



APWSS - 2015

Post-Conference Proceedings and Recommendations

25th Asian-Pacific Weed Science Society Conference
Hyderabad, India

13 - 16 October, 2015



Organized by

Indian Society of Weed Science

In collaboration with

**Indian Council of Agricultural Research
Directorate of Weed Research
PJT State Agricultural University**





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Preface

Weeds are a major biotic constraint in agricultural production systems worldwide. Besides reducing crop yield and quality, these unwanted plants adversely affect biodiversity, animal health and environmental quality. In fact, the problem of weeds is as old as the agriculture itself. Despite the development of weed management technologies, the weed related problems have been virtually increasing. This is due to adoption of so-called modern cultivation methods which also promote the growth of weeds. Threats posed by climate change, globalization, herbicide resistance development in weeds and commercialization of herbicide-tolerant crops are bound to accentuate the problem of weeds. Realizing the growing weed infestations in the cropped and non-cropped lands, agricultural scientists of the world have been undertaking research and sharing their findings at various platforms. One such initiative was taken way back in 1967 when weed scientists from 22 countries of the Asian-Pacific region met at the Hawaiian Island of Kauai to establish linkages and discuss what should be done in weed science. This meeting led to the birth of the Asian-Pacific Weed Science Society (APWSS), and since then, the Society has grown and developed into as a major international weed science society.

Over the years, the discipline of weed science has also developed in many countries and professional societies dealing with the subject have been established for mutual exchange and sharing of knowledge at regional level. Besides organizing various activities including conferences and symposia at the national level, these professional societies have also been providing a platform for sharing of international experiences on emerging issues in weed science. The APWSS has been providing a major platform for these regional weed science societies for organizing the APWSS Conferences every two years. Such conferences have been organized in different countries of the Asian-Pacific region like Philippines (1969, 1983, 2003), Malaysia (1971, 1997), New Zealand (1973), Japan (1975, 1995), Indonesia (1977, 1991, 2013), Australia (1979, 1993, 2011), India (1981), Thailand (1985, 1999), Taiwan (1987), Korea (1989), China (2001), Vietnam (2005), Sri Lanka (2007) and Pakistan (2010) by the respective weed science societies.

Silver Jubilee of the APWSS Conferences was organized at Hyderabad, India during 13-16 October, 2015. This was the biggest of all the Conferences organized so far with nearly 700 participants and 800 presentations including 200 oral / invited lectures. An initiative was taken by the Indian Society of Weed Science to bring out the Post-Conference Proceedings of the 25th APWSS. This publication contains information on the Conference, technical programme, plenary lectures, papers presented in different technical sessions and symposia, awards, publications, general recommendations, list of participants and glimpses of the Conference.

We are grateful to the delegates from different parts of the world for participating in this mega event and sharing their expertise for the growth of weed science in the Asian-Pacific Region. It is hoped that this document will serve as a reference material and keep memories of this Conference alive for a long time to come.

Dr. N.T. Yaduraju, President
Dr. A.R. Sharma, Organizing Secretary
25th APWSS Conference
Hyderabad, India

An Overview

Silver Jubilee Conference of the Asian-Pacific Weed Science Society (APWSS) on “Weed Science for Sustainable Agriculture, Environment and Biodiversity” was successfully organized during 13-16 October, 2015 at the Professor Jayshankar Telangana State Agricultural University (PJTSAU), Hyderabad. This mega event was organized by the Indian Society of Weed Science in collaboration with the APWSS, Indian Council of Agricultural Research (ICAR), Directorate of Weed Research (DWR) and PJTSAU, Hyderabad. Dr. A.R. Sharma, Organizing Secretary and Director, ICAR-DWR, Jabalpur delivered the welcome address. Dr. N.T. Yaduraju, Convener of Conference and President of APWSS/ISWS presented his Presidential Address. Dr. Steve Adkins, Immediate Past President, APWSS made a presentation on nearly five decades history of the APWSS. Dr. B.S. Chauhan from University of Queensland, Australia and Dr. Puja Ray from Presidency University, Kolkata, India were awarded ‘APWSS Young Scientist Awards’. In addition, five ‘Student Travel Grants’ and nine ‘Best Poster Awards’ were also given.

The Conference was inaugurated on 13th October, 2015 by Professor P. Appa Rao, Vice Chancellor of the University of Hyderabad as the Chief Guest and Dr. D. Rama Rao, Director, NAARM as the Guest of Honour. The Conference was attended by 690 registered participants including 107 from overseas and 46 from industries representing 25 countries of the world. In this Conference, 11 plenary presentations were made by the stalwarts in weed science who have made a mark at the International level. In all, there were 12 technical sessions in which 16 lead presentations and 106 oral presentations were made. There were 5 satellite symposia on different emerging topics, *viz.* Weed management in conservation agriculture; Weedy rice challenge in Asia: issues and options for management; Herbicide resistance: current status and future challenges globally; Biological control – progress and future prospects in Asia-Pacific region; and Utilization of weeds as bio-resources. These symposia were exclusively planned and organized by the identified world renowned weed scientists as conveners. Apart from this, 627 poster presentations were made during the Conference.

Silver Jubilee function of the APWSS Conferences and the book release ceremony of the special publication on “Weed Science in the Asian-Pacific Region” was held on 14th October, 2015. Exposure visits to the research farm of the University, Indian Institute of Rice Research, and International Crop Research Institute for Semi-arid Tropics (ICRISAT) were also arranged on 15th October, 2015. It was decided that the 26th APWSS Conference will be held in Kyoto, Japan during 19-22 September, 2017 and the 27th APWSS Conference in Kuching, Malaysia in 2019.

An overview of Conference was presented by Dr. N.T. Yaduraju, President, APWSS and Indian Society of Weed Science during the closing ceremony of the Conference on 16th October, 2015. He gave an account of the various activities and sessions conducted in this Conference. Following were the highlights of his speech:

- A pre-conference workshop on Statistical Software was organized by the International Weed Science Society (IWSS) and Gylling Data Management, which was attended by 25 participants on 12 October, 2015.
- On 12th October 2015, a meeting of the Executive Committee of APWSS was held in which various issues were discussed.
- During the Conference, 11 plenary presentations were made by the stalwarts in weed science.
- Twelve technical sessions were conducted in which 16 lead presentations were made. Out of 106 oral papers in the technical sessions which were selected from the contributory articles, 101 have been made.
- There were 5 symposia on different emerging topics, which were very well conducted by the identified conveners and attended by the participants.

- There were in all 627 posters, most of which were presented. A judging committee examined the posters and identified the best ones.
- This Conference was one of the largest and efforts were made to organize it in the best possible manner under the given circumstances. In all, there were 690 registered participants at this Conference, including 107 participants from overseas, and 46 from industries.
- Participants from 25 countries included Australia, Bangladesh, Canada, China, Germany, India, Indonesia, Israel, Italy, Japan, Malaysia, New Zealand, Nigeria, Pakistan, Philippines, Republic of Korea, Singapore, Sri Lanka, Sudan, Taiwan, Tanzania, Turkey, United Kingdom, United States of America and Vietnam.
- Donations were made for further strengthening the activities of ISWS. Dr. T.V. Muniyappa, former interim President of the Society donated a sum of Rs. 1.0 lakh for the ISWS Young Scientist Award. Dr. A.N. Rao contributed a sum of Rs.1.00 lakh for the ISWS Best Ph.D. Thesis Award. Dr. Megh Singh, University of Florida donated Rs. 1.0 lakh for the ISWS Student Travel Grant Fund. All the members of the Executive Committee of ISWS, all the scientists of DWR, and some other members contributed one day salary or pension towards this fund. Dr. B.S. Chauhan contributed his award money of Rs. 32,500/- towards this fund. Dr. M.K. Upadhyay of Canada also contributed Rs. 50,000 for further strengthening the activities of the ISWS.
- Dr. N.T. Yaduraju expressed surprise on financial position of APWSS. The total net balance of the Society was a mere US \$ 16,000, while it was more than US\$ 36,000 during 22nd Conference held in Australia, which after the Conference came down to less than US \$15,000.
- In order to improve the financial standing of APWSS, decisions were taken at the 24th Conference at Bandung, Indonesia. It was proposed that all the regional weed science societies should officially become members of the APWSS and pay a membership fee of US \$ 300.
- It was proposed that weed scientists should become members of the APWSS – annual membership of US \$ 10, and life membership of US \$ 150.
- It was expressed that APWSS will survive and move forward only if there is sufficient money available in the account. There is need to improve financial position significantly so that it should be in a position to sponsor the participation of at least one participant from each member country of the region.
- It was announced that the ISWS will contribute 10% of the Registration Fee collected at this Conference towards the APWSS. This should become a norm for all the future APWSS Conferences.
- It was hoped that the records made in this Conference will be broken at the 26th Conference to be held at Kyoto, Japan in 2017, and the Society will move forward at much greater speed than in the past.

Technical Programme 25th Asian Pacific Weed Science Society Conference

on

Weed Science for Sustainable Agriculture, Environment and Biodiversity

13-16 October, 2015, Hyderabad, India

Venue – PJTSAU, Auditorium, Rajendra Nagar, Hyderabad

Registration: Venue – PJTSAU, Auditorium

Monday, October 12, 2015; Time: 14:00-18:00 hrs

Tuesday, October 13, 2015; Time: 7:30-9:00 hrs

APWSS Executive Committee meeting–

Venue: Hotel Radisson, Hitech City, Hyderabad

Monday, October 12, 2015; Time: 18:00- 21:00 hrs

Tuesday, October 13, 2015

Venue: Main Hall

09.00– 10:30 **Opening ceremony**

10:31 – 11:00 **High Tea and Poster Sessions**

11:01 – 12.30 **Chair:** Steve Adkins

Rapporteur: J.S. Mishra

PLENARY PRESENTATION –1

R. Charudattan – Weed control with microbial bioherbicides

PLENARY PRESENTATION –2

R.K. Malik – Weed science and sustainable intensifications of cropping systems in South Asia

12:31– 13:30 **Lunch/Poster session**

13:31 – 14:15 **Chair:** Nilda R. Burgos

Rapporteur: T.K. Das

PLENARY PRESENTATION –3

J. Storkey – Reconciling crop production with biodiversity – a European perspective on weed management

TECHNICAL SESSIONS (Concurrent Sessions in Main Hall, Hall 1, 2 and 3)

Venue: Main Hall

14:16 – 18:00 TECHNICAL SESSION 1: Weed management options for rice and rice based cropping systems of Asian-Pacific region

Chair: Buddhi Marambe

Co-Chair: A.S. Rao

Rapporteur: M.S. Bhullar

Lead presentations:

- Sustainable weed management in dry-direct seeded rice in South Asia – **Gulshan Mahajan**
- Effects of soil moisture conditions on emergence of weeds and rice plants in soils from rainfed rice fields of lowland savanna of Ghana – **Hirohiko Morita**, Akira Uchino, Fuseini Abraham, Fulera Tahiru and Jun-Ichi Sakagami

Contributory articles:

- Bio-efficacy of post-emergence new generation herbicides in transplanted rice (*Oryza sativa* L.) – **Rathod Nilesh Dayaram**, Elizabeth K. Syriac and Sheeja K Raj
- Efficacy of herbicides and their combinations for control of complex weed flora in transplanted rice – **Sanjay M.T.**, G.N. Dhanapal, T.V.R. Prasad, G.R. Hareesh, T.V. Muniyappa, Veeresh Hatti and A. Geetha Kumari
- Energy analysis of weed management practices in aerobic rice – **B. Sreedevi**, P.C. Latha, A. Sandhyarani, D. Sreenivas
- Integrated weed management in rice-rice cropping system under east and south eastern coastal plain zone of Orissa – **S. K. Mohanty**, M.M. Behera, M.M. Mishra, R. Dash and P.J. Mishra
- Management of weeds under different establishment methods in dry direct-sown and aerobic rice (*Oryza sativa* L.) systems – **Sanjoy Saha**, Munda Sushmita, B.C. Patra, T. Adak, S. Singh and B.S. Chauhan
- Weed shift, soil health and crop productivity in rice (autumn) - rice (winter) sequence in relation to long term herbicide use – **J. Deka**, I.C. Barua, N.C. Deka, N. Borah, K. Mahanta and D.J. Rajkhowa
- Weed management in upland rice for productivity enhancement under hill eco-system of North-East India – **D.J. Rajkhowa**, R. Pradhan, A.K. Sarma, R. Krishnappa, N.S. Azad Thakur and S.V. Ngachan

16:01 – 16:30 **Poster session and Tea**

16:31 – 18:00 **Technical Session 1 Continue**

- Herbicides combinations for management of complex weed flora in drum seeded puddled rice of Telangana State – **M. Yakadri**, P. Leela Rani and T. Ramprakash
- Weed suppression abilities of rice varieties under aerobic rice system – **Manpreet Singh** and M.S. Bhullar
- Farmers' participatory approach: Bio-efficacy of sequential application of herbicides in rice-rice cropping system in Telangana State – **M. Malla Reddy**
- Direct seeded rice in north-western India: shift in weed flora and its management – **Dharam Bir Yadav**, Ashok Yadav and Gurjeet Gill
- Evaluation of new premix mixture penoxsulam + cyhalofop butyl for weed control in direct seeded puddled rice (*Oryza sativa* L.) – **Sheeja K. Raj** and Elizabeth K. Syriac
- Efficacy of Rinskor™ active against weed flora in different rice cultures of India – **Vinod Singh Mehra**, Mayank Yadav, Basweshwar Ghodki, Kiran Rajput, Monte Weimer and Lap Nguyen
- Use of dose-response relationship to identify herbicide's efficacy in a mixture – **Yogita Gharde**, Dibakar Ghosh, Raghwendra Singh, P.K. Singh and R.P. Dubey

Venue: Hall-1

14:16 – 16:00 **TECHNICAL SESSION-2: Weed biology and ecology**

Chair: Trevor James
Co-Chair: Denny Kurniadie
Rapporteur: Yogita Gharde

Lead presentations

- Weed seed atlas – ready reckoner for identification and seed regulation – **Shripati Cherry**
- Italian ryegrass: germination, biology, and interference with corn – **Vijay Nandula**
- Persistence and depth of emergence of wild proso millet seed in New Zealand soils – **Trevor James**

Contributory articles

- Management of weedy rice – Indian experience - **C.T. Abraham** and Nimmy Jose
- Density and nitrogen effects on the interference of *Phalaris minor* in wheat – **Rishi Raj**, T.K. Das, Ramanjit Kaur and Raj Singh
- Weed survey in sweet corn (*Zea mays saccharata* Sturt.) in Sumedang and Bandung Indonesia – **Denny Kurniadie**, Uum Umiyati and Dedi Widayat

16:01 – 16:30 **Poster sessions and Tea**

16:31 – 18:00 TECHNICAL SESSION–3: Weed biology and ecology including impact of changing climate**Chair:** Krishna N. Reddy**Co-Chair:** R.M. Kathiresan**Rapporteur:** Meenal Rathore**Lead presentations**

- Modelling as a tool to help understand, predict and manage weeds – **Michael Renton**
- Climate smart agriculture and indigenous management of invasive alien weeds – **R.M. Kathiresan**

Contributory articles

- Effect of resource conservation module of rice on weed infestation and sheath blight disease – **Chandra Bhanu** and V.P. Chaudhary
- Characterizing weed flora, shifts and nesting capacity of habitats in deep water rice areas of Assam – **I.C. Barua**, Jayanta Deka, Kaberi Mahanta, Mitali Devi and Rupam Sarma
- Exotic weed seeds in the imported germplasm – **Mool Chand Singh**, Anjula Pandey and Dinesh Chand

Venue: Hall-2**14.16 – 16:00 TECHNICAL SESSION–4: Allelopathy, the current status and role in weed management****Chair:** Bhagirath S. Chauhan**Co-Chair:** Ramesh K. Singh**Rapporteur:** Anil Duhan**Lead presentation:**

- Rice allelopathy in sustainable agriculture – **Hisashi Kato-Noguchi**

Contributory articles:

- Allelopathy – An natural tool for weed management in field crops -**Veeresh Hatti**, B. K. Ramachandrappa and M. T. Sanjay
- Phytoherbicides: opportunities and research needs. - **D. Subramanyam**, V. Sumathi, V. Umamahesh , N. Sunitha and G. Prabhakara Reddy
- Isolation and identification of putative allelopathic compound in *Cymbopogon nardus* – **Suwitchayanon Prapaipit** and Hisashi Kato-Noguchi
- The potent allelopathic substances of cogongrass rhizome extracts – **Masahiko Suzuki**, Tohru Tominaga and Hisashi Kato-Noguchi
- Optimized analytical techniques for extraction and separation of bioactive compounds from diverse plant types – **S. M. Biswas** and P.C. Bhowmik
- The allelopathic nature of *Parthenium* weed leaf litter: Will this change under a changed climate of CO₂ enrichment? – **Boyang Shi**, Zahid Hanif and Steve Adkins

Venue: Hall-2**16:31 – 18:00 TECHNICAL SESSION-5: Weed management in organic farming systems including weeds use****Chair:** Rick Llwellyn**Co-Chair:** Anuruddhika Abeysekara**Rapporteur:** C. Sarathambal**Lead presentation:**

- Prospects of botanical herbicides in system intensification – **R.K. Ghosh**

Contributory articles:

- Mechanized weed management in System of Rice Intensification (SRI) for its potential to enhance the productivity of irrigated rice (*Oryza sativa* L.) – **R. Mahender Kumar**, T. Vidhan Singh, B. Sreedevi, K. Surekha, Ch. Padmavathi, M.S. Prasad, B. Gangaiiah, T. Sudhaker, D. Sreenivas L.V. Subbarao, Muthuraman. P and V. Ravindra Babu

- Weed dynamics and rice productivity under organic conservation tillage practices in rice-vegetable pea cropping system of North East India – **Raghavendra Singh**, Subhash Babu, R.K. Avasthe and C.D. Phempunadi
- Weed management practices in maize under organic farming in rainfed hill-ecosystem – **Jayanta Layek**, Anup Das, Ramkrushna GI, D.P. Patel, Manoj Kumar, A. S. Panwar and S.V. Ngachan
- Effects of soil types on efficacy of S-metolachlor-treated oil palm frond mulch on inhibition of herbicide-resistant biotypes of goosegrass – **T.S. Chuah** and W.K. Lim

Venue: Hall-314:16– 16:00 **TECHNICAL SESSION- 6: Innovative weed management technologies**

Chair: A.N. Rao
Co-Chair: Michael Renton
Rapporteur: Anil Kumar

Lead presentation:

- Unmanned Aerial Vehicle: An Unique Platform for Low-Altitude Remote Sensing for Crop Management – **Krishna N. Reddy**

Contributory articles:

- Searching for potential future solutions for managing aquatic weeds – **Peter Harper**
- CRIJAF Nail Weeder – an innovative tool for weed management: Farmers' experience – **Shailesh Kumar**, A Shamna, S.K. Jha and A.K. Ghorai
- New herbicide application techniques for the management of aquatic weeds in Australasia – **William Chisholm**, Nimal Chandrasena and Peter Harper
- Herbicide Resistant Crops: A better option for Integrated Weed Management in India - **C. Chinnusamy**
- Management of weedy rice by DCA using novel wick applicator – **Nimmy Jose**, C.T. Abraham, Reena Mathew and S. Leena Kumari
- Residue of oil palm frond mulch as slow release carriers for herbicide – **M. Dilipkumar**, C.M. Mazira and T.S. Chuah
- New fangled strategies to exhaust the seed bank of the world's worst weed the *Cyperus rotundus* – **N. Viji** and C.R. Chinnamuthu

16:01 – 16:30 **Poster sessions and Tea**16:31 – 18:00 **TECHNICAL SESSION-7: Weed management in horticulture and plantation crops and crops other than rice**

Chair: R.K. Malik
Co-Chair: C. Chinnusamy
Rapporteur: Prashant Bodake

Contributory articles:

- The combination effect of MSMA and Diuron in controlling glyphosate resistant *Eleusine indica* in oil palm plantation – **Mohd Hefni Rusli**, Idris Abu Seman, Norman Kamarudin and Sim Khay Chuan
- Influence of weed management practices on weed dynamics and productivity of fennel (*Foeniculum vulgare* Mill.) - **Rajender Kumar**, Amandeep Singh Brar, B S Gill and Tarundeep Kaur
- Herbicides and polythene mulching effects on yield of irrigated cassava – **M. Nedunchezhiyan**, G. Byju, S.S. Veena and V. Ravi
- Effect of tillage and weed control methods on productivity and profitability of maize – **R.R. Upasani**, Sheela Barla, A.N. Puran, R. Thakur and M.K. Singh
- Weed control efficiency of different herbicides and their effect on growth and yield of American cotton in Northern India – **Kulvir Singh**, Pankaj Rathore and Kuldeep Singh
- Effect of weed management practices with fertility levels on weed shift and economics of groundnut in finger millet-groundnut cropping system in the Eastern dry zone of Karnataka – **G.N. Dhanapal**, M.T. Sanjay, G.R. Hareesh and Vinay B. Patil
- The efficacy of glyphosate monoammonium and other commercial herbicides to control volunteer oil palm seedlings in oil palm plantation – **Idris Abu Seman**, Maizatul Suriza Mohamed, Anthony Tan swee Hock and Sim Khay Chuan
- Effect of tank mix application of tembotrione and atrazine on weed growth and productivity of *kharif* maize – **B. Duary**, Pusal Sharma and K. Charan Teja

Wednesday, October 14, 2015

7:30 – 9:00 Posters

Venue: Main Hall

9:00 - 9:45 **Silver Jubilee and Book Launching ceremony**

Chair: N T Yaduraju

Moderator: Anis Rahman

Participants: V.S. Rao, Peter Michael, Steve Adkins, Nimal Chandrasena, A.N. Rao and H. Morita

9:46 – 10:30 **Chair:** R. Charudattan

Rapporteur: Gulshan Mahajan

PLENARY PRESENTATION – 4

V.S. Rao – Transgenic herbicide resistant crops for sustainable weed management in the Asian-Pacific region: Perspectives and alternatives

10:31 – 11:15 **Poster sessins and Tea**

11:16 – 12:30 **Chair:** Nimal Chandrasena

Rapporteur: R.S. Chhokar

PLENARY PRESENTATION – 5

Ian Heap – Herbicide resistance – A global perspective

PLENARY PRESENTATION – 6

Peter Michael – Towards a better understanding of weeds in the Asian-Pacific region

12:31 – 13:30 **Lunch/Posters**

13:31 – 14:15 **Chair:** Hiroshi Matsumoto

Rapporteur: I.C. Barua

PLENARY PRESENTATION – 7

P. Westerman – Functional biodiversity for sustainable weed management - Case studies and opportunities

SYMPOSIA (Concurrent sessions)

Venue: Main Hall

Symposium 1: Weed management in conservation agriculture

Conveners: Deirdre Lemerle; Michael Widderick; Toni Nugent

14:16 – 18:00

- Welcome to the symposium – **Deirdre Lemerle**
- A farmer’s perspective on weed management in CA – **Murray Scholz** (Farmer)
- Development and adoption of CA and herbicide use in Australia – **Rick Llewellyn**
- Integration of alternative chemical and non-chemical approaches for weed management to ensure herbicide durability – **M.J. Widderick**

- Weed management in CA in Bangladesh – **Mahfuza Begum**
- Weed management in CA in India – **Makhan Singh Bhullar**
- Effect of tillage sequence and weed management on weed dynamics and productivity of direct seeded rice-wheat cropping system – **Dhirendra Kumar Roy**
- Weed shift and seed bank studies in conservation agriculture under rainfed Alfisols in pigeon pea – **G. Pratibha**
- Managing weeds in rice-wheat system under conservation agriculture in black cotton soils – **V.P. Singh**
- Challenges and opportunities for future R&D collaboration and funding- **Open house discussion**

Venue: Hall-1

Symposium 2: Weedy rice challenge in Asia: issues and options for management

Conveners: Stephen Powles; Roberto Busi; Bhagirath S. Chauhan

14:16 – 18:00

- Welcome to the symposium – **Stephen Powles**
- ACIAR investments to improve weed control in rice in Asia and current focus on weedy rice – **Roberto Busi**
- Weedy rice and weed management issues in direct-seeded rice (DSR) systems – **Bhagirath S. Chauhan**
- Weedy rice - The Indian Scenario – **Meenal Rathore**
- Enhancing Awareness on Weedy Rice Management in the Philippines – **Edwin Martin**
- Diagnostic survey of a rice-based cropping system in Vietnam with emphasis on weedy rice (*Oryza sativa* f. spontanea) – **Nghia Nguyen Khoi**
- Distribution patterns of weedy rice (*Oryza sativa* f. spontanea) populations in different climatic zones in Sri Lanka – **Shyama Weerakoon**
- Present status and management approaches of weedy rice in Japan – **Hiroaki Watanabe**
- Herbicide resistant weeds in Malaysian rice fields: will weedy rice become the next candidate? – **Muhammad S. A. Hamdani**
- Clearfield rice: key challenges on a global perspective and lessons to be learnt in Asia – **Nilda R. Burgos**
- How predictable are weedy rice infestations: modelling insights into management – **Francesco Vidotto**
- How to model spatial spread and weediness traits of weedy rice? – **Michael Renton**
- Weedy rice management in Europe and insights to Asian rice systems – **Maurizio Tabacchi**
- General discussions / questions – **Moderator: Stephen Powles**

Venue: Hall-2

Symposium 3: Herbicide resistance: current status and future challenges globally

Convener: Prashant Jha; Dr. Ian Heap

14:16 – 18:00

- Welcome to the symposium – **Moderator: Prashant Jha**
- Status of herbicide-resistant weeds globally – **Ian Heap**
- Herbicide resistance in weeds: survey, characterization, and mechanisms – **Vijay Nandula**
- Resistance evolution among *Echinochloa* species in the Southern USA – **Nilda R. Burgos**
- Key herbicide-resistant weeds in the cereal production systems of US Great Plains – **Prashant Jha**
- Herbicide-resistant weeds in the northern region of Australia – **Bhagirath S. Chauhan**
- Management of multiple herbicide resistance in *Phalaris minor* in India – **Samunder Singh**
- Multiple herbicide resistance in key broadleaf weeds in US Great Plains – **Phillip W. Stahlman**
- Molecular cytogenetic mechanism(s) of EPSPS gene amplification in glyphosate-resistant weeds – **Mithila Jugulam**
- Herbicide-resistant weeds: management strategies and upcoming technology – **Krishna Reddy**
- Modelling the evolution of herbicide resistance in weeds: current knowledge and future – **Muthukumar Bagavathiannan**
- Herbicide-resistance in weeds and crops: interactions and impact on farming sustainability – **Baruch Rubin**
- Conclusions from oral/poster presentations – **Prashant Jha**

Venue: Hall-3**Symposium 4: Biological control – progress and future prospects in Asia-Pacific region****Convener:** K. Dhileepan, Dr. R. Charudattan, Dr. Gadi, V.P. Reddy

14:16 – 18:00

- Welcome to the symposium – **K. Dhileepan**
- Prospects for extending the success in the biological control of *Parthenium* weed in Australia into the Asia - Pacific region – **K. Dhileepan**
- Use of plant pathogens as weed biocontrol agents in the Asia - Pacific region – **Marion Seier**
- Multitrophic interactions in weed biocontrol – its role and future – **Puja Ray**
- Semiochemicals in classical biological control of weeds: challenges and opportunities - **N. Bakthavatsalam**
- Biological control of weeds in India: current status and prospects – **Sushilkumar**
- Prospects of biological control of major invasive alien weeds in forest ecosystems in India – **A. Balu**
- Concluding remarks – **K. Dhileepan**

Venue: Hall-4**Symposium 5: Utilization of weeds as bio-resources****Convener:** Nimal Chandrasena

14:16 – 18:00

- Welcome to the Symposium – **Nimal Chandrasena**
- Liabilities or Assets? Perspectives on 'Weeds and Their Values' – **Nimal Chandrasena**
- Weed utilization in Japan: A History – **Hirohiko Morita**
- Allelochemicals and natural products from weeds – **Yoshiharu Fujii**
- Utilization of weeds and agro-waste for compost and vermi-compost making – **Sushilkumar**
- Bio-prospecting the food potential of weedy relatives of crops: Studies with *Echinochloa* species and *Physalis* species – **Bhumesh Kumar**
- Water quality improvement in wetland treatment systems with emergent and free-floating weed species - **Premraj Khankhane**
- Water Hyacinth: Beautiful Blue Devil or Cinderella? – **Puja Ray** and Nimal Chandrasena
- Wetland colonizers to anti dandruff dermatitis – a scientific validation of Indigenous Technical Knowledge on Ipomoea – **Nabanita Chakraborty**
- Medicinal compounds from weeds – **Yoshiharu Fujii**
- Open Discussion on Future of Utilization and Conclusions: (**Moderator: Nimal Chandrasena**)

19:00-22:00 **Cultural programme and dinner****Thursday, October 15, 2015****Field Visit and Sightseeing Trips****Field trip – 1** (Local sightseeing)**Field trip – 2** (Ramoji Film City)**Field trip – 3** (Visit to Agriculture Research Station, PJTSAU and ICRISAT)

Friday, October 16, 2015

Venue: Main Hall

9.00-10:30 **Chair:** Prasanta C. Bhowmik

Rapporteur: M. Madhavi

PLENARY PRESENTATION – 8

Nimal Chandrasena – Of weeds and men: Some perspectives

PLENARY PRESENTATION – 9

Steve Adkins – Biology, ecology and management of the invasive *Parthenium* weed (*Parthenium hysterophorus* L.)

10:31-11:00 **Poster sessions and Tea**

11:01-12:30 **Chair:** Baruch Rubin

Rapporteur: Neelam Sharma

PLENARY PRESENTATION – 10

B. Marambe – Strengthening the capacity to control invasive alien species - Sri Lankan experiences

PLENARY PRESENTATION – 11

Chris Parker – Parasitic weeds and their control: Are we winning?

12.31-13.30 **Lunch/Posters**

TECHNICAL SESSIONS (Concurrent Sessions in Main Hall, Hall 1, 2, 3 and 4)

Venue: Main Hall

13:31-16:00 **TECHNICAL SESSION–8: New herbicide molecules and products: the role of herbicide industry**

Chair: L.S. Brar

Co-Chair: M. Dilipkumar

Rapporteur: P.J. Khankhane

Lead presentations:

- History of auxin herbicides (2,4-D to aryloxyacetic acids): Discovery of novel chemistry with new uses and attributes – **Monte R. Weimer**
- Adjuvants and Agrochemicals – **Megh Singh**

Contributory articles:

- Development and global utility of Penoxsulam in Rice – **Rick Mann**
- Efficacy of Assert™ herbicide against weed flora in transplanted rice in India – **Basweshwar Ghodki**, Vinod Singh Mehra, Mayank Yadav and Richard K. Mann
- Efficacy of Vivaya™ herbicide against weed flora in different rice cultures™ in India – **Mayank Yadav**, Vinod Singh Mehra, Basweshwar Ghodki and Richard K. Mann
- Zeozyme and lanthanum doped nano particle embedded in a polystyrene film - As photocatalyst for degradation of diuron in ecosystem – **Bhomi Reddy Saranya**, Velayudham Sathiyarayanan and **Sinthalapadi Thulasiramaraja Maheswari**
- New weed control solution for non-crop land and soybean from ADAMA – **Srinivasan Rengan**
- QUELEX™ herbicide (halauxifen methyl + florasulam): A New Post-Emergent Broadleaf Weed Herbicide Product for China Winter Wheat Production Systems – **M.S. Lee**, Jack Wu, Roger Gast

- Effectiveness of 'Zechor' (Flucetosulfuron 10% WG), a sulfonylurea herbicide – **INDOFIL Representative**
- Discovering new herbicide by utilizing intermediate derivatization – **Madhuban Gopal**, A. Upadhyay, T.K. Das and Rajesh Kumar
- Herbicide Tolerant Crops, an important component of Integrated Weed Management – **Monsanto representative**
- Rinskor™ active in wet seeded rice in China – **Zhen W. Yao**

Venue: Hall 1**13:31-16:00 TECHNICAL SESSION–9: Weed management options for crops and cropping systems (other than rice) of Asian-Pacific region****Chair:** Michael Widderick**Co-Chair:** Samunder Singh**Rapporteur:** V.S.G.R. Naidu**Lead presentations:**

- Integrated weed management options in Australian agriculture – **Bhagirath S. Chauhan**

Contributory articles:

- A potential herbicide mix formulation to control a broad spectrum of weeds in cotton – **A.S. Tomar**, Burhanuddin Bohra and G.V. Dalal
- Integrating herbicidal and conventional approach for profitable weed management in groundnut – **Parvender Sheoran**
- Weed management options and strategies in pulse crops in India – **Narendra Kumar**, S.S. Singh, C.S. Praharaj and Ummed Singh
- Weed management in relay crop of blackgram – **A.S. Rao**
- Weed management in rainfed agriculture in India: Issues and future strategies – **K.A. Gopinath**, Ch. Srinivasa Rao and G. Ravindra
- Weed flora and yield of winter maize + potato intercropping system as influenced by weed management – **Paramjeet Kour**, Anil Kumar, Jai Kumar, B.C. Sharma and Amit Mahajan
- Integrated weed management in spring sugarcane – **P.M. Chaudhari**, K.C. Ombase, D.S. Bhoite, U.S. Barve, S.K. Ghodke and S.M. Pawar
- Weeds and weed control in finger millet {*Eleusine coracana* (L.) Gaertn.} in India – A review – **A.N. Rao**, J.K. Ladha and S.P. Wani
- Energy usage and benefit-cost analysis of cotton under various weed management practices – **P. Leela Rani**, M. Yakadri, N. Mahesh and P. Spanda
- Efficacy of new herbicide molecules in rainy-season grain sorghum – **J.S. Mishra**, S.S. Rao and J.V. Patil
- Bio-efficacy of post-emergent tembotrione application on weed dynamics and productivity of Kharif maize in rainfed foothill and mid hill conditions of J & K – **Jai Kumar**, Anil Kumar, V. Sharma, R. Bharat and A.P. Singh
- Efficacy of herbicide mixture for weed management in Bt-cotton – **M. Madhavi** and T. Ramprakash

Venue: Hall 2**13:31-16:00 TECHNICAL SESSION–10: Herbicides persistence and soil health****Chair:** P.C. Rao**Co-Chair:** Shashi Bala Singh**Rapporteur:** Partha P. Choudhury**Lead presentation:**

- Adsorption and desorption behaviour of the herbicide glyphosate in agricultural soils and their effect on bioavailability – **Nghia K Nguyen**

