Nitrogen Transformation from Potato and Rotational Crop Residues

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Abstract

This study was conducted to determine the amount of nitrogen (N) from the crop residues and soil organic matter transformed into inorganic forms, i.e. ammonium and nitrate forms, during January through September 2000 in a sandy soil under irrigation. Corn, wheat, and potato residues were evaluated. The dry weight of corn, wheat, and potato residues sampled in the 0-12 inch depth soil in January 2000 (after the respective crops were harvested in the fall of 1999) were 11.8, 9.0, and 3.7 ton/acre, respectively. The total N content in the above residues were 355, 338, and 108 lbs/acre, respectively. By March 2000, the residue weights have decreased to 5.7, 3.4, and 2.1 ton/acre, respectively, along with the respective total N contents of 169, 102, and 61 lbs/acre.

The residue weights further decreased to 1.1 - 1.7 ton/acre by September 2000 across all crop residues, with the total N content of 32 to 53 lbs/acre. The mineralized N, as both ammonium and nitrate forms, in the top 12-inch depth soil during January through September 2000 were 171, 129, and 72 lbs/acre from corn, wheat, and potato residue plots. The above values represented 48, 38, and 67 percentage of the total N in the respective crop residues measured in January 2000. This study demonstrated the transformation of N from potato residue was more rapid as compared to that from corn and wheat residues.

Introduction

Residue decomposition and the subsequent release of nutrients from organic source into inorganic forms from vegetative crop residues render the nutrient available. With respect to nitrogen (N) nutrition, decomposition of crop residues results in the production of ammonium and nitrate forms of N. This process generally called as “nitrogen mineralization.” Potato production in the irrigated Pacific Northwest (PNW) is under three to four years of rotation with wheat, corn, alfalfa, or other crops. Nitrogen dynamics in the soil under any of the above crops in a rotation system impacts the overall N transformation and transport in the soil which can impact N availability for the subsequent crops as well as potential loss of N forms.

Nitrogen mineralization in the soil is a continuous microbial process dependent on environmental factors. Therefore, N mineralized during the crop growing season provides a source of available N for the crop. On the contrary, N mineralized during the off-season can be subject to various losses. The rate of N release will vary with soil temperature, soil moisture, and type of organic matter. In the irrigated potato rotations in central Washington, soil moisture is fairly well controlled over the growing season, but soil temperature and the plant residue in soil vary considerably depending on the rotational crop preceding potato. The purpose of this study was to increase the understanding of N release pattern from crop residue as well as soil organic matter in irrigated potato rotations production systems. The management of rotational crops and an estimation of nutrient contribution from the residue of preceding crops is important to fine tune the nutrient requirement of potato.

The objectives of this study were: (i) To measure the amount of crop residue following potato, corn, wheat, or alfalfa; (ii) To evaluate N mineralization from the above crop residue

Materials and methods

The experiment was conducted in a Quincy fine sand soil near Paterson, WA. The technique adapted in this study is widely recognized and used in several in-situ mineralization studies (Cabrera, et al, 1994; Schepers and Meisinger, 1994; Cassman and Munns, 1980; Dou, et al, 1997). PVC columns (8 inch diameter x 14 inch height) were driven into soil to 12-inch depth. The columns were capped to prevent any precipitation or irrigation application on the soil inside the column which could leach the mineralized nutrients beyond the depth of sampling, thus, could underestimate the mineralization. Each column had 8 holes (½ inch diameter) along the wall to facilitate lateral flow of air and water between the bulk soil and the soil inside the column to maintain the soil condition inside the column as nearly similar to those of the bulk soil. The portion of the column above ground (2 inch) had 2 holes above the surface of the soil to facilitate air exchange to maintain conditions inside the column nearly similar to those in the field.

During the installation of these columns, soil samples were taken adjacent to the column at 0-6 inch and 6-12 inch depths representing the area of the column. This initial soil sample was used to characterize the initial content of nitrate (NO_3-N) and ammonium (NH_4-N) at field moist condition at the time of installation of the incubation columns, thus, represent baseline conditions for the incubation period. The weight of soil at each depth segment was measured. Each depth soil sample was sieved to separate all plant residue. The soil was air-dried and weight recorded. The plant residue was cleaned in tap water with final rinse in distilled water, dried at 74^0 C for 72 hours, and dry weight was recorded.

The concentrations of carbon and nitrogen were measured using a CNS analyzer (Leco Corporation). The N concentration and dry weight of the plant residue were used to calculate the total amount of N present in the plant residue at the beginning of the experiment within the area of soil column. This represents the potentially mineralizable N (PMN) that was available for mineralization. The rapidity of mineralization, however, is dependent on climatic conditions and cultural practices. The estimate of potentially mineralizable N provides the basis to calculate the proportion of the total N being mineralized over a specific incubation time.

