

# Weed Science in the Asian-Pacific Region

Editors

V.S. Rao • N.T. Yaduraju • N.R. Chandrasena • Gul Hassan • A.R. Sharma

The Asian-Pacific (AP) countries cover a wide geographical area, with diverse landscapes, climates, societies, cultures, economies, arable lands, agriculture systems and weed problems. They include those in South Asia, East Asia, South-East Asia, West Asia and Oceania, besides the United States of America. The AP region, which accounts for bulk of the global agricultural production, is home to world's most diverse weed problems in a wide range of crops and croplands as well as non-cropping and aquatic systems.

This book, edited by five reputed international weed scientists, contains 19 chapters authored by 47 weed scientists from 19 countries. It provides a mine of information on different aspects of this ever-growing field of weed science. These include prominent weed species in crop and non-crop systems; invasive and parasitic weeds; innovative strategies in weed management; synthetic herbicides; allelopathy and allelo herbicides/chemicals; bio-herbicides/agents; herbicide application; herbicide-resistant weeds and their management; herbicide-resistant biotech crops, adoption, regulation policies, benefits and concerns; omics and genomics and their application for better weed management; research, education, extension and training in weed science; professional weed science societies; herbicide industry; emerging concerns and opportunities in weed management; and future outlook on developments in weed science.

A book of Asian-Pacific Weed Science Society published by:

Indian Society of Weed Science  
Directorate of Weed Research  
Indian Council of Agricultural Research  
Jabalpur 482 004, Madhya Pradesh  
India  
Website: [www.isws.org.in](http://www.isws.org.in)

© 2015 Indian Society of Weed Science

ISBN 13: 978-81-931978-0-6

Price:  
₹ 1,000 (Individuals in India)  
₹ 2,500 (Libraries & Institutions in India)  
US\$ 75 (Overseas)



Weed Science in the Asian-Pacific Region



In commemoration of

Silver Jubilee APWSS Conference, Hyderabad, India



Asian-Pacific Weed Science Society  
Indian Society of Weed Science



# **Weed Science in the Asian-Pacific Region**

In commemoration of  
**The Silver Jubilee Conference, Asian-Pacific Weed Science Society**

Editors

**V.S. Rao**

**N.T. Yaduraju**

**N.R. Chandrasena**

**Gul Hassan**

**A.R. Sharma**



**Asian-Pacific Weed Science Society**



**Indian Society of Weed Science**

**Correct citation:** Author(s). 2015. Title of Chapter. pp. \_\_\_ *In:* V.S. Rao, N.T. Yaduraju, N.R. Chandrasena, G. Hassan and A.R. Sharma. Weed Science in the Asian-Pacific Region. An Asian-Pacific Weed Sci. Soc. Public. Indian Soc. Weed Sci., Jabalpur, India. 389 pp.

A book of Asian-Pacific Weed Science Society published by:  
Indian Society of Weed Science  
Directorate of Weed Research  
Indian Council of Agricultural Research  
Jabalpur 482 004, Madhya Pradesh, India.  
Website: [www.isws.org.in](http://www.isws.org.in)

© 2015 Indian Society of Weed Science

ISBN 13: 978-81-931978-0-6

This book contains information obtained by authors from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the authors, editors and publishers cannot assume responsibility for the validity of all materials or the consequences of their use. The authors have attempted to trace the copyright holders of all material reproduced in this publication. If any copyright material has not been acknowledged, please write and let us know so we may rectify later.

No part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without the written permission from the publishers.

**Price:** ₹ 1,000 (in India); US\$ 75 (Overseas)

**Cover page:** Logo of the APWSS indicating the globe has been superimposed with the major weed species of the world, which include (in sequence): *Phalaris*, *Avena*, *Echinochloa*, *Cyperus*, *Ageratum*, (cropland weeds); *Parthenium*, *Mikania*, *Alternanthera*, *Chromolaena*, *Mimosa*, *Saccharum* (non-cropland weeds); *Eichhornia*, *Salvinia*, *Ipomoea* (aquatic weeds); and *Striga*, *Orobancha*, *Cuscuta* (parasitic weeds). (Designed by: Mr. V.K.S. Meshram and Mr. Sandeep Dhagat, DWR, Jabalpur, India)

**Printed at:**

Balajiscan Private Limited, Lakadikapul, Hyderabad 500 004, India.  
Tel: 91-40-23303424 / 25, 9848032644, 9248007730-39.

