PROCEEDINGS OF THE
THIRD INTERNATIONAL
TURFGRASS RESEARCH
CONFERENCE

Sponsored by the International Turfgrass Society, July 11–13, 1977,
Munich, West Germany

James B. Beard, editor

Published by
The American Society of Agronomy, the Crop Science Society of America,
the Soil Science Society of America, and
the International Turfgrass Society
Madison, Wisconsin, USA
FOREWORD

It is again our pleasure and professional opportunity to collaborate with the International Turfgrass Society (ITS) in the publication of these proceedings of the Third International Turfgrass Research Conference. Members of the American Society of Agronomy (ASA), the Crop Science Society of America (CSSA), and the Soil Science Society of America (SSSA) have actively participated in the Conference and thus all four collaborating societies share in presenting this written record in the conviction that it will provide useful documentation to the pursuit of turfgrass science in all parts of the world.

ITS is now more than a decade old. It was organized on the occasion of the First International Turfgrass Research Conference in Harrogate, England, in July 1969. The Second Conference, held in Blacksburg, Virginia, 19–21 June 1972, gave strong evidence of the truly international scope of turfgrass science. Not only were there more scientists present from outside the United States than from within, but total attendance for that second conference was double the first.

And now the efforts of 91 scientists from 12 countries as reported during the July 1977 meetings in Munich, Germany, are recorded here. Thus, an expanding breadth and diversity of participants should provide the individual working as a turfgrass researcher, extension specialist, classroom teacher, industry representative, or practicing turfgrass professional manager with insights and perspectives that will strengthen each one's capacity to perform their chosen roles.

And again participation grows—in the 1977 conference there were 266 participants from 19 countries, an increase over the second conference of 74 participants.

We congratulate all those who shared in making this contribution possible, who labored to present this current summary of turfgrass science in a condensed source to assist all who pursue the field.

Roger L. Mitchell, President
American Society of Agronomy

William E. Larson, President
Soil Science Society of America

Billy E. Caldwell, President
Crop Science Society of America
PREFACE

The future quality of life of man on this earth would be bleak without the aesthetic and functional contributions of turfs and ornamental plants. Man has chosen to cultivate turfgrasses for his benefit since the 13th century when turfs, as we know them today, started to evolve in England. The culture of turfs has increased steadily during the past four centuries in the industrialized countries of the world. The continuing effort to seek an improved quality of life is one that people will not readily abandon. In fact, the proper use of plants in environmental manipulation is an important aspect that is receiving greater attention than ever before. The willingness to invest time and money in maintaining turfs in order to provide a more favorable environment for human activities is evidence that turfs are an important aspect in a desirable quality of life.

In the future there will no doubt be changes in the types of turfs and the ways they will be maintained. These changes will be affected by higher energy costs for maintenance and more limited water supplies in many locations. We will need turfgrasses and cultural practices that require less energy and water inputs, but at the same time continue to provide quality, functional turfs to meet the needs of a modern society. These projected changes present us with a challenge and justification for turfgrass research that is greater than it has ever been. As a science, turfgrass culture is just in its infancy compared to most areas of applied plant science.

The first concepts of an International Turfgrass Research Conference evolved during discussions between Bjarne Langvad and myself at East Lansing, Michigan, in the fall of 1966. The initial projection was that if 20 persons attended the first conference it would be judged successful. In fact, the First International Turfgrass Research Conference held in 1969 at Harrogate, England, had 83 registrants representing 13 countries, with 99 papers presented. The second conference, held at the Virginia Polytechnic Institute and State University in the United States in 1973, had 247 registrants from 15 countries, with 80 research papers presented. Most recently, at the third International Turfgrass Research Conference in Munich, West Germany, 229 persons attended from 17 countries, with 95 papers presented. Participation at these conferences is strong evidence of the growing interest and activity in turfgrass research and education.

The Proceedings represents a permanent record of the concepts, research results, and descriptive information presented at the conference. It is particularly significant that this is the only publication which brings together a summary of the representative research activities currently being conducted throughout the world. The Proceedings facilitates communications among turfgrass researchers and educators.
As editor, I would like to express appreciation for the cooperation and very hard work of the Editorial Board members and Domenic Fuccillo in preparation of the Proceedings. The Associate Editors assumed responsibility for conducting the initial review for specific subject matter areas. Each paper was reviewed by a minimum of three turfgrass scientists, with at least one reviewer being from a European country. The cooperation of individual authors during the revision of manuscripts is also appreciated.