The incubation columns were excavated at the end of the incubation period for analysis of KCl extractable NH_4-N and NO_3-N in the 0-6 inch and 6-12 inch depth soil sample. The difference in concentrations of NH_4-N and NO_3-N in the soil sample at the end of incubation period and those at initial time represents the amount of N being mineralized. This procedure was repeated over several time intervals to determine N mineralization at different incubation times over the entire year.

The duration of incubation was longer during the cool season, as compared to that during the warmer season, since the rate of N mineralization is slow in the cool season. Summation of mineralized N at each time interval over a given length of time, thus, represents the total N (NH_4-N plus NO_3-N) being mineralized for the total duration of the study. The mineralized N as percent of total N in the plant residue (PMN) at the beginning of the study provided an estimate of percent mineralization.

Results and discussion

This study measures the total quantity of mineralized N in the top 12 inch depth soil. However, the measured quantity is not an indication of plant available N. That portion of N mineralized during off-season and/or the portion of mineralized N leached below the rooting depth will not be available to the plants.

Under Pacific Northwest growing conditions, soil temperatures can be relatively warm in the fall after the harvest of most crops. This provides favorable conditions for rapid N mineralization. The fate of these available forms of N is unclear since this time of the year the soil is either bare or, if planted with cover crop, the crop is in an early growth stage with very little nutrient uptake. This study began in January 2000; therefore, no data are available on the N mineralization during the preceding fall after crops were harvested in 1999.

The crop residue separated from the soil represents the residue available for decomposition during the rest of the year (Table 1). The total N in the residue on an area basis represents the total N that is available for mineralization, hence, potentially mineralizable nitrogen. Table 1 provides crop residue weights in January, March, May, and September 2000. The total N content was measured in the respective crop residues. The residue dry weight and total N concentrations were used to calculate the total N in the residue, i.e. potentially mineralizable N at various times during the residue sampling. The crop residue sampling and evaluation of N mineralization for alfalfa residue plots began in May 2000.

The crop residue weights in January 2000 were 21,268; 16,272; and 7,004 lbs/acre in the 0-6 inch depth and 2,495; 1,817; and 518 lbs/acre in the 6-12 inch depth soil for corn, wheat, and potato, respectively (Fig. 1).

The residue weights at the beginning of 2000 potato growing season (March) were 8,283; 5,003; and 2,372 lbs/acre in the 0-6 inch depth and 3,017; 1,773; and 1,694 lbs/acre in the 6-12 inch depth for corn, wheat, and potato residues, respectively (Fig. 1, Table 1). This represents the largest decrease in residue weights among all the incubation periods for the 0-6 inch depth in this study. The potentially mineralizable N amounts at the beginning of crop season (March 2000) were 124, 75, and 36 lbs/acre in the 0-6 inch and 45, 27, and 25 lbs/acre in the 6-12 inch depth soil for corn, wheat, and potato, respectively.

The measured values of N mineralization in the NO_3-N and NH_4-N forms during various incubation periods are shown in Fig. 3. During the duration of this study, i.e., January through September 2000, the cumulative amounts of nitrogen mineralized in the form of NO_3-N from corn, wheat, and potato residues were 77, 93, and 45 lbs/acre, respectively, in the 0-6 inch depth, and 79, 19, and 12 lbs/acre, respectively, in the 6-12 inch depth. The corresponding values for NH_4-N were 11, 10, and 11, and 5, 6, and 4 lbs/acre (Figs. 2a and 2b).

The mineralized nitrogen in both depths and both forms (NO_3-N and NH_4-N) were 76, 65, and 35 lbs/acre for March through September, or 37, 28, 21 lbs/acre for March through July from corn, wheat, and potato residues, respectively (Figs. 3a and 3b). The mineralized N values for each of the growing season was greater from corn residue as compared to either wheat or potato residue.

The gravimetric soil moisture content of the soil samples at various incubation durations and soil temperature data are shown in Figs. 4 and 5. The soil moisture content varied about 8 percent during most of the year and increased to about 10 percent in July through September 2000.

Acknowledgements

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Table 1. Dry weight of crop residues, and total N in the crop residue (i.e. potentially mineralizable nitrogen - PMN) in the 0-12 inch depth soil sampled at various times in year 2000. The respective crops were harvested in the fall of 1999.

	------Residue dry weight (ton/acre)-------				--------Residue total N (lbs/acre)--------			
Crop Residue	Jan	Mar	May	Sept	Jan	Mar	May	Sept
Corn	11.8	5.7	2.5	1.7	355	169	74	53
Wheat	9.0	3.4	1.7	1.1	338	102	62	38
Potato	3.7	2.1	0.9	1.1	108	61	28	32

Fig. 1 Dry weight of plant residue (lbs/ac) from corn, wheat, potato, and alfalfa at 0-6 and 6-12 inch depth in a Quincy fine sand during January through September 2000. Alfalfa residue mineralization measurements began in May 2000.

