9

77

9.8

BARD

FINAL REPORT

PROJECT NO. I-125-80

Transformation of Fertilizer and Organic Nitrogen in Soil as Affected by Soil Factors

A. Hadas, J. Letey, Jr., S. Feigenbaum, A. Feigin,
D. Levanon, W.M. Jarrell, W.T. Frankenberger, Jr.

HFE

630.72

BAR

2nd copy

1985

Date: March, 1985.

BARD,
P.O. Box 6,
Bet Dagan, ISRAEL.

BARD Project No. I-125-80

Title of Research Project:

TRANSFORMATION OF FERTILIZER AND ORGANIC NITROGEN
IN SOIL AS AFFECTED BY SOIL FACTORS

Name of Investigators:

Principal Investigator: Aviva Hadas

Cooperating Investigator(s): Sala Feigenbaum, A. Feigin, D. Levanon,
J. Letey, Jr., W.M. Jarrell, W.T. Frankenger, Jr.

Name and Address of Affiliated Institutions:

Principal Institution: Agricultural Research Organization,
Bet Dagan, 50-250, Israel.

Cooperating Institution(s): The Regents of the University of California,
University of California, Riverside,
Riverside, Ca. 92521, U.S.A.

Project's starting date: October 1, 1981.

Type of Report: Final

Signatures:

Principal Investigator

Institution's Authorizing Official

.....
Aviva Hadas

.....
Yisroel Eshdat
Dr. YUVAL ESHDAT
Head, Div. for Research Projects and Budgets
Agricultural Research Organization

RECEIVED
BARD PROJECTS
1985-03-25

1) Soils - Nitrogen content

$$\frac{630.72}{\text{BAR}} : 631.411 : 631.847$$

TABLE OF CONTENTS

	<u>Page</u>
A. Abstract	1
B. Objectives of the research	2
C. Research report	4
I. Distribution of nitrogen forms and availability indices in profiles of differently managed soil types.	4
II. Nitrogen mineralization rates in profiles of differently managed soil types.	31
III. Nitrogen mineralization in soil profiles in-situ compared with incubation tests.	65
IV. Nitrification rates in profiles of differently managed soil types.	82
V. Biological aspects of Nitrogen transformations	108
a. Nitrification	
b. Mineralization	
VI. Nitrogen transformation and movement under drip irrigated tomatoes.	144
VII. Effect of Terrazole on nitrogen transformations and movement.	165
VIII. Soil nitrogen transformations as affected by salinity.	183
D. Description of cooperation	209
E. Benefit to agriculture	210

A. Abstract

Nitrogen transformations were studied in different soil types, depths and agricultural management practices. Soil N mineralization and NH_4 nitrification rates were determined in incubation experiments and the distribution of NH_4 and NO_3 were determined under various fertilization and irrigation practices. Mineralization rate decreased with soil depth, more than did organic N content, however, about 30% of N mineralized in soil profiles was contributed by soil layers deeper than 60 cm. This was verified under field conditions in undisturbed soil profiles. Potentially mineralizable N (N_0), obtained from one-parameter-rate equations, was highly correlated with various soil N forms (which were all significantly correlated with soil total N). The best chemical and biological estimates of N_0 were amino acids in soil acid hydrolyzate and CO_2 production rate at the 1st week of incubation respectively, both decreasing with soil depth more than total N. Nitrification rate was well-correlated with the growth rate of the nitrifying bacteria. The maximal rate and the delay period of nitrification were greatly affected by soil depth, soil pH or HCO_3^- content and by previous agricultural management of the soils. Increased salinity decreased nitrification and promoted ammonia volatilization, the effect depending on soil type and on the amount and type of salts and N source added. Application of urea ammonium nitrate to a sandy loam by drip irrigation produced a remarkable drop in soil pH in the vicinity of the emitter. Coating $(\text{NH}_4)_2\text{SO}_4$ with Terrazole inhibited nitrification under field conditions, retaining more NH_4 in the soil profile and decreasing movement and denitrification even at high irrigation rates.

B. Objectives of the research

The general objective of the research was to study nitrogen transformation rates in soil, mainly ammonium nitrification and organic N mineralization, as affected by soil types, soil depths and different agricultural management practices. Soil types were expressed in terms of general soil properties such as texture, pH, electrical conductivity, organic N content, and specific properties, like soil nitrogen forms and microbial activity, which affect or reflect soil N transformations. Agricultural management included different irrigation practices, salinity induced by added salts, fertilizer management and the effect of previous management of the field on N transformation rates.

The specific objectives, corresponding to the different parts of the research, were as follows:

1. To study the distribution of soil organic N forms in profiles of different soil types. To find relations between the various N forms tested, in order to ultimately choose a suitable index for predicting the potentially mineralizable nitrogen or N mineralization rate.
2. To determine soil N mineralization rate in different soil types and depths, and to evaluate the contribution of deeper soil layers to N mineralized in soil profiles. To fit rate equations and to relate the obtained rate parameters to N availability indices or N fractions in soil.
3. To verify, under field conditions, the N mineralization rate in soil profiles and the contribution of deeper soil layers as obtained by incubation experiments.
4. To determine the rate of nitrification of added ammonium in soil profiles of differently managed soil types. To relate the rate constants

- to soil properties and soil depth. To determine immobilization of added N and mineralization when ammonium fertilizer is added to soils.
5. To investigate the effect of soil type and soil depth on the growth rate and potential activity of the nitrifying bacteria. To study the composition and activity of the mineralizing microflora in profiles of differently managed soil types.
 6. To study the effect of soil salinity, induced by chloride and sulfate salts, on ammonification of urea, nitrification and ammonia volatilization.
 7. To follow the fate of nitrogen from surface and subsurface applied liquid urea-ammonium nitrate (UAN) added to soil through a drip system and to determine the influence of UAN on soil pH.
 8. To study N transformations and movement in soil as influenced by water application rate and Terrazole nitrification inhibitor.

