs in PLATES II-IV.

Plants in SOIL C (Black Muck) made very little growth and after six weeks in the pots showed chlorosis and stunting to such a degree that the experiment with this series of plants was discontinued and no further observations were made.

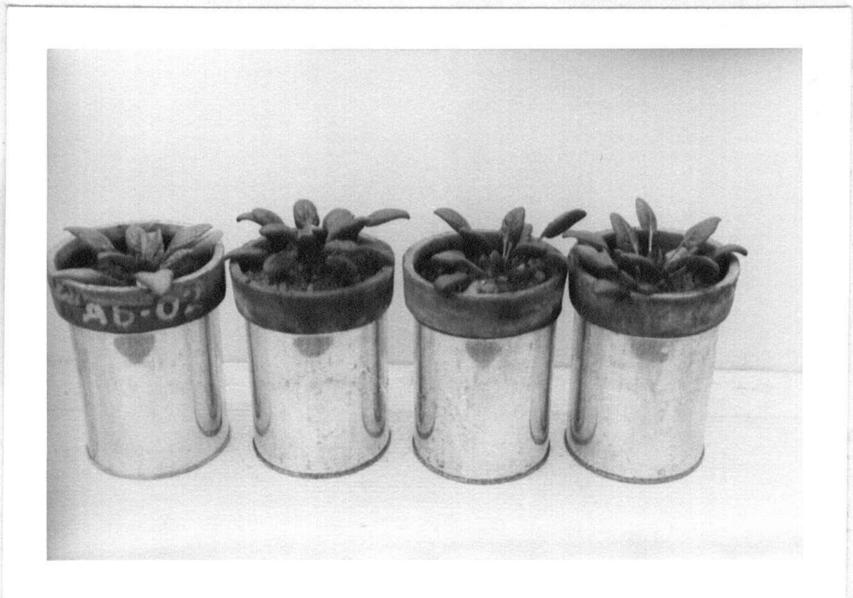
<u>Fresh Weight</u>: Due to the small size of the plants, they were not weighed individually. The twelve plants growing in the top pot of each soil type were weighed and the average fresh weight per plant was calculated. Similarly, the plants of the middle and bottom pots were weighed and the average weights found. The three plants in the top, middle, and bottom pots of each check soil were also weighed and the average weight recorded. The average fresh weights per plant are shown in TABLE V along with the increase in weight and the percentage increase as a result of the fertilizer application.

PLATE I



POT SETUP IN RACKS FOR PERCOLATION TEST

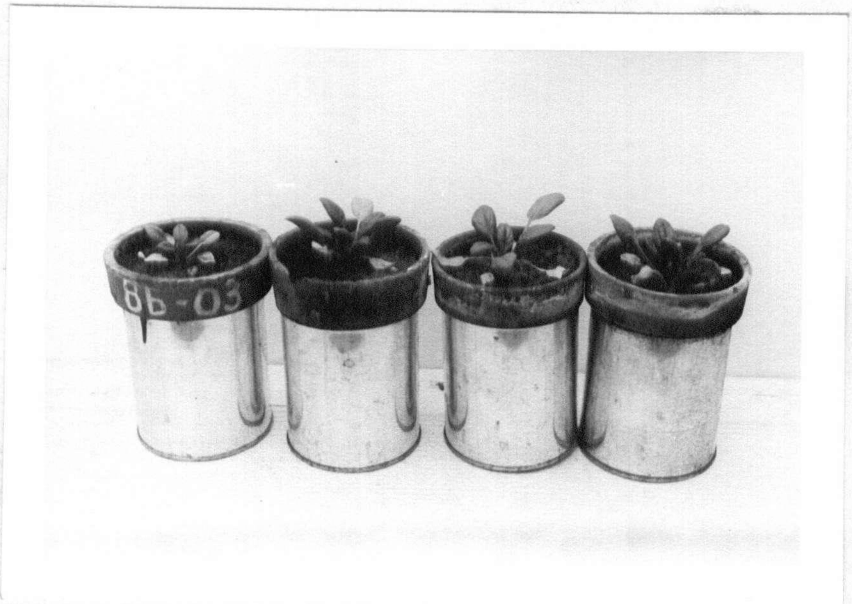
PLATE II



PLANT GROWTH IN SOIL A (LADNER CLAY)

(Check, Top, Middle, and Bottom Pots)