Contributory articles:

- Estimation of major herbicides in paddy field and ground water using GCMS-Tandem Mass Spectrometry – **Anil Duhan**, S.S. Punia, Dimple Rani and Dharambir Yadav
- Correlation and regression studies on herbicide movement in soils of Andhra Pradesh – **S. Rama Lakshmi**, P.C. Rao and M. Madhavi
- Leaching of cyhalofop-butyl in sandy loam soil in field lysimeters – **Shobha Sondhia**
- Effect of glyphosate formulations on earthworm and micro flora in soil – **C.R. Shitha**, K.M. Durga Devi and C.T. Abraham

- Long term effect of herbicides on enzymes and enzymatic activities in major soils under intensive and long term fertilizer experiments in India – **R.H. Wanjari** and Muneshwar Singh
- Suitable herbicide combinations for the weed management in vegetable pea under conservation agriculture – **Raj Singh**
- Persistence and degradation kinetics (T_{1/2}) of pyrazosulfuron-ethyl in soil under aerobic condition – **S.R. Vikram**, G.R. Hareesh, G.N. Dhanapal and Pati Narendra
- Bio-efficacy of pre and post emergence herbicides in green gram and their residual effect on succeeding mustard crop – **S.S. Punia**, Anil Duhan, Dharambir Yadav and Mohammad Irfan
- Herbicidal effects on soil and crop health in cotton – **Rajanand Hiremath**, G. S. Yadahalli, B.M. Chittapur, V.G. Yadahalli and B.G. Koppalkar
- Monitoring of herbicide residues in vegetable crops of Himachal Pradesh – **Neelam Sharma**, Dinesh Badiyala and Nitasha Thakur

Venue: Hall 3

13:31-16:00 **TECHNICAL SESSION-11: Management of problematic (including alien invasive and parasitic) weeds**

Chair: C.T. Abraham

Rapporteur: M.T. Sanjay

Lead presentation:

- Can invasive weeds be stopped? – **Prasanta C. Bhowmik**

Contributory articles:

- Weeds including *Cyperus rotundus* management in soybean – **T.K. Das**
- Effectiveness of arbuscular mycorrhizal fungi against *Striga* emergence in sugarcane and sorghum – **P. Jones Nirmalnath**, Netravati Meti, Madhura A. Sagarkar, Ramesh Babu and K.S. Jagadeesh
- Applicability of borax and thiourea for management of *Orobanche* – **Chinnaswamy Kannan**, Aditi Pathak and Binne Zwanenburg
- Management of *Striga* scourge in sugarcane – Lessons from the strategic participatory research – **Ramesh Babu**, Sudheendra Saunshi, Sujata Guled, Reena Rajput and Gourishankar Sajjanar
- Biological management of *Orobanche crenata* on tomato using native fungi and their metabolites – **Aditi Pathak** and C Kannan
- Eradication of quarantine weed *Ambrosia psilostachya* in Karnataka – **N. Sathyanarayana**, N.V. Kulkarni, T.V. Ramachandra Prasad, M.T. Sanjay and K. Satyagopal
- Control of Hemiparasite, *Dendrophthoe falcata* on Tree Crops – **T. Girija**
- Herbicide resistant weeds and their management in wheat – **R.S Chhokar**, R.K. Sharma and Indu Sharma

Venue: Hall 4

13:31-16:00 **TECHNICAL SESSION-12: Tillage, nutrients, seeding time, soil and water in relation to weed management in Asia-Pacific region**

Chair: Vijay Nandula

Rapporteur: G.N. Dhanapal

Lead presentation:

- Conventional and conservation agricultural systems – **A.R. Sharma**

Contributory articles:

- Conservation agriculture (CA)-based practices reduced weed problem in wheat and caused shifts in weed seedbank community in rice-wheat cropping systems - **Virender Kumar**, Daniel C. Brainard, P.C. Sharma, H.S. Jat, R.K. Malik, D.K. Sharma, A. McDonald
- Tillage and weed management for improving productivity and nutrient uptake of soybean – **U.K. Behera**, A.R. Sharma, A. Monsefi, Swarna Ronanki, Arup Layek and B. Bhargavi
- Tillage, crop establishment and weed management methods on microbial and soil organic carbon of rice under rice based conservation agricultural system – **R. Govindan**, C. Chinnusamy, N.K. Prabhakaran and R. Shanmugasundram
- Effect of time of planting and weed management in direct seeded aromatic rice of foot hills Jammu and Kashmir Himalayas – **Neetu Sharma**, Anil Kumar, Jai Kumar, Amit Mahajan and Lobzang Stanzen

- Integration of nitrogen fertilizer timing and weed management practices affects weed dynamics and competition in dry-seeded rice (*Oryza sativa* L.) – **Ramesh K. Singh**, Santosh Kumar and R.N. Meena
- Weed management in no-tilled maize (*Zea mays* L.) within rice residue for small land holder – **Pijush Kanti Mukherjee** and Anwesh Rai
- Efficient weed management through conservation agricultural practices – **U.P. Singh**, J.S. Mishra, M. Das, H.S. Ravi Kumar, J. Padmavathi, Himanshu Singh, Lakhapati Singh, Tanay Joshi, Nikhil K. Singh and Rakesh Kumar
- Weed Management and conservation agriculture in rice-wheat cropping System – **V. Pratap Singh**, S.P. Singh, Tej Pratap A. Kumar, A. Banga and Neema Bisht
- Impact of tillage, residue and weed management on growth and yield of rabi maize – **Raghwendra Singh**, R.P. Dubey, V.P. Singh, Dibakar Ghosh, C. Sarathambal, K.K. Barman, P.P. Choudhury and A.R. Sharma
- Time of start of irrigation and weed management practices on nutrient uptake of crop and weed in dry seeded irrigated (semi dry) rice – **G. Sreenivas**, D. Raji Reddy and N. Mahesh
- Impact of conservation tillage on weed dynamics in the Rice- Rice cropping system – **K. Subrahmaniyan**, V. Ravi, P. Parasuraman, E. Subramanian, G. Senthil Kumar and R. Rajendran
- Weed management in soybean under conservation agriculture – **A.K. Vishwakarma**, R.S. Chaudhary, N.K. Sinha, K. Bharti, B.P. Meena and R.H. Wanjari
- Tillage and Integrated weed management impact on weed dynamics, production and economics at soybean- onion crop system – **P. Bodake**

16:01-16:30 **Poster sessions and Tea**

Venue: Main Hall

16:31-18:00 **Closing Ceremony**

PLENARY LECTURES

Plenary lecture - 1

Speaker: Dr. R. Charudattan – Weed control with microbial bioherbicides

Dr. R. Charudattan, an emeritus professor of Plant Pathology, University of Florida made a presentation on brief history, accomplishments, challenges and shortcomings in weed control using microbial herbicides. Highlights of the presentation were progress in microbial herbicide research field, technology development, product introduction and knowledge contribution since 1980s. He also informed about newly-developed bioherbicides, viz. ‘Organo-Sol’ [composed of five species of lactobacilli, citric acid (2%) and lactic acid (1.8%) in fermented milk] in Canada against clovers (*Trifolium repens* and *T. pretense*); ‘*Phoma macrostoma*’ (a fungal pathogen) for broad-spectrum weed control and for controlling Canada thistle in wheat and pumpkin; ‘Opportune’ [contains the bacterial (actinomycetes) species *Streptomyces acidiscabies*, the causal agent of a scab disease in potato] for pre and post-emergence for broad-spectrum weed control and ‘SolviNix RLC’, the world’s first herbicide containing a plant virus ‘TMGMV U2’ for control of *Solanum viarum*. He also talked about several other mycoherbicide products which are in pipeline.

Recommendations

- Bioherbicides play crucial role in managing herbicide resistant, invasive and parasitic weeds and responding to the need of organic agriculture
- Under the changing scenario of weed management, newer microbial bioherbicides need to be developed and demonstrated
- New ways of using microbes and microbially activated mechanisms for weed control are to be discovered

Plenary lecture - 2

Speaker: Dr. R.K. Malik – Weed science and sustainable intensification of cropping systems in South Asia

Dr. R.K. Malik from International Maize and Wheat Improvement Center (known by its Spanish acronym CIMMYT for Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), India highlighted the attainment of higher crop productivity from existing land with minimal environmental impact and risk associated with climate change, which is needed to meet the future food demand. He stressed upon that weed management, especially through herbicides should not be seen in isolation but it has to be looked beyond the herbicides and weeds. Sustainable intensification and integrated weed management appears more relevant to monitor and manage issues such as weed flora shift and herbicide resistance. In South Asia, conservation agriculture (CA)-based crop management practices has shown many benefits, but their adoptions at large scale is still a challenge. CA-based technologies, especially zero tillage (ZT) has not only improved the productivity and resource-use efficiency, but also favoured weed management in rice-wheat, pearl millet-wheat and soybean – wheat cropping sequences. ZT can shifts competition in favour of crops. ZT in combination of pre-plant weed management using non-selective herbicides and crop/cropping system intensification can minimize the problem of perennial weeds, he added. Dr Malik also pointed out the major issues of rice, like puddling, transplanting, continuous flooding, labour scarcity and wheat viz., intensive tillage and burning crop residues in rice-wheat cropping system, and advocated machine transplanting and direct seeding (DSR) in rice with appropriate management of weeds. Use of hybrid rice varieties appeared to be more productive and profitable in both DSR and machine transplanting. He also raised prominent issues like weed flora shift in DSR (dominance of *Leptochloa* and *Eragrostis*) due to change in rice ecology. Weedy rice in rice-rice ecology and volunteer rice in low land ecology of DSR were the emerging weeds. Dust mulching in DSR has reduced the weed infestation up to 60%. Finally he suggested using short duration rice cultivars and long duration wheat with integrated weed management, maintaining crop residues, short duration summer greengram for sustaining the productivity of rice-wheat system in South Asia. Dr. Malik emphasized ‘Virtuous cycle’ rather than ‘vicious cycle’ of weed management.

Recommendations

- Dust mulching needs to be promoted to reduce the weed infestation in direct-seeded rice.
- Short-duration rice cultivars and long-duration wheat followed by short-duration summer greengram with integrated weed management and maintaining crop residues can be helpful in sustaining the productivity of rice-wheat system in South Asia.
- Integrated approach of weed management with sustainable intensification was recommended to tackle the emerging problem of weed shift and herbicide resistance.

Plenary lecture - 3

Speaker: Dr. J. Storkey – Reconciling crop production with biodiversity – a European perspective on weed management

Dr. J. Storkey introduced the topic and expressed his concerns about intensive agricultural system with over-reliance on herbicides and other external inputs, which have aggravated weed problem/shift and caused damage to the field level biodiversity. Soil fertility and intensity of disturbances are main drivers of plant communities at the field scale. Disturbances help in selection of functionally contrasting species. Increased fertilizer use has led to fewer and more competitive weeds. Intensification has acted like a filter. Countries with higher yields have more number of rare weed species. He emphasized the need of weed conservation for their functions in the ecosystems and highlighted the role of cereal cultivars and simple crop rotations with fewer control measures for better weed management. He emphasized that there should be common agricultural practices (CAPs), which should have greening measures. Dr. Storkey suggested possible field management for conserving biodiversity that include re-diversifying of the systems with habitat and weed management. The approaches should include: hedge row management; field strip/ cultivated strip management; sown grass buffer strip; and growing crops with reduced inputs.

Recommendations

- Judicious use of fertilizer to check weed growth
- Need of weed conservation for their functions in the ecosystems
- Simple crop rotations with fewer control measures for better weed management
- Under the changing scenario of weed management, newer microbial bioherbicides need to be developed and demonstrated

Plenary lecture - 4

Speaker: Dr. V.S. Rao – Transgenic herbicide resistant crops for sustainable weed management in the Asian-Pacific region: Prospective and alternatives

During his presentation, it was discussed that the adoption of herbicide resistant crop (HRC) has the potential to solve the problem of weeds. For example, glufosinate- and glyphosate-resistant rice cultivars were developed through transgenic technologies. Imidazolinone-resistant rice was developed through chemically induced seed mutagenesis and conventional breeding and it conveys resistance to the imidazolinone group of herbicide. These herbicides share some important and unique characteristics such as broad-spectrum control of grasses and broad-leaf weeds, long-term weed control, flexibility in crop rotation, a biodegradable nature, and effectiveness at low doses, therefore reducing the total amount of herbicide released in the environment. Explicit guidelines must be adhered to when using HRC. If compatible species are sympatrically distributed and their flowering time is similar, then gene flow is ubiquitous even in self-pollinated crops. Herbicide-resistant crops appear very promising. The evolution of herbicide-resistant weeds due to increased reliance on a single herbicide for weed control is a potential concern. About 310 weed biotypes have evolved resistance to 19 different target-site chemistries. The evolution of herbicide resistance in weeds through selection pressure imparts greater risk than the development of resistance through gene flow in related species in which the frequency of interspecific hybridization and subsequent introgression is low. For example, gene flow from imidazolinone-resistant rice cultivars to weedy rice could, however, hasten resistance development in weedy rice because this herbicide group exerts strong selection pressure. But, problems can be diminished with the use of integrated weed management strategies. The use of HRC requires meticulous stewardship to prevent outcrossing. Consequently, in order to follow stewardship recommendations, farmers would need to understand the risks and the consequences of gene flow and they should be trained. The advantage of such a system is that the certified seed, produced on quality-controlled production farms, will be free of weed seeds, including wild relatives of rice, and as such will minimize the spread of weedy and wild rice biotypes. Establishment of effective public-private partnerships might go a long way towards the spread of this technology. It was highlighted that HRC suffers from several concerns and these can be minimized by adoption of sustainable weed management practices, maintaining isolation distances between transgenic and non-transgenic crop varieties, temporal isolation, biological confinement, advanced techniques in generating genetically modified crops such as intragenesis, cisgenesis, site directed mutagenesis *etc.* For example, gene flow to conventional rice cultivars may cause a subsequent indirect flow of transgenes to wild rice in adjacent fields. Despite the potential benefits of HRC as a weed management tool, it is necessary to fully assess the potential adverse consequences of the widespread adoption of HRC.

Recommendations

- Adoption of herbicide resistant crop (HRC) must be at higher rate.
- Use of integrated approach to mitigate herbicides resistance must be advocated
- Assessment of potential adverse consequences of widespread adoption of HRC must be done

Plenary lecture - 5

Speaker: Dr. Ian Heap – Herbicide resistance - A global perspective

Dr. Heap said that herbicide resistant weeds are a global problem and presently 461 unique resistance biotypes of 247 species (144 dicot weeds and 103 grasses) are being reported from 12,000,000 fields/sites. The greatest problems with herbicide resistant weeds are in North America while Africa has relatively less problem of herbicide resistance in weeds due to less herbicide usage. Herbicide resistant weeds continue to challenge the long term viability of global cropping systems. Maximum cases of herbicide resistance are in wheat crop followed by corn, and in Asia maximum cases of herbicide resistance are in rice crop. The greatest problems globally with herbicide weeds are against ALS inhibitor and ACCase inhibitor herbicides. The evolution of multiple herbicide resistance in weeds and non-availability of new herbicide chemistry molecules is the biggest hurdle in herbicide resistance management. The future of weed control is dependent on understanding evolutionary pressures and utilizing a diversity of weed control strategies in order to destabilize evolution of herbicide resistant weeds.

Recommendations

- Evolutionary pressures to mitigate herbicide resistance must be understood
- Use of diversified weed control strategies must be adopted in order to destabilize evolution of herbicide resistant weeds

Plenary lecture - 6

Speaker: Dr. Peter Michael – Towards a better understanding of weeds in the Asian-Pacific region

Dr. P. Michael emphasized the need on proper weed identification and said that this job has been made easier by good quality digital photography. It is desirable to take photographs not only of whole plants but also detailed pictures of important plant parts. A compilation of books should be made being useful in weed identification. Although, still many weedy groups require better collections and serious taxonomic study for their better understanding. It is more important to encourage young scientists with an interest in plants to become active in studies on weeds. Also, there is need of continuation of educational courses in taxonomic methods.

Recommendations

- There is an urgent need of proper and precise weed identification
- Compilation of publications with weed identification features from seed to flowering must be done
- Need of continuation of educational courses in taxonomic methods must be advocated

Plenary lecture - 7

Speaker: Dr. Paula R. Westerman – Functional biodiversity for sustainable weed management: Case studies and opportunities

Dr. Westerman mentioned that agricultural intensification has substantially increased crop productivity but at considerable cost to environment and biodiversity. Concentrating on European agricultural systems, she pointed out that loss of biodiversity can hinder the functioning of agro-ecosystems and the services they provide, such as natural weed control. Weed seeds support an extensive seed-based food web that can help conserving biodiversity in agro-ecosystems; simultaneously seed predation can be an important tool in more sustainable weed management. Weed seed predation is currently too variable to constitute a reliable weed control measure. Unfortunately, there are large gaps in our understanding of the sources of variability and their relative importance. The acceptance and implementation of granivory as a weed management tool may be more problematic due to the dual role of granivores as both pests and beneficial. Highlighting two case studies, one the effect of irrigation and tillage on seed predation in Catalonia, NE Spain, and another the weed seed predation in a diversified cropping system in the US Corn belt in Iowa. Dr. Westerman has shown that there is a considerable potential for intentional regulation of seed predation via crop and soil management. And, the weed seed predation can be combined with other tactics of weed management in an integrated approach. The challenge is to figure out how best make use of the services of seed predators in mitigating the effect of agricultural intensification on agro-ecosystem biodiversity.