C. Research Report

I. DISTRIBUTION OF NITROGEN FORMS AND AVAILABILITY INDICES IN
IN PROFILES OF DIFFERENTLY MANAGED SOIL TYPES

Aviva Hadas, Sala Feigenbaum, A. Feigin and Rita Portnoy

ABSTRACT

Various chemical methods have been used to predict the nitrogen mineralization potential of soils, but studies were mostly restricted to surface soil layers to which N mineralization is mainly attributed. In this study the distribution of N forms, extracted from soil by different chemical methods, and the relationship between them was determined within the profiles of several soil types. All N parameters tested were significantly correlated with total N. The fractions of several N parameters of total N changed with soil depth: oxidative release of NH_4 by acid KMnO_4 , N extracted by NaHCO_3 and NH_4 and hexamine in soil acid hydrolyzate increased, whereas amino acids and amidase activity decreased with soil depth. Soil type also influenced some N parameters: acid KMnO_4 extracted relatively more NH_4 from calcareous than noncalcareous soils; a smaller fraction of total N was acid hydrolyzable in soils with a greater surface area.

Amino acids in the hydrolyzate and amidase activity seem more promising for the prediction of mineralizable N, when considering the whole soil profile, than the other N

parameters, because of their greatest decrease with soil depth.

INTRODUCTION

The rate of nitrogen mineralization in soils can be directly measured by incubating soil samples in controlled environmental conditions. However, incubation techniques are time consuming and therefore often not practical for predicting mineral N contribution from soil organic N and fertilization planning. Consequently, several chemical extraction methods have been suggested to either predict the quantity of mineral N that the soil will release for a growing crop (Selmer-Oslen et al., 1981; Fox & Piekielek, 1978a), or to predict the potentially mineralizable nitrogen of soils (Stanford & Smith, 1976; Stanford & Smith, 1978). The different empirical methods extract certain fractions of soil organic N and their effectiveness varies probably with soil type and mainly with soil pH. Much better defined fractions of soil organic N can be obtained by acid hydrolysis and chemical fractionation of the hydrolyzate (Bremner, 1965). These fractions could provide a comparative basis for evaluating the empirical extractions in various soil types or soils from fields with a different history.

The quantity of decomposable organic nitrogen, which determines the rate of mineralization, also affects the

potential enzyme activity in soil. Correlations have been found between the activity of several enzymes and extractable organic N (Spalding & Duxbury, 1977) or mineralization rate (Abdelmagid, 1982).

The contribution of mineral N from organic sources is usually attributed to the surface soil only, since microbial activity in deeper soil layers is much smaller. Therefore very little information has been collected on the various chemical indices, as well as enzyme activities, in whole soil profiles. However, plant roots live, die and decompose in soil layers as deep as 1 m and more, and indeed some evidence on N-mineralization in soil profiles has been reported (Cassman & Munns, 1980; Powers, 1980).

The objectives of the present work were: (a) to clarify the distribution of N extracted from soil by means of different chemical methods within soil profiles and in different soil types; (b) to study the relations between organic N forms, N extracted by chemical methods and amidase activity in soils and (c) to choose a suitable index for predicting the potentially mineralizable N (Stanford & Smith, 1972) or N mineralization rate.

MATERIALS AND METHODS

Soils were sampled from various locations in Israel, representing different climatic conditions, soil parent materials and cropping management. The definition of soil

types and some of the sampling places were determined by the aid of the soil survey of Israel soils (Dan & Koyumdjisky, 1979; Dan et al., 1981; Dan & Singer, 1973). General information about the soils is summarized in Table 1. The Alumim soil profile was uncultivated and sampled according to its pedological horizons. Bet Dagan samples were taken from a 22 year-old "permanent plot" experiment, testing the response of field crops to N,P,K levels and manure. During the last 4 years the field was cropped with cotton. Samples were taken from the control, unfertilized treatment and from the highest N, P, K treatment with manure very 7 years (2 years prior to sampling). The Gilat soil profile was taken from an uncultivated field (for at least the last 20 years) near a 20 year-old "permanent plots" experiment testing the effect of N fertilization in combination with manuring on vegetable crops; Two top soil layers were sampled from that experiment 1 year later, one from an unfertilized control plot and the other from a high N and manure treatment. The Kedma profile was sampled at a clay quarry (formerly a cultivated field) according to its pedological horizons. All the soil samples were air-dried, crushed, sieved to pass a 2-mm screen and stored at room temperature for at least two months prior to chemical analyses.