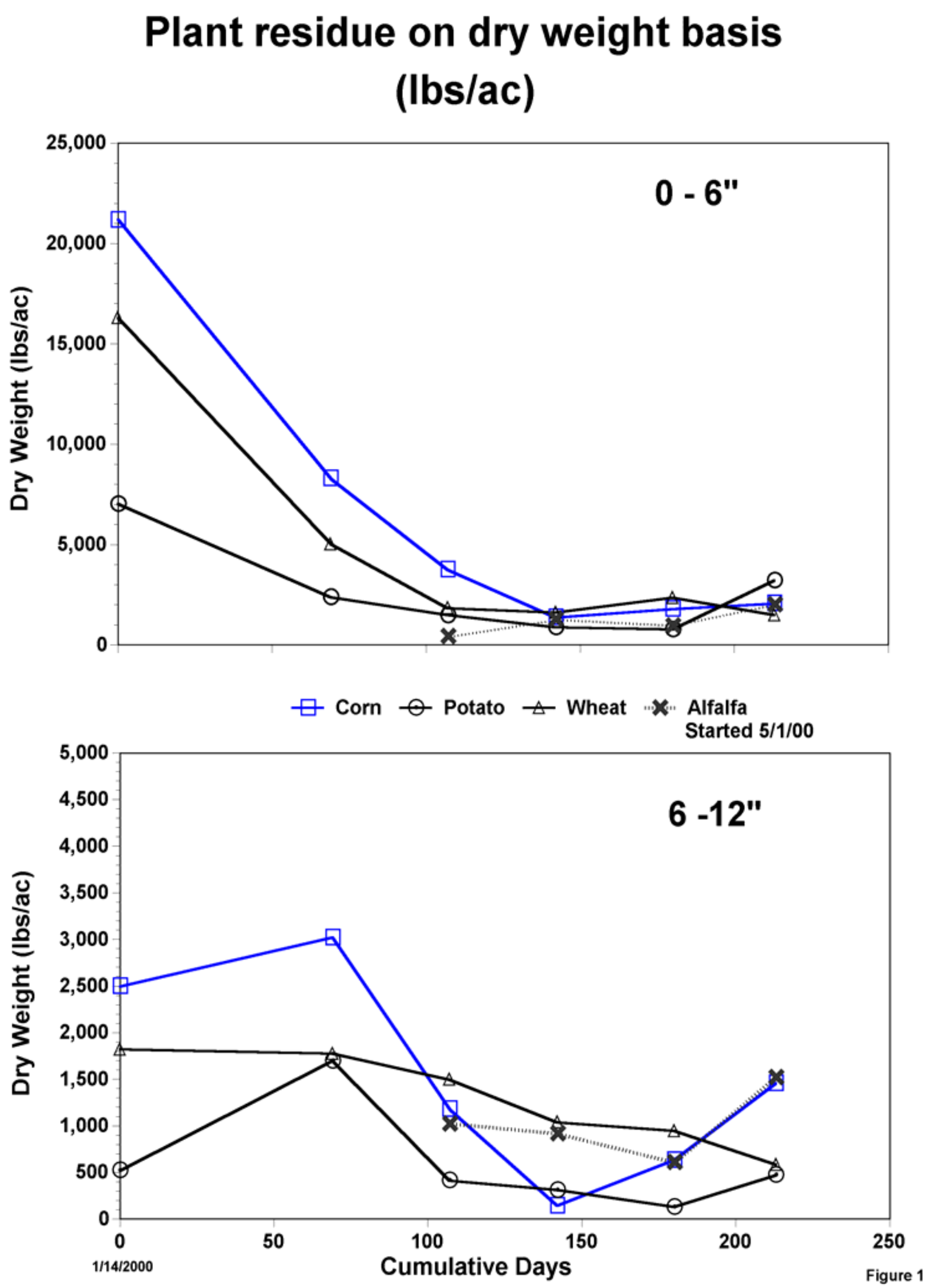