Recommendations

- Conservation of biodiversity in agro-ecosystems must be taken care off
- Weed seed predation can be an important tool in more sustainable weed management, hence some research work must be focused on this important aspect

Plenary lecture - 8

Speaker: Dr. Nimal Chandrasena – Of weeds and men: Some perspectives

Dr. Nimal Chandrasena, Principal Ecologist, GHD Pvt Ltd. made a very interesting presentation in which he discussed about negative impacts of weeds like, it reduces agricultural production, quality, and quantity; add production costs and weed control cost; negative impacts on water ways; environmental impacts and so on. He also talked about interaction of weeds with sustainable ecosystems (rivers, catchments and urban), agriculture, climate change, men, environment *etc.* He said that weeds are not only weeds from our egotistical point of view, because they grow where we do not want them. In nature, however, they play an important and interesting role. They resist conditions, which cultivated plants cannot resist, such as drought, acidity of soil, lack of humus and mineral deficiencies. Actually they represent human beings' failure to master the soil, they grow abundantly wherever people have made mistakes, and they simply indicate our errors and nature's corrections. He also said that there are 18-24% genetic similarities between humans and weeds. Then, he talked about the beneficial effects of weed in terms of its biodiversity values, part of 'wild nature', ecosystem services provided by them, edible weeds, medicinal value, pollution remover *etc.* In his concluding remarks he said that weeds are not the culprits; they are just a symptom of the real cause: ecologically destructive land-use practices by humans like, land clearing, monoculture cropping, overgrazing, introductions of species for short-term profit, population explosion, unplanned development *etc.*

Recommendations

- Weeds are useful to maintain the ecological balance, hence human practices need to be monitored including, land clearing, monoculture cropping, overgrazing, introductions of species for short-term profit, population explosion, unplanned development *etc.*

Plenary lecture - 9

Speaker: Dr. Steve Adkins – Biology, ecology and management of the invasive parthenium weed (*Parthenium hysterophorus* L.)

Dr. Steve Adkins is Professor of Plant Physiology at The University of Queensland (UQ), Australia. In his presentation, he emphasized on infestation, wide distribution of Parthenium weed, its control measures *etc.* It was highlighted that Parthenium weed has infested 200,000 km² of area in Australia. Parthenium is a native of American tropics but over the years it has got introduced to many countries of the world and it is likely, that it may spread to every corner of the world in the coming future. In many countries, it entered accidentally through animals (Sri Lanka), pasture seed lots (Australia), vehicles (Nepal), food aid and grain shipment (India, Ethiopia) *etc.* Later, he emphasized on issues related to human health especially about contact dermatitis, animal health, allelopathic effects as well as environmental health. He also discussed in detail about seed biology and said that it produces more than 25,000 seeds/plant, ability to spread seeds and its genetic variability. At last, he stressed upon its management through preventive, chemical through registered herbicides and biological means by use of biological agent, suppressive plants, plant suppression + biological control.

Recommendations

- Preventive measures need to be taken to stop further spread of parthenium weed
- IWM is most effective management option to control Parthenium weed, hence should be adopted

Plenary lecture - 10

Speaker: Dr B. Marambe – Strengthening the capacity to control Invasive Alien Plants- Sri Lankan experience

Dr. Marambe elaborated the significance of biodiversity at global level and methods to safeguard the biodiversity with special reference to Sri Lanka. It was highlighted that Sri Lanka has the highest species diversity per unit land area of all Asian countries in terms of flowering plants and all vertebrate groups, excluding birds. The Country has been identified by Conservation International as one of 34 global biodiversity "hotspots" based on a number of endemic plants and vertebrates, their density and remaining primary vegetation relative to original. Sri Lanka's lowland rainforests, montane rainforests and south western rivers and streams are listed in WWF's Global 200 eco-regions because it is one of the most biologically distinct eco-regions of the planet. As per Government of Sri Lanka's National report to the Convention on Biological diversity, about 44% of all flowering plants in Sri Lanka and 46% of vertebrate species are threatened to extinction. Further, the speaker discussed how Invasive Alien Species are threat to the globally significant biodiversity in Sri Lanka and to environmental and economic well being of the nation. Weeds like Lantana & mesquite

(*Prosopis juliflora*) have invaded many biodiversity rich areas and has drastically reduced the grazing land available for wild animals. Aquatic weeds have invaded water bodies, checking water flow and affecting the preferred habitat of many wild species. Invasive weeds like *Salvinia molesta* and *Eichhornia crassipes* affected water movement in rivers resulting in flash floods through choking waterways. These species provide idle habitat for breeding of mosquito species, thus seriously threatening human well being. Dr. Marambe informed that invasion of alien plant species may be intentional or accidental. But deliberately introduced plants sometimes for a specific purpose escape from their point of introduction and become invasive. He explained this by citing the example of *Salvinia molesta*, which was introduced in Sri Lanka as educational material, escaped human management and became most troublesome aquatic invasive flora. Some instances were quoted by the speaker, where the control measures adopted against one invasive alien plant species caused more spread. One example cited was of mechanical removal of water hyacinth causing its further spread due to contamination of machinery used.

Dr Marambe highlighted the role of stakeholder organizations and their responsibilities in Sri Lanka for management of diversity and Invasive Alien Species. The detailed protocols developed for Invasive Alien Species and regulatory measures being taken in Sri Lanka for prevention and control of IAS were also discussed. It was mentioned that IAS management activities can be strengthened by development and implementation of programmes in form of sharing information and collaborative trainings.

Recommendations

- Strengthening the institutional capacities in Sri Lanka to manage the biodiversity and control IAS
- Policy statements or working mechanisms to tackle the issues related to IAS
- Need based specific techniques and best practices to tackle IAS
- Legal provisions stipulated by various laws should be enforced for prevention of introduction and spread of IAS
- A planned approach should be adopted to educate public about IAS and their impacts
- Communication, education and awareness should be given due importance about IAS

Plenary lecture - 11

Speaker: Dr Chris Parker – Parasitic weeds and their control: Are we winning?

Dr. Parker discussed spread and management of the most problematic root parasites in family Orobanchaceae *i.e.* witchweed and broomrapes in detail. These root parasites have minute seeds which may persist in soil for more than ten years and germinate in response to specific stimulus exuded from roots of potential hosts. Low soil fertility and intensification of cropping system have also contributed to the problematic root parasites. Occurrence and damaging potential of different species of witchweed and broomrape was also discussed in detail. The problematic parasitic weeds in other families' *i.e.* Convolvulaceae and Loranthaceae was also discussed. *Cuscuta campestris* was considered most important species of weedy dodder. It has wide host range and it also infest most broad-leaved field and vegetable crops. In India, crop losses from the species ranged from 31-34% in greengram and blackgram, and upto 87% in lentil. Species like *Cassutha filiformis*, *Dendrophthoe* spp., *Tapinathus* spp., *Viscum album*, *Arceuthobium* spp. cause local problems on various tree species. The future of the proliferation and control of parasitic weeds was highlighted in both positive and negative prospects by the speaker. Dr. Parker commented that all control measures available *viz.* herbicides, integrated weed control, use of growth regulator (malic hydrazide), use of trap crops to stimulate suicidal germination, use of allelopathy to counter parasitic weeds, naturally herbicide resistant crop varieties and GM varieties, biocontrol agents are far from satisfactory results and continuous threat of increasing intensity of these parasitic weeds remains. Dr. Chris concluded that at present we are not really in *win-a-win* situation in case of parasitic weeds, and more concerted efforts are needed.

Recommendations

- Integrated approach must be adopted to manage parasitic weeds

TECHNICAL SESSIONS

Technical Session 1: Weed management options for rice and rice-based cropping systems of Asian-Pacific region

Lead presentations: Dr. Gulshan Mahajan from India discussed about sustainable weed management in dry-seeded rice in South-Asia and advocated IWM for achieving sustainable and long-term weed control in direct seeded rice (DSR). Dr. Hirohiko Morita from Japan indicated possibility of reducing weed emergence with seeding rice under 15% soil moisture contents.

Contributory presentations: Dr. Sanjoy Saha indicated that drill-seeding of rice was better during wet- and spot seeding during dry- seasons. Dr. Manpreet Singh reported higher weed competitive ability of short duration rice varieties compared to medium duration varieties under DSR. Dr. Dharam Bir Yadav informed about shift in weed flora with dominancy of grassy weeds and perennial sedges under DSR advocated IWM in direct-seeded rice for better weed management. Dr. B. Sreedevi reported higher energy output and energy ratio with pendimethalin *fb* bispyribac-sodium in aerobic rice. Dr. D.J. Rajkhowa recommended cyhalofop-butyl *fb* 2,4-D for weed management in upland rice under north-east hill ecosystem. For drum seeded puddled rice, Leela Rani recommended pyrazosulfuron-ethyl *fb* manual weeding. Dr. Yogita Gharde reported antagonism among fenoxaprop and metsulfuron when used in mixture in direct-seeded rice. S K Raj recommended pre-mix of penoxsulam + cyhalofop-butyl for direct-seeded puddled rice. Dr. N.D. Rathod advocated post-emergence application of carfentrazone-ethyl for broad-leaf weed control in transplanted rice. Dr. M.T. Sanjay recommended sequential applications of pretilachlor and ethoxysulfuron for broad-spectrum weed control in rice. Dr. S.K. Mohanty reported effective weed control with pretilachlor *fb* chlorimuron+metsulfuron in summer rice and butachlor *fb* chlorimuron + metsulfuron in winter season rice. Dr. M. Malla Reddy suggested that sequential application of pretilachlor *fb* bispyribac were found effective for weed control at farmers' fields in rice-rice cropping system. Dr. J. Deka favoured rotational use of butachlor and pretilachlor along with 25 % substitution of fertilizer with FYM, in rice - rice cropping for weed control and maintaining soil health. Dr. Vinod Mehra reported broad spectrum weed control in all the rice establishment methods with Rinskor.

Technical Session 2: Weed biology and ecology

Lead presentation: A lead presentation on “Weed seed atlas – ready reckoner for identification and seed regulation” was delivered by Dr. Shripati Cherry. He covered topics like importance of seed, history of seed testing, seed quality, seed identification tools and common seed morphology. He also highlighted the gaps in weed seed science in India. Second lead presentation on “Italian ryegrass: germination, biology and interference with corn” was delivered by Dr. Vijay Nandula. He discussed in detail about glyphosate-resistant ryegrass and its management.

Contributory presentations: First presentation was made by Dr. C.T. Abraham on ‘Management of weedy rice – Indian experience’. He covered the extent of infestation of weedy rice in India along with its characteristics. He also discussed variability in weedy rice morphotypes. Dr. Rishi Raj presented contributory article on density and nitrogen effects on the interference of *Phalaris minor* in wheat. He discussed height, density and tillers of *P. minor* and yield attributes of wheat, and economic thresholds level of *P. minor*. Third presentation was on “Weed survey in sweet corn in Sumedung and Bandung Indonesia” by Dr. Denny Kurniadie. He discussed the weed problem in Indonesia and identified weed species in sweet corn.

Technical Session 3: Weed biology and ecology including impact of climate change

Lead Presentations: First presentation was delivered by Dr. Michael Renton from University of Western Australia, Perth on “Modelling as a tool to help understand, predict and manage weeds” wherein utility of different models, their applications and need were discussed in details. Second presentation was delivered by Dr. R.M. Kathiresan from India on “Climate smart agriculture and indigenous management of invasive alien weeds”. Dr. Kathiresan discussed the invasiveness of *Prosopis* and the different methods for its management. He also discussed the soil temperature and moisture regimes in which *Parthenium hysterophorus* flourished in Indian subcontinent. He revealed facts about the amphibian nature of *Leptochloa* and methods for its management. He also talked on use of Coleum powder to manage water hyacinth in water bodies.

Contributory presentations: Dr. Chandra Bhanu talked on “Effect of resource conservation module of rice on weed infestation and sheath blight disease” wherein, he confirmed more weeds in a zero tilled rice field in comparison to conventionally tilled field. He also reported more incidence of leaf sheath blight disease in plants under zero till. Dr. I.C. Barua delivered a talk on “Characterizing weed flora, shifts and nesting capacity of habitats in deep water rice areas of

Assam". He highlighted weed shift in Assam region and emphasized on change in weed flora in rice fields under transplanted autumn rice and flooded rice fields. Dr. Mool Chand made a presentation on "Exotic weed seeds in the imported germplasm" where he talked about the Indian weed quarantine inspection system and requested the urgent need to strengthen it by recruiting experienced professionals for the purpose and requested recommendations from the house for it. Speaker emphasized for an urgent need to wisely screen intentional imports of natural germplasm sought for research purposes.

Technical Session 4: Allelopathy: the current status and role in weed management.

Lead presentation: In his lead presentation on "Rice allelopathy in sustainable agriculture", Prof. Hisashi Kato-Naguchi from Japan stressed on the importance of allelopathy in weed control. He reported about efficient extraction of 'momilactone B' and its effect on root and shoot growth of *E. crus-galli* and rice.

Contributory presentations: Dr. Veeresh Hatti presented a talk on "Allelopathy – A natural tool for weed management in field crops". He highlighted about over-use of agrochemicals and importance of allelopathy in reducing weed losses. Dr. D. Subramanyam made a presentation on "Phytoherbicides: opportunities and research needs". He explained about some lead molecules used for development of new synthetic herbicides for cost-effective and environment-friendly methods for weed management. Dr. S. Prapaipit presented on "Isolation and identification of putative allelopathic compound from *Cymbopogon nardus*" and informed that an active compound was isolated and identified as *N*-octanoyl tyramine, which had growth inhibitory activity on the test plants. Dr. Masahiko Suzuki presented his work on the potent allelopathic substances of cogongrass rhizome extracts and explained that abscisic acid, 5-methoxyflavone, 5, 2'-dimethoxyflavone, methyl caffeate were identified as inhibitory substances from cogongrass rhizomes. Dr. Suparna Mandal Biswas made a presentation on "Optimized analytical techniques for extraction and separation of bioactive compounds from diverse plant types". She highlighted the role of *C. viscose* plant extract as potent bioactive compound. Dr. Boyang Shi talked on the "Allelopathic nature of *Parthenium* weed leaf litter". He concluded that *Parthenium* weed leaf litter has allelopathic effect on several plant species.

Dr. B.S. Chauhan asked about the mechanism, utility, scopes and constraints in allelochemical synthesis and its feasibility and availability regarding its application at the farmer fields. Dr. Ghosh informed the house that allelochemicals extraction and identification are the major constraints in their practical applicability.

Technical Session 5: Weed management in organic farming system including weed use

Lead presentation: Dr. R.K. Ghosh from India made presentation on "Prospects of botanical herbicides in system intensification" and emphasized the system intensification, modern concept of weed management and allelopathy. He also stressed that natural green labeled organic chemicals are more safe for soil microflora population. He also highlighted the bio-herbicidal effect of *Calotropis procera* against monocot weeds.

Contributory presentations: Dr. R. Mahander Kumar talked about mechanized weed management in SRI and its potential to enhance the productivity of irrigated rice. Based on multi-location trials, he opined that SRI has the potential to enhance the productivity of the rice with reduced inputs in different agro-ecological situation and soil types across the country with reduction in drudgery of weeding in rice. Dr. R. Singh presented paper on weed dynamics and rice productivity under organic conservation tillage practices in rice-vegetable pea cropping system of north-east India. He discussed the status of agriculture in NE region, and effect of organic N uses on weed density and tillage. He found the zero tillage with recommended dose of nitrogen substituted in 1:1 ratio of FYM and vermicompost + biofertilizer (50% FYM + 50% VC + biofertilizer) was most effective for reducing weed pressure and enhancing rice productivity under organic management condition of Sikkim Himalayas. Dr. Jayantha Layak presented on weed management practices in maize under organic farming in rainfed hill ecosystem. He presented the sustainable weed management practices for maize under organic production system, bioherbicides and mulching with weed biomass. Mulching with weed biomass such as fresh *Chromolaena* (after earthing up) and soybean green manuring in maize + hand weeding once are the recommendable options for sustainable maize production under high rainfall hill ecosystem of north-east India. Dr. T.S. Chaah spoke on effect of soil types on efficacy oil palm frond mulch on management of herbicide resistant biotypes of goosegrass. Combination of chemical and physical methods through oil palm frond mulch treated with S-metolachlor provided control herbicide resistant biotypes of goose grass.

Technical Session 6: Innovative weed management technologies

Lead presentation: Dr. Krishna N. Reddy from USA discussed the role of UAVs and elaborated upon various applications of remote sensing, GPS and GIS for enhancing weed management, invasion detection and crop management as a whole. UAV based system supplements satellite, aircraft and ground based platforms with their surveillance, protection and high

resolution crop and field monitoring for minute details like herbicide injury, crop stage, field data, varietal data, irrigation etc. UAVs have the advantages like being cost effective and easy to maneuver that can aid efficiently the area of weed management. Responding to the questions raised in this regards for availability of software to individual scientists, the speaker informed the house about various companies who are into it.