Two types of papers were approved for publication. The first portion of the Proceedings contains research papers which represent a new contribution to the scientific field and which test hypotheses through replicated treatments that can be analyzed statistically to establish the validity of the investigation. The second group of papers are Observational Notes which make a contribution to the general knowledge in the field through descriptions of turfgrass conditions or problems that are being reported for the first time. Finally, the meeting minutes and official actions of the International Turfgrass Society, a glossary of the turfgrass terms used in the Proceedings, and a subject index, are included in the back of the book.

As with its two predecessors, this Third International Turfgrass Research Conference Proceedings will serve as a valuable reference for turfgrass researchers, teachers, adult education instructors, research and development specialists with private companies, and students of Turfgrass Science. The ultimate goal is that through the information contained in the Proceedings the public will benefit from lower cost, simplified turfgrasses and cultural systems which still retain their important functional and aesthetic benefits and thus enhance the physical, mental, and environmental quality of life for the peoples of this earth.

James B. Beard
Turfgrass Physiologist
Texas A&M University
College Station, Texas
CONTENTS

Foreword ................................................................. iii
Preface ........................................................................ v
Participants and Contributors ........................................ xiii
Conversion Factors for English and Metric Units ............... xxi

SECTION I BREEDING AND CULTIVAR EVALUATION

1 Comparisons of Micro-trials and Spaced Plant Nurseries
   with Dense Swards as Means for Evaluating Turfgrass
   Genotypes
   B. Bourgoin & P. Mansat ........................................... 3

2 The Breeding of Lines of Agrostis tenuis Sibth. and
   Festuca rubra L. Tolerant of Grass-killing Herbicides
   R. Fisher & C. E. Wright ........................................... 11

3 An Approach to Turfgrass Cultivar Evaluation
   A. J. Turgeon & J. M. Vargas, Jr. .............................. 19

4 Differences in Sod Strength, Rooting, and Turfgrass
   Quality of Kentucky Bluegrass Cultivars Resulting
   from Seasonal and Environmental Conditions
   L. H. Taylor & R. E. Schmidt ................................... 31

5 Perennial Ryegrass Mowing Quality and Appearance
   Response to Three Nitrogen Regimes
   V. A. Gibeault & D. Hanson .................................... 39

6 The Principles of Blending Kentucky Bluegrass
   Cultivars for Disease Resistance
   J. M. Vargas, Jr. & A. J. Turgeon ............................ 45

7 The Performance of Phleum and Cynosurus on
   Sports Fields
   C. Mehnert .......................................................... 53

8 Turfgrass Seed Mixtures in the United Kingdom
   J. P. Shildrick ....................................................... 57

9 Response of Warm- and Cool-Season Turfgrass Polystands
   to Nitrogen and Topdressing
   D. T. Hawes ........................................................ 65

10 Seasonal Performance of Selected Temperate Turfgrasses
    Overseeded on Bermudagrass Turf for Winter Sports
    R. E. Schmidt & J. F. Shoulders ............................. 75

SECTION II GROWTH AND DEVELOPMENT

11 The Effects of Stage of Seedling Development on
    Selected Physiological and Morphology Parameters
    in Kentucky Bluegrass and Red Fescue
    J. V. Krans & J. B. Beard ................................... 89
12 Tillering and Persistency in Perennial Ryegrass
   J. W. Minderhoud ........................................... 97

13 Variations in the Growth and Development of Annual
   Bluegrass Populations Selected from Seven Different
   Sports Turf Areas
   W. A. Adams & P. J. Bryan ................................. 109

14 Comparisons of Direct and Indirect Determinations of
   Root Weights of Several Turfgrasses
   W. Opitz von Boberfeld ................................. 117

SECTION III  ENVIRONMENT STRESS

15 Root Growth and Phosphorus Responses Among Clones
   of Creeping Bentgrass at Low Temperatures
   W. R. Kneebone & G. V. Johnson .......................... 125

16 Temperature Influences on Mineral Nutrient Distribution
   in Two Kentucky Bluegrass Cultivars
   J. E. Kaufmann & D. E. Aldous ......................... 135

17 Influence of Aeration and Genotype upon Root Growth
   of Creeping Bentgrass at Supra-Optimal Temperatures
   K. W. Kurtz & W. R. Kneebone .......................... 145

18 Cold Acclimation and Deacclimation in Cool Season
   Grasses
   D. B. White & M. H. Smithberg .......................... 149

19 Anatomical and Physiological Effects of Air Pollutants
   on Turfgrasses
   V. B. Youngner & F. J. Nudge .......................... 155

