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FOREWORD

This is a remarkable book about a remarkable crop. The book began as a revision of American Society of Agronomy Monograph 15, “Alfalfa Science and Technology”, but expanded into the most comprehensive treatment of the accumulated knowledge on alfalfa \(\textit{Medicago sativa L.}\) currently available.

The subject matter of the book ranges from the most fundamental aspects of alfalfa genetics to practical information on alfalfa management. The authors have extremely diverse backgrounds, perspectives, and areas of expertise. This book will be a valuable research and teaching reference, and it should form the basis upon which to launch new research efforts on alfalfa production and use. Hopefully, it will stimulate expanded effort to exploit the still untapped potential of this important species.

We particularly appreciate the efforts of Dr. A. A. Hanson in managing the final review of the book and the important contributions of others in making this a truly excellent product, one in which the American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America can be justly proud. As officers of the tri-societies, we wish to thank W-L Research, Inc., a firm with major involvement in alfalfa research and seed marketing, for permitting A. A. Hanson to edit the monograph as part of his regular employment, and for covering expenses involved in his communication with others.

American Society of Agronomy  
Crop Science Society of America  
D. R. Keeney, \textit{president}, 1988  
Soil Science Society of America
This monograph is a testament to the oldest cultivated forage crop, alfalfa; a crop that has increased in importance over time as a mainstay in the production of livestock products. In many countries, including those in North America, alfalfa is the basic component in feeding programs for dairy cattle, as well as an important feed for beef cattle, horses, sheep, and other classes of livestock. Furthermore, alfalfa enhances the stability of agricultural production systems by improving soil productivity and reducing losses of soil and water.

The importance of alfalfa in world agriculture can be attributed to a number of morphological and physiological characteristics that contribute to its high yield of nutritious herbage, rapid recovery after cutting, longevity, and tolerance to environmental stress. Also, symbiotic N\(_2\) fixation in alfalfa eliminates the need for chemical N, and adds a beneficial carryover effect in crop rotations. In spite of the recognized merits of alfalfa, the crop would not enjoy a competitive advantage in many regions and agricultural zones in the absence of research. Thus, the success of alfalfa production in many countries documents the research efforts of scientists who have adapted germplasm, improved understanding of crop requirements, developed superior cultivars resistant to major pest insects and diseases, advanced seed production technology, and increased efficiency in animal feeding. Recent history suggests that research efforts to maintain and enhance the contribution of alfalfa must be strengthened, in response to new problems and opportunities that will arise with the anticipated trend to more intensive agricultural production systems.

Many major developments have occurred since the publication in 1972 of Monograph 15, *Alfalfa Science and Technology* edited by Clarence H. Hanson. These numerous changes provide the basis for this revision and a new title, *Alfalfa and Alfalfa Improvement*.

Authors exercised judgment in preparing material for inclusion in the revised edition. In some chapters they have included salient information from the previous publication, while in others the authors present a solid inventory of recent achievements with limited reference to older literature. This approach has been effective in providing a comprehensive overview of new and emerging areas of science, together with a balanced assessment of other topics in which new developments have had a modest impact. A significant feature and strength of the new monograph rests on the inclusion of complete citations to the most recent literature. In addition, much new information is presented from such diverse fields as interspecific hybridization, tissue culture and genetic engineering, N\(_2\) fixation, carbon assimilation and partitioning, pest control, crop management, crop utilization, and breeding.

The revision of *Alfalfa Science and Technology* was initiated under the leadership of co-editors D. K. Barnes and R. R. Hill, Jr., who, with an editorial committee consisting of G. H. Heichel, O. J. Hunt, K. T. Leath, G. C. Marten, and M. B. Tesar, identified topics for inclusion and con-
tacted specialists to prepare authoritative chapters for publication. Co­editors and members of the editorial committee were assigned respons­ibility for chapters in their respective areas of expertise. In this capacity they received manuscripts, arranged for peer reviews, and corresponded with authors in the revision of manuscripts. Subsequently, I was asked to finalize the monograph in an effort to expedite publication. Efforts of the editorial committee are recognized by identifying them as associate editors.