## Preface

The Asian-Pacific Weed Science Society (APWSS) was founded in 1967 when a group of 87 weed scientists from 22 countries met at Honolulu, Hawaii, USA. Since then, the Society met 23 times, biennially, before the current 25<sup>th</sup> conference in Hyderabad, India (Appendix). This is the second time India is hosting an APWSS conference, the first one being in November 1981 in Bangalore.

The Asian-Pacific (AP) countries cover a wide geographical area, with diverse landscapes, climates, societies, cultures, economies, arable lands, agriculture systems and weed problems. They include those in South Asia, East Asia, South-East Asia, West Asia and Oceania, besides the United States of America. With a combined total of 4.5 billion people in 2015, these nations account for about 61% of the current world population of 7.3 billion, while occupying just 37% of the Earth's land mass and 48% of the global gross arable land. Seven of the 10 most populous nations in the world are in this region. These include China, India, USA, Indonesia, Pakistan, Bangladesh and Japan which account for a little over 50% of the global population.

This region is home to some of the oldest civilizations and richest countries in the world for millennia. Currently, it accounts for four (USA, China, Japan and India) of the top 10 global economies and 58% of world's GDP on the basis of both nominal and purchasing power parity valuation. It is also the powerhouse of global science and technology, including agriculture and biotechnology.

The AP region accounts for bulk of the global agricultural production. For example, it contributes 95% of tea and 80% of rice and groundnut (peanut), besides 70% of pulses (grain legumes). It also contributes 40–60% of wheat, maize (corn), sugarcane and cotton in addition to about 30% of sorghum and soya bean. Not to be left behind is over 95% of the global production of spices and herbs. This region, with both tropical and temperate climates prevailing, is also home to world's most diverse weed problems in a wide range of crops. It accounts for all of the 10 world's worst weed species in addition to hundreds of other annual and perennial weeds that plague the cropland and aquatic systems, adversely impacting the agriculture, economy and environment of the AP region.

During its 48 years of existence, APWSS has expanded tremendously as had the field of weed science. The number of herbicides—the major driving force of modern weed management—which stood around 70 in 1967 rose to more than 300 by 1990. Yet, weed problems have continued to rise. One major problem presently plaguing the world, including the AP countries, is the development of resistance in more than 246 weed species to 157 different herbicides. This is due to the direct consequence of injudicious and indiscriminate herbicide use. The adoption of herbicide-resistant transgenic biotech crops over the past two decades has added a new dimension to the field of weed science.

As APWSS holds its Silver Jubilee Biennial Conference, it was decided to commemorate the occasion by bringing out a publication on the current status of weed science in each of the member countries. Thus, this publication offers an unique opportunity not only for member countries in the region but also for the other countries in the world in contextualizing weed problems and sharing information on best practices.

This book presents 19 chapters from as many countries and these were contributed by 47 weed scientists. These chapters provide a mine of information on different aspects of this ever-growing and vital field in agricultural science. These include prominent weed species in crop and non-crop systems; invasive and parasitic weeds; innovative strategies in weed management; synthetic herbicides; allelopathy and allelo-herbicides/chemicals; bio-herbicides/agents; herbicide application; herbicide-resistant weeds and their management; herbicide-resistant biotech crops, adoption, regulation policies, benefits and concerns; omics and genomics and their application for better weed management; research, education, extension and training in weed science; professional weed science societies; herbicide industry; emerging concerns and opportunities in weed management; and future outlook on developments in weed science. We are aware that there is a wide variation in the way authors covered and discussed some of these topics in their chapters, but that is how we learn from the strengths of each other so that the field of weed science in the AP region as a whole is further strengthened.

We sincerely express our appreciation and thanks to Dr. Sushil Kumar, Principal Scientist, Directorate of Weed Research, Indian Council of Agricultural Research, Jabalpur and Dr. T. Ramprakash, Senior Scientist, PJTSAU, Hyderabad for their assistance in publishing this book.

We state that the findings, views and opinions expressed in this book are solely those of authors of the chapters but do not reflect the official policy of APWSS and the editorial board. Assumptions made in the chapters are not reflective of the position of APWSS.

V.S. Rao

N.T. Yaduraju

N.R. Chandrasena

Gul Hassan

A.R. Sharma



## Editors

### Dr. V.S. Rao (Chief Editor)



Dr. V.S. Rao, a Ph.D. in Weed Science from Cornell University, Ithaca, NY, USA, has served universities (including Cornell) and research institutions in USA and India as a faculty member, senior scientist, director and adviser for over 50 years. He has vast experience of researching herbicide action mechanisms besides developing weed management programs in several crops. He authored numerous research publications besides books, including “Principles of Weed Science” (1983; 2000) and “Transgenic Herbicide Resistance in Plants” (2015). Dr. Rao is the recipient of Lifetime Achievement Award of Indian Society of Weed Science, TANA Award for Excellence in Science, USA, etc. He is currently an Affiliate Member, Department of Plant Sciences, University of California, Davis, CA, USA.