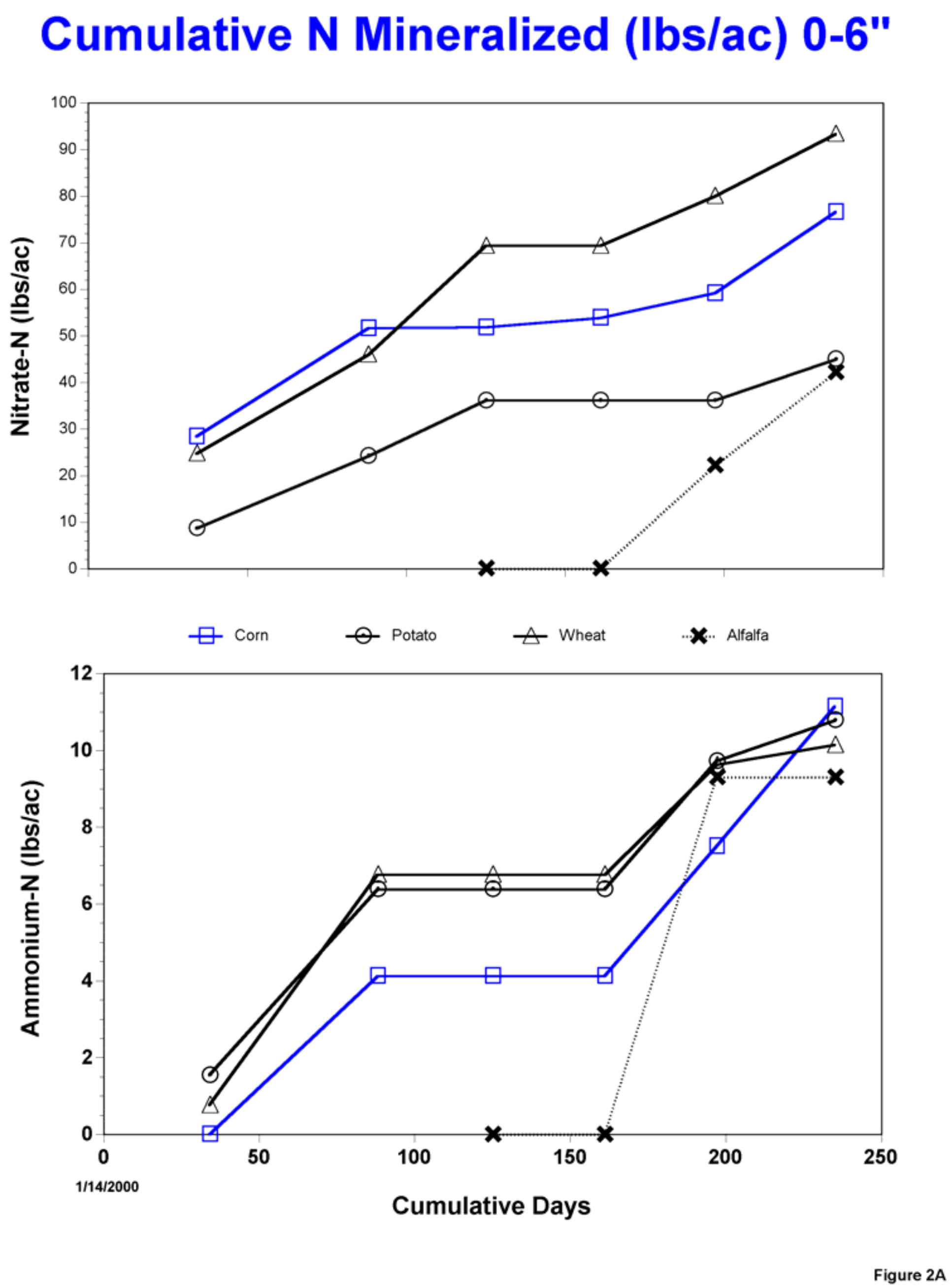