As senior editor, I assumed sole responsibility for final editorial clear­ance and submitting all chapters to the Society for publication. Full credit must be given to authors and coauthors who prepared the 34 informative chapters; to my co-editors and associate editors for their efforts in ar­ranging for reviews and revisions; to numerous scientists who reviewed individual chapters; and to the managing editor and Society staff for bringing the monograph to press. Although credit must be assigned as stated, I remain accountable for any oversights and deficiencies that should have been corrected during the final review.

Grateful acknowledgment is extended to my employer, W-L Research, Inc., who provided me with time to edit the monograph as a part of my regular duties, and for covering expenses involved in communicating with authors. My contribution would have been impossible in the absence of support from W-L Research, Inc.

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<th>Title and Affiliation</th>
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<tbody>
<tr>
<td>George R. Manglitz</td>
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</tr>
<tr>
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<td>Lead Scientist, USDA-ARS, Minnesota Agricultural Experiment Station, St. Paul, Minnesota</td>
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**Conversion Factors for SI and non-SI Units**

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<th>Column 2 (non-SI Unit)</th>
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<tr>
<td>hectare, ha</td>
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<tr>
<td>acre</td>
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<td>acre</td>
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<td>square meter, m²</td>
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<td>square mile, mi²</td>
<td>4.05 X 10³</td>
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<tr>
<td>square meter, m²</td>
<td>10.76</td>
<td>square foot, ft²</td>
<td>9.29 X 10⁻²</td>
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<tr>
<td>square millimeter, mm² (10⁻⁶ m²)</td>
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<td>square inch, in²</td>
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<tr>
<td>cubic meter, m³</td>
<td>9.73 X 10⁻¹</td>
<td>acre-inch</td>
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<td>35.3</td>
<td>cubic foot, ft³</td>
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<td>cubic meter, m³</td>
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<td>cubic inch, in³</td>
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<tr>
<td>liter, L (10⁻¹ m³)</td>
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<tr>
<td>liter, L (10⁻¹ m³)</td>
<td>0.265</td>
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<tr>
<td>liter, L (10⁻¹ m³)</td>
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<td>pint (fluid), pt</td>
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continued on next page
To convert Column 1 into Column 2, multiply by

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<th>non-SI Unit</th>
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<td>gram, g (10^{-3}) kg</td>
<td>pound, lb</td>
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<tr>
<td>gram, g (10^{-2}) kg</td>
<td>ounce (avdp), oz</td>
<td>28.4</td>
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<tr>
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<td>pound, lb</td>
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<tr>
<td>kilogram, kg</td>
<td>quintal (metric), q</td>
<td>(10^2)</td>
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<tr>
<td>kilogram, kg</td>
<td>ton (2000 lb), ton</td>
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<tr>
<td>kilogram, kg</td>
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<tr>
<td>megagram, Mg (tonne)</td>
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**Mass**

- \(0.893\) kilogram per hectare, kg ha\(^{-1}\)
- \(7.77 \times 10^{-2}\) kilogram per cubic meter, kg m\(^{-3}\)
- \(1.49 \times 10^{-2}\) kilogram per hectare, kg ha\(^{-1}\)
- \(1.59 \times 10^{-2}\) kilogram per hectare, kg ha\(^{-1}\)
- \(1.86 \times 10^{-2}\) kilogram per hectare, kg ha\(^{-1}\)
- \(0.107\) liter per hectare, L ha\(^{-1}\)
- \(893\) tonnes per hectare, t ha\(^{-1}\)
- \(893\) megagram per hectare, Mg ha\(^{-1}\)
- \(0.446\) megagram per hectare, Mg ha\(^{-1}\)
- \(2.24\) meter per second, m s\(^{-1}\)

**Yield and Rate**

- \(0.12\) pound per acre, lb acre\(^{-1}\)
- \(12.87\) pound per bushel, lb bu\(^{-1}\)
- \(67.19\) bushel per acre, 60 lb
- \(62.71\) bushel per acre, 56 lb
- \(53.75\) bushel per acre, 48 lb
- \(9.35\) gallon per acre
- \(1.12 \times 10^{-3}\) pound per acre, lb acre\(^{-1}\)
- \(1.12 \times 10^{-3}\) pound per acre, lb acre\(^{-1}\)
- \(2.24\) ton (2000 lb) per acre, ton acre\(^{-1}\)
- \(0.447\) mile per hour