Contributory presentations: Dr. Peter Harper presented the future solutions for managing aquatic weeds and emphasized on the role of hydrogel for aquatic weed control with diquat. Carfentrzone and fluridone could also be used alternatively with hydrogel. These practices were found to be eco-friendly to the aquatic life under Australian conditions. Dr. Shaliesh Kumar presented a new tool “Nail Weeder” for weed management, which saves Rs. 10,000 to 15,000/ha and achieved extra net return of about Rs. 17,000. This tool can simultaneously perform weeding and thinning and remove more than 80% of weeds. Dr. William Chisholm talked about herbicidal aquatic weed management options with diquat and endothal. Endothal was very effective in water bodies for eradication of weeds. Hydrogel + diquat are also being applied with handguns and helicopter. Dr. C. Chinnusamy deliberated upon glyphosate tolerant crops, which enhanced 30-40% grain yield and provided a weed control efficiency of more than 97%. Ms Nimmy Jose presented on the efficacy of wick applicator in herbicide application for management of weedy rice and also discussed about cost-effectiveness of different prototypes of wick applicator. Dr. M. Dlipkumar presented the positive role of palm frond mulch with pre-emergence herbicides that enhanced the bio-efficacy and phytotoxicity on persistent weeds due to slow release of herbicides besides reducing the rate by more than 80%. Ms N. Viji discussed the role of iron oxide and zinc oxide nanoparticles in degrading phenolics through advance oxidation process in *Cyperus rotundus* tubers that broke the dormancy of tubers and made them to germinate thus leading to depletion tuber number in soil that helps in suppressing future generations of weed.

Technical Session 7: Weed management in horticulture and plantation crops and crops other than rice

In this session, 7 presentations were made on weed management in different plantation crops *i.e.* oil palm, fennel, cassava, and in other crops like cotton, maize and groundnut. Glyphosate resistance in *Eleusine indica* has been reported. But this can be effectively controlled by premix of Monex HC or Monex HC + paraquat dichloride. The problem of volunteer oil palm seedling can be managed effectively by glufosinate mono-ammonium. Grasses and broad-leaved weeds in fennel can be managed with application of pendamethalin 0.5 kg/ha + hand weeding (40 DAS) without any phytotoxicity. In comparison to black polythene mulch, 2 hand weeding with post-emergence application of glyphosate reduced the weed problem effectively in cassava. But the quality of cassava such as starch concentration and soil microbial quality reduced enormously due to delay in glyphosate application by 4-5 days. Maize crop yields can be improved with integrated weed management practices in zero tillage conditions. The *Ipomoea* species in cotton can be managed effectively with pyriproxyfen-sodium + quizalofop-ethyl + hand hoeing with higher yield. In a finger millet-groundnut system, pre-emergence application of dimethalin and alachlor gives higher pod yield and B:C ratio in groundnut.

Technical Session 8: New herbicide molecules and products: the role of herbicide industry

Lead presentations: Dr. Monte Weimer from USA presented major events that led to the discovery of auxin herbicides. He highlighted that investigating effect of plant growth regulator on plant was major event for discovery of phenoxy-carboxylic acid, which was the base for benzoic acid. In case of pyridine-carboxylic acids, identification of picloram after application of a nitrification inhibitor with ammonia; structural modifications of picloram led to other pyridines; aminopyralid discovered from novel electrolysis reaction utilized to produce clopyralid. In his subsequent presentation related to discovery and development of new rice herbicide, he highlighted Rinskor as a latest aryloxyacetic herbicide currently in development stage by Dow AgroSciences. It will offer an alternative mode of action herbicide for the control of grass, broad-leaf, and sedges in rice and other crops. According to him, first registrations of Rinskor are anticipated in 2017 to 2018. Second lead presentation was delivered by Dr. Megh Singh from USA, who emphasized the importance of adjuvants and surfactants which are cheaper, environment friendly and are useful for farmers. He gave an account of spray modifiers adjuvants *i.e.* activators, utility modifiers, stickers, spreaders, deposit builders, film formers, thickening agents, foams etc.

Contributory presentations: Dr. Rick Mann presented development and global utility of penoxsulam in rice, which provides pre-emergence and post-emergence control of important grassy weed *Echinochloa* species, as well as many other broad-leaf and annual sedge weeds in rice. He informed that penoxsulam is now commercialized as a pre-emergence herbicide both in transplanted and direct-seeded rice in several countries (Granite™ SC in India), and new pre-mixtures are being developed that include penoxsulam + butachlor. Dr. Basweshwar Ghodki from Dow AgroSciences gave presentation on new post-emergence broad-spectrum herbicide ‘Assert’ which contains penoxsulam and is based on unique oil dispersible (OD) formulation. Dr. Mayank Yadav from the Dow AgroSciences discussed about the efficacy of another new Vivaya™ herbicide which is broad-spectrum pre-mix herbicide consisting of penoxsulam plus cyhalofop in

oil dispersible formulation with adjuvant and provides rice growers a new option for superior control of complex weed flora in rice. Dr. B.R. Saranya presented about the photocatalytic degradation of pollutants in ecosystem mediated by Zeolite-Na-Y and Lanthanum ions doped TiO₂ (1:5) embedded into polystyrene film. The reusability of the photocatalytic film was successfully examined six times without any significant loss in catalytic activity. Dr. Srinivasan Rengan from ADAMA highlighted new weed control solution for non-crop land and soybean crop. Application of 'Zoomer 43.5 SC' (glyphosate + oxyfluorfen) with foliar and soil activity for tea, non-crop situations, orchards and plantation crops and provides management of many grasses, sedges and broad-leaved weeds. 'Glyder' was found useful as pre- and post-emergence herbicide for non-crop. While 'Shaked' was found useful for control of weeds in soybean, blackgram, greengram, groundnut, pigeonpea, cluster bean and pea. 'Tamar' is selective systemic pre- and post-emergence herbicide effective for weed management in sugarcane. 'Dekel' for Onion and 'Racer' (flurochloridone) for potato, sunflower, carrot and onion are the product in pipelines.

Dr. M.S. Lee highlighted effectiveness of QuelexTM herbicide as new post-emergent for broad-leaf weeds for winter wheat production systems in China. He also throw light on the utility of 'quelex 20% WG' for effective control on *Capsella bursa-pastoris*, *Descurainia sophia*, *Galium aparine* and *Stellaria media*. Representative from INDOFIL highlighted the effectiveness of 'Zechor' (flucetosulfuron 10% WG), a sulfonylurea herbicide co-developed by LG Life Sciences and the Korea Research Institute of Chemical Technology. Dr. Madhuban Gopal emphasized on the discovery of new herbicides utilizing intermediate derivatization by random chalcone synthesis. He pointed out that chalcones have an opportunity to behave as potent herbicidal agents and have excellent scope for further chemical modification to optimize it to be a candidate for new herbicide molecule. Zhen W. Yao from DOW AGROSCIENCE, presented efficacy of RinskorTM active in wet seeded rice in China.

Technical Session 9: Weed management options for crops and cropping systems (other than rice) of Asian-Pacific region

Lead presentation: Dr. B.S. Chauhan from Australia presented his lead article on "Integrated weed management options in Australia" and covered several of means of weed management in Australia. Increasing crop competitiveness and opting seed growing competitive varieties, practices aiming at reducing soil weed seed bank, minimizing the revolution of herbicides resistance and prolonging the efficacy *etc.* are some of the important aspects discussed in this presentation. Double knock technology *i.e.*, sequential application of the non-selective herbicides is effective in managing weeds development of herbicide resistance.

Contributory presentations: The first presentation was on potential herbicide mix formulation to control a broad spectrum of weeds in cotton. Mixed micro emulsion concentrate (MEC 10%) comprising of pyriithiobac-sodium (6%) + quizalofop-ethyl (4%) at 125 g/ha provided into higher weed control efficacy in cotton. Second presentation was on integrating herbicide and conventional approach for profitable weed management in groundnut. Application of pendimethalin (PE) 0.75 kg/ha + imazethapyr (PoE) 0.05 kg/ha at 20 DAS + HW at 45 DAS effectively managed the weeds in groundnut and it was comparable with two hand weedings at 3 and 6 weeks after sowing. Third presentation was on weed management options and strategies in pulse crops in India. *Phalaris minor*, *Cyperus rotundus* and other weeds were reduced after introduction of mungbean in rice-wheat cropping systems. Maize + sesamum reduced the weed density in subsequent pulse crop compared to maize alone. Fourth presentation was on weed management in relay crop of blackgram after removal of paddy. Broadcasting of pendimethalin 1.5 kg/ha mixed in 50 kg of sand, and spraying of buflurofen 16.5% + clodinafop-propargyl 18% 25 g/ha at 25-30 DAS effectively controlled the *Vicia sativa* in blackgram. Fifth presentation was on weed management in rainfed agriculture in India. Issues and future strategies were discussed in detail. Various issues and problems in managing weeds under rainfed situation were also discussed. New technologies like CRIDA precision planting-cum-herbicide application and other low cost implements for the use of weed management were discussed. Sixth presentation was on weed flora and yield of winter maize + potato intercropping system. Winter maize + potato along with atrazine PE 0.5 kg/ha or alachlor PE 1.5 kg/ha can be the best for better weed control and realising higher yields. Seventh presentation was on integrated weed management in spring sugarcane. Metribuzin 1 kg/ha PE + 2,4-D kg/ha spray at 60 DAP + hoeing at 90 DAP planting recorded higher weed control efficiency and higher cane yield. Next presentation was on weeds and weed control in finger millet. In drill sown finger millet, bensulfuron-methyl PE (0.6%) + pretilachlor (6%) 10 kg/ha effectively managed the weeds. Ninth presentation was on energy usage and benefit cost analysis of cotton under various weed management practices. Inputs and outputs of cotton was referred in terms of energy usage and energy production. Tenth presentation was on bioefficacy of post-emergent tembotrione application on weed dynamics and productivity of *kharij* maize in rainfed foot hill and mid-hill conditions of J&K. Tembotrione application 120 g/ha at 15 DAS or 30 DAS provided effective weed management in maize. Last presentation was on efficacy on herbicide mixture for weed management in Bt-cotton. Pyriithiobac-sodium + quizalofop-ethyl 10% (MEC premix) 100 g/ha was found very effective in controlling weeds in cotton with no residual effect on succeeding greengram crop.

Technical Session 10: Herbicide persistence and soil health

Lead presentation: Dr. Nghia K. Nguyen, Cantho University, Vietnam explained the adsorption-desorption behaviour of glyphosate in soils collected from Germany and Slovenia. Glyphosate can be strongly adsorbed, but weakly desorbed in soils. Desorption of glyphosate in soils had a much stronger positive correlation with the cumulative mineralization of glyphosate than the dissolution of glyphosate.

Contributory presentations: Dr. Anil Duhan presented his observation on herbicide contaminations in ground water and food chain. He found the presence of pretilachlor residues above permissible limits at 4 out of 21 sites in underground water, 10 out of 107 sites in rice grains and 4 out of 107 sites in straw samples. A study on correlation and regression of herbicide movement in soil was explained by Dr. Ch. S. Rama Laxmi. Relative mobility of oxadiargyl and butachlor in two different soils under two different moisture levels was worked out. Dr. Shobha Sondhia delivered her presentation on the leaching behaviour of cyhalofop-butyl in sandy-loam soil in lysimeter. Cyhalofop-butyl could leach to subsurface soil and posed moderate leaching risk at higher rainfall and saturated soil moisture conditions. Dr. C.R. Shitha did not observe any inhibitory effect of glyphosate applied at recommended dose on soil microflora. Dr. R.H. Wanjari gave a presentation on 'long-term effect of herbicides on enzymes and enzymatic activities in major soils under intensive and long-term fertilizer experiments'. A temporary adverse effect of herbicide application was observed on microbes in terms of population and enzymatic activities for initial period, however, it recovered gradually within two weeks of herbicide application. Dr. Raj Singh discussed about suitable herbicide combinations for the weed management in vegetable pea under conservation agriculture. The application of pendimethalin 0.5 kg/ha (PE) + residue 2 t/ha + imazethapyr 0.075 kg/ha as POE was most effective in controlling weeds, improving pod yield and productivity of vegetable pea. Dr. S.R. Vikram showed in his presentation that pyrazosulfuron-ethyl was a short-lived herbicide in soil under aerobic condition. Dr. S.S. Punia presented the study on the bioefficacy of some herbicides applied on greengram and their carry-over effect on the succeeding crop mustard. He concluded that pre-emergence application of a ready-mix combination of pendimethalin + imazethapyr at 1000 g/ha can safely be used to control weeds in greengram without any residual carry-over effect on succeeding mustard crop.

A presentation on 'Herbicidal effects on soil and crop health in cotton' was delivered by Dr. R. Hiremath. Pre-emergence herbicides like diuron and pendimethalin had little injurious effect initially. Pre-emergence herbicides caused a temporary and recoverable decrease in soil dehydrogenase activity. Dr. Neelam Sharma surveyed herbicide usage and their concentration in vegetables of two districts of Himachal Pradesh. She identified the contamination of metribuzin and alachlor in several vegetables. She pointed out that 1.2% of samples were contaminated above MRL values. Towards the end, Dr. Shashi Bala Singh suggested to maintain one treatment of pure active ingredient along with other treatments to evaluate the effect of adjuvants. This was in connection with the presentation on the effect of herbicide on earthworm. Finally, the Chairman advised to develop simulated model to predict persistence and movement of herbicides in the soil.

Technical Session 11: Management of problematic weeds (including alien invasive and parasitic weeds)

Lead presentation: Dr. Prasanta C. Bhowmik from USA gave an over view of invasive weed problems in USA and Asia-Pacific region. He talked upon important alien weeds and effect of climate change on the problems of alien weeds. He discussed research priorities for management of alien weeds and concerted efforts to stop the spread of invasive weeds by understanding the mechanisms to explain invasive success of an invader in its naturalized range. Early detection plans to identify the invasive species and to identify the impact of invasive weeds on agriculture and horticulture was advocated by him.

Contributory presentations: Dr. T.K. Das discussed about the competition of *Cyperus rotundus* with soybean especially where pre-emergence herbicides are used to control other weeds in soybean. Zero tillage combined with tank-mix pre-emergence application of pendimethalin 0.5 kg/ha + imazethapyr 0.075 kg/ha resulted in better weed control and higher soybean yield. Prospects of using potassium nitrate and imazethapyr for management of *Cyperus rotundus* was also dealt. Chairman suggested the speaker to have due caution while recommending potassium nitrate as it is explosive in nature. Dr. P. Jones Nirmalnath indicated that arbuscular mycorrhizal fungi inoculation inhibited *Striga* emergence significantly in both sugarcane and sorghum. Dr. C. Kannan reported that application of stimulant nijmegen-1 and borax/thiourea (1 mM) simultaneously inhibited the germination of *Orobanche* in tomato. Phytotoxicity studies suggested that borax and thiourea were not causing any toxicity when applied at lesser doses upto 5 mM, but when applied at higher dose of 10 mM and more, caused phytotoxicity on tomato. Dr. Ramesh Babu reported that deep application of oxyfluorfen 250 g/ha into the furrows at 90 DAP was very effective in killing *Striga* much before it damages crop as it directly attacks seed bank in the soil. Surface application of herbicide mixture (oxyfluorfen 125 g/ha + 2,4-D sodium salt 2 kg/ha) at 110-150 DAP after emergence of *Striga* prevents further enrichment of *Striga* seed bank. Dr. Aditi Pathak reported that application of spore suspension and crude metabolite extract of *Penicillium oxalium* as seed treatment followed by foliar

application caused significant reduction in stalk emergence of *Orobanche crenata* in tomato. The reduction in emergence of the flowering stalks would reduce the development of the parasite and thus the host crop may escape the infection during its critical stages.

Dr. N. Satyanarayana presented about the occurrence of quarantine weed *Ambrosia psilostachya* in Tumkur District of Karnataka. NIPHM, Hyderabad in collaboration with UAS, Bangalore; DWR, Jabalpur; KSDA, Govt. of Karnataka organized a project to delimit and contain the quarantine weed in collaboration with local farmers. The extensive awareness creation, stakeholder sensitization and intensive herbicide sprays in farmers fields and non-cropped areas infested with *Ambrosia psilostachya* has resulted in stopping the weed spread to new areas and in suppressing the weed population in infested areas. Dr. Girija presented about control of hemiparasite *Dendrothae falcata* on tree crops in Kerala. The use of ethephon and 2,4-D for managing *Dendrothae falcata* was explained. Directed spraying of ethephon at 8,000 to 10,000 ppm defoliated the parasite completely in host plants - mango, cocoa and sapota without regrowth for at least 6 months. Dr. R.S. Chhokar dealt about management of herbicide resistant weeds in wheat. He suggested the use of pendimethalin, pyroxasulfone, flufenacet against multiple herbicide resistant *Phalaris minor* and *Polygogon*.

Technical Session 12: Tillage, nutrients, seeding time, soil and water in relation to weed management in Asia-Pacific region

Lead Presentation: Dr. A.R. Sharma from India gave a detailed account on “Conventional and conservation agriculture systems”. He highlighted the advantages of conservation agriculture systems and various success stories of adoption of these technologies in India.