Oxidative release of $\text{NH}_4\text{-N}$ by acid permanganate was determined in 0.05N and in 0.1N KMnO_4 after a preliminary

extraction with acid, according to Stanford and Smith (1978).

Ammonium-N released from soils was determined after heating soil samples with 2N KCL in an oven at 80°C for 20 h according to Oien and Selmer-Olsen (1980).

Nitrogen extraction with NaHCO_3 as suggested by McLean (1964) to estimate N supplying capability of soils, and the UV absorption of this extract (Fox & Piekielek, 1978), were slightly modified in this work. In a preliminary test correlations between organic N content and optical density at 260 u of NaHCO_3 extracts were better when the NaHCO_3 concentrations were 0.03 N or 0.1 N rather than the one suggested by McLean (1964) (0.01 N). Furthermore, the extraction duration of 1/2 hour was preferred over 1/4 hour due to more consistent and and less time dependent results.

Organic forms of N in the soil profiles were analyzed in acid hydrolyzate (Bremner, 1965).

Amidase activity in the soils was determined by the method suggested by Frankenberger & Tabatabai (1980) using formamide as the substrate. The incubation temperature was $35 \pm 0.2^\circ\text{C}$ and $\text{NH}_4\text{-N}$ was determined in soil extracts after centrifugation and not in soil suspensions.

All extracts were performed in duplicates and ammonium N was determined by steam distillation.

General soil properties were also determined: pH in a saturated soil paste; EC and HCO_3^- concentration in saturation extract; saturation and air dry gravimetric moisture content; CaCO_3 content by the volumetric calcimeter method (Black et al., 1965); cation exchange capacity by sodium saturation (Black et al., 1965); organic carbon by the Schollenberg method (Black et al., 1965); total nitrogen by semimicro-Kjeldahl (Black et al., 1965).

RESULTS AND DISCUSSION

Several general properties of the soils are shown in Table 2. The C/N ratio was generally between 9 and 11 with only a few exceptions, mainly in Gilat, and with no systematic trend with depth. The CEC and air dry moisture content were highly correlated (Table 5). Both parameters were used to calculate the specific surface area (S) according to regression equations found by Banin and Amiel (1969/70), and the results were very similar. Therefore only S obtained from the air dry moisture content (W_{ad}) by the equation

$$W_{ad} = 0.025 S + 0.488$$

was presented in Table 2.

The results of the nitrogen analyses are presented in Table 3. The total level N was relatively high in the top layer of the uncultivated Alumim soil, in the Golan 37 soil, which was under very extensive use and in Eden soil. It

decreased with depth in all soils though not to the same extent.

The amounts of N extracted from soil by different extracts were all significantly correlated with total N in soil (Table 4) and were therefore presented in Table 3 as the fraction of total N rather than in terms of absolute content in soil. This made it easier to compare between soil types and soil layer.

The level of oxidative release of $\text{NH}_4\text{-N}$ by acid KMnO_4 was in the range of 6 to 10% of total N in the top soil layers (Table 3). This coincided generally with Stanford & Smith (1978), who found that about half of the potentially mineralizable N (No), (which was in most of their soils 10-20% of total N) was extracted by this method. The 0.05N KMnO_4 extracted slightly less $\text{NH}_4\text{-N}$ but they were highly correlated with each other (Fig. 1, Table 4). More N was extracted by this method from soils with high CaCO_3 content and pH above 8, like Eden, Gilat, Alumim and Kedma, than from the noncalcareous soils. The permanganate extractable $\text{NH}_4\text{-N}$ decreased with soil depth but its fraction of total N (Table 3) was larger in deep soil layers. However, Stanford et al. (1974) found that the ratio of potentially mineralizable N to total N dropped in soil layers below 30 cm, therefore the acid permanganate extract does not seem to

be a good estimate of N_o when dealing with whole soil profiles.

A very small fraction of total N appeared as hot KCl extractable NH_4 -N (Table 3), only about twice as much as exchangeable NH_4 . It did not show a consistent trend to change with soil depth, indicating that its absolute values decreased with depth, parallel to total N. Gilat soil had a relatively higher content of hot KCl extractable NH_4 than all other soils, which were mostly in the range of 1.5 to 3% of total N. This percentage was greater than in the soils tested by Oien and Selmer-Olsen (1980), which were richer in organic matter content. Compared with the acid permanganate extract, the hot KCl extracted a very small proportion of the N_o of our soils. It probably is more suitable to predict available N in soils of cold climate with a high organic matter content (Selmer-Olsen et al., 1981), and a relatively low mineralization rate.

The amount of total N extracted by $NaHCO_3$ was less than the NH_4 -N released by acid permanganate. The N extracted by 0.03N $NaHCO_3$ from the top soil layers was about 4% of total N in soil (Table 3) but its proportion increased below the depth of 60 cm. A smaller fraction of N was $NaHCO_3$ extractable in the highly calcareous Eden soil. The highest fraction was found in Gilat which has also a fairly high $CaCO_3$ content. The optical density of the 0.03N $NaHCO_3$

extract at 260 um was in the range of 0.06 to 0.4 and was highly correlated with the extractable N (Table 4). Alumim top-soil layer (0-5 cm) had a much higher O.D., which deviated considerably from the regression lines of O.D as a function of extractable N. The same was true for the 0.1N NaHCO_3 extract, though the correlation was slightly lower than the former (Table 4), mainly because of the data of Alumim 0-5 cm which were beyond the range of precise O.D. readings (Fig. 2). The correlation between N extracted by both NaHCO_3 concentrations was very high, the 0.1 N extracting only slightly more than the 0.03N NaHCO_3 (Table 4). A significant correlation was found between the O.D. of the extracts and soil organic carbon content (Table 5), Similar to what Michrina et al. (1982) had shown, though it was smaller than the correlation with organic N in the extracts.