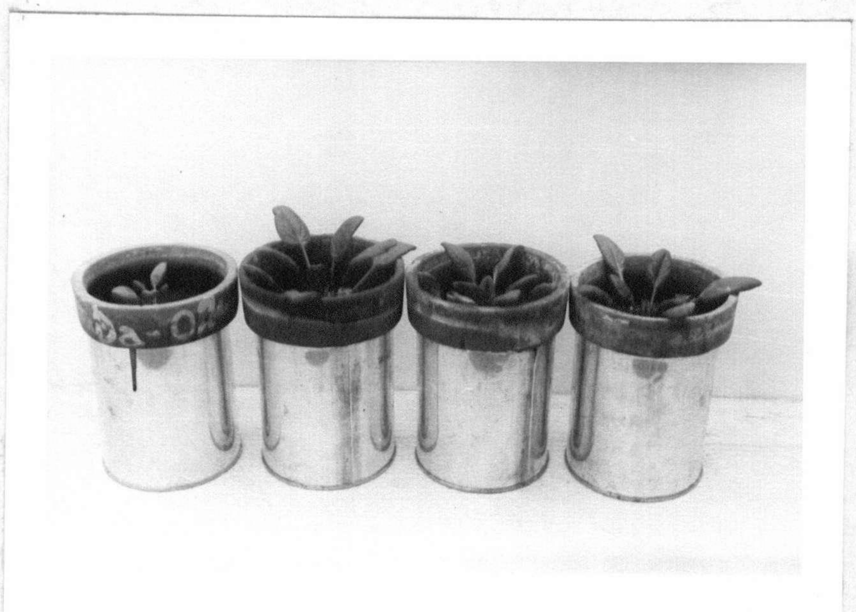
PLATE III



PLANT GROWTH IN SOIL B (CUSTER LOAM)

(Check, Top, Middle, and Bottom Pots)

PLATE IV



PLANT GROWTH IN SOIL D (UPLAND SANDY LOAM)

(Check, Top, Middle, and Bottom Pots)

TABLE I

Colour of the First Percolate

	Test	Check
SOIL A	Orange-yellow	Faint yellow
SOIL B	Almost colourless	Colourless
SOIL C	Light brown	Orange-yellow
SOIL D	Light brown	Very faint yellow

TABLE II

Bacterial Growth in the First Percolate

	Test	Check
SOIL A	+	-
SOIL B	+	-
SOIL C	+++	-
SOIL D	++++	-

KEY:

-	None
+	Slight
++	Moderate
+++	Heavy
++++	Very Heavy

TABLE III

pH of the Third Percolate

	Test	Check
SOIL A	pH 7.0	pH 6.5
SOIL B	pH 5.0	pH 6.5
SOIL C	pH 4.0	pH 4.5
SOIL D	pH 7.5	pH 7.0

TABLE IV

Nitrogen Analysis of the Percolates

	Total Nitrogen mg. per litre				Nitrate Nitrogen mg. per litre		
	First	Second	Third	Total	First	Second	Third
SOIL A							
Test	75	100	15	190	-	20	10
Check	60	75	10	145	15	15	7
Increase	15	25	5	45			
SOIL B							
Test	200	100	50	350	-	30	12
Check	100	25	10	135	25	15	7
Increase	100	75	40	215			
SOIL C							
Test	200	175	50	425	-	20	12
Check	100	100	25	225	15	15	12
Increase	100	75	25	200			
SOIL D							
Test	750	250	25	1025	-	25	15
Check	200	25	15	240	50	20	12
Increase	550	225	10	785			

TABLE V

Average Fresh Weight - Grams Per Plant

	Top Pot	Middle Pot	Bottom Pot
SOIL A			
Test	2.52	2.16	2.56
Check	0.70	1.67	1.87
Increase	1.82	0.49	0.69
Percent Increase	262	29	37
SOIL B			
Test	0.86	0.67	0.60
Check	0.30	0.53	0.40
Increase	0.56	0.14	0.20
Percent Increase	187	26	50
SOIL C			
		NO DATA	
SOIL D			
Test	1.90	1.30	1.30
Check	0.35	0.35	0.37
Increase	1.55	0.95	0.93
Percent Increase	444	272	251

Note: TEST: Average of 12 replications
CHECK: Average of 3 replications

4. DISCUSSION OF RESULTS:

(a) Colour of the First Percolate:

Reference to TABLE I shows that the greatest colour change in the first percolate between fertilized and unfertilized soils occurred in SOIL D (Upland Sandy Loam) and comparison with TABLE IV shows that by far the greatest loss of total nitrogen also occurred from this soil. Here the relation between colour change and degree of leaching seems to end, for moderately heavy losses of total nitrogen occurred from SOIL B (Custer Loam) and SOIL C (Black Muck) whereas the colour changes were slight; and in the case of SOIL A (Ladner Clay) the colour change was quite pronounced but the loss of nitrogen was comparatively small.