### Dr. N.T. Yaduraju (Editor)



Dr. N.T. Yaduraju obtained his graduate and postgraduate degrees from the University of Agricultural Sciences, Bangalore, India and Ph.D. from the University of Reading, UK. He was actively involved in research and teaching in agronomy, weeds and weed management at the Indian Agricultural Research Institute, New Delhi from 1976 to 2000. As Director of Directorate of Weed Research, Indian Council of Agricultural Research at Jabalpur, India from 2000 to 2005, Dr. Yaduraju gave leadership and new direction to weed science in the country. He has over 200 research publications and is the Fellow of the Indian Society of Weed Science (ISWS) and a recipient of the ISWS Gold Medal. He is currently serving as President of ISWS and Asian-Pacific Weed Science Society.

### Dr. N.R. Chandrasena (Editor)



Dr. N.R. Chandrasena, a Ph.D. in Weed Science was from the University of North Wales, Bangor, U.K., was an Associate Professor in Botany (Merit) and served the University of Colombo, Sri Lanka from 1977 to 1993. Since migrating to Australia, he has been a researcher and a consultant for more than 20 years improving catchments through restoration of waterways, wetlands and damaged ecosystems through re-vegetation. Dr. Chandrasena has worked internationally in several countries, and also for Sydney Water Corporation as a Principal Scientist and Natural Asset Manager for 12 years, before becoming a Principal Ecologist for Ecowise Australia (and ALS), and subsequently, GHD.

### Dr. Gul Hassan (Editor)



A Ph.D. from Oregon State University, Corvallis, Oregon, USA, Dr. Gul Hassan is a Professor in the Department of Agriculture, Shaheed Benazir Bhutto University, Sheringal, Upper Dir, Pakistan. Earlier, he was a Professor and Chairman, Department of Weed Science, University of Agriculture, Peshawar, Pakistan. He has over 230 research publications in national and international journals. Dr. Hassan organized several national and international weed science conferences including the 22nd Asian-Pacific Weed Science Conference as a Secretary of Weed Science Society of Pakistan and Asian-Pacific Weed Science Society. He is the Managing Editor of Pakistan Journal of Weed Science Research and credited with supervising dozens of doctoral and master's degree students.

### Dr. A.R. Sharma (Editor)



Dr. A.R. Sharma obtained B.Sc. from Himachal Pradesh Krishi Vishwa Vidyalaya, Palampur; M.Sc. from Punjab Agricultural University, Ludhiana and Ph.D. from Indian Institute of Technology, Kharagpur. He was a Professor of Agronomy, Indian Agricultural Research Institute, New Delhi before becoming Director, Directorate of Weed Research, Indian Council of Agricultural Research, Jabalpur in 2012. He has made outstanding contributions in tillage and weed management, conservation agriculture and nutrient management. Dr. Sharma published over 200 research papers and received ICAR Jawaharlal Nehru Award, KRIBHCO Award for Outstanding Research, ISCA Pran Vohra Award, IARI Hooker Award, etc. He is a Fellow of National Academy of Agricultural Sciences, Indian Society of Agronomy, and Indian Association of Soil and Water Conservationists.