The acid hydrolyzable N represented a fairly constant fraction of total N within the soil profiles (Table 3) in spite of the decrease of organic N content with depth. However, the fractions varied considerably among soils: less than 50% of total N in Eden and in the Golan soils, between 45 and 65% in Akko and Bet Dagan soils (both cultivated clay soils) about 75% in the uncultivated Alumim and Kedma soils (differing in texture but initiated from similar parent material) and up to 95% in the uncultivated Gilat soil. The

two cultivated soil samples from Gilat were closer in their relative hydrolyzable N content to the cultivated Bet Dagan soil.

The hydrolyzable N fraction was negatively correlated with air dry moisture content (or surface area) of the soils (Fig. 3, Table 5), namely a longer time would be required to hydrolyze the same percentage of total N from soils with a larger specific surface area. The data scattering in Fig. 3 shows that the Golan and Eden soils deviated below the line. This may be explained by the clay mineral composition of these soils: mainly kaolinite in the Golan soils and a high CaCO_3 content in Eden. The relation between surface area and moisture content (Banin and Amiel, 1969/70) is mainly based on montmorillonite soils, which have a higher moisture absorbing capacity relative to their surface area. The deviation of Golan and Eden could also be partially explained by their high N content and the significant negative relation found between total N and the hydrolyzable N fraction (Table 5). This however does not fit the constant fraction obtained along the soil profiles where total N decreased considerably.

The concentrations of the different forms of N in the hydrolyzate were within the ranges reported in the literature (Bremner, 1967; Meints and Peterson, 1977; Smith et al., 1980). The relative concentration of amino acids

decreased with soil depth while all other N forms either increased or did not change relative to soil total N (Table 3). Of all chemical forms of N measured amino acids in the hydrolyzate was the only one that decreased with depth more than total N, indicating a decrease in the availability of organic N to microorganisms with soil depth. There were considerable differences in the amino acid fraction of total N among soils. This was partly a result of the relative amount of total hydrolyzed nitrogen that was, as can be seen in the significant correlation between total N and amino acid N in the hydrolyzate (Table 5). But even relative to total hydrolyzable N, the level of amino acids in the top soil layers of Alumim, Gilat and Kedma (all in the southern part of the country or lately uncultivated soils) was a half or more of total hydrolyzable N, whereas in all other soils it was only about 30-40% of it. This probably indicates some differences in the composition of the organic N in the soils. A small decrease in the relative concentration of amino acids in cultivated compared with un-cultivated soils was reported by Meints and Peterson (1977) and by Keeney and Bremner (1964), but the main influence of cultivation or of manuring (Smith et al., 1980) was on the absolute content of the different N forms as well as total N. A comparison between Gilat's permanent plot samples and the uncultivated Gilat soil profile revealed a strong influence of intensive

cropping on the composition of organic N, while fertilizer additions, as shown by the two Bet Dagan and the two Gilat appropriate samples, had almost no influence.

Amidase activity in the top soil layers ranged between 45 and 325 mg kg⁻¹ (Table 3). Values above 250 were obtained in soils which were either rich in total N or had a large specific surface area. Both parameters were significantly correlated with amidase activity (Table 5). Amidase activity decreased with soil depth more than total N, indicating a relation not only to total organic matter but also to its composition or its mineralizability. There was however no correlation between amidase activity and the relative amount of amino acids or NH₄-N in the hydrolyzate, which could be considered as indices of the composition of organic N. A significant correlation was found between amidase activity and amino acids in the acid hydrolyzate (Table 5), but there was a very evident separation of the soil to two groups: 1. Eden, Bet Dagan and Akko; 2. All the rest (Fig. 4). Separate calculations for each group resulted in two very different regression equations with much higher correlation coefficients. There are several common characteristics in each group, although none explains the difference completely: a. Specific surface area was relatively high in group 1 and was indeed positively correlated with amidase activity and negatively with

hydrolyzable N or amino acids. b. Group 1 consisted of cultivated soils, a situation that could enhance amidase activity. c. Group 2 included all the southern soils, which were formed under semi-arid conditions, while group 1 was formed under more humid conditions (Eden was formed under local hydromorphic conditions) and this could affect the composition of organic matter (such as a higher protein content). On the other hand, there were a few exceptions, indicating that not all the soils obeyed the above-mentioned orders: 1. Kedma had a low amidase activity, although its surface area was large. 2. Gilat control and NM samples and Golan soil were cultivated and their amidase activity was relatively low. 3. The Golan soils represent humid climatic conditions, yet they belonged to the arid soil group. The characteristics mentioned above could be the reasons for the grouping of the soils and the exceptions could result from local effects (e.g. microclimate).