20 Tolerance of Turfgrass Cultivars to Salt
   K. Ahti, A. Moustafa & H. Kaerwer ........................ 165

SECTION IV  SOIL REACTION, FERTILIZATION, AND
   ROOT ZONE MODIFICATION

21 Lime Responses of Kentucky Bluegrass and Tall Fescue
   Cultivars on an Acid, Aluminum-Toxic Soil
   J. J. Murray & C. D. Foy ................................. 175

22 Nitrogen Leaching in Bermudagrass Turf: Daily Fertigation
   vs. Tri-weekly Conventional Fertilization
   G. H. Snyder, E. O. Burt & J. M. Davidson ................ 185

23 Proposed Standards and Specifications for Quality of
   Sand for Sand-Soil-Peat Mixes
   G. R. Blake ................................................ 195

24 Bentgrass Growth in Relation to Soil Properties of
   Typic Hapludalfs Soil Variously Modified for a
   Golf Green
   R. E. Schmidt ............................................. 205
SECTION V WEED CONTROL

25 Differences in Tolerance of Bermudagrass and Zoysiagrass Cultivars to Herbicides
   B. J. Johnson .................................................. 217

26 Development and Rooting of Kentucky Bluegrass Sod as Affected by Herbicides
   J. A. Jagschitz .................................................. 227

27 Goosegrass Control in Bermudagrass
   S. W. Bingham & R. L. Shaver ................................. 237

28 The Effects of Repeated Applications of Bensulide and Tricalcium Arsenate on the Control of Annual Bluegrass and on Quality of Highland Colonial Bentgrass Putting Green Turf
   R. L. Goss, T. W. Cook, S. E. Brauen & S. P. Orton ........ 247

29 Glyphosate for Torpedograss and Bermudagrass Control
   E. O. Burt .................................................. 257

SECTION VI DISEASES AND NEMATODES

30 Yellow Tuft Disease of Turfgrasses: A Review of Recent Studies Conducted in Rhode Island
   N. Jackson .................................................. 265

31 Snow Molds on Minnesota Golf Greens
   W. C. Stienstra .................................................. 271

32 Snow Mold Resistance in Turfgrasses and the Need for Regional Testing
   J. D. Smith .................................................. 275

33 The Possibility of Controlling Fairy Ring and Rust Diseases in Lawns with Benodanil
   R. Heimes & F. Loecher ........................................ 283

34 Role of a Soil Fungicide and Two Nematicides in Maintaining Bermudagrass and Creeping Bentgrass Turf
   R. V. Sturgeon, Jr. & K. E. Jackson .......................... 293

SECTION VII CULTURAL PRACTICES AND SYSTEMS

35 Effects of Growth Retardants on the Shoot and Root Growth of Roadside Turfgrasses
   R. C. Wakefield & S. L. Fales .................................. 303

36 Growth Retardant Effects on Grasses for Roadsides
   R. W. Duell, R. M. Schmit & S. W. Cosky .......................... 311

37 Turfgrass Growth Reduction by Means of a New Plant Growth Regulator
   P. E. Schott, H. H. Nölle & H. Will .......................... 325
38 Influence of Silica on Chemical Composition and Decomposition of Turfgrass Tissue
   J. R. Street, P. R. Henderlong & F. L. Himes ............................... 329

39 Influence of Fertilizer Rate, Mower Type, and Thatch Control on Colonial Bentgrass Lawn Turf
   C. R. Skogley ................................................................. 337

40 Effects of Nitrogen Fertilization and Cutting Height on the Shoot Growth, Nutrient Removal, and Turfgrass Composition of an Initially Perennial Ryegrass Dominant Sports Turf
   W. A. Adams ................................................................. 343

SECTION VIII SOD PRODUCTION AND ESTABLISHMENT

41 Investigation of Net-Sod Production as a New Technique
   J. B. Beard, D. P. Martin & F. B. Mercer .................................. 353

42 Techniques for Rapid Sod Production
   R. E. Burns ................................................................. 361

43 Effect of Cultural Factors on Tall Fescue-Kentucky Bluegrass Sod Quality and Botanical Composition
   J. R. Hall, III ............................................................... 367

44 Seedling Competition of Kentucky Bluegrass, Red Fescue, Colonial Bentgrass, and Temporary Grasses
   R. E. Engel & J. R. Trout .................................................... 379

45 Research into the Establishment of Roadside Embankments
   P. Henensal, G. Arnal & J. Puig ............................................ 391

46 Studies on the Development of Turfgrass Seedings on Roadsides in the Federal Republic of Germany
   W. Trautman & W. Lohmeyer .................................................. 401