## Authors

- Ms. Anuruddhika Abeysekera, Rice Research and Development Institute, Department of Agriculture, Batalagoda, North Western Province, Sri Lanka.
- Dr. J. Adam, School of Plant Biology, Faculty of Natural and Agricultural Sciences, The University of Western Australia, Perth, Western Australia, Australia.
- Dr. Tahir H. Awan, International Rice Research Institute (IRRI), Los Baños, Philippines.
- Dr. B.B. Baki, Formerly, Institute of Biological Sciences, University of Malaya, Kuala Lumpur, Malaysia. Currently, Department of Biological Sciences, Faculty of Science, Taif University, Taif, Saudi Arabia.
- Dr. Aurora M. Baltazar, Professor, University of the Philippines Los Baños (UPLB), Los Baños, Philippines.
- Dr. P.D. Champion, National Institute of Water and Atmospheric Research, PO Box 11-115, Hamilton 3251, New Zealand.
- Dr. Nimal R. Chandrasena, Principal Ecologist, GHD Pty Ltd., Parramatta, NSW, 2050 Australia.
- Dr. Bhagirath S. Chauhan, Principal Research Fellow, The Centre for Plant Science, Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Toowoomba, Queensland 4350, Australia.
- Dr. Duong Van Chin, Director, Thanh Agricultural Research Center (DT ARC), An Giang Province, Vietnam.
- Dr. Dharma Raj Dangol, Professor, Natural History Museum, Institute of Science and Technology, Tribhuvan University, Swayambhu, Kathmandu, Nepal.
- Dr. Gul Hassan, Professor, Botany/Weed Science, Shaheed Benazir Bhutto University, Sheringal, Dir Upper, Khyber Pakhtunkhwa, Pakistan.
- Dr. Swarna Herath, Rice Research and Development Institute, Department of Agriculture, Batalagoda, North Western Province, Sri Lanka.
- Dr. Hongjuan Huang, Associate Professor, Key Laboratory of Weed and Rodent Biology and Management, Institute of Plant Protection (IPP), Chinese Academy of Agricultural Sciences (CAAS), No. 2 West Yuanmingyuan Road, Haidian, Beijing 100193, China.
- Dr. Zhaofeng Huang, Post-Doctoral Fellow, Key Laboratory of Weed and Rodent Biology and Management, Institute of Plant Protection (IPP), Chinese Academy of Agricultural Sciences (CAAS), No. 2 West Yuanmingyuan Road, Haidian, Beijing 100193, China.
- Dr. A. Jalaluddin, School of Plant Biology, Faculty of Science, The University of Western Australia, Perth, Western Australia, Australia.
- Dr. T.K. James, AgResearch, Ruakura Research Centre, Private Bag 3123, Hamilton 3240, New Zealand.
- Dr. Stephen B. Johnson, Weed Ecologist, NSW Department of Primary Industries, 1447 Forest Road, Orange, NSW, 2800, Australia.
- Dr. S.M. Rezaul Karim, Weed Scientist and Professor, Department of Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh; Faculty of Agro Based Industry (FIAT), University Malaysia Kelantan (UMK), Campus Jeli, 17600 Jeli Kelantan, Malaysia.
- Dr. Do-Soon Kim, Associate Professor, Department of Plant Science, Seoul National University, Korea Secretary, Asian-Pacific Weed Science Society.
- Dr. Denny Kurniadi, Head Department of Agronomy Faculty of Agriculture, University of Padjajaran, Jl. Raya Jatinangor Km 21, Bandung, Indonesia.
- Dr. Mar Mar Kyu, Emeritus Professor, Yezin Agricultural University, Yezin, Nay Pyi Taw, Myanmar.
- Dr. In-Yong Lee, Crop Protection Division, National Academy of Agricultural Science, Rural Development Administration, Korea.
- Dr. A.A. Majrashi, Department of Biological Sciences, Faculty of Science, Taif University, Taif, Saudi Arabia.



- Dr. Chanya Maneechote, Plant Protection Research and Development Office, Department of Agriculture, Chatuchak, Bangkok 10900, Thailand.
- Mrs. Aye Aye Mar, Deputy Director (Retired), Weed Science Section, Plant Protection Division, Department of Agriculture, Yangon, Myanmar.
- Dr. Buddhi Marambe, Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka.
- Dr. Khan Bahadar Marwat, Vice Chancellor, Shaheed Benazir Bhutto University, Sheringal, Dir Upper, Khyber Pakhtunkhwa, Pakistan.
- Dr. Hamid Rahimian Mashhadi, Department of Agronomy, Faculty of Agriculture, University of Tehran, Karaj, Iran.
- Dr. Hiroshi Matsumoto, Professor, Faculty of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki 305-8572, Japan.
- Dr. Maor Matzrafi, Institute of Plant Sciences and Genetics in Agriculture, RH Smith Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot 761001, Israel.
- Dr. Mehdi Minbashi Moeini, Iranian Research Institute of Plant Protection, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran.
- Dr. M.S. Mispan, Institute of Biological Sciences, University of Malaya, Kuala Lumpur, Malaysia.
- Dr. Noushin Nezamabadi, Iranian Research Institute of Plant Protection, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran.
- Dr. Kee-Woong Park, Department of Crop Science, Chungnam National University, Daejeon, Korea.
- Dr. Tae-Seon Park, Crop Production & Physiology Research Division, National Institute of Crop Science, Rural Development Administration, Korea.
- Dr. A.I. Popay, 14 Dillon Place, Hamilton 3216, New Zealand.
- Dr. A. Rahman, AgResearch, Ruakura Research Centre, Private Bag 3123, Hamilton 3240, New Zealand.
- Dr. A.N. Rao, Visiting Scientist, ICRISAT Development Center and International Rice Research Institute, International Crop Research Institute for the Semi-Arid Tropics, Patancheru, Hyderabad 502324, India.
- Dr. V.S. Rao, Former Research Scientist, Seed and Vegetable Sciences, New York State Agri. Expt. Station, Cornell University, Geneva, New York, USA; Affiliate Member, Department of Plant Sciences, University of California, Davis, CA, USA; Address: 10113 Waterfield Dr., Elk Grove, CA 95757, USA.
- Dr. Hamid Reza Sasanfar, Iranian Research Institute of Plant Protection, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran.
- Dr. Baruch Rubin, Professor Emeritus of Weed Science, Institute of Plant Sciences and Genetics in Agriculture, RH Smith Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot 760001, Israel.
- Dr. Titiek Setyowati, Researcher and National Project Coordinator, Center for Conservation and Rehabilitation Research and Development, Jln. Gunung Batu No. 5, Bogor, Indonesia
- Mrs. Than Than Soe, Director, Agronomy, Agricultural Economics and Statistics Division, Department of Agricultural Research, Yezin, Nay Pyi Taw, Myanmar.
- Dr. Soekisman Tjitrosemito, Affiliate Weed Scientist, BIOTROP, Jln Raya Tajur, Km6, Bogor, Indonesia.
- Dr. Shouhui Wei, Associate Professor, Key Laboratory of Weed and Rodent Biology and Management, Institute of Plant Protection (IPP), Chinese Academy of Agricultural Sciences (CAAS), No. 2 West Yuanmingyuan Road, Haidian, Beijing 100193, China.
- Dr. Eskandar Zand, Iranian Research Institute of Plant Protection, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran.
- Dr. Chaoxian Zhang, Professor, Key Laboratory of Weed and Rodent Biology and Management, Institute of Plant Protection (IPP), Chinese Academy of Agricultural Sciences (CAAS), No. 2 West Yuanmingyuan Road, Haidian, Beijing 100193, China.