Conclusions

All the N parameters tested were significantly correlated with total N in soils, which leaves it as a rough universal indicator of any form of N in soil. Consequently, all N forms measured were also correlated with each other. But additionally to total N other soil properties also affected the amount of N extracted by the different methods: a large specific surface area reduced the efficiency of acid

hydrolyzate; a high CaCO_3 content in soil increased the relative amount of N extracted by acid KMnO_4 ; soil depth increased the proportion of N extracted by KMnO_4 , by NaHCO_3 and the NH_4 and hexosamine in acid hydrolyzate, while the proportion of amino acids and the amidase activity decreased, indicating changes in the composition of organic matter with depth. The agronomic history and soil formation had probably also some effect on the organic matter composition.

The level of amino acids in soil hydrolyzate and amidase activity seem more promising than the other N parameters for the prediction of mineralizable N, when considering the soil profiles, because they reflect the decrease in the availability of organic or total N with depth. The correlation of these soil properties with total N was smaller (though significant) than that of other N parameters and this could be an advantage indicating that they might provide a more refined index of mineralizable N.

Literature

1. Abdelmagid, H.M. 1980. Factors affecting nitrogen mineralization and nitrate reduction. Ph.D. diss. (M.A. Tabatabai, instructor) Iowa State Univ.

2. Banin, A. and A. Amiel. 1969/70. A correlative study of the chemical and physical properties of a group of natural soils of Israel. *Geoderma* 3: 185-198.
3. Black, C.A. (ed) 1965. *Methods of Soil Analysis*. Agronomy No. 9, Amer. Soc. Agron., Madison, Wisconsin USA.
4. Bremner, J.M. 1965. Organic forms of nitrogen. In: C.A. Black, ed. *Methods of Soil Analysis*, Agronomy No. 9. Amer. Soc. Agron. Madison, Wisconsin, USA. PP. 1238-1255.
5. Bremner, J.M. 1967. Nitrogenous Compounds. In: A.D. McLaren and G.H. Peterson, eds. *Soil Biochemistry*. Marcel Dekker Inc., New York. pp. 19-66.
6. Cassman, K.G. and D.N. Munns. 1980. Nitrogen mineralization as affected by soil moisture, temperature and depth. *Soil Sci. Soc. Amer. J.* 44: 1233-1237.
7. Dan, J., R. Gerson, Hanna Koyumdjisky and D.H. Yaalon. 1981. *Aridic Soils of Israel: Properties, Genesis and Management*. Special publ. 190. Div. of Scientific Publ., Volcani Center, Bet Dagan, Israel.
8. Dan, J. and Hanna Koyumdjisky (eds.) 1979. *The Classification of Israel Soils*. Special Publ. 137. Div. of Scientific Publ. Volcani Center, Bet Dagan, Israel.
9. Dan, J. and A. Singer. 1973. Soil evolution on basalt

- and basic pyroclastic materials in the Golan Heights. *Geoderma* 9: 165-192.
10. Fox, R.H. and W.P. Piekielek. 1978a. Field testing of several nitrogen availability indexes. *Soil Sci. Soc. Amer. J.* 42: 747-750.
 11. Fox, R.H. and W.P. Piekielek. 1978b. A rapid method for estimating the nitrogen-supplying capability of a soil. *Soil Sci. Soc. Amer. J.* 42: 751-753.
 12. Frankenberger Jr., W.T. and M.A. Tabatabai. 1980. Amidase activity in soils: I. Method of assay. *Soil Sci. Soc. Amer. J.* 44: 282-287.
 13. Keeney, D.R. and J.M. Bremner. 1964. Effect of cultivation on the nitrogen distribution in soils. *Soil Sci. Soc. Amer. Proc.* 28: 653-656.
 14. MacLean, A.A. 1964. Measurement of nitrogen supplying-power of soils by extraction with sodium bicarbonate. *Nature* 203: 1307-1308.
 15. Meints, V.W. and G.A. Peterson. 1977. The influence of cultivation on the distribution of nitrogen in soils of the Ustoll suborder. *Soil Sci.* 124: 334-342.
 16. Michrina, B.P., R.H. Fox and W.P. Piekielek. 1982. Chemical characterization of two extracts used in determination of available soil nitrogen. *Pl. and Soil* 64: 331-341.

17. Oien, a. and A.R. Selmer-Olsen. 1980. A laboratory method for evaluation of available nitrogen in soil. *Acta Agr. Scand.* 30: 149-156.
18. Powers, Robert F. 1980. Mineralizable soil nitrogen as an index of nitrogen availability to forest trees. *Soil Sci. Soc. Amer. J.* 44: 1314-1320.
19. Selmer-Olsen, A.R., A. Oien, R. Baerug and I. Lyngstad. 1981. Evaluation of a KCl-hydrolyzing method for available nitrogen in soil by pot experiment. *Acta. Agr. Scand.* 31: 251-255.
20. Smith, S.J., A.C. Mathers and B.A. Stewart. 1980. Distribution of nitrogen forms in soil receiving cattle feed lot waste. *J. Environ. Qual.* 9: 215-218.
21. Spalding, B.P. and J.M. Duxburg. 1977. Enzymatic activities and extractable organic matter in soil invaded by *Lycopodium tristachyum* fairy rings. *Soil Sci. Soc. Amer. J.* 41: 1109-1113.
22. Stanford, G., J.N. Carter and S.J. Smith. 1974. Estimates of potentially mineralizable soil nitrogen based on short-term incubations. *Soil Sci. Soc. Am. Proc.* 38: 99-102.
23. Stanford, G. and S.J. Smith. 1972. Nitrogen mineralization potential of soils. *Soil Sci. Soc. Am. Proc.* 36: 465-472.