Fig. 2 Cumulative mineralization of NO_3-N and NH_4-N from corn, wheat, potato, and alfalfa residue at 0-6 inch (a) and 6-12 inch (b) depth in a Quincy fine sand during January through September 2000. Alfalfa residue mineralization measurements began in May 2000.



Cumulative N Mineralized (lbs/ac) 6-12"

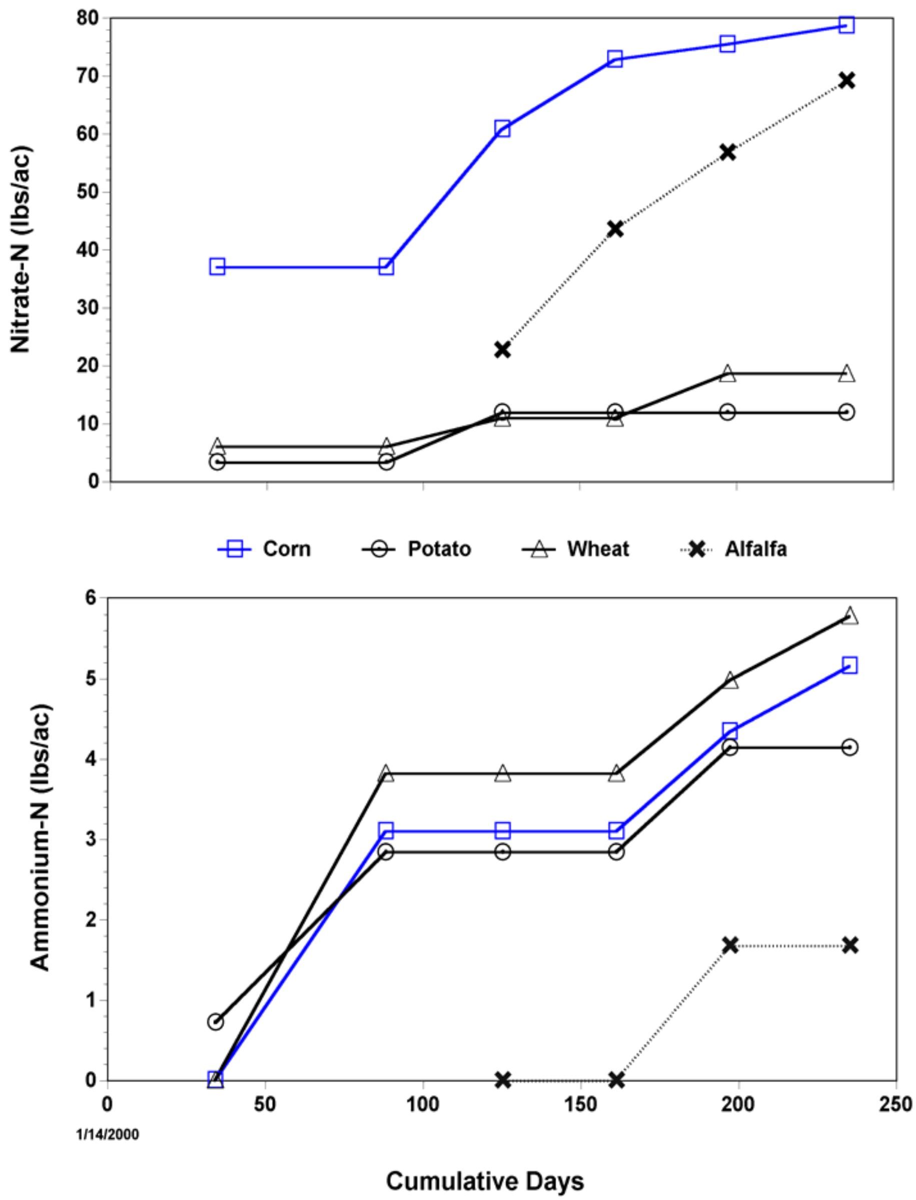
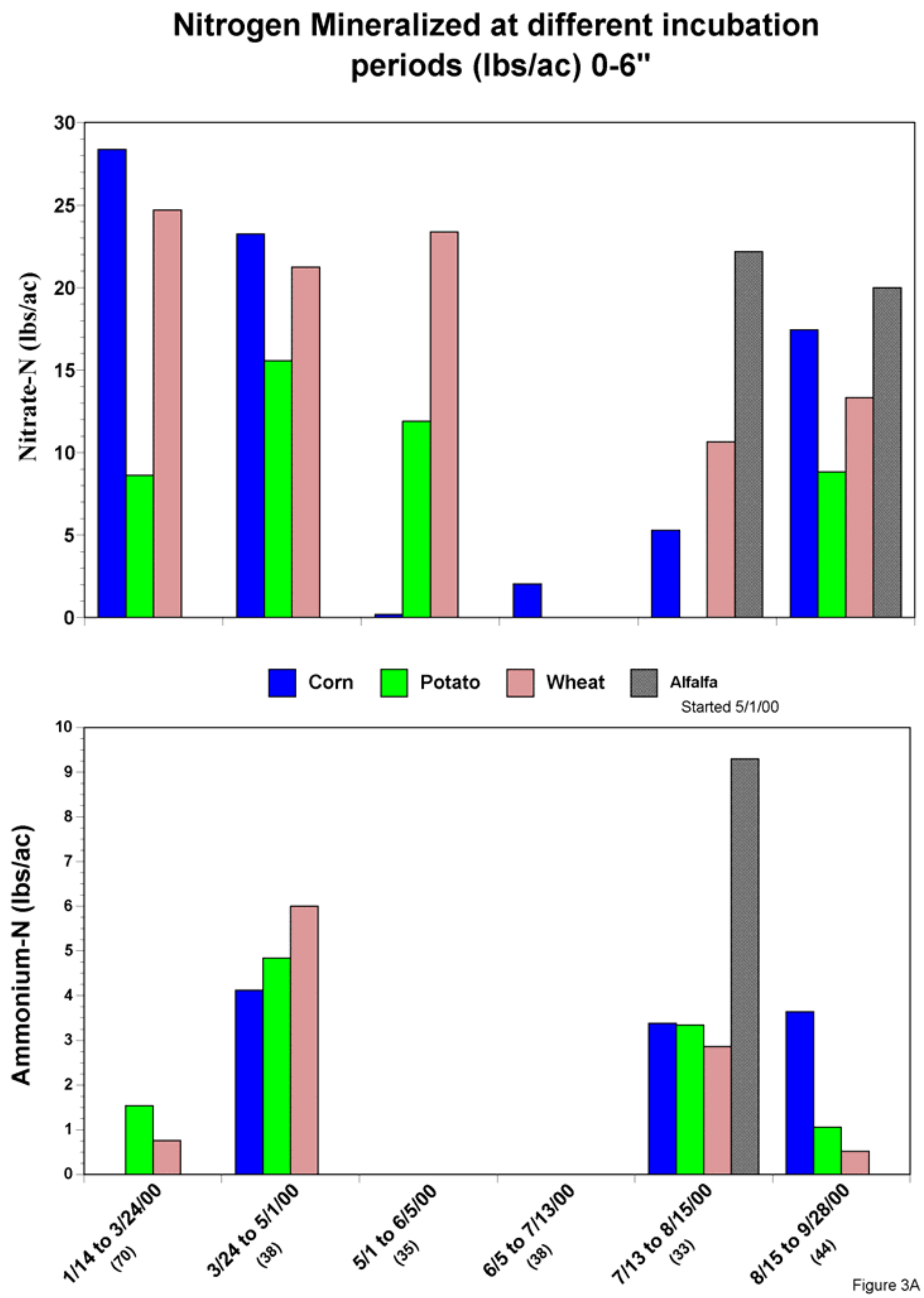