# Contents

<i>Preface</i>	i
<i>Editors</i>	iii
<i>Authors</i>	v
1. <b>Status of Weed Science in the United States of America</b> V.S. Rao	1
2. <b>History and Status of Weed Science in New Zealand</b> A. Rahman, T.K. James, A.I. Popay and P.D. Champion	35
3. <b>Status of Weed Science in Iran and Future Directions</b> Eskandar Zand, Hamid Rahimian Mashhadi, Noushin Nezamabadi, Hamid Reza Sasanfar and Mehdi Minbashi Moeini	67
4. <b>Weeds and Weed Management in India: A Review</b> A.N. Rao and B.S. Chauhan	87
5. <b>Weed Management in Australia: An Overview and Prognosis</b> Nimal R. Chandrasena and Stephen B. Johnson	119
6. <b>Status of Weed Science in the Philippines</b> Bhagirath S. Chauhan, Tahir H. Awan and Aurora M. Baltazar	151
7. <b>Status of Weed Science in Pakistan</b> Gul Hassan and Khan Bahadar Marwat	177
8. <b>Weed Science in Malaysia: An Analysis</b> M.S. Mispan, A. Jalaluddin, A.A. Majrashi and B.B. Baki	197
9. <b>Weeds and Weed Management in Agricultural and Natural Ecosystems: An Overview of the Sri Lankan Context</b> Buddhi Marambe, Anuruddhika Abeysekera and Swarna Herath	213
10. <b>Current Status and Problems of Weed Management in Japan</b> Hiroshi Matsumoto	241
11. <b>Weed Management in Israel – Challenges and Approaches</b> Baruch Rubin and Maor Matzrafi	253
12. <b>Weed Management in Major Annual Crops in Vietnam</b> Duong Van Chin	271
13. <b>Weed Research and Weed Science in Bangladesh</b> S.M. Rezaul Karim	281
14. <b>Status of Weed Management in Thailand</b> Chanya Maneechote	291
15. <b>Status of Weed Science in Nepal</b> Dharma Raj Dangol	305
16. <b>Weed Science Advances in China</b> Chaoxian Zhang, Zhaofeng Huang, Hongjuan Huang and Shouhui Wei	323
17. <b>Status of Weed Science in Indonesia</b> Soekisman Tjitrosemito, Titiek Setyowati and Denny Kurniadie	341
18. <b>Current Status of Weed Science in Myanmar</b> Mar Mar Kyu, Aye Aye Mar and ThanThan Soe	363
19. <b>Status of Weed Science in Korea</b> Do-Soon Kim, In-Yong Lee, Tae-Seon Park and Kee-Woong Park	373
<i>Author Index</i>	386
<i>Appendix</i>	388