SECTION IX OBSERVATIONAL NOTES

1 Characteristics, Breeding Methods, and Seed Production of Poa supina Schrad.
   P. Berner ................................................................. 409

2 Observations on Differently Adapted Grasses for Turf in Central Italy
   A. Panella ................................................................. 413

3 Some Ecological Observations on Turf Establishment and Culture of Turfgrasses in Cool Regions of Japan
   Y. Oohara ................................................................. 419

4 Evolution of Improved Lawngrasses in America: A Review of Major Events Leading to the Kentucky Bluegrass Cultivar Revolution
   R. W. Schery ............................................................. 423
5 Tree Shade Adaptation of Turfgrass Species and Cultivars in France
   A. Chesnel, R. Crosie & B. Bourgoin .............................. 431
6 Some Physical Aspects of Sports Turfs
   P. Boekel .................................................................. 437
7 Soil Conditioning by Synthetic Media
   H. Franken ............................................................... 443
   A. L. M. van Wijk & J. Beening ...................................... 451
9 The Influence of Deicing Salts on Soil and Turf Cover
   H. G. Brod & H.-U. Preusse .......................................... 461
10 Observations of Fusarium roseum F. sp. cerealis
    (Synd. & Hans.) on Turfgrasses in Sweden
    S-O Dahlsson ............................................................ 469
11 The USGA Stimpmeter for Measuring the Speed of Putting Greens
    A. M. Radko ............................................................. 473
12 Structuring Courses in Turfgrass Science to Stimulate Improved Management Practices
    H. H. Williams .......................................................... 477
13 The Problems and Present State of Public Green Spaces, Parks, and Sports Grounds in Prague, Czechoslovakia
    B. Konicek ................................................................ 485

SECTION X APPENDIXES

   Research Conference Program ........................................ 491
   Constitution and Bylaws ................................................ 497
   Minutes: ITRC Planning Meeting of the ITS Executive Committee .... 501
   Minutes: Executive Committee ........................................ 503
   Full Membership Meeting .............................................. 504
   Treasurer's Report ...................................................... 506
   Glossary of Turfgrass Terms ......................................... 507

INDEX .......................................................................... 517
PARTICIPANTS & CONTRIBUTORS

W. A. Adams* Soil Science Unit, University College of Wales, Aberystwyth, United Kingdom
K. Ahti* Northrup-King & Co., 1500 Jackson St., N.E., Minneapolis, Minnesota 55413
G. L. Akesson AB Hammenhoks Fro, 270 50, Hammenhok, Sweden
D. E. Aldous* Environmental Horticulture, Massey University, Palmerston North, New Zealand
Manfred Altenburg-Herfurth Ringstr. 17, 3302 Cremlingen 1, Germany
Jan Andringa Cebecco-Handelsraad, Plantage Willem 111, Elst (Utr.), Netherlands
G. Arnal* Laboratoire Regional de l'Ouest Parisien 12, Rue Leisserenc de Bort BP 108, 78 195 Trappes Cedex, France
Jobst von Arnim Versuchsstation Christinenthal, 2211 Christinenthal, Germany
J. M. Audy FNAMS, 9, Rue des Fleures, 49000 Angers, France
Giacomo Barabino Intercachel SA-15, Cendrier-Centre, 1201 Geneva, Switzerland
Hans Baukloh Kleinwanzlebener Saatzucht AG, Postfach 146, 3352 Einbeck, Germany
J. B. Beard* Department of Soil & Crop Sciences, Texas A&M University, College Station, Texas 77843
Philipp Berner* Saatzucht Steinach, D-8441 Steinach uber Straubing, West Germany
J. Beving* Institute for Land & Water Management Research, P.O. Box 35, 6700 AA Wageningen, The Netherlands
S. W. Bingham* Plant Pathology & Physiology Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061
G. R. Blake* Soil Science Department, University of Minnesota, St. Paul, Minnesota 55108
P. Blumberg S/48 Gruenanlagen GmbH, Holzhausenstr. 18, 5020 Frechen 5, Germany
P. P. Boekel* Lutsborgsweg 68, Haren (Gr.), Netherlands
Peter Boeker Institut für Pflanzenbau, Katzenburgweg 5, 5300, Bonn, West Germany
Bernard Bonay Veyret 16, Rue Cortambert, 75016, Paris, France
R. W. Bond 26 Cornig Road, Willowdale, Ontario, M2J 2L7, Canada
P. Boskovic Sport Object Adviser, Dr. Ribara 1, 21000 Novi Sad, Yugoslavia
Bernard Bourgoin* Station d'Amelioration des Plantes Fourrageres, 86600 Lusignan, France
Peter Bowen Fisions Ltd., Levington Research Station, Levington, Ipswich, Suffolk, IP10 OLU, United Kingdom
S. E. Brauen* Western Washington Research and Extension Center, Puyallup, Washington 98371
H. G. Brod* Justus-Liebig Univ., Bottengasse 12, 6308 Butzbach 8, West Germany
Jurgen Bronner Im Johannistall 11, 5600 Wuppertal 1, West Germany
Richard Brunner Sachsenspiegelstr. 11, 8000, Munchen 50, West Germany