Contributory presentations: Dr. Virender Kumar emphasized that conservation agriculture - based practices reduced weed problem in wheat and caused shifts in weed seed bank community in rice-wheat cropping systems. Dr. U.K. Behera talked about tillage and weed management for improving productivity and nutrient uptake in soybean. Dr. R. Govindan presented paper entitled “Tillage, crop establishment and weed management methods on microbial and soil organic carbon of rice under rice based conservation agricultural system. Dr. Neetu Sharma talked about effect of time of planting and weed management in direct seeded aromatic rice of foot hills Jammu and Kashmir Himalaya”. Dr. K. Ramesh presented his experiences on effect of nitrogen fertilizer timings and weed management practices on weed dynamics and competition in dry-seeded rice. Dr. Pijush K. Mukherjee presented paper on weed management in no-tilled maize. Dr. U.P. Singh presented paper on efficient weed management through conservation agricultural practices. Dr. V. Pratap Singh presented paper on weed management and conservation agriculture in rice-wheat cropping system. Dr. Raghendra Singh presented paper on impact of tillage, residue and weed management on growth and yield of rabi maize. Dr. G. Sreenivas presented paper on time of start of irrigation and weed management practices on nutrient uptake of crop and weeds in dry seeded irrigated (semi-dry) rice. Dr. K. Subrahmaniyan highlighted the impact of conservation tillage on weed dynamics in the rice-rice cropping system. Dr. A.K. Vishwakarma presented paper on weed management in soybean under conservation agriculture. Dr. P.S. Bodake presented paper on tillage and integrated weed management impact on weed dynamics, production and economics at soybean- onion cropping system.

SYMPOSIA

Symposium- 1

Weed management in conservation agriculture

Conveners: Deirdre Lemerle, Michael Widderick and Toni Nugent

Conservation agriculture (CA) with crop residue or stubble retention and minimal soil disturbance (*e.g.* zero tillage) is very important for improving soil quality and productivity. However, this technology leads to increased dependence on herbicides and the rapid development of herbicide resistance. Many small holder farmers in Asia are still practicing aggressive tillage for growing crops. Lack of adoption of CA practices is likely due to many factors, including: lack of knowledge, complexity of the system and need for change in mindset, unavailability of suitable planting equipment, and limited access to herbicide technologies. In some countries rapid adoption of herbicides due to rising labour costs is leading to considerable risks of environmental pollution, human and animal safety, and the development of herbicide resistant weeds. However, opportunities are arising to address some of these challenges and increase adoption of CA. Research is needed to examine the role of the ‘traditional’ weed control tactics used in Asia in combination with herbicide technology. In this symposium, in depth discussion was made on challenges and opportunities for managing weeds under CA system. The presentations were as follows:

Presentation 1: Conservation farming in southern Australia: A farmer’s experience of managing herbicide resistance

Speaker: Murray Scholz Scholz, Farming Company, “Dunoon”, Australia

Mr. Murray Scholz Scholz, a farmer by profession shared his experiences of CA in southern Australia for managing herbicide resistance. He told that conservation farming was started in the late 1970s with the introduction of Sprayseed® (paraquat + diquat) followed by glyphosate and Hoegrass® (diclofop-methyl). He recalled that with the increased use of nitrogen fertilizer, it was a golden era for growing crops. Weed control worked very well for a number of years. It was not obvious to us at the time that we had moved away from an integrated weed management system (IWM) that had diverse weed control methods to a system. He emphasized the use of multiple non-herbicidal methods with strategic use of herbicides to drive down the seed bank so the chances of herbicide resistance developing are much reduced. He suggested constant surveillance and appropriate management. Mr. Scholz shared that dependency only on herbicides for weed control is unsustainable. He strongly advocated the introduction of non-herbicide methods of weed control.

Presentation 2: Development of conservation agriculture and herbicide use in Australia

Speaker: Rick Llewellyn, CSIRO Agriculture, Waite Campus, Urrbrae SA 5064, Australia

Dr. Rick Llewellyn highlighted the development of CA over the past two decades in Australia, which has been transformed by the shift from multiple cultivations of typically fragile soil to extensive use of no tillage systems and crop residue retention. The availability of cost-effective herbicide options was a major influencing factor on the rate of change. He shared that despite the challenges of extensive and continually increasing incidences of herbicide resistance, Australian grain growers managed to keep weed populations and consequent crop yield losses due to weeds at relatively low level. Dr. Rick informed that Australian farmers have also demonstrated flexibility in the application of no-tillage and crop residue retention with cultivation and residue burning continuing to be used as weed control options. He emphasized the need for flexibility and capacity to adapt when faced with the constantly evolving challenges of maintaining weed control in cropping-intensive systems.

Presentation 3: Integration of alternative chemical and non-chemical approaches for weed management to ensure herbicide durability

Speaker: M.J. Widderick, Department of Agriculture and Fisheries, Toowoomba, Queensland, Australia

Dr. Widderick shared that Australian farming systems is based mainly on CA which heavily dependent on herbicides for weed control. He highlighted key benefits of CA like reduction in soil erosion, soil moisture conservation, improved soil biological activity and ultimately high crop production and less production cost. Dr. Widderick also agreed that weeds have been a major constraint to conservation agriculture systems, which resulted over-reliance on herbicides resulted in herbicide resistant weeds across Australia’s key cropping regions. This current situation has forced the Australian farming industry to ‘think outside the square’ in order to retain the benefits gained through CA, while achieving optimal weed control and crop production. He discussed various

chemical and non-chemical tactics being used in Australian agriculture to preserve the useful life of important herbicides and the need for their integration.

Presentation 4: Weed management in conservation agriculture in Bangladesh

Speaker: Mafuza Begum, Bangladesh Agricultural University, Mymensingh, Bangladesh

Dr. Mafuza Begum narrated weed management in conservation agriculture in Bangladesh. She informed that CA is a newly practiced system in Bangladesh. Although CA reduces labour and fuel requirement and improve soil health, limited technical knowledge, unavailability of required machineries, lack of government policies, poor extension linkage, lack of awareness on herbicides use, insufficient research funding are the obstacles towards adopting CA in Bangladesh. She suggested to integrate different cultural, mechanical and biological methods along with the herbicides.

Presentation 5: Weed management in conservation agriculture in India

Speaker: Makhan S. Bhullar, Punjab Agricultural University, India

Dr. M.S. Bhullar discussed that adoption of CA in India was still in an early stage but has been successfully used in the irrigated rice-wheat cropping systems of the Indo-Gangetic Plains (IGP). He told that increased weed problems during the 'transition period' tends to be the most common hurdle in adoption of CA by farmers. He realized that herbicide use has been an important component of weed management in CA systems leading threat of herbicide resistance. He advocated the need of integrating non-chemical weed control tactics with herbicides. Farmer-participatory model of research has proved highly effective in developing CA in rice-wheat system in the IGP. He shared that at present residue retention on farmers' fields tends to be low due to residue burning, which required greater awareness of the benefits of residue retention for improved soil health through extension campaign in the IGP. Dr. Bhullar advocated the need of extension efforts for its adoption in non rice-wheat cropping systems in India.

Presentation 6: Effect of tillage sequence and weed management on weed dynamics and productivity of direct seeded rice-wheat cropping system

Speaker: Dharendra Kumar Roy, Rajendra Agricultural University, Pusa, Bihar, India

Dr. Roy informed that in recent years, the major emphasis in the rice-wheat system has been on alternative resource conservation technologies for both rice and wheat. Benefit of adopting such system is reduction in cost of cultivation and energy consumption, sustained productivity, and increase the profit of farmers. Weed infestation, however continues to be a major bottleneck in direct seeded rice. He shared the results of a long-term trial on tillage in rice-wheat cropping system.

Presentation 7: Weed shift and weed bank studies in conservation agriculture under rainfed conditions

Speaker: G. Pratibha, ICAR–Central Research Institute for Dryland Agriculture, Hyderabad, India

Dr. Pratibha emphasized the need of CA in rainfed agriculture due to heterogeneous soil profiles i.e. high slopes, physical constrains like crusting and hard pans, extreme spatial and temporal variability in rainfall, low rainwater use efficiency, deterioration of soil health and overall low productivity. She discussed the CA in pigeonpea–castor cropping system. She explained that as CA is relied on herbicides, soil moisture is pre-requisite condition for the activity of most of soil applied herbicides. She also cautioned that use of excessive herbicides in CA may lead to weed shift, herbicide resistance, adverse effects on the environment, persistence, leaching and GHG emissions.

Presentation 8: Managing weeds in rice-wheat system under conservation agriculture in black cotton soils

Speaker: V.P. Singh, ICAR-Indian Institute of Sugarcane Research, Lucknow, India

Dr. Singh presented the results of CA in rice-wheat system of black cotton soil of Madhya Pradesh. He discussed the constraints of adoption of this technology in central India. He explained why weed management is problem in CA system. Unlike in the conventional agriculture system, absence of tillage practice under CA system leads to presence of more weed seeds on the soil surface, which favours relatively higher weed germination. A weed flora shift in the crop field is another problem often encountered due to changes in the soil environment funder conservation farming practices. Dr. Singh shared his experience of CA in rice-wheat-greengram cropping system in central India. He concluded that benefits of CA can well be taken in black cotton soils as weed menace under this system can be managed by integrating suitable herbicides in the weed management programme. Since, CA advocates sowing the seeds in untilled land and without removing the crop residues which are in a sharp contrast to the traditional belief of the farmers, hence, tremendous amounts of efforts will be needed to pursue the farmers' for adoption of CA technology.

Symposium 2

Weedy rice challenge in Asia: issues and options for management

Conveners: Stephen Powles, Roberto Busi and Bhagirath S. Chauhan

It is universally acknowledged that rice is the world's most important food source and staple food for more than half of the world population. Asia is the world's largest rice producing region (approx. 134 million ha in Asia of a total of 153 million hectares globally). However, the ability to produce adequate rice for the ever-increasing human population will represent a major future challenge. At present, several factors like increasing pressure on water resources; expansion of urban and industrial sectors with subsequent competition for land; the increase in costs of labour, etc. have led to a major shift and change from flooded transplanted to direct-seeded rice (DSR). DSR offers many advantages and opportunities, especially a greater water productivity and labour savings. Weedy rice is a serious threat to sustainable rice production, particularly in direct seeded rice, as it affects crop production, harvest quality, and farmers' income. Due to many morphological and physiological similarities between weedy rice and rice plants, the management of weedy rice is a difficult and complex long-term endeavour.

Presentation 1: The weedy rice threat to global food security in Asia

Speaker: R. Busi, School of Plant Biology, University of Western Australia

Dr. Bushi discussed the threat posed by weedy rice in the world especially in context to South-Asia Pacific regions and the ways of its management. He discussed aspects like the land area devoted to rice, resources available, and breeding programs to produce rice varieties. However, as in all major changes, there are some unforeseen negative outcomes. Weedy rice (red rice), a conspecific weed of cultivated rice (*Oryza sativa* L.), is a significant problem throughout the world and an emerging threat in many Asian regions where it was previously absent. For example, weedy rice infestations are at increase in DSR systems in different countries including Malaysia, Sri Lanka, Thailand, India, Korea, Philippines and Vietnam. He found that shift to DSR accompanied by widespread, often exclusive, use of herbicides for weed control in rice can rapidly result in many problems including increased infestation of weedy rice. He discussed that some herbicides are toxic to germinating rice seedlings unless a specific herbicide safener is mixed with the herbicide compound in commercially available formulated products. He advocated dissociated use of herbicide and specific safener for effective weedy rice control without causing injury to the rice crop.

Presentation 2: Weedy rice problem in direct-seeded rice systems

Speaker: Bhagirath S. Chauhan, University of Queensland, Toowoomba, Queensland, Australia

Dr. Chauhan discussed that growers are shifting towards direct-seeded rice systems due to more profitable and sustainable than flooded transplanted rice because they require less water and less labour than the traditional method of transplanted rice. He discussed the advantages of DSR but considered weedy rice the main biological constraint to the production of direct-seeded rice systems. He informed the weedy rice threat in countries, such as Malaysia, Philippines, Sri Lanka, Thailand, and Vietnam where, direct seeding is the dominant rice establishment method. In his opinion, in Asia, weedy rice was reported to have greater nitrogen-use efficiency for shoot biomass than cultivated rice. In a recent survey in Vietnam, weedy rice infestation was the worst problem encountered in wet direct-seeded rice; however, most growers were aware of the presence of weedy rice in their fields and the damage it does to the crop. In a previous survey in the Philippines, about 40% of the growers did not know that seeds of weedy rice have dormancy. In the same survey, cutting the weedy rice panicles at harvest was practiced by majority of the respondents (82%). He suggested the need to increase awareness about weedy rice among Asian growers.

Presentation 3: Weedy rice - the Indian scenario

Speaker: Meenal Rathore, ICAR-Directorate of Weed Research, Jabalpur, MP India

Dr. Rathore discussed the weedy rice infestation scenario in India. She was also of the opinion that infestations have increased with a shift from transplanting to direct seeding of rice. To add to the problem, elevated CO₂ was found to enhance competition from weedy rice in rice production and reduce consumable rice production. She informed that weedy rice infestation ranged from 5-60% in different states in India with 11.3 to 44.3% in cultivated fields. A yield reduction by 30-60% was reported in rice agricultural fields of Kerala. Recently, Jharkhand recorded 24-32% infestation of weedy rice across Ranchi, Khunti, and East Singhbhum areas with an estimated yield loss of 10-45%. Heavy infestation of weedy rice was seen in eastern and southern India where direct seeding of rice is common though it is yet not a problem in Haryana

and Punjab where paddy is cultivated through the transplanting method. She also shared her research work done at Directorate of Weed Research on phenotypic variations collected from different geographical regions falling into different agro-climatic zones of India. Statistical analysis revealed the morphotypes to cluster up with either cultivated or wild rice, or as an independent cluster. She also discussed the response of weedy rice to elevated CO₂, which varied between morphotypes, even at the molecular level. She advocated to raise awareness among farmers and stressed the urgent attention from multidisciplinary scientists to develop efficient technologies for its management.

Presentation 4: Enhancing awareness on weedy rice management in Iloilo, Philippines

Speaker: Edwin C. Martin, Philippines Rice Research Institute, Nueva Ecija, Philippines

Dr. Martin showed the importance and benefits of using an integrated approach to manage weedy rice. The collaborative work of the weed experts with the social science and communication groups also ensured that management and awareness on weedy rice was achieved in the areas. Each group build on the work of the other and thus activities proved to be more focused and specific. He stressed the need of greater awareness among the farmers for weedy rice management.

Presentation 5: Diagnostic survey of a rice-based cropping system in Vietnam with emphasis on weedy rice (*Oryza sativa* f. *spontanea*)

Speaker: Tran thi Ngoc Son, Vietnam

Dr. Ngoc documented most details of cultural practices related to DSR cultivation after a two year surveys. The farmers revealed that they had very good 'knowledge of the attributes of weedy rice' and weedy rice is hard to control in broadcast crops. Weedy rice infestation was the worst problem encountered in DSR at the survey sites.

Presentation 6: Distribution patterns of weedy rice (*Oryza sativa* f. *spontanea*) populations in different climatic zones in Sri Lanka

Speaker: S.R. Weerakoon, Sri Lanka

Dr. Weerakoon presented her findings on distribution patterns of weedy rice populations in different climatic zones of Sri Lanka. She reported that weedy rice were sporadically originated in the respective ecological zones associated with *O. nivara* for dry and intermediate zone; and with *O. rufipogon* for wet zone weedy rice ecotypes.

Presentation 7: Present status and management approaches of weedy rice in Japan

Speaker: Hiroaki Watanabe, NARO Tohoku Agricultural Research Center, Japan

Dr. Watanabe opined that increase of weedy rice in transplanted rice in Japan seems to be due to widespread use of selective rice herbicides. Rice farmers usually use very safe rice herbicide only one time in the season achieving effective control of rice weeds. For example, sequential applications of the effective herbicide pretilachlor in transplanted rice help to much reduce weed infestations, although this has little efficacy in controlling weedy rice. He suggested the use of alternative methods as part of an integrated weed management (IWM) approach to solve the problem of weedy rice.

Presentation 8: Herbicide resistant weeds in Malaysian rice fields: Will weedy rice become the next candidate?

Speaker: Muhammad Saiful Ahmad Hamdani, Department of Crop Science, Universiti Putra Malaysia

Dr Hamdani opined that the occurrence of resistance in weedy rice to the IMI-herbicide has already taken place in the Malaysian CPS rice fields. Without appropriate management, this weed is likely to become the next and major herbicide resistance weed problem in Malaysian rice fields.

Presentation 9: ClearfieldTM rice: key challenges on a global perspective and lessons to be learnt in Asia

Speaker: Nilda Roma-Burgos, University of Arkansas, Fayetteville, AR, USA

Dr. Nilda Roma-Burgos opined that controlling weedy rice during the rice growing season is possible with ClearfieldTM technology, which allows the application of imidazolinone herbicides (imazethapyr, imazamox, imazapic, imazapyr) to rice. The technology was highly effective and is an excellent tool to have in direct-seeded rice systems. Dr. Nilda reported significant yield increases in areas that were otherwise rendered unproductive by severe weedy rice infestation. However, in cases where there are weedy rice escapes, hybridization between the weed and the crop occurs and ALS resistant weedy rice arising from pollen flow has been documented in regions where ClearfieldTM rice was grown.

Presentation 10: How predictable are weedy rice infestations: modelling insights into management**Speaker:** Francesco Vidotto, Università di Torino, Italy

Dr. Vidotto gave an illustration of rice scenario in Europe and Italy, weed problems and increasing problem of weedy rice. He also discussed the effectiveness of the modelling to ascertain the weedy rice problem and their influence in weed management.

