

THE JOURNAL OF **AGRICULTURAL SCIENCE**

Climate Change and Agricultural Research Papers



journals.cambridge.org/ags

CAMBRIDGE
UNIVERSITY PRESS

The Journal of Agricultural Science

SENIOR EDITORS

Dr. P. Bilbrough

University of Newcastle, School of Agriculture, Food & Rural Development, Newcastle upon Tyne NE1 7RU, UK

Prof. J. Wiseman

University of Nottingham, School of Biosciences, Sutton Bonington Campus, Loughborough, Leicestershire LE12 5RD, UK

EDITORIAL BOARD

T. Aveling, *University of Pretoria, South Africa*

B. Barkla, *Southern Cross University, Australia*

R. Bhatta, *National Institute of Animal Nutrition and Physiology, India*

S. Bittman, *Agassiz Research Centre, Canada*

M. D. Casler, *US Dairy Forage Research Center, Madison, USA*

S. Ceccarelli, *ICARDA, France*

E. Charmley, *CSIRO, Australia*

A. Cobb, *Harper Adams University, UK*

B. R. Cullis, *University of Wollongong, Australia*

W. Dandeniya, *University of Peradeniya, Sri Lanka*

J. Dijkstra, *Wageningen University, The Netherlands*

R. Dinkins, *USDA-ARS, USA*

R. N. Edmondson, *Warwick HRI, Wellesbourne, UK*

J. Eitzinger, *University of Natural Resources and Applied Life Sciences (BOKU), Vienna*

W. Erskine, *CLIMA, University of Western Australia, Australia*

A. Fahey, *University College Dublin, Ireland*

O. Fenton, *Teagasc, Ireland*

J. France, *University of Guelph, Canada*

S. Guo, *Nan Jing Agricultural University, China*

G. Hoogenboom, *University of Florida, USA*

F. G. Horgan, *University of Technology Sydney, Australia*

A. Kohli, *IRRI, Manila, the Philippines*

S. Lopez, *Universidad de León, Spain*

P. Lund, *Aarhus University, Denmark*

G. Marion, *Biomathematics and Statistics Scotland, UK*

S. Orlandini, *University of Florence, Italy*

H. Piepho, *University of Hohenheim, Germany*

R. Ragab, *Centre for Ecology & Hydrology, UK*

C. K. Reynolds, *University of Reading, UK*

J. A. Rooke, *SAC, Edinburgh, UK*

T. Rose, *Southern Cross University, Australia*

L. Shalloo, *Teagasc, Ireland*

N. St. Pierre, *Ohio State University, USA*

P. Williams, *Queen's University, Belfast, UK*

F. Xu, *Huazhong Agricultural University, China*

SUBMISSIONS

The Journal has moved to electronic submission. Manuscripts should be uploaded to <http://mc.manuscriptcentral.com/jagricsci>. Double-blind refereeing has also been adopted, therefore the authors' names, addresses and emails should be removed from the main document and uploaded as a title page in a separate file, tagged 'Not for Review'. Help is available on the website.

SUBSCRIPTIONS

The Journal of Agricultural Science (ISSN 0021-8596) is published eight times a year in January, March, April, May, July, August, September and November. Eight parts form a volume. The subscription price (excluding VAT) of Volume 154 (2016) (which includes delivery by air where appropriate, plus electronic access to institutional subscribers) is £1421 net (US \$2366) in the USA, Canada and Mexico). Single parts are £204 net (US \$340) in the USA, Canada and Mexico. The electronic only price available to institutional subscribers is £1083 (\$1860 in USA, Canada and Mexico). Back issues are also available.

Orders, which must be accompanied by payment, may be sent to a bookseller, subscription agent or direct to the publisher: Cambridge University Press, University Printing House, Shaftesbury Road, Cambridge CB2 8BS, UK; or in the USA, Canada and Mexico: Cambridge University Press, Journals Fulfillment Department, Cambridge University Press, 1 Liberty Plaza, Floor 20, New York, NY 10006, USA. EU subscribers (outside the UK) who are not registered for VAT should add VAT at their country's rate. VAT registered subscribers should provide their VAT registration number. Japanese prices for Institutions are available from Kinokuniya Company Ltd, PO Box 55, Chitose, Tokyo 156, Japan.

POSTMASTER: send address changes in the USA, Canada and Mexico to: The Journal of Agricultural Science, Cambridge University Press, 1 Liberty Plaza, Floor 20, New York, NY 10006, USA. Claims for missing issues should be made immediately on receipt of the subsequent issue.

© Cambridge University Press 2016

COPYING

No contents may be reproduced by any means without the permission of Cambridge University Press. This journal is registered with the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, USA (www.copyright.com). Organizations in the USA who are also registered with the CCC may therefore copy material (beyond the limits permitted by sections 107 and 108 of US copyright law) subject to payment to CCC. This consent does not extend to multiple copying for promotional or commercial purposes. ISI Tear Sheet Service, 3501 Market Street, Philadelphia, PA 19106, USA, is authorized to supply single copies of separate articles for private use only. Organizations authorized by the Copyright Licensing Agency may also copy material subject to the usual conditions. For all other use, permission should be sought from the Cambridge or the American Branch of Cambridge University Press.

INTERNET ACCESS

This journal is included in the Cambridge Journals Online service which can be found at <http://www.journals.cambridge.org> For further information on other Press titles access www.cambridge.org

This journal issue has been printed on FSC-certified paper and cover board. FSC is an independent, non-governmental, not-for-profit organization established to promote the responsible management of the world's forests. Please see www.fsc.org for information.

CAMBRIDGE UNIVERSITY PRESS

University Printing House, Shaftesbury Road, Cambridge CB2 8BS, United Kingdom
1 Liberty Plaza, Floor 20, New York, NY 10006, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
Ruiz de Alarcón 13, 28014 Madrid, Spain
Dock House, The Waterfront, Cape Town 8001, South Africa

Printed in the UK by Bell & Bain Ltd., Glasgow.