24. Stanford, G. and S.J. Smith. 1976. Estimating potentially mineralizable soil nitrogen from a chemical index of soil nitrogen availability. Soil Sci. 122: 71-76.
25. Stanford, G. and S.J. Smith. 1978. Oxidative release of potentially mineralizable soil nitrogen by acid permanganate extraction. Soil Sci. 126: 210-218.

Table 1: Classification and general description of the soils

Soil location	Classification	Average yearly rainfall mm	Parent material	Texture	Previous management
Alumim	Calcic Mollic Haploxeralf	370	Aeolian loess	Sandy to silty loam	Uncultivated
Bet Dagan	Typic Chromoxerert	560	Alluvial clay	Clay	Field crop rotation followed by 4 years irrigated cotton
Gilat	Typic Haplargid	240	Aeolian loess	Sandy to silty loam	Experimental station; uncultivated area
Akko	Typic Chromoxerert	580	Alluvial clay	Clay	Cultivated, irrigated
Eden	Typic Camborthid	340	Lisan marle	Clay	Cultivated, irrigated
Qedma	Typic Chromoxerert	440	Aeolian clay	Clay	Uncultivated several years
Golan 70	Rhodoxeralf	850	Tuff	Silty loam - clay	Cultivated
Golan 37	Rhodoxeralf	950	Basalt	Silty loam - silty clay	Cropped with wheat, unfertilized, unirrigated

Table 2: General soil properties

Soil	Layer	Organic C g/100g	C/N	Moisture content air dry g/100g	pH	EC dSm	HCO ₃ ⁻ mol m ⁻³	CEC mole(Na ⁺)kg ⁻¹	Total CaCO ₃ g/100g	Specific surface area* m ² g ⁻¹
Alumim	0 - 5	1.26	9.5	2.79	7.82	0.67	3.80	0.17	10	90
	5 - 20	0.87	9.8	3.09	8.13	0.33	2.05	0.16	12	105
	20 - 50	0.34	9.6	3.41	8.29	0.33	1.80	0.16	15	115
	50 - 85	0.24	10.1	3.62	8.29	0.33	1.56	0.16	20	125
	85 - 125	0.22	10.3	3.72	8.35	0.25	1.65	0.17	23	130
	125 - 165	0.17	10.0	3.82	8.53	0.41	2.15	0.20	16	135
BD Control (Bet Dagan)	0 - 20	0.76	11.0	7.25	7.98	0.83	2.50	0.49	7	270
	20 - 40	0.72	10.8	7.25	7.96	0.58	1.84		7	270
BD NPKM	0 - 20	0.83	10.3	7.30	7.83	1.58	2.45	0.49	7	270
	20 - 40	0.81	10.7	7.32	7.87	1.22	1.85		7	275
	40 - 60	0.66	10.6	7.41	7.91	1.16	1.35		7	275
	60 - 90	0.58	12.1	7.60	7.96	1.08	1.30		9	285
	90 - 120	0.55	12.0	7.56	7.96	1.25	1.10		8	285
Gilat	0 - 20	0.62	13.1	2.35	7.87	1.03	3.58	0.12	16	75
	20 - 40	0.52	11.7	2.31	8.09	0.83	2.48	0.11	16	75
	40 - 60	0.24	7.5	2.50	8.23	0.83	2.29		20	80
	60 - 80	0.19	10.3	2.93	8.39	0.70	2.08		26	100
	80 - 100	0.14	9.3	2.88	8.28	1.50	2.08		24	95
Akkko	100 - 120	0.20	14.6	3.18	8.33	2.08	1.95		22	110
	120 - 150	0.13	8.4	3.47	8.61	0.75	3.37		20	120
	0 - 20	0.76	10.0	9.47	7.70	0.62	1.44	0.56	1	360
Eden	20 - 40	0.66	11.2	10.14	7.71	0.50	1.25	0.54	1	390
	40 - 60	0.51	10.8	10.74	7.75	0.58	1.24	0.54	1	410
	0 - 20	1.54	11.0	6.22	8.07	1.25	2.42	0.27	39	230
Qedma	20 - 40	1.12	11.0	6.08	8.16	0.92	2.28	0.30	39	220
	40 - 60	0.77	11.6	6.32	8.24	0.92	2.25	0.36	41	230
	0 - 9	0.68	10.1	5.57	7.97	0.75	2.66	0.28	17	205
Golan 70	9 - 25	0.57	9.3	6.10	8.08	0.67	1.94	0.28	14	225
	25 - 58	0.40	8.7	6.56	8.17	1.16	1.62	0.33	17	240
	58 - 86	0.34	11.0	6.72	8.37	0.83	2.32	0.41	19	250
	86 - 160	0.30	11.1	6.43	8.60	0.83	2.30	0.34	18	240
Golan 37	0 - 20	0.78	10.3	4.96	6.60	0.16	0.60	0.27	0	180
	20 - 40	0.56	9.1	5.76	6.70	0.16	0.55	0.27	0	210
	40 - 60	0.39	8.1	5.36	6.88	0.16	0.55	0.32	0	195
Golan 37	0 - 20	1.13	9.3	4.2	5.99	0.16	0.60	0.22	0	150
	20 - 40	0.74	8.4	5.0	5.64	0.13	0.44	0.24	0	180