Figure 2B

Fig. 3 Mineralization of NO_3-N and NH_4-N for various incubation periods from corn, wheat, potato, and alfalfa residues at 0-6 inch (a) and 6-12 inch (b) depth in a Quincy fine sand during January through September 2000. Alfalfa residue mineralization measurements began in May 2000.



Nitrogen Mineralized at different incubation periods (lbs/ac) 6 - 12"

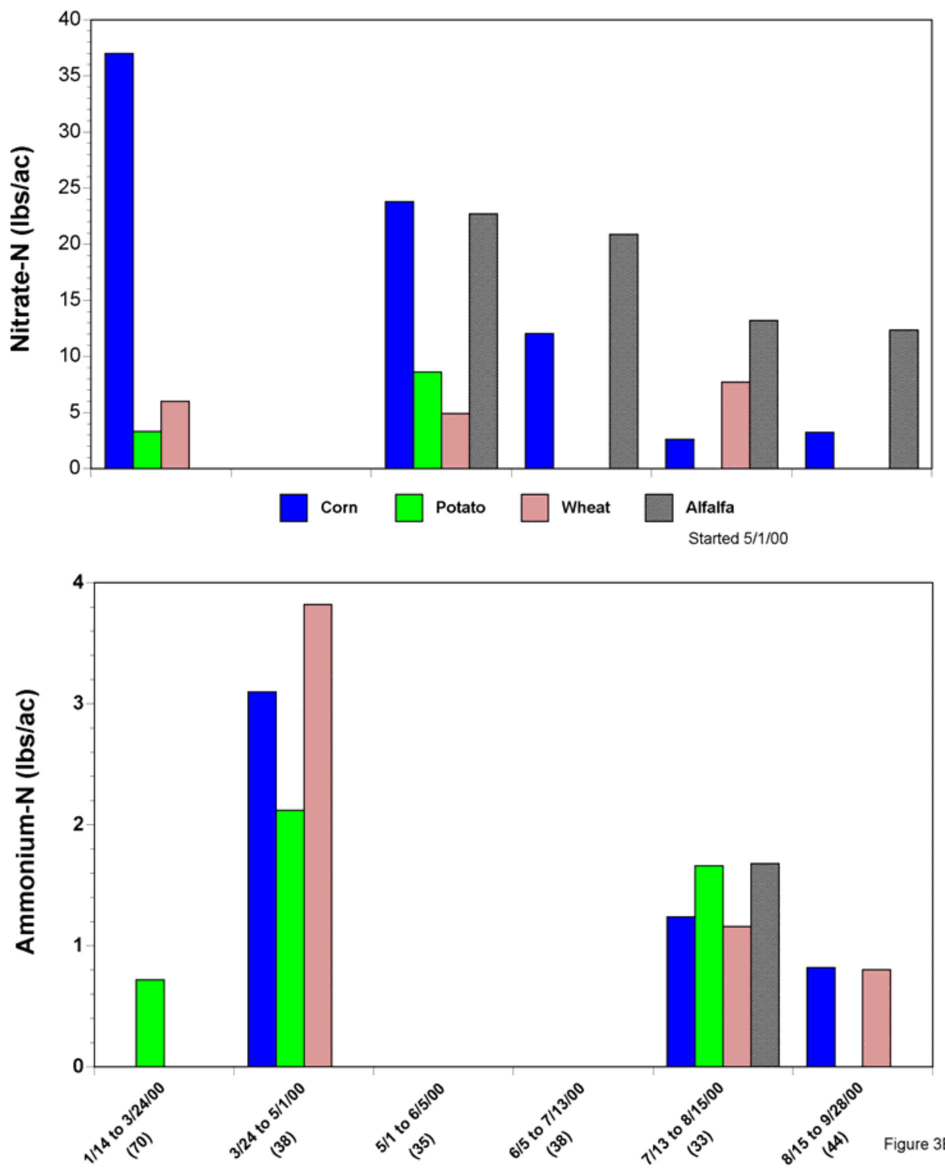


Figure 3B

Fig. 4 Gravimetric soil moisture content at 0-6 inch depth of a Quincy fine sand in the incubation columns to evaluate mineralization of corn, wheat, potato, and alfalfa residues during January through September 2000. Alfalfa residue mineralization measurements began in May 2000.

