

THE JOURNAL OF **AGRICULTURAL SCIENCE**

Climate Change and Agriculture Research Paper in this
issue



[cambridge.org/ags](https://www.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

Adibe Abdalla, *Universidade de São Paulo, USP – CENA, Brazil*

M. Aduli, *College of Public Health, Medical and Veterinary Sciences, James Cook University, Australia*

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*

G. Cantalapiedra, *INRA - VetAgro Sup, Saint-Genes-Champagnelle, France*

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

S. Ceccarelli, *ICARDA, France*

E. Charmley, *CSIRO, Australia*

B. S. Chauhan, *University of Queensland, Australia*

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*

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

O. Fenton, *Teagasc, Ireland*

J. Giráldez, *Instituto de Ganadería de Montaña (CSIC-Universidad de León), Spain*

G. Hervás, *Instituto de Ganadería de Montaña (CSIC-Universidad de León), Spain*

G. Hoogenboom, *University of Florida, USA*

A. Hristov, *Pennsylvania State University, USA*

X. Jin, *INRA, UMR-EMMAH, UMT-CAPTE, France*

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

V. A. Kuttappan, *Novus International Inc., USA*

S. Lopez, *Universidad de León, Spain*

P. Lund, *Aarhus University, Denmark*

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

S. Orlandini, *University of Florence, Italy*

K. Panten, *Julius Kühn-Institut, Germany*

H. Piepho, *University of Hohenheim, Germany*

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

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

D. Rubiales, *Institute for Sustainable Agriculture, CSIC, at Córdoba, Spain*

L. Shalloo, *Teagasc, Ireland*

L. Silva, *Old Alliance for Agriculture & Food Innovation, University of Queensland, Australia*

Wenxue Wei, *Institute of Subtropical Agriculture Chinese Academy of Sciences, China*

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 ten times a year in January, March, April, May, July, August, September, October, November and December. Ten parts form a volume. The subscription price (excluding VAT) of Volume 157 (2019) (which includes delivery by air where appropriate, plus electronic access to institutional subscribers) is £1739 net (US \$2896) in the USA, Canada and Mexico). Single parts are £200 net (US\$333) in the USA, Canada and Mexico. The electronic only price available to institutional subscribers is £1327 (\$2278 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.

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 can be found online at Cambridge Core cambridge.org/journals

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