*Calculated from the air dry moisture content (Banin and Amiel, 1969/70)

Table 3: Nitrogen forms in soil profiles - relative to total N

Soil	Layer	Total N	NH ₄ -N in KMnO ₄ 0.1N	NH ₄ -N in Hot KCl	NaHCO ₃ 0.03N		Acid hydrolyzable N					Amidase activity
					total N	optical density	total	NH ₄	Hexos- amine	Serine Treonine	α amino acids	
cm		mg kg ⁻¹	-----g/100 g total N in soil-----			-----g/100g total N in soil-----					mg kg ⁻¹ h ⁻¹	
Alumim	0 - 5	1320	6.0	1.43	3.9	0.76	74	10.4	7.2	5.8	39	281
	5 - 20	890	6.9	1.05	3.7	0.30	74	11.3	7.8	5.8	40	198
	20 - 50	360	11.3	2.12	5.7	0.09	86	16.0	10.1	6.0	38	72
	50 - 85	240	12.4	2.47	6.9	0.06	73	19.4	7.0	6.6	33	33
	85 - 125	210	12.6	2.16			76	19.4	9.6	6.5	31	30
	125 - 165	170	14.6	1.88			73	20.6	10.3	6.2	30	11
BD Control (Bet Dagan)	0 - 20	670	8.6	1.93	4.0	0.16	63	14.5	4.5	5.7	24	277
	20 - 40	660	8.2	1.39	3.2	0.13	63	14.5	4.7	5.6	23	266
BD NPKM	0 - 20	810	8.7	1.47	3.9	0.17	64	16.3	3.8	5.8	24	327
	20-- 40	760	7.6	2.13	3.8	0.14	66	14.1	5.4	5.3	21	312
	40 - 60	620	8.8	2.02	3.8	0.11	63	12.9	6.1	5.4	13	221
	60 - 90	480	10.2	1.97	4.5	0.09	62	12.8	7.5	4.8	13	158
	90 - 120	460	10.0	2.60	4.5	0.07	56	11.6	8.1	4.6	13	145
Gilat	0 - 20	470	9.8	5.79	7.3	0.41	95	18.1	6.9	9.6	48	146
	20 - 40	440	8.9	2.84	6.3	0.24	93	15.8	8.4	8.0	48	124
	40 - 60	310	10.9	2.33	7.2	0.15	85	20.9	6.1	9.0	44	75
	60 - 80	180	15.5	3.35	9.7	0.08	78	27.8	1.9	9.8	40	46
	80 - 100	150	16.6	7.34	12.1	0.06	87	24.5	6.0	7.6	41	27
	100 - 120	140	18.1	4.50	13.0	0.05	85	25.0	10.4	8.9	34	20
	120 - 150	155	14.4	3.71	11.4	3.05	68	21.0	5.8	8.1	21	32
		480					71	18.8	3.3	10.7	23	44
Gilat control												
Gilat NM	0 - 20	600					63	17.3	4.7	9.4	24	72
Akko	0 - 20	760	8.3	2.91	4.7	0.14	58	12.2	7.4	5.6	16	257
	20 - 40	580	8.6	2.99	4.7	0.10	62	13.5	9.6	4.7	16	229
	40 - 60	470	8.1	2.43	4.4	0.08	55	12.8	7.7	4.4	15	154
Eden	0 - 20	1410	9.2	1.44	2.7	0.40	44	9.1	4.4	3.5	19	325
	20 - 40	1030	11.3	1.47	3.1	0.31	48	11.1	5.6	4.1	22	283
	40 - 60	660	12.2	2.64	3.3	0.15	50	12.6	6.1	4.1	20	180
Qedma	0 - 9	670	10.7	2.56	5.3	0.30	75	14.1	4.9	6.5	42	148
	9 - 25	610	9.4	1.67	4.8	0.16	74	13.0	5.7	5.8	37	119
	25 - 58	470	11.2	1.74	5.3	0.10	74	15.4	7.5	5.5	34	149
	58 - 86	310	13.5	2.09	6.8	0.08	77	17.3	8.4	6.0	36	72
	86 - 160	270	13.1	2.34	7.3	0.08	73	16.7	8.7	4.4	31	37
Golan 70	0 - 20	750	7.2	2.06	4.4	0.18	49	11.2	7.6	4.1	20	93
	20 - 40	620	6.9	2.11	4.1	0.12	47	9.3	9.6	4.5	15	67
	40 - 60	480	6.4	2.28	3.9	0.12	47	10.6	8.6	4.2	12	60
Golan 37	0 - 20	1220	6.5	1.43	3.6	0.42	50	7.5	7.9	4.7	19	171
	20 - 40	880	6.9	1.31	4.3	0.36	43	7.6	7.6	5.6	16	85