* All names followed by an asterisk indicate contributors.
Toyoji Hosotsuji 3-13-8, Minamiaoyama, Minato-Ku, Tokyo, Japan
W. W. Huffine Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma 74014
M. O. Humphreys Department of Botany, University of Liverpool, P.O. Box 147, Liverpool L69 3BX, United Kingdom
Shinsaku Ideta 1-15-8, Nishishinjuku, Shinjuku-Ku, Tokyo, Japan
Franz Indra
K. E. Jackson* 115 Life Science East, Oklahoma State University, Stillwater, Oklahoma 74078
Noel Jackson* Department of Plant Pathology, 223 Woodward Hall, University of Rhode Island, Kingston, Rhode Island 02881
J. A. Jagschitz* Plant & Soil Science Department, Rhode Island Agricultural Experiment Station, Kingston, Rhode Island 02881
Dora Joge Samen-Mauser, Zurichstr. 98, Postfach 8600, Dubendorf, Switzerland
B. J. Johnson* Department of Agronomy, University of Georgia Experiment Station, Experiment, Georgia 30212
G. V. Johnson* Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma 74074
H. A. Jonnson Weibullsholm Plant Breeding Institute, Fack, 261 20, Landskrona, Sweden
H. E. Kaerwer* Northrup-King & Co., 1500 Jackson St., N.E., Minneapolis, Minnesota 55413
Saburo Kakuda Hodoagaya Country Club, 1324 Kami-kawai-cho, Asahiku, Yokohama-Shi, Japan
H. A. Kamp Veldkantweg, Eerbeek, Netherlands
Ir. Kamps Vijfhoevenlaan 4, Postbox 35, 5250 AA Vlijmen, Netherlands
Alfred Karban Waldstr. 2, 5307 Wachtberg-Pech, Germany
Ernst Karpf Fa. Euflor GmbH, Nymphenburger Str. 120, 8000 Munchen, West Germany
J. E. Kaufmann* Department of Crop & Soil Sciences, Michigan State University, East Lansing, Michigan 48824
Cornelius Kennema P.O. Box 49, Hoogezaand, Netherlands
Klaus Kind Am Bierkeller 10, 8751 Eschau, Germany
Hiroshi Kizawa 1-15-8, Nishishinjuku, Shinjuku-Ku, Tokyo, Japan
Barbara Klinzmann 2331 Hohenlieth, Post Holsee, Eckernförde, Germany
W. R. Kneebone* Department of Plant Sciences, University of Arizona, Tucson, Arizona 85721
Bretislav Konicek* CSTV/Czechoslovak Association for Physical Culture, Praha-Strahov, Czechoslovakia
Hermann Koppius Gounopstraat 35, Zevenaar, Netherlands
J. V. Krans* Department of Agronomy, P.O. Box 5248, Mississippi State, Mississippi 39762
H. U. Krebs G. R. Vatter AG, Samen, Sagestr. 65, 3098 Konitz, Switzerland
Jutta Kruger Moosstr. 20, 8050 Freising, Germany
K. W. Kurtz* California State Polytechnical University, 3801 Temple Avenue, Pomona, California 91768
Claude Lambert Ste Truffaut, 21, rue des Pepinieres, Les Noels, 41350 Vineuil, France
E. R. Larsen 3560 Tjotta, Norway
Werner Lanz Landwirtschaftliche Versuchstation, BASF AG, Postfach 220, 6703 Limburgerhof, West Germany
F. B. Ledeboer Cloverdale Nursery, 2528 N. Cloverdale, Boise, Idaho 83702
J. Leinauer Ludwigstr. 11, 8922 Peiting/Obb., Germany
Francis Lenaire Station d’Agronomie, Rout de St. Clement, Beaucouze, 49000 Angers, France
Francis Lenior
F. Loecher
W. Lohmeyer
Roger Loiseau
Ernst Lutke Entrup
Yoshisuke Maki
Johannes von Malek
Paul Mansat
Horst Mark
D. P. Martin
Marc Masson
Volker May
Clemens Mehnert
F. B. Mercer
Gunther Michelman
J. W. Minderhoud
Osamu Mizutani
Roland Moesch
Uwe Moller
Gunter Molzahn
W. C. Morgan
Yoshihiro Mori
Norbert Mott
Adly Moustafa
K. G. Muller-Beck
J. J. Murray
Roland Muse
Hideo Nabeshima
Shigemasa Nagae
R. W. Nelson
Maria Nejez
Mitsutaka Nishimura
F. J. Nudge
Yoichi Oohara
N. D. Olsen
W. O. von Boberfeld
Siegfried Orberger
S. P. Orton
Motonori Otsuka