Thus it seems that the colour of the percolate as a result of adding fish proteinate to a soil is not necessarily a measure of the amount of nitrogen carried out in the leachate, particularly in fine-textured soils.

Since the nitrogen fraction of the fertilizer is not held in all soils to the same degree as are the total organic constituents of the fertilizer, no direct relation can be said to exist between loss of nitrogen and the colour change induced in the percolate.

(b) Bacterial Growth in the First Percolate:

The amount of bacterial growth in the first percolate from the soils receiving fish proteinate agrees to some degree with the increased nitrogen in the percolate, to the extent that in the leachate from SOIL A (Ladner Clay) the nitrogen content was low and growth was slight, and in the leachate from SOIL D (Upland Sandy Loam) the nitrogen content was very high and growth was very heavy. Although the amount of proteinate nitrogen was the same in the percolates from SOIL B (Custer Loam) and SOIL C (Black Muck), bacterial growth was considerably heavier in the latter.

Since the percolate from soils receiving no fertilizer were fairly high in total nitrogen in some cases but showed no growth of bacteria, it appears that bacterial activity depends on the form in which the nitrogen occurs. However, since the growth in the leachate is not proportional in all cases to the amount of nitrogen derived from the proteinate, another factor must be present in varying amounts, and it is suggested that organic matter carried down in the drainage water may be the factor involved.

(c) pH of the Third Percolate:

No consistency is apparent in the effect of the proteinate on the reaction of the soil percolate, as it will be observed in TABLE III that the pH was raised in two cases and lowered in two cases compared with the percolates from soils which had received no fertilizer. However, since the Hydrion paper method of measuring acidity is not sensitive to fine gradations, it is suggested that differences of 0.5 one way or the other should be ignored, and for practical purposes it can be said that the fish proteinate caused no change of pH in SOILS A, C, and D.

The pronounced increase of acidity in SOIL B (Custer Loam) is apparently associated with bacterial activity and the organic matter fraction of the soil. It will be observed that in the Black Muck a reduction of pH also occurred, whereas in the mineral soils the pH showed a tendency to rise as a result of the fertilizer application.

(d) <u>Nitrogen Analysis of the Percolate</u>:

Leaching of total nitrogen from the different soils varied widely. Thus it is seen in TABLE IV that the total nitrogen lost from SOIL D (Upland Sandy Loam) was very large, whereas the amount lost from SOIL A (Ladner Clay) was comparatively slight, and the losses from SOIL B (Custer Loam) and SOIL C (Black Muck) were intermediate.

The increase in total nitrogen leached in the three percolates as a result of the addition of fish proteinate is shown for purposes of comparison between the different soils.

These increases in nitrogen lost through leaching can be expressed in simple ratios or "Leaching Factors" as follows:

SOIL A (Ladner Clay)	2
SOIL B (Custer Loam)	10
SOIL C (Black Muck)	9
SOIL D (Upland Sandy Loam)	35

It is interesting to note that in SOIL A (Ladner Clay) the losses of nitrogen from both test and check pots were greater in the second than in the first percolate. Apparently the long interval between the leachings caused more of the nitrogen to become soluble and free in the soil.

There seems to be no particular significance to the losses of nitrate nitrogen, especially in view of the fact that estimations for the first percolate are missing.

(e) Retention of Nitrogen:

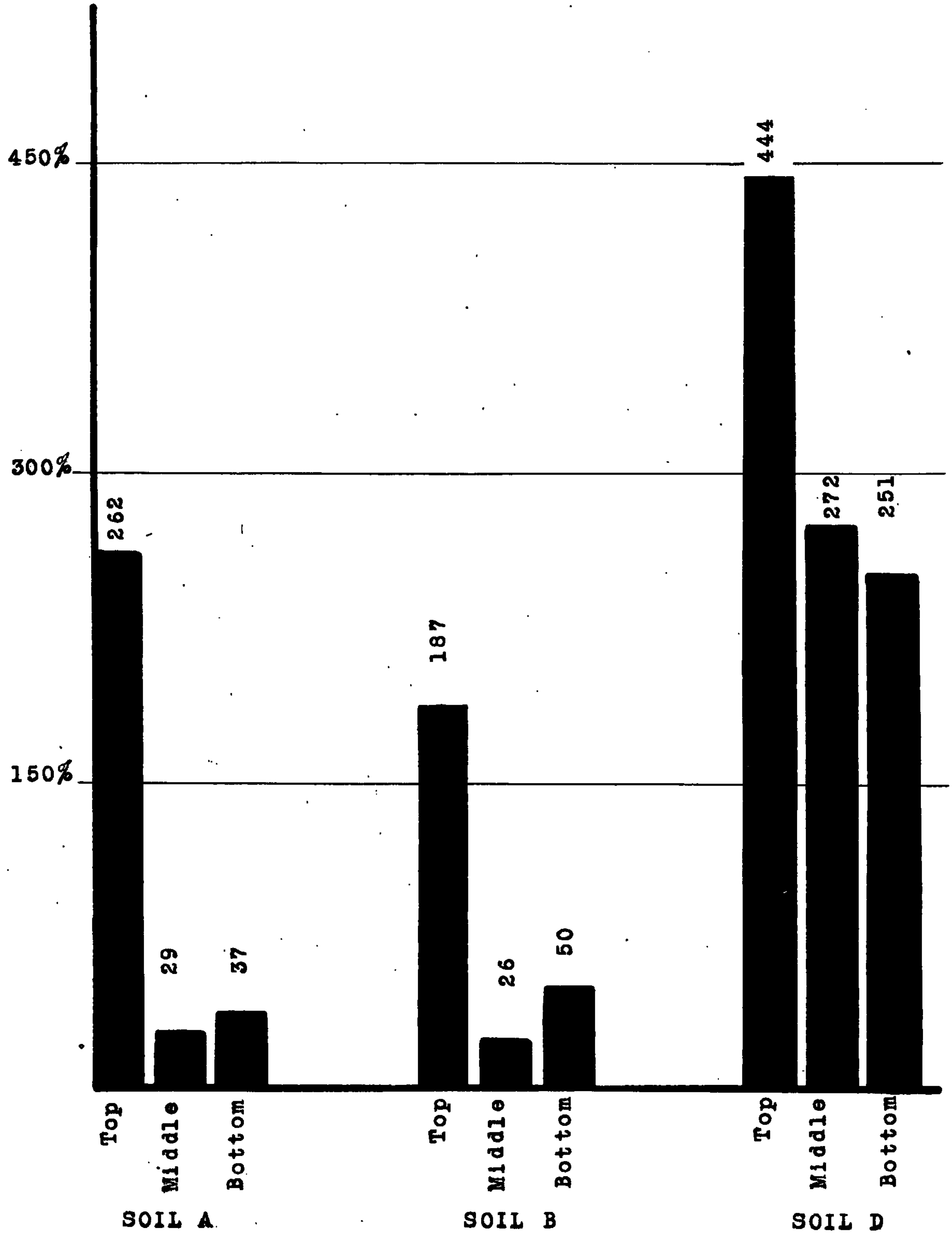
Conrad interprets his results of the growing test by observing the relative growth in the top pot compared to growth in the middle and bottom pots of the test columns, and unless the differences are very great, he seems to conclude that retention was slight. In the present experiment, however, three leachings were carried out instead of one, with the result that a larger proportion of the nutrient material was carried down from the top pot to the middle and bottom pots in both test and check columns. Hence it appears that a better estimation of retention can be arrived at by finding the increase in plant growth at each pot level resulting from the application of the fish proteinate. The increase is expressed as a percentage of the fresh weight of plants in the check pots, as shown in TABLE V.

When a comparison is made on the basis of percentage increase in growth, it becomes evident that response in the top pots is considerably greater than in the middle and bottom pots. These data are interpreted graphically in FIGURE I.

To facilitate comparisons between different soil types, a

FIGURE I

Percentage Increase in Fresh Weight
in Top, Middle, and Bottom Pots.



"Retention Factor" is derived by dividing the increase in the top pot by the increase in the bottom pot. (The bottom pot, rather than the one showing the lowest percentage increase, was chosen arbitrarily for the sake of uniformity). In integral numbers the retention of the proteinate in the different soils is then shown as follows:

SOIL A (Ladner Clay)	7
SOIL B (Custer Loam)	4
SOIL C (Black Muck) .	-
SOIL D (Upland Sandy Loam)	2

Further examination of the results of this experiment give some indication of the nature of the retention in the soil as well as its degree.

