The Role of Phosphorus in Agriculture
The Role of Phosphorus in Agriculture


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FOREWORD

Without phosphorus in the environment no living organisms could exist. Phosphorus is present in all plant and animal tissue. It is necessary for such life processes as photosynthesis, the synthesis and breakdown of carbohydrates, and the transfer of energy within the plant. Phosphorus is taken up by the plant from the soil. Unless the soil contains adequate phosphorus or it is supplied to the soil from external sources, plant growth will be limited.

Phosphorus does not occur as abundantly in soils as does the other major nutrients, nitrogen and potassium. The content of phosphorus ranges from about 100 to 2,500 kg/ha and averages about 1,000 kg/ha in the surface 20 cm of a soil. Phosphorus occurs in both inorganic and organic forms in the soil. Only a small fraction of the total phosphorus is in a form available to plants.

Plants do not require as large quantities of phosphorus as they do nitrogen and potassium. But phosphorus is just as essential. Unlike nitrogen which can be returned to the soil by fixation from the air, phosphorus cannot be replenished except from external sources once it leaves the soil in agricultural products or by erosion.

The phosphorus contained in 9,400 kg/ha of corn grain (150 bu/acre) contains about 25 kg/ha of phosphorus or about 1/40 of that contained in the surface 20 cm of a typical American soil. Removal of phosphorus from the soil in food or fiber crops over a few decades can be a significant portion of that contained in the pedon. Thus, under many systems of farming, phosphorus must be supplied to the soil from external sources, principally as mineral phosphorus fertilizer, with smaller amounts from agricultural processing and municipal wastes.

Because of the importance of phosphorus in agriculture and because of the limited supplies in most soils, members of the American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America believe that this monograph is a much needed treatise on the subject. Its purpose is to examine all aspects of the manufacture and of supplies of phosphorus fertilizers and the best possible management of phosphorus as a plant nutrient in agriculture. The editors and the authors are outstanding authorities in the field. The monograph will be of value to all scientists, students, and administrators who deal with phosphorus in agriculture.

June 1980

Roger L. Mitchell, president
American Society of Agronomy

Billy E. Caldwell, president
Crop Science Society of America

William E. Larson, president
Soil Science Society of America
PREFACE

The Role of Phosphorus in Agriculture is a compilation of papers presented at a symposium held at Muscle Shoals, Alabama, June 1-3, 1976, and cosponsored by the Tennessee Valley Authority, the American Society of Agronomy, the Soil Science Society of America, and the Crop Science Society of America. The objectives of the symposium were to assemble recognized authorities to summarize current knowledge about phosphorus as it relates to agriculture and to provide an authoritative reference work on this subject.

Much of the credit for the scope and range of topics in this book goes to the Planning Committee, which consisted of E. O. Huffman, S. R. Olsen, and Alex Pope, with F. E. Khasawneh and E. C. Sample as cochairmen. The committee spent many hours outlining a comprehensive coverage of fertilizer phosphorus and choosing a slate of authors knowledgeable about each topic. Through their efforts the book achieves the goal of covering phosphorus from the mine to the end use in fertilizers. Topics include: (i) surveys of world and U.S. phosphate ore deposits, and evaluation of these raw materials; (ii) new developments in phosphoric acid and phosphate fertilizer technology and in processing low-grade deposits; (iii) patterns in supply-demand trends of phosphate fertilizers; (iv) reactions of phosphate fertilizers in soils and methods of assessing the status of soil phosphorus, including residual and organic forms; (v) agronomic factors related to the effectiveness of various phosphate sources, both inorganic and organic; (vi) phosphate nutrition of major crops and the relationship between crop nutrition and nutrition of humans and animals; and (vii) the impact of fertilizer phosphorus on the environment. The committee felt that symposium topics should be restricted to phosphorus as a nutrient; hence, phosphorus in organophosphate pesticides is not included in the book.

The authors represent a cross section of disciplines and organizations including academic, governmental, and industrial. The Editorial Committee is grateful to these authors and to the organizations they represent for their outstanding contributions. We are especially grateful to these authors for taking additional time to ensure that coverage of their subject matter is current and up-to-date in spite of the time which has elapsed since the symposium. The committee also acknowledges the assistance of numerous anonymous reviewers.