Rue Emile Semal 21, 1310 Gaillenarde-La Hulpe, Belgium
Kropsburgstra. 34, 6703 Limburgerhoff, BRD, West Germany
Bundesforschungsanstalt fur Naturschutz und Landschaftskologie, Heerstr. 110, D5300 Bonn 2, West Germany
Los Goderies, 72000 Ruaudin, France
Landsberger Str. 2, 4780 Lippstadt, West Germany
Hokkaido Nat'l Agricultural Experiment Station, Hit-sujigaoka, Toyohira-ku, Sapporo 061-01, Japan
Stattl. Lehr-u. Versuchsanstalt, fur Gartenbau, Diebsweg 2, 6900 Heidelberg, West Germany
S.A.P.F., 86600 Lusignan, France
Staudinger Str. 72, 8000 Munchen 83, West Germany
Societe L. Claus, 91220 Bretigny, sur Orge, France
Westendstr. 16, 8016 Feldkirchen, Germany
Lehrstuhl fur Gronlandlehr, 8050 Freising-Weihenstephan, Germany
Zuchtstation NFG, 2831 Kirchseele, Germany
Haarweg 33, Wageningen, Netherlands
2271, Nishikataokushinden, Kuwana-Shi, Mie-ken, Japan
Cellsystem AG/SA, Winkelstr. 19, 4665 Oftringen, Switzerland
Compo GmbH, Postfach 2107, 4400 Munster, West Germany
HESA, Bismarck-Str. 59, 6100 Darmstadt, West Germany
73813 Cholame Dr., Diamond Bar, California 91765
6-18-5, Shimbashi, Minato-Ku, Tokyo, Japan
Landesanstalt fur Okologie, Landwirtschaftsentwicklung u., Forstplanung, Zum Breijpott 15, 4190 Kleve-Kellen, Germany
Northrup-King & Co. Research Station, Research Road, Eden Prairie, Minnesota 55344
SEA, USDA, Field Crops Laboratory, Rm. 333, B-001, BARC-West, Beltsville, Maryland 20705
M.R.I. Route 113, Souderton, Pennsylvania 18964
No. 211, 23, Chihaya 1-chome, Higashi-Ku, Fukuoka-Shi, Fukuoka-Ken, Japan
1318-1, Kamiwajiro, Higashi-Ku, Fukuoka-Shi, Fukuoka-Ken, Japan
Jacobsen Manufacturing Company, 1721 Packard Avenue, Racine, Wisconsin 53403
Freytaggasse 21/13, 1210 Wien, Austria
41-411, Higashihashi-Cho, Ashiya-Shi, Hyogo-Ken, Japan
Department of Agronomy, University of California, Riverside, California 92502
29-1, Nishi 3-jo, Minami, Obihiro-Shi, Hokkaido, Japan
D. L. F. Oestergade 7-9, 4000 Roskilde, Denmark
Institut fur Pflanzenbau, Katzenburgweg 5, 5300 Bonn, West Germany
Gesellschaft Gruen, Bruggenstr. 22, 4390 Gladbeck, West Germany
Rt. 1, P.O. Box 722, Sumner, Washington 98390
9-21, Minamikasugaoka 5-chome, Ibaraki-Shi, Osaka-Fu, Japan
A.L.M. van Wijk*
J. M. Vargas, Jr.*
Walter Versteeg
Roelot Vijn
Edmond de Vilmorin
Felix Riem Vis
Reimer Vogel
Gerhard Voigtlander
James Vorst
Harm Vos
Dieter Wagner
Helmut Wagner
R. C. Wakefield*
Arnold Walker
P. L. Waller
J. R. Watson
Peter Weibull
D. B. White*
Hannelore Will*
H. H. Williams*
C. E. Wright*
Hisashi Yanagi
Masayoshi Yoshida
Isao Yoshikawa
V. B. Youngner*
F. Xaver Zacherl