Presentation 11: How to model spatial spread and weediness traits of weedy rice?**Speaker:** Michael Renton, University of Western Australia, Australia

Dr. Renton invoked the discussion on use of modelling in weedy rice study and its management. He informed about various models in use for integrated management of weeds. He opined the use of models to know the best way to manage weedy rice, in general and in specific situations and what is the best way to stop the future evolution of weedy rice. He stressed that with the help of suitable model people can be convinced to adopt best practice.

Presentation 11: Weedy rice management in Europe and insights to Asian rice systems**Speaker:** Maurizio Tabacchi, Italy

Dr. Tabacchi presented rice cultivation scenario in Europe and informed that about 60% of rice area in Europe is affected with weedy rice infestations. He told that weedy rice problems have increased rapidly after 1980. He discussed various management practices being adopted in Europe for weed rice. Along with other methods, Dr. Tabacchi emphasized the use of Clearfield® rice technology to manage weedy rice in Europe and also discussed the main issues and constraints. He advocated that despite of strong selection pressure due to ALS inhibitor herbicides leading to resistant populations of several weeds, Clearfield® rice technology will still remain largely effective in controlling weedy rice. Italian rice industry is making strong efforts at different level to maintain system efficacy.

Symposium 3

Herbicide resistance: current status and future challenges globally**Conveners:** Prashant Jha and Ian Heap

Weeds are a major biotic constraint in agricultural production systems worldwide. Besides reducing crop yield and quality, these unwanted plants adversely affect biodiversity, animal health and environmental security. In fact, the problem of weeds is as old as the agriculture itself as almost all crop plants have been domesticated from their wild relatives only. Despite the development of weed management technologies, the weed related problems have been virtually increasing. This is due to adoption of so-called modern cultivation methods which also promote the growth of weeds. The threats posed by climate change, globalization, herbicide resistance development in weeds and commercialization of herbicide-tolerant crops are bound to accentuate the problem. Herbicide-resistant weeds combined with the decline in development of new herbicide sites of action present a serious challenge the long term viability of current weed control practices in global cropping systems. Multiple resistance (with combinations of both target site and non-target site mechanisms) in *Alopecurus*, *Amaranthus*, *Avena*, *Conyza*, *Echinochloa* and *Lolium* species are the biggest impending threat to sustained weed control.

Presentation 1: Herbicide resistance a global perspective**Speaker:** Ian Heap, Weed Science LLC, Corvallis, USA

Dr. Heap discussed to adopt integrated weed management practices to prolong the useful life of herbicides. He informed that there are currently 459 unique cases (species x site of action) of herbicide resistant weeds with approximately 11 new cases being reported every year. Herbicide resistant weeds have been reported in 86 crops in 66 countries and have evolved resistance to 22 of the 26 known herbicide sites of action. In the mid to late 1990s the introduction of Roundup Ready crops solved serious ALS and ACCase inhibitor resistance problems in soybean, corn, and cotton however the over reliance on glyphosate over a massive area eventually created its own resistance problems. New herbicide resistant crops, such as synthetic auxin resistance in soybean, corn, and cotton will enable growers to control some glyphosate resistant weeds, but they themselves will eventually succumb to resistance quickly unless they are well managed. He advocated use of integrated weed management incorporating any economic combination of weed

control strategies, which may include preventative measures, monitoring, crop rotations, tillage, crop competition, harvest weed seed control, the use of different herbicide sites of action in rotation, sequence, and mixtures, herbicide resistant crops, biological controls, crop competition, nutrition, burning, and hand weeding. He suggested to vary weed control strategies to destabilize evolution, because history has shown us that any consistent practice to control weeds year after year will result in directed evolution towards their survival.

Presentation 2: Herbicide resistance in weeds: Survey, characterization, and mechanisms

Speaker: V.K. Nandula, USDA, Agricultural Research Service, USA

Dr. Nandula presented the work of characterization and mechanisms of herbicide resistance in relation to the target site. He gave an illustration of current methodologies employed in herbicide resistance mechanisms research including biochemical (enzyme kinetics and assays), physiological (photosynthesis, transpiration, respiration, chlorophyll biosynthesis, absorption and translocation using radioisotopes (Nandula and Vencill 2015), and molecular (DNA and RNA-based) techniques. Newer mechanisms of herbicide resistance will most likely be discovered in the near future through the applications of 'omics' tools. Dr. Nandula stressed the need of accurate and timely diagnosis of the nature and level of herbicide resistance in a weed population and knowledge about the inherent resistance mechanism (s) involved to strengthen the efforts towards devising sound herbicide resistant weed management strategies.

Presentation 3: Resistance evolution among *Echinochloa* species in the Southern USA

Speaker: Nilda Roma-Burgos, University of Arkansas, Fayetteville, AR, USA

Dr. Nilda presented the resistance problem in *Echinochloa* species in the southern USA. It was informed that most predominant species in the southern USA was junglerice. Specifically in Arkansas, junglerice occurs in about 65% of the rice production fields, while barnyardgrass was present in about 25%, of rice fields surveyed between 2012 and 2014. *E. muricata* (rough barnyardgrass) was found in 30% of the rice fields where it occurs mostly in the peripheries of rice paddies, with a few cases inside the paddy. Thus, in 30% of the fields, *Echinochloa* infestation was not limited to a single species but various combinations of these species. Only 35% of fields are infested with junglerice alone and 7% are infested with barnyardgrass alone. Notwithstanding the relative species abundance, *Echinochloa* species have co-evolved complex resistance patterns to various herbicides. In rice production, the stacking of resistance traits in *Echinochloa* was facilitated by successive selection with herbicides of different modes of action. This was demonstrated by the resistance evolution among *Echinochloa* populations in Arkansas rice fields. First was resistance to propanil in 1989, following three decades of widespread use. Quinclorac was introduced in 1992 to mitigate resistance to propanil; in 1999, a population with multiple resistance to propanil and quinclorac was confirmed. The commercialization of Clearfield® rice in 2002 allowed for the increased use of ALS inhibitors for *Echinochloa* control, in addition to the main purpose of controlling weedy rice. In 2008, the first ALS resistant barnyardgrass in the southern US was confirmed. Selective grass herbicides (cyhalofop and fenoxaprop) are also used in rice production.

Presentation 4: Key herbicide-resistant weeds in the cereal production systems of US Great Plains

Speaker: Prashant Jha, Montana State University, Huntley, USA

Dr. Prashant Jha informed that glyphosate (burndown), ACCase-inhibitors, ALS inhibitors, and synthetic auxins were the most commonly used herbicide chemistries in cereal production in US Great Plains. He found wild oat resistant to ACCase-inhibitors was widespread across the US Great Plains wheat belt. Wild oat resistance to ALS-inhibitors has also been documented. Recently, wild oat strains with multiple resistance to ACCase-inhibitors, ALS-inhibitors, and difenzoquat have been reported in Montana, USA. Green foxtail resistance to ACCase-inhibitors has also been reported in this region. Prickly lettuce biotypes resistant to ALS inhibitors and synthetic auxins (2,4-D, dicamba, and MCPA) are known to occur in wheat fields. Russian thistle has developed resistance to ALS-inhibitors used in wheat. Dr. Jha categorized recent evolution of glyphosate-resistant kochia in ten states and presence of auxinic (dicamba and fluroxypyr)- and ALS inhibitor-resistant kochia as a potential threat to cereal production in the US Great Plains.

Presentation 5: Herbicide-resistant weeds in the northern grain region of Australia

Speaker: Bhagirath S. Chauhan, University of Queensland, Toowoomba, Queensland, Australia

Dr. Bhagirath Chauhan presented overall scenario of herbicide-resistant weeds in northern grain region of Australia from where maximum number of glyphosate-resistant weeds have been reported. Other than glyphosate, many weeds evolved resistance to ALS and ACCase inhibiting herbicides. The conservation tillage practices, intensive use of

herbicides, introduction of glyphosate-tolerant crops, and highly diverse weed populations due to soil and weather characteristics were the major factors contributing to the rapid rate of herbicide resistance evolution in this region. Unlike the other regions in Australia, the tropical and subtropical climate with rainfall distributed during summer and winter facilitates abundance and diversity in weed populations. Opportunities exist in diversifying herbicide management through herbicide rotations, including residual herbicides, practicing the double knock tactic (sequential application glyphosate followed by paraquat), and by applying combination of herbicides from different modes of action. The weed management in fallows and non-cropped areas are a major concern in the northern region. He found the high cost of other herbicides as the major factor that prevents growers from trying herbicides other than glyphosate for fallow weed management. He hoped that WeedSeeker® sensor technology will help to reduce the overspray of herbicides in Australia.

Presentation 6: Management of multiple herbicide resistant in *Phalaris minor* in India

Speaker: Samunder Singh, CCS Haryana Agricultural University, Hisar, India

Dr. Samunder Singh presented the overall picture of problem of multiple herbicide resistance in *Phalaris minor* Retz. (Littleseed canary grass), the most ubiquitous weed of wheat in North India which has become the most difficult weed denting wheat productivity. It has evolved multiple resistance to the recommended herbicides, isoproturon (PSII), diclofop-methyl, fenoxaprop-P-ethyl, clodinafop-propargyl, pinoxaden (ACCase), sulfosulfuron and premix of mesosulfuron+iodosulfuron (ALS inhibitors) mediated by enhanced metabolism and target site mutations. Dr. Singh suggested an integrated approach adopting appropriate cultivation methods, sowing time, seed rate, competitive varieties, crop rotation, mixed farming, choice of herbicide, surfactants, synergistic mixture or sequential partner, their application rates, timings, application methods, nozzles types, water volume, herbicide rotations, time of fertilizer and irrigation, straw management, scouting for escapes and weed flora shift, mechanical control methods, seed contamination/ movement, applying the knowledge of weed biology and biotechnology tools for the management of multiple herbicide resistant of *P. minor*.

Presentation 7: Multiple herbicide resistance in key broadleaf weeds in US Great Plains

Speaker: Phillip W. Stahlman, Agricultural Research Center, Kansas State University, Hays, USA

Dr. Stahlman presented the overall view of herbicide resistance in broad-leaf weeds of US Great Plains. He cited the example of Kochia (*Kochia scoparia* Schrad.) and Palmer amaranth (*Amaranthus palmeri* S. Watson) as two such broadleaf weeds of great economic importance in the North American Great Plains. He concluded that at least one population of kochia in Kansas has evolved resistance to four herbicide modes of action and at least two Palmer amaranth populations has evolved resistance to three herbicide modes of action.

Presentation 8: Molecular cytogenetic mechanism(s) of EPSPS gene amplification in glyphosate-resistant weeds

Speaker: Mithila Jugulam, Kansas State University, USA

Dr. Jugulam presented the role of molecular cytogenetic mechanism in developing glyphosate resistance weeds. In the US, glyphosate-resistant kochia (*Kochia scoparia*), waterhemp (*Amaranthus rudis*) and Palmer amaranth (*Amaranthus palmeri*), are serious threat to sustained agricultural productivity. Research results suggested that mechanisms of EPSPS gene amplification in glyphosate-resistant weeds appeared to be species specific. The EPSPS gene amplification may have occurred via unequal recombination in kochia or possibly mediated by transposons in Palmer amaranth. He hoped more affirmative results from the experiments in progress to determine the mechanisms of amplification in these species.

Presentation 9: Herbicide-resistant weeds: management strategies and upcoming technologies

Speaker: Krishna N. Reddy, USDA, Agricultural Research Service, Stoneville, Mississippi, USA

Dr. Reddy presented the overall view of herbicide resistance in weeds of soybean, corn, cotton, and canola. The consistent weed control and economic benefits of HRCs encouraged the farmers to plant more area with HRCs each year in countries where adopted. In the US, 94% of soybean, 91% of cotton, and 89% of corn area was planted with glyphosate-resistant (GR) cultivars in 2014. He highlighted the technology which is in the early stages of its development that has potential to combat HR weeds is use of RNA interference (RNAi) technology (BioDirect™ by Monsanto). The use of RNAi involves the topical application of doublestranded RNA (dsRNA) to interfere with the expression of herbicide resistance genes in weeds.

Presentation 10: Modeling the evolution of herbicide resistance in weeds: current knowledge and future directions

Speaker: Muthukumar Bagavathiannan, Texas A&M University, USA

Dr. Bagavathiannan presented the role of modelling in herbicide resistance in weed. He informed that simulation models are being used to gain a deeper understanding of herbicide resistance evolution and to devise effective management strategies. A prime benefit is that models allow for the comparison of various management options and evaluate the relative benefits of different management combinations in reducing the risk of resistance. Simulation models have been instrumental in understanding the evolutionary dynamics of herbicide resistance in weeds and making informed management decisions for preventing/delaying resistance. He hoped that continued improvements in model development and analysis will be critical to address the complex interactions involved in herbicide resistance evolution.

Presentation 11: Effect of elevated temperature on glyphosate and dicamba efficacy in broad-leaf weeds

Speaker: Mithila Jugulam, Kansas State University, USA

Herbicide efficacy is known to be influenced by environmental factors including temperature. Many studies have reported decreased herbicide efficacy at higher temperatures, but some have reported the opposite trend. Dr. Jugulam presented the results which suggested that in both kochia and Palmer amaranth, the efficacy of glyphosate or dicamba was increased to control plants grown under low than high temperatures. More importantly, the increased efficacy of these herbicides under low temperature was attributed to increased translocation of dicamba or absorption of glyphosate in kochia. In a recent study, we concluded that Palmer amaranth was more sensitive to mesotrione (a carotenoid biosynthesis inhibitor) at cooler temperatures due to rapid metabolism of mesotrione and increased expression of target gene

Presentation 12: Herbicide-resistance in weeds and crops: interactions and impact on farming sustainability

Speaker: B. Rubin, Hebrew University of Jerusalem, Rehovot, Israel

Dr. Rubin presented an overview of herbicide –resistance in weeds and crops, which have spread now all over the world in annual and perennial crops mainly due to misuse of herbicides. Weeds resistant to triazines, ALS, ACCase and PPO inhibiting herbicides and glyphosate have evolved in all continents threatening the sustainability of crop production. Over reliance on chemical control, repeated use in perennial crops, lack of crop and herbicide rotations combined with reduce tillage resulted in evolution of numerous weed species resistant virtually to most herbicidal mode of actions (MOA). Lack of a novel MOA of herbicides aggravates the situation. Altered target site (TS) caused by point mutation(s) in the binding site sequence and a non-target site (NTS) mechanisms may render weeds resistant to herbicides. The pattern of herbicide-resistant weeds evolution is well demonstrated in the case of glyphosate-resistant (GR) weeds. Dr. Rubin hoped that recent introduction of the new GM crops stacked with two or more herbicide-resistance traits (e.g., glufosinate, 2,4-D, dicamba, HPPD), if used wisely, may offer the farmer new prospects in weed management but can turn failure due to misuse and multiple herbicide resistance. He suggested that in order to combat herbicide-resistant weeds and maintain sustainable farming, we should not rely on herbicides as the only way to control weeds. We should readopt weed management methods such as timely cultivation, crop density, rotation of crops and herbicides that lead to “good agricultural practices (GAP)”.

Symposium 4

Biological control – Progress and future prospects in Asia-Pacific region

Conveners: K. Dhileepan, R. Charudattan and Gadi V.P. Reddy

Invasive plant species are one of the most serious threats to biodiversity and sustainable development in the Asia-Pacific region. Biological control has proven to be effective in managing some of the perennial weeds. The biological control of weeds evolved from India with the instance of prickly pear. Soon it spread to other countries and now has become one of the important methods to suppress many terrestrial and aquatic weeds world over. The importance of biological control has increased due to over use of herbicides resistance in weeds and environmental and health problems. The biological control programs have provided satisfactory to adequate control of a many invasive weeds in the APWSS.

Presentation 1: Prospects for extending the success in the biological control of Parthenium weed in Australia into the Asia-Pacific region

Speaker: K. Dhileepan Department of Agriculture and Fisheries, Queensland, Australia

Dr. K. Dhileepan highlighted the problem of Parthenium hysterophorus (Asteraceae), an annual herbaceous plant native to the tropical Americas as a major weed of tropical and subtropical regions of Australia. It was informed that biological control of Parthenium in Australia commenced in 1977 and, since then, nine insect species and two rust fungi have been released. All agents established at some localities, but the time taken for their establishment varied widely and ranged from one to 14 years. Only a few of the agents proven to be effective in Australia have been introduced into other countries including India, South Africa, Ethiopia, Sri Lanka and Papua New Guinea (PNG). The leaf-feeding beetle, the only agent deliberately introduced against Parthenium in India, now occurs widely in India and in the neighboring Pakistan and Nepal. He told that stem galling moth and the summer rust, sourced from Australia, have been released in Sri Lanka, but so far there is no indication of their field establishment. The leaf-feeding beetle from Australia has also been released in PNG and Vanuatu. There is an increasing interest in the Asia-Pacific region in exploiting other biological control agents known to be successful in Australia. He suggested probable bioagents which may be introduced into India and other countries in the Asia Pacific, based on field host specificity, widespread establishment and damage levels in Australia such as the stem-boring weevil, the seed-feeding weevil, the root-feeding clear-wing moth and the parthenium summer rust. He also recommended use of climate matching tools to identify climatically favorable release sites and adoption of community-based programs for rearing and release of biological control agents.

