

0021-8596

Volume 147 Part 4 August 2009



# THE JOURNAL OF AGRICULTURAL SCIENCE

Featuring  
Modelling Animal Systems  
Papers in this issue

CAMBRIDGE  
UNIVERSITY PRESS



# The Journal of Agricultural Science

## Senior Editors

**Prof. R. E. L. Naylor**, *University of Aberdeen, Room 517 MacRobert Building,  
581 King Street, Aberdeen AB24 5UA, UK*

**Prof. J. Wiseman**, *University of Nottingham, School of Biosciences,  
Sutton Bonington Campus, Loughborough, Leicestershire LE12 5RD, UK*

## Editorial Board

**M. Abberton**, *IGER, Aberystwyth, UK*  
**T. Aveling**, *University of Pretoria, South Africa*  
**P. Bilsborrow**, *Newcastle University, UK*  
**S. C. Bishop**, *Roslin Institute, Edinburgh, UK*  
**M. D. Casler**, *US Dairy Forage Research Center,  
Madison, USA*  
**B. R. Cullis**, *Wagga Wagga Agricultural Institute,  
Australia*  
**J. Dijkstra**, *Wageningen University,  
The Netherlands*  
**R. N. Edmondson**, *Warwick HRI,  
Wellesbourne, UK*  
**W. Erskine**, *CLIMA, University of Western  
Australia, Australia*  
**J. France**, *University of Guelph, Canada*  
**P. Hobbs**, *Cornell University, Ithaca, NY*  
**G. Hoogenboom**, *The University  
of Georgia, USA*

**M. O. Humphreys**, *Institute of Grassland and  
Environmental Research, Aberystwyth, UK*  
**R. Hunter**, *CSIRO, Livestock Industries, Division  
of Tropical Production, Queensland, Australia*  
**P. S. Kettlewell**, *Harper Adams University  
College, UK*  
**D. B. Lindsay**, *Cambridge, UK*  
**S. J. Mooney**, *University of Nottingham, UK*  
**C. K. Reynolds**, *University of Reading, UK*  
**H. Riley**, *Norwegian Institute for Agricultural and  
Environmental Research, Kapp, Norway*  
**J. A. Rooke**, *SAC, Edinburgh, UK*  
**P. E. Russell**, *Cambridge, UK*  
**U. R. Sangakkara**, *University of Peradeniya,  
Sri Lanka*  
**N. St. Pierre**, *Ohio State University, USA*  
**C. Watson**, *Scottish Agricultural College,  
Aberdeen, UK*

## 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 six times a year in February, April, June, August, October and December. Six parts form a volume. The subscription price (excluding VAT) of Volume 147 (2009) (which includes delivery by air where appropriate, plus electronic access to institutional subscribers) is £645 net (US \$1185.00 in the USA, Canada and Mexico). Single parts are £106 net (US \$197 in the USA, Canada and Mexico). The electronic only price available to institutional subscribers is £545.00 (\$1010.00 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, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 8RU, UK; or in the USA, Canada and Mexico: Cambridge University Press, Journals Fulfillment Department, 100 Brook Hill Drive, West Nyack, New York 10994-2133. 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, 100 Brook Hill Drive, West Nyack, New York 10994-2133. Claims for missing issues should be made immediately on receipt of the subsequent issue.

(Continued on inside back cover)