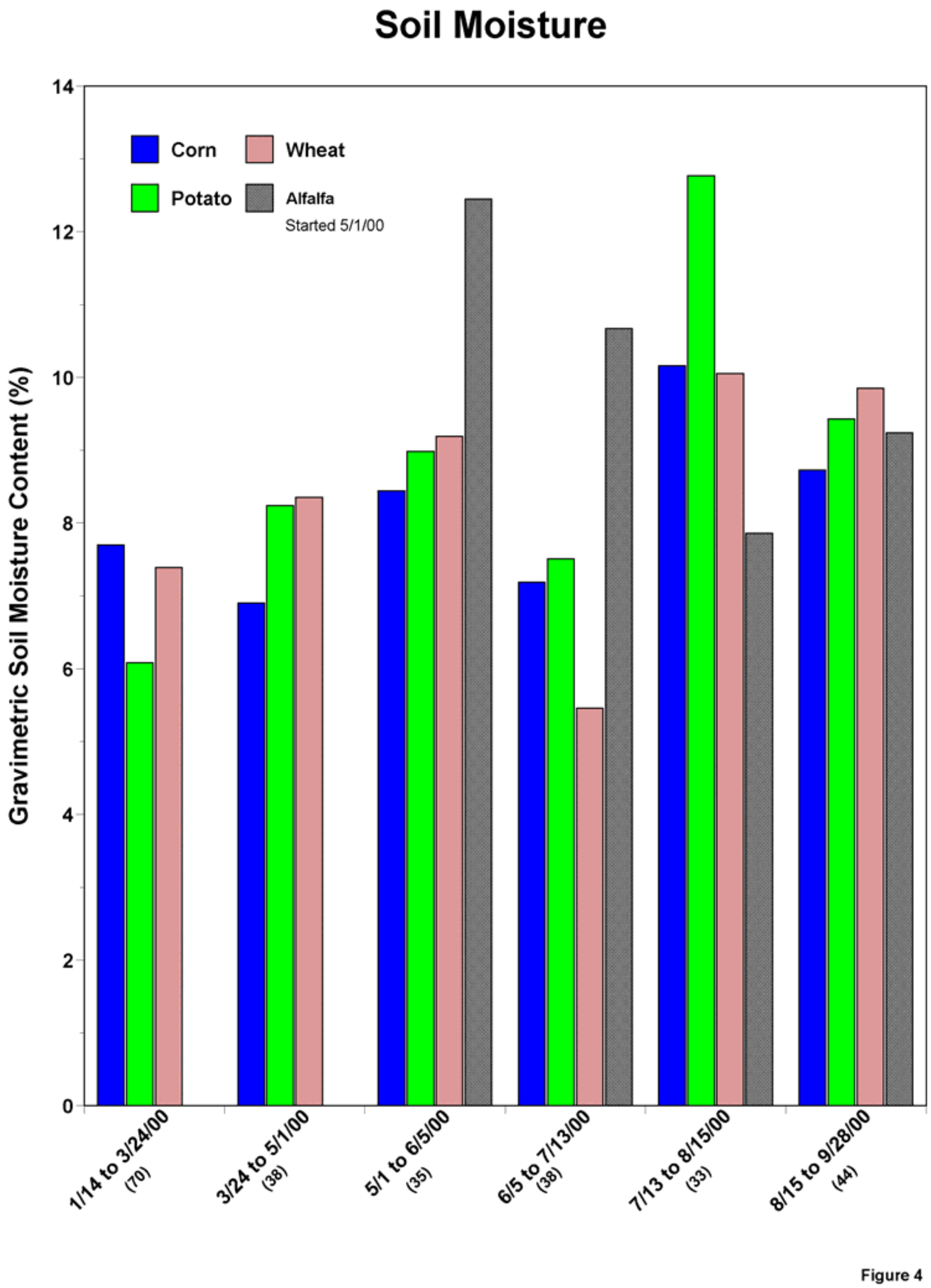


Fig. 5 Summary of soil temperatures in the top 8-inch