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J. H. Smith and J. R. Peterson

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# Energetics of Nitrogen Transformations

R. F. Harris

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# Nitrogen Transfers and Mass Balances

R. D. Hauck and K. K. Tanji

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It is highly appropriate that Nitrogen in Agricultural Soils is dedicated to the memory of Dr. George Stanford, whose research career over the past 4 decades centered chiefly on elucidating nitrogen behavior and transformations in soils as a basis for achieving more effective use of nitrogen fertilizers.

Born 7 March 1916 near Pierre, South Dakota, he received his B.S. degree from South Dakota University in 1938. His research career and studies for advanced degrees began in 1939 at Iowa State University. The M.S. degree was received in 1941 and the Ph.D. in 1947. This period included military service as an infantry officer in World War II.

His professional career was spent at Cornell University (1948–50); Iowa State University (1950–55); TVA (1955–60); Hawaiian Sugar Planters Association and Hawaii Agricultural Experiment Station (1960–65); and USDA, Beltsville, Maryland (1965–80). He retired as a research soil scientist from USDA due to ill health that culminated in his death on 28 January 1981.

Dr. Stanford's research accomplishments were numerous and had considerable influence on soil fertility practices at a time when major expansion in fertilizer use was just beginning. His major research accomplishments dealt with ammonium fixation in soils; a rapid greenhouse-laboratory method for evaluating the relative effectiveness of diverse nitrogen, phosphorus, and potassium sources; optimal use of nitrogen fertilizer on sugarcane; development of a nitrogen availability index (extractable ammonia) for rapidly estimating the nitrogen-supplying capacities of soils; denitrification and nitrogen losses from soils; and long-term field experiments using stable nitrogen isotopes.

Throughout his career, Dr. Stanford's fine qualities as a researcher and team leader were often demonstrated. His careful planning, attention to detail, and good judgment contributed greatly to the success of experiments. He directly involved himself in all phases of the work. His ability to assimilate research data and to reduce it to its most significant terms was a trait admired by all who knew him.

Dr. Stanford's research greatly expanded our knowledge of nitrogen in agronomic systems and has resulted in more than 75 publications. He devoted a large share of his life to nitrogen research, and his findings will continue to influence the trends in research on this important element for years to come. His frank and forthright manner left no doubt as to where he stood on critical or controversial issues. His approach to research was realistic and involved a critical examination of the problems, alternate procedures, possibilities for success, and what contribution the research results made to scientific knowledge and to practical solutions. All those who conduct research in the future may do well to follow his example.
GENERAL FOREWORD

*Nitrogen in Agricultural Soils* is an update of the 1965 edition of *Soil Nitrogen*, ASA Monograph 10, and replaces the depleted supply of *Soil Nitrogen*. The new book incorporates the significant advances made in this field during the past 17 years and is the 22nd monograph in the series *Agronomy* that was started in 1949. The first six volumes were published by Academic Press, Inc., New York. In 1957, the American Society of Agronomy took over publication of the monographs and continued to be the sole publisher through the 18th monograph published in 1977. The Crop Science Society of America and the Soil Science Society of America were invited to participate in the series and have been copublishers since 1977. The monographs represent an important and continuing effort of the associated societies, their officers, and the 11,700 members located in 100 countries to provide mankind worldwide with the most recent information available.

On behalf of the members of the associated societies and myself, I sincerely thank the Editorial Committee members chaired by Dr. F. J. Stevenson for their diligent work, the many authors for their writings, Managing Editor Richard C. Dinauer for his inexhaustible patience in the compilation of the contents of this book, and all others who have contributed directly or indirectly to the accomplishment of this worthy project.

December 1981

MATTHIAS STELLY

*Executive Vice President, ASA-CSSA-SSSA and Editor-in-Chief, ASA Publications*

FOREWORD

The nitrogen reactions in soils and the nitrogen nutrition of crops are insufficiently understood. Soil nitrogen derived from organic matter is essential for plant growth and the formation of proteins required by living matter. The principal source of protein for a major portion of the human population is cereal grain. Humans depend on foraging animals to capture plant proteins and provide meat and milk. These basic characteristics of soil nitrogen challenge our interest in the mechanisms and processes by which people obtain food and fiber products.