Institute for Land and Water Management Research, P.O. 35, Wageningen, Netherlands
Department of Botany and Plant Pathology, Michigan State University, East Lansing, Michigan 48824
Heidemy Nederland B.V., Postbus 139, Arnhem, Netherlands
Cebeo Handelsraad, Vijfhoevenlaan 4, Vlijmen, Netherlands
42, Avenue Franklin Roosevelt, 72210 Avon, France
Institute for Soil Fertility, Oosterweg 92, Haren (Gr.), Netherlands
Wolf-Gerate GmbH, Gregor-Wolf-Str., 5240 Betzdorf, West Germany
Lehrstuhl fur Grunlandlehre, 8050 Freising-Weihenstephan, Germany
Department of Agronomy, Purdue University, West Lafayette, Indiana 47907
Rivro, Postbox 32, Wageningen, Netherlands
Landwirtschaftliche Versuchsstation, BASF AG, Postfach 220, 703 Limburgerhof, West Germany
Krieger Str. 3, 8000 Munchen 90, West Germany
Plant & Soil Science Department, University of Rhode Island, Kingston, Rhode Island 02881
GRO-Green Product, Inc., 717 Elk Street, Buffalo, New York 14210
Fisons, Ltd., Levington Research Station, Levington, Ipswich, Suffolk, IP10 OLU, United Kingdom
The Toro Company, One Appletree Square, 8009-34th Avenue South, Minneapolis, Minnesota 55420
Saatzuchtanstalt Weibullsholm, Fack, 261 20 Landskrona, Sweden
Department of Horticulture and Landscape Architecture, University of Minnesota, St. Paul, Minnesota 55108
Landwirtschaftliche Versuchsstation, BASF AG, Postfach 220, 6703 Limburgerhof, West Germany
1128 East 80th Street, Los Angeles, California 90001
Department of Agricultural Biology, Queen’s University of Belfast, Newforge Lane, Belfast BT9 5PX, Northern Ireland
Toyo Green Co., Ltd., Nr. 4 Taiso, Koami Bldg. I-1-6, Nihonbashi Ningyo-Cho Chuo-Ku, Tokyo 103, Japan
Faculty of Agriculture, Shizuoka University, 836 Ohya, Shizuoka 422, Japan
3-1-5, Kawamo, Takarazuka-Shi, Hyogo-Ken, Japan
Department of Agronomy, University of California, Riverside, California 92502
Strassen-u. Teerbau Gmbh, Drachenseestr. 10, 8000 Munchen 70, West Germany
### CONVERSION FACTORS FOR ENGLISH AND METRIC UNITS