In the case of the light soil (SOIL D, Upland Sandy Loam) it appears that the fish proteinate was washed down into the middle and bottom pots and into the drainage water collected during the first leaching procedure. This conclusion is borne out by the pronounced change in colour of the percolate and the heavy bacterial growth. The proteinate held in the soil layers was subsequently broken down at a comparatively rapid rate and became available for plant growth; hence the growth at all levels was very high compared to the checks.

In the heavier soils, however, the proteinate was almost completely retained in the top pot and apparently only a small soluble fraction percolated through the middle and bottom pots and into the excess leachate collected for analysis. If such were the case, the soluble material should be more concentrated in the bottom than in the middle pot, and therefore increased growth should be greater in the bottom pot. Such was the case in both SOIL A (Ladner Clay) and SOIL B (Custer Loam), as is clearly shown in FIGURE I. Since the proteinate was held very largely in the top pot, growth at that level was much greater than in the middle and bottom pots. Due, however, to the slow rate of availability in these heavy soils, the increased growth compared to check plants was much less than in the light soil.

In view of the above observations, it seems that the fish proteinate is retained in the soil in its original form rather than as a product of enzyme or bacterial decomposition; in other words, retention of this material is a physical rather than a chemical phenomenon.

(f) <u>Availability of the Fertilizer:</u>

Although the main object of the experiment was to estimate the degree of retention of the fish proteinate in representative types of soils, another aspect of the relation between soils and the fertilizer is evident in the results of the leaching and growing tests. Theoretically, the retention factor as derived from growth response should be inversely proportional to the degree of leaching, if the retained fertilizer is used with the same degree of efficiency in all soils. That this is not the case is shown by a comparison of the leaching and retention factors:

	Leaching	Retention
SOIL A (Ladner Clay)	2	7
SOIL B (Custer Loam)	10	4
SOIL C (Black Muck)	9	-
SOIL D (Upland Sandy Loam)	35	2

In the case of SOIL D leaching was extremely high but increase in plant growth was also extremely high. Possible reasons for these results were soil factors such as acidity, aeration, and biological activity, all of which affected the rate of breakdown of the fish proteinate and its availability for plant growth. In this case the fertilizer material retained in the soil was used efficiently and good plant growth resulted. The opposite is true in the case of the heavier soils (SOILS A and B) from which leaching was relatively low, but increase in plant growth was not high.

Thus it appears that plant response to the addition of fish proteinate to the soil depends to a large degree upon the rate at which the nitrogenous material is made available to the plants, and availability in turn depends upon the physical structure of the soil and its suitability for active bacterial decomposition of the proteinate.

5. CONCLUSIONS:

The results of this experiment indicate that the fish proteinate possesses some very desirable properties as a potential nitrogen fertilizer. In spite of severe leaching, it is strongly retained in soils, particularly those of fine texture. Although the rate of availability tends to be slow, especially in heavy soils, this feature may be advantageous in the case of certain perennial or long-season crops for which an immediate supply of nitrogen is not essential.

This material should be satisfactory as a source of nitrogen for light soils when applied on the surface because it seems probable that the fertilizer will not be leached by moderate rainfall beyond the depth of root growth, and that the rate of availability will be sufficiently high to provide adequately for sustained plant growth.

In heavy soils, where the nitrogen is strongly retained and only slowly available, it seems that greater benefit would be derived if the material were incorporated in the soil to some depth, rather than allowed to remain on the surface.

Although the fish proteinate has undeniable value as a source of nitrogen for plant growth, its use as a fertilizer cannot be recommended at the present time. The tendency of the material to absorb moisture from the air presents a serious difficulty. Even if the material could be maintained in powder form by special care in packaging and storage, the problem of application would remain, and it is evident from the limited observations made during this experiment that the fish proteinate could not be applied by ordinary mechanical means. A second drawback of the material is its tendency to form a hard, almost impervious crust, particularly on sandy soil.

It is concluded, therefore, that until these undesirable properties of the material have been overcome, the fish proteinate should not be put on the market as a commercial fertilizer.

6. <u>SUMMARY</u>:

Water in three separate applications was allowed to percolate through columns of pots containing different types of soils to which fish proteinate had been added only in the top pot. The volume of water was sufficient to saturate all the soil and to give a small excess for analysis. Plants were subsequently grown in all pots and the increased growth in different pot levels was used as a measure of nitrogen retention.

On the whole the fish proteinate was well retained, particularly in heavy soils, but the retained fertilizer was more efficiently utilized in light soil.

The tendency of the fish proteinate in its present form to absorb moisture from the air and to cause the formation of a hard crust, especially in the light soil, are definite drawbacks, and it is concluded that these undesirable features must be overcome before the product should be put on the market.

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