**Specific Surface**

- \(0.1\) square centimeter per gram, cm\(^2\) g\(^{-1}\)
- \(10^{-3}\) square millimeter per gram, mm\(^2\) g\(^{-1}\)
### Pressure

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<td>9.90</td>
<td>megapascal, MPa (10^6 Pa)</td>
<td>0.101</td>
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<td>1.00</td>
<td>megapascal, MPa (10^6 Pa)</td>
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<tr>
<td>2.09 × 10^-2</td>
<td>pascal, Pa</td>
<td>1.00</td>
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<td>1.45 × 10^-4</td>
<td>pascal, Pa</td>
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<td>6.90 × 10^-3</td>
<td>gram per cubic centimeter, g cm^-3</td>
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### Temperature

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<tr>
<td>1.00 (K - 273)</td>
<td>Kelvin, K (9/5 °C + 32) Celsius, °C</td>
<td>1.00 (°C + 273)</td>
</tr>
<tr>
<td>5/9 (°F - 32)</td>
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<td>5/9 (°F - 32)</td>
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### Energy, Work, Quantity of Heat

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<td>0.239</td>
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<td>erg</td>
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<td>2.387 × 10^-3</td>
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<tr>
<td>10^-5</td>
<td>foot-pound</td>
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<tr>
<td>10^-2</td>
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### Transpiration and Photosynthesis

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<td>3.60 × 10^-2</td>
<td>milligram per square meter second, mg m^-2 s^-1</td>
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<td>5.56 × 10^-3</td>
<td>milligram (H2O) per square meter second, mg m^-2 s^-1</td>
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<td>10^-4</td>
<td>milligram per square meter second, mg m^-2 s^-1</td>
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</tr>
<tr>
<td>35.97</td>
<td>milligram per square meter second, mg m^-2 s^-1</td>
<td>2.78 × 10^-2</td>
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### Plane Angle

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<tr>
<td>57.3</td>
<td>radian, rad</td>
<td>1.75 × 10^-2</td>
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### Conversion Factors for SI and non-SI Units

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</table>

#### Electrical Conductivity

- 10 siemen per meter, S m^{-1} = millimho per centimeter, mmho cm^{-1} = 0.1

#### Water Measurement

- 9.73 × 10^{-3} cubic meter, m^3
- 9.81 × 10^{-3} cubic meter per hour, m^3 h^{-1}
- 4.40 cubic meter per hour, m^3 h^{-1}
- 8.1 hectare-meters, ha-m
- 97.28 hectare-meters, ha-m
- 8.1 × 10^{-2} hectare-centimeters, ha-cm

- acre-inches, acre-in = 102.8
- cubic feet per second, ft^3 s^{-1} = 101.9
- U.S. gallons per minute, gal min^{-1} = 0.227
- acre-feet, acre-ft = 0.123
- acre-inches, acre-in = 1.03 × 10^{-2}
- acre-feet, acre-ft = 12.33

#### Concentrations

- 1 centimole per kilogram, cmol kg^{-1} (ion exchange capacity) = milliequivalents per 100 grams, meq = 1
- 0.1 gram per kilogram, g kg^{-1} = percent, %
- 1 milligram per kilogram, mg kg^{-1} = parts per million, ppm = 1

#### Radioactivity

- 2.7 × 10^{-11} bequerel, Bq = curie, Ci = 3.7 × 10^{10}
- 2.7 × 10^{-2} bequerel per kilogram, Bq kg^{-1} = picocurie per gram, pCi g^{-1} = 37
- 100 gray, Gy (absorbed dose) = rad, rd = 0.01
- 100 sievert, Sv (equivalent dose) = rem (roentgen equivalent man) = 0.01

#### Plant Nutrient Conversion

<table>
<thead>
<tr>
<th>Elemental</th>
<th>Oxide</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>P_2O_5</td>
<td>0.437</td>
</tr>
<tr>
<td>K</td>
<td>K_2O</td>
<td>0.830</td>
</tr>
<tr>
<td>Ca</td>
<td>CaO</td>
<td>0.715</td>
</tr>
<tr>
<td>Mg</td>
<td>MgO</td>
<td>0.602</td>
</tr>
</tbody>
</table>