To convert column 1 into column 2, multiply by

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td></td>
</tr>
<tr>
<td>kilometer, km</td>
<td>mile, mi</td>
</tr>
<tr>
<td>0.621</td>
<td>1.609</td>
</tr>
<tr>
<td>meter, m</td>
<td>yard, yd</td>
</tr>
<tr>
<td>1.094</td>
<td>0.914</td>
</tr>
<tr>
<td>centimeter, cm</td>
<td>inch, in</td>
</tr>
<tr>
<td>0.394</td>
<td>2.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Area</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>kilometer², km²</td>
<td>mile², mi²</td>
</tr>
<tr>
<td>0.386</td>
<td>2.590</td>
</tr>
<tr>
<td>247.1</td>
<td>0.00405</td>
</tr>
<tr>
<td>hectare, ha</td>
<td>acre, acre</td>
</tr>
<tr>
<td>2.471</td>
<td>0.405</td>
</tr>
<tr>
<td>are, a</td>
<td>1,000 ft²</td>
</tr>
<tr>
<td>1.076</td>
<td>0.929</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Volume</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>meter³, m³</td>
<td>acre-inch</td>
</tr>
<tr>
<td>0.00973</td>
<td>102.8</td>
</tr>
<tr>
<td>hectoliter, hl</td>
<td>cubic foot, ft³</td>
</tr>
<tr>
<td>3.532</td>
<td>0.2832</td>
</tr>
<tr>
<td>hectoliter, hl</td>
<td>bushel, bu</td>
</tr>
<tr>
<td>2.838</td>
<td>0.352</td>
</tr>
<tr>
<td>liter</td>
<td>bushel, bu</td>
</tr>
<tr>
<td>0.0284</td>
<td>35.24</td>
</tr>
<tr>
<td>liter</td>
<td>quart (liquid), qt</td>
</tr>
<tr>
<td>1.057</td>
<td>0.946</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Mass</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ton (metric)</td>
<td>ton (U.S.)</td>
</tr>
<tr>
<td>1.102</td>
<td>0.9072</td>
</tr>
<tr>
<td>quintal, q</td>
<td>hundredweight, cwt</td>
</tr>
<tr>
<td>2.205</td>
<td>0.454</td>
</tr>
<tr>
<td>kilogram, kg</td>
<td>pound, lb</td>
</tr>
<tr>
<td>2.205</td>
<td>0.454</td>
</tr>
<tr>
<td>gram, g</td>
<td>ounce (avdp), oz</td>
</tr>
<tr>
<td>0.035</td>
<td>28.35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Pressure</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>bar</td>
<td>lb/inch², psi</td>
</tr>
<tr>
<td>14.50</td>
<td>0.06895</td>
</tr>
<tr>
<td>bar</td>
<td>atmosphere, atm</td>
</tr>
<tr>
<td>0.9869</td>
<td>1.013</td>
</tr>
<tr>
<td>kg (weight)/cm²</td>
<td>atmosphere, atm</td>
</tr>
<tr>
<td>0.9678</td>
<td>1.033</td>
</tr>
<tr>
<td>kg (weight)/cm²</td>
<td>lb/inch², psi</td>
</tr>
<tr>
<td>14.22</td>
<td>0.07031</td>
</tr>
<tr>
<td>kg (weight)/cm²</td>
<td>lb/1,000 ft³</td>
</tr>
<tr>
<td>14.70</td>
<td>0.06805</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Yield or Rate</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ton (metric)/hectare</td>
<td>ton (U.S.)/acre</td>
</tr>
<tr>
<td>0.446</td>
<td>2.24</td>
</tr>
<tr>
<td>kg/ha</td>
<td>lb/acre</td>
</tr>
<tr>
<td>0.892</td>
<td>1.12</td>
</tr>
<tr>
<td>quintal/hectare</td>
<td>hundredweight/acre</td>
</tr>
<tr>
<td>0.892</td>
<td>1.12</td>
</tr>
<tr>
<td>kg/are</td>
<td>lb/1,000 ft³</td>
</tr>
<tr>
<td>2.05</td>
<td>0.488</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Temperature</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fahrenheit</td>
<td>°C</td>
</tr>
<tr>
<td>0°F</td>
<td>17.8°C</td>
</tr>
<tr>
<td>32°F</td>
<td>0°C</td>
</tr>
<tr>
<td>212°F</td>
<td>100°C</td>
</tr>
<tr>
<td>68</td>
<td>5 (°F - 32)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Water Measurement</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>hectare-meters, ha-m</td>
<td>acre-feet</td>
</tr>
<tr>
<td>8.108</td>
<td>0.1233</td>
</tr>
<tr>
<td>hectare-meters, ha-m</td>
<td>acre-inches</td>
</tr>
<tr>
<td>97.29</td>
<td>0.01028</td>
</tr>
<tr>
<td>hectare-centimeters, ha-cm</td>
<td>acre-feet</td>
</tr>
<tr>
<td>0.08108</td>
<td>12.33</td>
</tr>
<tr>
<td>hectare-centimeters, ha-cm</td>
<td>acre-inches</td>
</tr>
<tr>
<td>0.973</td>
<td>1.028</td>
</tr>
<tr>
<td>meters³, m³</td>
<td>acre-inches</td>
</tr>
<tr>
<td>0.00973</td>
<td>102.8</td>
</tr>
<tr>
<td>hectare-centimeters/hour, ha-cm/hour</td>
<td>feet³/sec</td>
</tr>
<tr>
<td>0.981</td>
<td>1.0194</td>
</tr>
<tr>
<td>hectare-centimeters/hour, ha-cm/hour</td>
<td>U.S. gallons/min</td>
</tr>
<tr>
<td>440.3</td>
<td>0.00227</td>
</tr>
<tr>
<td>meters³/hour, m³/hour</td>
<td>feet³/sec</td>
</tr>
<tr>
<td>0.00981</td>
<td>101.94</td>
</tr>
<tr>
<td>meters³/hour, m³/hour</td>
<td>U.S. gallons/min</td>
</tr>
<tr>
<td>4.403</td>
<td>0.227</td>
</tr>
</tbody>
</table>

### Plant Nutrition Conversion—P and K

\[
P \text{(phosphorus)} \times 2.29 = P_{2}O_{5}\]
\[
K \text{(potassium)} \times 1.20 = K_{2}O\]