Special recognition also goes to Richard C. Dinauer, Matthias Stelly, and other members of the headquarters office of the American Society of Agronomy for their help with the symposium and in editing and publishing this book. The assistance of Mrs. Peggy Kelley of the Tennessee Valley Authority in planning and conducting the symposium, handling most of the correspondence, and in editing the manuscripts is gratefully acknowledged.

May 1980

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Tennessee Valley Authority, Muscle Shoals, Alabama

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North Carolina State University, Raleigh, N.C.
AN OVERVIEW—A LOOK AHEAD

This symposium on The Role of Phosphorus in Agriculture is most timely. New challenges are facing us of a magnitude and nature that we have never encountered before. World food and fiber needs are increasing rapidly. The quality of phosphate ores is declining so that new technology must be introduced or shortages will develop. Environmental quality concerns are appearing in mining, manufacture, and use of phosphates. Ways to conserve energy in fertilizer manufacture and use are becoming important in view of energy shortages. Farming systems are changing, and farmers are placing ever greater emphasis on inputs to increase yields and profits. Residual levels of applied phosphorus are building in many intensively farmed soils of the industrial nations on the one hand while many developing nations are having to consider farming the extremely P-deficient high P-fixing acid soils in the tropics and subtropics.

The symposium addresses itself directly to many of these challenges. Its main purpose, however, is to review in depth the present state of knowledge in all phases of phosphorus technology and manufacture, the status of raw materials, reactions and interactions of P in soils, methods for predicting P needs of crops, and nutrition of major crops and animals. Most of the symposium’s reviewers also have pointed out the key problems and areas needing further research.

More research in practically all phases of phosphorus in agriculture, both short and long term, is needed and could have tremendous impact upon farmers, consumers, the fertilizer industry, and entire nations. Many of the pressing problems facing us need immediate solution. It is recognized too that research in phosphorus in agriculture involves a highly complex and difficult area.

There is no substitute for phosphorus in the production of crops and animals for food, fiber, and other essential needs. It behooves researchers, administrators, and governmental institutions alike to take necessary steps to increase research activity in phosphorus for agriculture.

July 1979

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

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<td>0.035 gram, g</td>
<td>ounce (avdp), oz</td>
<td>28.35</td>
<td></td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>14.50 bar</td>
<td>lb/inch², psi</td>
<td>0.06895</td>
<td></td>
</tr>
<tr>
<td>0.9869 bar</td>
<td>atmosphere, atm</td>
<td>1.013</td>
<td></td>
</tr>
<tr>
<td>0.9678 kg (weight)/cm²</td>
<td>atmosphere, atm</td>
<td>1.033</td>
<td></td>
</tr>
<tr>
<td>14.22 kg (weight)/cm²</td>
<td>lb/inch², psi</td>
<td>0.07031</td>
<td></td>
</tr>
<tr>
<td>14.70 atmosphere, atm</td>
<td>lb/inch², psi</td>
<td>0.06805</td>
<td></td>
</tr>
<tr>
<td><strong>Yield or Rate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.446 ton (metric)/hectare</td>
<td>ton (U.S.)/acre</td>
<td>2.24</td>
<td></td>
</tr>
<tr>
<td>0.892 kg/ha</td>
<td>lb/acre</td>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td>0.892 quintal/hectare</td>
<td>hundredweight/acre</td>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
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</tr>
</tbody>
</table>
| \[
\left(\frac{9}{5}^\circ C\right) + 32 \quad \text{Celsius} = \quad \frac{5}{9} (^\circ F - 32) \quad \quad \text{Fahrenheit}
\]
| 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 meters³/hour, m³/hour                | feet³/sec                                     | 101.94                                        |                                               |
| 4.403 meters³/hour, m³/hour                  | U.S. gallons/min                              | 0.227                                         |                                               |
| **Plant Nutrition Conversion—P and K**        |                                               |                                               |                                               |
| \[P \text{ (phosphorus)} \times 2.29 = P_2O_5 \] |                                               |                                               |                                               |
| \[K \text{ (potassium)} \times 1.20 = K_2O \] |                                               |                                               |                                               |

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