depth for January through September 2000.

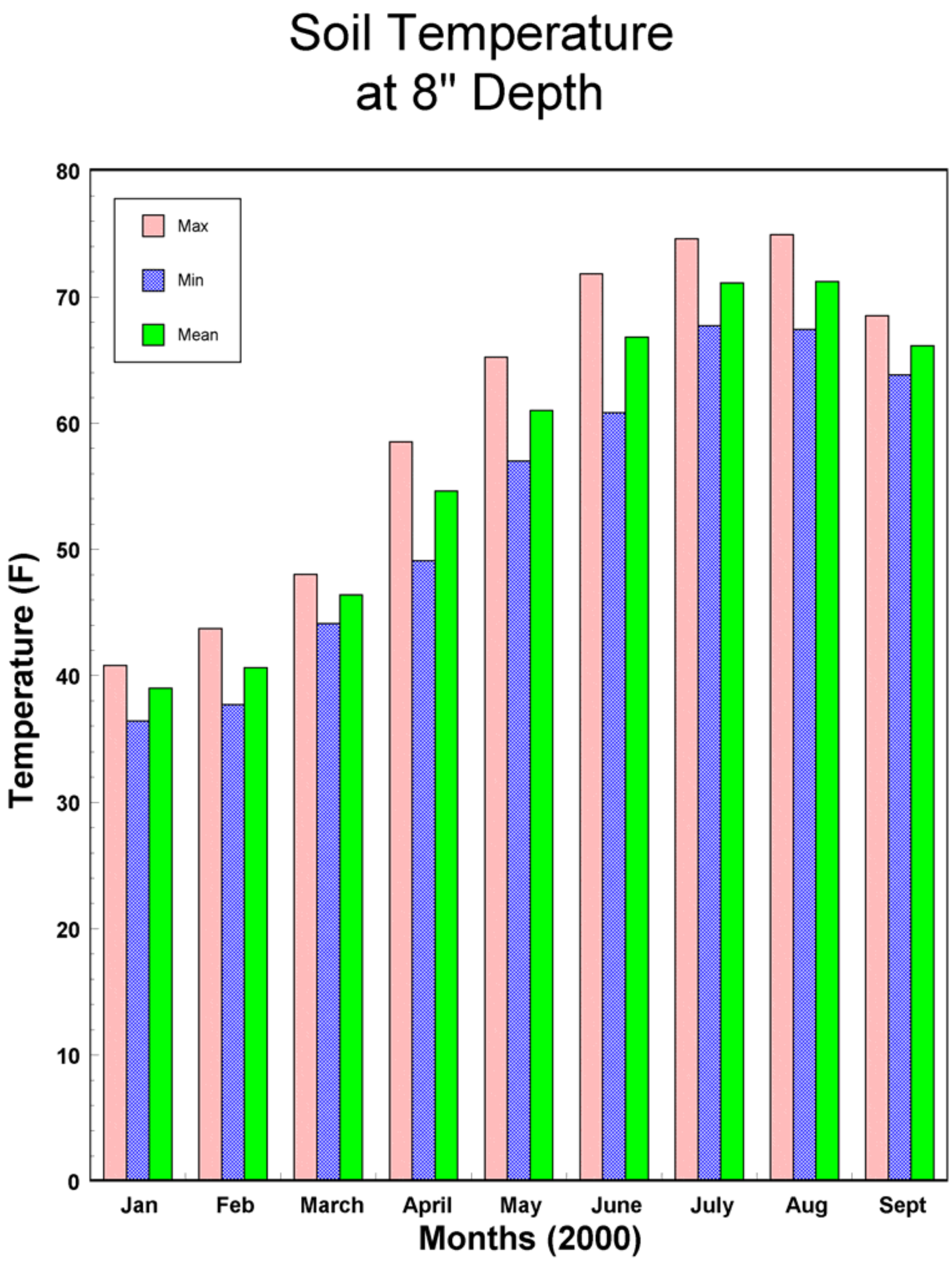


Figure 5