Table 4: Linear relations between soil parameters

Variables*		Number of observations	Regression equation $y = bx + a$	Correlation coefficient	Comments
y	x				
KMN1	TOTN	36	$y = 0.065x + 14.8$	0.892	
KMN1	KMN05	38	$y = 1.62x - 15.6$	0.975	
HOTKC1	TOTN	36	$y = 0.010x + 6.4$	0.659	
BICN03	TOTN	34	$y = 0.023x + 13.5$	0.868	
OD03	BICN03	72	$y = 0.016x - 0.25$	0.897	Alumim 0-5 deviated considerably Without Alumino-5
OD1	BICN1	76	$y = 0.018x - 0.31$	0.825	
OD03	BICN03	70	$y = 0.013x - 0.18$	0.873	
OD1	BICN1	74	$y = 0.011x - 0.15$	0.866	
BICN1	BICN03	36	$y = 1.18x - 2.35$	0.962	
HTOTN	TOTN	38	$y = 0.50x + 75$	0.898	
AMINO	TOTN	38	$y = 0.22 + 17.9$	0.742	

* KMN1 = KMnO_4 0.1N extractable $\text{NH}_4\text{-N}$, mg kg^{-1} ; TOTN = Total N mg kg^{-1} ;
 KMN05 = KMnO_4 0.05N extractable $\text{NH}_4\text{-N}$; mg kg^{-1} ; HOTKC1 = Hot KCl extractable $\text{NH}_4\text{-N}$, mg kg^{-1} ;
 BICN03 = NaHCO_3 0.03N extractable N, mg kg^{-1} ; OD03 = Optical density of NaHCO_3 0.03N extract.
 BICN1 and OD1 = The same as the former but with NaHCO_3 0.1N; HTOTN = Acid hydrolyzable total N, mg kg^{-1} ;
 AMINO = Amino acid in acid hydrolyzate, mg kg^{-1} .

Table 5: Correlations between soil parameters

Variables*	No. of observations	Correlation coefficient	Comments ⁺
CEC x HYG	26	0.962	
HOTKC1 x KMN1	36	0.619	
BICN1 x KMN1	38	0.700	Eden - very high KMN1
BICNO3 x HOTKC1	34	0.699	
ODO3 x C	36	0.744	
OD1 x C	38	0.699	
PHTOTN x HYG	36	-0.545	
PHTOTN x TOTN	38	-0.558	
HTOTN x KMN1	36	0.751	
HTOTN x BICNO3	34	0.897	
PAMINO x PHTOTN	38	0.569	
AMINO x KMN1	36	0.630	
AMINO x BICNO3	34	0.824	
AMIDAS x TOTN	38	0.758	
AMIDAS x S	36	0.497	
AMIDAS x AMINO	38	0.543	
AMIDAS x AMINO	13	0.856	Bet Dagan, Acco, Eden
AMIDAS x AMINO	25	0.961	All the rest
AMIDAS x KMN1	36	0.770	
AMIDAS x BICNO3	34	0.558	

* In addition to variables described in Table 4: CEC = cation exchange capacity; HYG = Air dry moisture content; C = Total organic carbon; PHTOTN = Acid hydrolyzable N, percentage of total N; PAMIN = Amino acid in hydrolyzate, percent of total N; AMIDAS = Amidase activity; S = Specific surface area.

+ All correlations were significant at a level of 0.01.

Figure 1: Relation between oxidative release of NH₄-N from soil by 0.1N and 0.05N KMnO₄ in acid. The line is the calculated linear regression.

Figure 2: Relation between optical density and N content of NaHCO_3 0.1 M soil extracts.

Figure 3: Relation between acid hydrolyzable N fraction of total soil N and the hygroscopic moisture content of the soils. The line is the calculated linear regression.

Figure 4: Relation between amidase activity and amino acids in soil acid hydrolyzate. The lines are calculated linear regressions for two soil groups.

D. Cooperation

The cooperation between the parties involved in this project was mainly in exchange of information and ideas and discussion of experimental results which took place mostly during meetings in Riverside and in Bet Dagan.

Nitrogen transformations in soil have been investigated by all parties but the general objective of the project has been divided into two main lines: The transformation of fertilizer N under different irrigation and fertilization practices or salinity of water added to soils was the main subject studied by the Riverside group. The Israeli group concentrated on studying the rate of soil N mineralization and nitrification as affected by soil depth and soil types receiving different previous agricultural management.

E. Benefit to Agriculture

Basic knowledge on N transformation rates and its dependence on soil properties enables the prediction of nitrogen behavior in soil under different agricultural practices. Decisions to apply the proper amount of fertilizer, at the time it is required, are greatly improved when the contribution of available N from different soil layers, as a function of time, can be estimated by means of a chemical extract or a quick biological assay. The distribution of ammonium and nitrate with time and depth depends on the rate of nitrification, which has been investigated in different soil profiles as a function of soil properties and agricultural practices. Fertilizer use can be improved, minimizing NH_4 loss by volatilization and NO_3 loss by leaching or denitrification, when knowing the NH_4/NO_3 distribution and its effect on soil. For instance, urea ammonium nitrate applied by drip irrigation decreased soil pH, which might reduce NH_4 volatilization in alkaline soils and inhibit nitrification in neutral or acidic soils.