An increase in the protein content of cereal grains would enhance the nutritional status of the human population. In many soils and for many crops, farmers increase the nutrient supply of nitrogen by the addition of various forms of nitrogen to the soil or by biological dinitrogen fixation with legumes. Plants consume only about 50% of the added nitrogen forms, and there is a strong need to increase this utilization level. The nitrogen cycle in soils follows a complex series of reactions that require continuing study to utilize this nutrient more effectively and to assure an adequate supply for plants. In the overall process of removing barriers to crop productivity, nitrogen supply to plants plays a major role.

We express appreciation and gratitude to Dr. F. J. Stevenson, editor, and his editorial committee, Drs. J. M. Bremner, R. D. Hauck, and D. R. Keeney for their important functions leading to this publication. We acknowledge and thank the
authors for their cooperation and efforts and the help of society members who reviewed manuscripts. We are grateful to the Headquarters staff for editorial and production efforts, which makes it possible to place this fine volume in your hands.

November 1981

STERLING R. OLSEN  KENNETH J. FREY  BOBBY A. STEWART
president ASA  president CSSA  president SSSA

PREFACE

*Nitrogen in Agricultural Soils* provides an authoritative review of the principles governing the behavior of nitrogen in the soil-plant system. The volume supersedes ASA Monograph 10 *Soil Nitrogen*, published in 1965. Significant advances on all aspects of the subject have been made since that time, and the need had arisen for a compilation and critical analysis of current knowledge. Material contained in the 1965 monograph has been extensively revised and updated, and new chapters have been introduced in response to increasing concern about energy conservation and preservation of the environment. Authors were allowed considerable latitude in developing their topics, with the result that both panoramic and specific views have been presented for each major component of the soil nitrogen cycle.

The volume covers many facets of soil nitrogen, including forms and distribution, biological and nonbiological transformations, gains, losses, and recycling, plant availability and uptake, modeling and transport, pesticide interactions, experimental approaches, and economic implications of restrictions on fertilizer nitrogen use. The field of study is broad and has involved researchers working in many specialized areas. Because of the voluminous literature that has accumulated over the past two decades, an exhaustive coverage of the literature was not always possible, and selection of references has often been rather arbitrary. The editors and authors apologize for omission of important work.

The editorial committee expresses appreciation to the authors and the organizations they represent for cooperation and support. Acknowledgment is given to Richard C. Dinauer, Matthias Stelly, and other members of the Headquarters staff for advice and assistance in editing and preparing the manuscripts for publication. We pay special tribute to George Stanford, author of Chapter 17, whose untimely death occurred while the monograph was in progress. The assistance of J. J. Meisinger in proofreading and indexing Dr. Stanford’s chapter is gratefully acknowledged.

August 1981

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### CONVERSION FACTORS FOR U. S. AND METRIC UNITS

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| 0°C    |                |         |                                               |
| 100°C  |                |         |                                               |
| **Water Measurement**                         |          |          |                                               |
| 8.108  | hectare-meters, ha-m | acre-feet | 0.1233                                      |
| 97.29  | hectare-meters, ha-m | acre-inches | 0.01028                                   |
| 0.08108 | hectare-centimeters, ha-cm | acre-feet | 12.33                                       |
| 0.973  | hectare-centimeters, ha-cm | acre-inches | 1.028                                       |
| 0.00973 | meters³, m³ | acre-inches | 102.8                                       |
| 0.981  | hectare-centimeters/hour, ha-cm/hour | feet³/sec | 1.0194                                      |
| 440.3  | hectare-centimeters/hour, ha-cm/hour | U.S. gallons/min | 0.00227                                   |
| 0.00981 | meters²/hour, m²/hour | feet³/sec | 101.94                                      |
| 4.403  | meters²/hour, m²/hour | U.S. gallons/min | 0.227                                      |

#### Plant Nutrition Conversion—P and K

- **Phosphorus (P)**
  \[ P \text{ (phosphorus)} \times 2.29 = P_2O_5 \]
- **Potassium (K)**
  \[ K \text{ (potassium)} \times 1.20 = K_2O \]