Presentation 2: The potential of fungal pathogens for classical biological control of invasive alien weeds in the Asia-Pacific region

Speaker: Marion Seier, CABI, Egham, TW209TY, UK

Dr. Seier categorized Australia and New Zealand within the Asia Pacific region as two countries most experienced in the use of biological control in integrated weed management. She featured fungal pathogens amongst some of their most successful classical biocontrol agents released. In Australia effective control of rubber vine, *Cryptostegia grandiflora* (Apocynaceae), native to Madagascar, through release of the highly specific rust *Maravallia cryptostegiae* in 1995 has averted the threat posed by the invasive to tropical ecosystems in Northern Queensland, as well as hugely benefitted Queensland's agriculture. For New Zealand a comparable "fungal" success was the release of the white smut fungus *Entyloma ageratinae* to control its Mexican host mistflower, *Ageratina riparia* (Asteraceae), an alien invasive threatening native woodland plant species. She emphasized that fungal pathogens can have equally high potential to be employed on a wider scale against target weeds affecting several countries in the region. The rust pathogen *Puccinia xanthii* controlling *Xanthium strumarium* (Asteraceae) in non-arid regions of Australia was under evaluation for control of the weed in Papua New Guinea and has also recently been introduced into the Cook Islands. She also discussed the recent introduction of promising rust pathogen *Puccinia spegazzinii* employed for control of the invasive neo-tropical vine *Mikania micrantha* (Asteraceae) in India, released in India (2005). The Asia Pacific region has not only received numerous fungal weed biocontrol agents over the years but has also been the source of pathogens for biological control of invasive weeds elsewhere. She informed the likely introduction of rust *Puccinia komarovii* var. *glanduliferae* ex India for release in the UK for control of invasive Himalayan Balsam, *Impatiens glandulifera* (Balsaminaceae), and more research initiatives exploring the potential of the region's mycoflora for weed biocontrol are under way.

Presentation 3: Role of multi-trophic interactions in weed biological control – Its future

Speaker: Puja Ray, Department of Biological Sciences, Presidency University, Kolkata, India

Dr. Puja Ray discussed the increasing investigations on insect plant-pathogen interactions. Such interactions influence how plant communities affect herbivore/pathogen communities and in turn, how herbivore/pathogen affect the composition of plant communities. Such studies can form the interface between weed biological control and restoration of healthy, chemical free environment. She hoped that studies on multi-trophic interaction may hold great importance in weed biological control and can introduce a new era of progress in weed management research. She highlighted analyses of efficacy of multi-trophic interactions in eradicating invasive weeds more effectively. She suggested that extensive studies involving multi-trophic interactions should be an essential part of pre-release evaluation studies to enhance the success rates of biological control of noxious weeds.

Presentation 4: Progress and prospects of biological control of weeds in India**Speaker:** Sushilkumar, ICAR-Directorate of Weed Research, Jabalpur, India

Dr. Sushilkumar presented the overall view of problematic terrestrial and aquatic, weeds which need biological control approaches in India for their management. He cited the aquatic weeds like *Eichhornia carassipes* (Pontederiaceae), *Salvinia molesta* (Salviniaceae), *Hydrilla verticillata* (Hydrocharitaceae), *Pistia stratiotes* (Araceae), *Ipomoea aquatica* (Convolvulaceae) etc. are problematic in India in different type of aquatic bodies. The increasing problem of *Parthenium hysterophorus* (Asteraceae) was highlighted, which has invaded about 35 million hectares of land in India, responsible for loss of crop productivity, biodiversity and many health problems in human beings. He informed that so far in India, about 30 exotic weed biological control agents have been introduced into quarantine of which six could not be released in the field, 3 could not be recovered after release while 21 were established and recovered. From these established biological control agents, 7 are providing excellent control, 4 substantial control and 9 partial control. He emphasized the need of some promising bioagents, which have been introduced in other countries and have shown varying degrees of success through combined effects. He cited the example of Australia, where 11 biological control agents have been introduced against *P. hysterophorus* alone. He stressed the need of introduction of such successful biological control agents against some of the problematic weeds like *P. hysterophorus*, *E. carassipes*, *P. stratiotes*, *Alternanthera philoxeroides* (Amaranthaceae) etc.

Presentation 5: Semiochemicals in classical biological control of weeds: challenges and opportunities**Speaker:** N. Bakthavatsalam, National Institute of Agriculturally Important Insect resources, Bengaluru, India

Dr. Bakthavatsalam highlighted the possible role of semiochemicals in biological control approaches. He cited many examples of such use in biological control of insect pests. He was optimistic that semiochemicals may be of tremendous use in biological control of weeds too.

Presentation 6: Prospects of biological control of major invasive alien weeds in forest ecosystems in India**Speaker:** A. Balu, Institute of Forest Genetics and Tree Breeding, Coimbatore, India

Dr. Balu presented the overall picture of invasive weeds of forest such as *Chromolaena odorata*, *Mikania micrantha*, *Lantana camara* and *Parthenium hysterophorus*. He emphasized the need of introduction of effective bioagents in forest ecosystems also. He was hopeful that bioagent will work more effectively in the non-disturbed area in forest.

Presentation 7: Programs of major invasive weeds in the Western Pacific**Speaker:** PM Innovation Lab, Virginia Tech, Blacksburg, VA 24061, USA

Invasive plant species are one of the most serious threats to biodiversity and sustainable development in the Western Pacific. Biological control has proven to be effective in managing some of the perennial weeds. *Lantana camara* (Verbenaceae) was one of the plants recognized as an invasive weed by the Invertebrate Consultants Committee for the Pacific of the National Research Council and its natural enemies were introduced from Hawaii starting in 1948. The Siam weed, *Chromolaena odorata* (Asteraceae) was targeted for biological control in 1983, ivy gourd, *Coccinia grandis* (Cucurbitaceae) in 2002, *Mimosa diplotricha* (Mimosaceae) in 2008, and *Micania micrantha* (Asteraceae) in 2011. The biological control programs have provided satisfactory (*C. coccinia* and *C. odorata*) to adequate (*L. camara*) control of a few invasive weeds in the Western Pacific. However, biological control agents introduced for *M. micrantha* and *M. diplotricha* have either not established or not effective and hence additional efforts for their establishment and spread are required.

Symposium 5**Utilization of weeds as bio-resources****Convener:** Nimal Chandrasena, New South Wales, Australia

The Symposium on Weed Utilization was convened by Dr. Nimal Chandrasena (Sydney, Australia). The Symposium attracted participants with varied interests and included academics, students and industry. The topic stimulated discussions on two main sub-themes: (a) how best to 'utilize' the colonising strengths of weeds for the benefits of societies, and (b) how weed biomass can be used in productive ways, so as to make utilization a management tool.

Presentation 1: Liabilities or Assets? Perspectives on ‘Weeds and Their Values’**Speaker:** Nimal Chandrasena, New South Wales, Australia

In the introductory presentation, Dr. Nimal Chandrasena discussed some characteristics of weeds, which give this group of plants extraordinary strengths to colonize disturbed habitat. Many people have strong negative attitudes towards weeds, and a tendency to label a large number of potentially useful plant resources as invasive species, which should be controlled at any cost, while ignoring considerable evidence of the uses of these plants. This attitude may stem from the strong, traditional focus on the negative impacts of weeds, including the losses of agricultural production caused by weeds, and the threats they may pose to biodiversity. The focus in most countries has been so much on waging a protracted war on weeds that people have tended to overlook the potential of using these plants as resources. An enlightened view would demonstrate that ‘not all weeds are bad all the time’, and the problems caused by weeds are mostly site-specific, and depend on many interacting factors. He appealed for a much broader, ecological understanding of weeds as opportunistic, ‘colonizing species’, whose strengths could be exploited and used for a variety of benefits. Other major areas of significant interest include the use of the colonising strengths of several species in the remediation of water and terrestrial environments that have been damaged by human activities. Among some outstanding prospects are the potential to use aquatic species, such as Water Hyacinth [*Eichhornia crassipes*] in pollution removal, and the use of some strong colonisers in wastewater treatment systems, or in the rehabilitation of riparian zones of watercourses and rivers. The Common Reed [*Phragmites australis*] and Cattails (*Typha* spp.) are examples of such taxa. Globally, there is also considerable interest in using the large biomass produced by these species in a variety of beneficial ways, including as raw materials for a range of products and as bio-fuels of the future (bio-char) and compost. In addition, there are many opportunities for using colonising plants in phyto-remediation, to scavenge soil pollutants. Furthermore, the awareness of the role of weeds as part of biological diversity is increasing, and there is continuing interest in creating more sustainable farming systems, in which colonising species are appreciated. There are also significant opportunities to further exploit chemical warfare between plants (allelopathic phenomena) in beneficial ways. These include the discovery of new bioactive chemicals and the use of allelopathic plant residues within low input agricultural systems. Many colonising plants are useful in providing such benefits.

Presentation 2: Weed utilization in Japan: a history**Speaker:** Hirohiko Morita, Research Institute of Japan Association for Advancement of Phyto-Regulators, Kashiwada, Japan

Professor Morita from Japan discussed how weeds have been recognized as wild plants growing most closely around human beings. While they have been eliminated as harmful pests in agricultural production in Japan, throughout the history of Japan, many weeds have been utilized as substitute foods, herbal medicines, green manures, materials of industrial crafts, resources for producing new crops and so on. Particularly, since Edo period (1603-1868) when a Japanese word “Zassou” meaning arable weed was used first in 1828, a vast amount of historical literature exists in Japan. The Japanese uses of weeds and their utilization for human benefits have been published under topics, such as advancement of agricultural technologies, food shortages, as a result of poor harvests and the spread of herbal medicines introduced from countries like China. Adding to the past history of utilization of plants and weeds, accumulated over times, studies on the topic have been activated from 1980s by the Weed Science Society of Japan (established in 1962). Many examples of weed utilization were discussed, mainly as substitute foods in Japan, highlighting the historical records of weeds as ‘famine food’. Professor Morita also pointed out the importance of promoting the subject of weed utilization and the sharing of knowledge and accumulated experiences through the activities of the Weed Science Society of Japan and other forums.

Presentation 3: Allelochemicals and natural products from weeds**Speaker:** Yoshiharu Fujii, Tokyo University of Agriculture and Technology, Tokyo, Japan

Professor Fujii explained that allelopathy phenomena in nature and agricultural fields have three different applications or expressions. One is allelopathy of weeds as one of the detrimental effects of weeds on crops; and the other is the reciprocal effect - allelopathy of crops on weeds, which can be used to discourage and inhibit the growth of weeds. Utilization of allelopathic cover crops to inhibit the growth of weeds is a common, alternative way of weed control. The third field of application is to make novel natural products, including new herbicides from allelochemicals. Professor Fujii highlighted the recent recognition of the discovery of Artemisinin, an allelochemical from *Artemisia annua* (Sweet Wormwood) for malaria control. Artemisinin was discovered by Tu Youyou, a Chinese scientist, who was awarded half of the 2015 Nobel Prize for Medicine for her discovery. Treatments containing an artemisinin derivative are now standard

treatment worldwide for *Plasmodium falciparum* malaria. He also presented an illuminating account of current research, screening methods being used to discover novel bio-active compounds and various classes of highly bio-active allelochemicals from weeds with potential applications in weed science.

Presentation 4: Utilization of weeds and agrowaste for compost and vermi-compost making

Speaker: Sushilkumar, ICAR-Directorate of Weed Research, Jabalpur, India

Dr. Sushilkumar discussed the impacts of intensive farming - depletion of soil nutrients, which leads to an imbalance of available nutrients and loss of soil fertility, resulting in drastic reductions in crop productivity. Productivity of the soils cannot be sustained with inorganic fertilizer alone; organic manures are essential for sustainable farming. Composting and producing vermi-compost (using earthworms) are highly effective in re-cycling nutrients in biodegradable organic wastes. Composting provides a way not only of reducing amount of waste that needs to be disposed of, but also of converting it in to a product that is useful for crop production. However, conversion of weed biomass into effective compost and vermi-compost involves skill and a process to follow. Complete killing of weed seeds is a prerequisite in making compost from weeds. Ideally, weeds should be picked before they reach maturity and set seeds. Temperatures in the range of 55-60 °C should be produced in compost to destroy weed seeds, such as those of *Parthenium* and grasses. This cannot be achieved when compost is made in above ground aerated pits made of bricks, having holes. On the other hand, burial of *Parthenium* and grass weed biomass in a 3 m deep pit allows composting to occur under anaerobic conditions that kills weed seeds. Additions of dung slurry and urea assist in the breakdown process, which makes good compost after 2-4 months with a yield of about 35% of initial biomass. Dr. Sushilkumar also discussed aspects of vermicomposting, which involves the use of earthworms for recycling of organic waste to the soil. Research indicates that *Parthenium* seeds remain viable even if passed from the guts of earthworms. Therefore, biomass of such weeds needs to be collected for vermicomposting before they flower. High quality vermicompost can also be made from aquatic weed, such as Water Hyacinth (*Eichhornia crassipes*), Water fern (*Azolla*), Water Lettuce (*Pistia stratiotes*) and *Ipomoea aquatica*, all of which have high water contents. Adding of dung slurry and turning hasten the process of decomposing of weed biomass. Two turning of heap are required at 20 days interval for aquatic weeds and 4-6 turning are required for terrestrial weeds to hasten the process of decomposing. Only cooled and partially decomposed weed biomass can be fed to earthworms; if earthworms are released in hot decomposed biomass, they would die. The paper illustrated one aspect of utilization of weeds; i.e. encouragement of weed management and deriving an added benefit by using the removed weed biomass in practical ways to recycle large amounts of nutrients and improve soil fertility in agricultural fields.

Presentation 5: Bio-prospecting the food potential of weedy relatives of crops: studies with *Echinochloa* species and *Physalis* species

Speaker: Bhumesh Kumar, ICAR-Directorate of Weed Research, Jabalpur, India

Dr. Bhumesh Kumar presented an account of two well-known weedy taxa: *Echinochloa crusgalli* (Barnyard grass), *Physalis peruviana* (Cape gooseberry) and *Physalis minima* (Wild cherry). These species are known to have high genetic variability, display large variations in morphological traits, grow in relatively harsh conditions, and nutritionally high in value. He explained that globally, almost 80% of our plant food supply comes from just 20 kinds of plants; hence, the sources of food lack diversification. To tackle crop failures and malnutrition, diversification of food is essential, to ensure availability and access to a variety of complimentary food types to poor people. The results of the study suggest that *Echinochloa* and *Physalis* are both climate resilient, of high nutritional value, and potentially acceptable by consumers. Both are profitable to the farmers to grow as 'future complementary food' for the poor, and as a component of climate-smart agriculture. Dr. Bhumesh Kumar expressed the view that weedy relatives of some crops are sources of food that have hitherto been not adequately studied. There are many 'wild' species in the world with colonizing abilities, which are suitable for human consumption. Developing such species will help in providing better nutritional quality to poor populations; provide additional income from farming, as well as resilience to ensuing climate variability and scarcity of resources, such as water.

Presentation 6: Beautiful blue devil or Cinderella? Perspectives on opportunities with water hyacinth

Speaker: Puja Ray, Department of Biological Sciences, Presidency University, Kolkata, India

Dr. Puja Ray discussed utilization opportunities with Water Hyacinth [*Eichhornia crassipes*], which is much maligned as "The Beautiful Blue Devil", which continues to be regarded as the world's worst aquatic weed. Paradoxically, globally-abundant information on the uses of Water Hyacinth appears to indicate that the plant's strengths can be widely exploited to benefit human societies. Utilization may not be an option in some countries, such as Australia,

given the capacity of the species to aggressively invade waterways. However, it is a workable approach, particularly in regions and countries where the species is native (*i.e.* South and Central Americas), and where it has become naturalized (*i.e.* South-Asia, including India, Bangladesh, Sri Lanka and Thailand).

Presentation 7: Water quality improvement in wetland treatment systems with emergent and free-floating weed species

Speaker: Premraj J. Khankhane, ICAR-Directorate of Weed Research, Jabalpur, India

Dr. Khankhane demonstrated how colonizing species can be used in wetland treatment systems to treat wastewater contaminated with sewage, dairy waste or industrial pollutants in urban environments. In India, it is estimated that more than 38,000 million litres of sewage water per day is generated, out of which only 35% is treated. Vegetables, grown as human animal food, are at risk due to the potential uptake of heavy metals in untreated wastewater, which is often used for irrigation. The abundance of aggressive colonisers, such as *Arundo donax* (Giant Reed), *Typha latifolia* (Cattail) and *Eichhornia crassipes* (Water Hyacinth) in wastewater drains and contaminated lagoons is testimony to such species having a capacity to accumulate urban pollutants within their plant parts. Research at Jabalpur, conducted at two contaminated sites: *i.e.* DWR point of Karonda drain and the Urdua village of Pariyet River, evaluated the performance of several species for heavy metal removal in a Constructed Wetland set-up. The Constructed Wetlands systems with *Arundo donax* and *Typha latifolia* demonstrated that these species not only tolerated high concentrations of various pollutants, but were highly efficient in removing total suspended solids, odours, some dissolved heavy metals and nutrients without any clogging of the treatment system. The treated wastewater could then be discharged for irrigation through gravity flow. The removal of various contaminants by the colonizing species was variable, but highly significant, compared with untreated drain water. On a pilot-scale system at Urdua, Water Hyacinth was much more efficient than Water Lettuce in reducing the heavy metal- Chromium, turbidity and chloride. The research established that both emergent and free-floating, aquatic colonizing species can be used in different combinations and designs in Constructed Wetland systems to remove contaminants in different settings.

Presentation 8: Wetland colonizers to anti-dandruff dermatitis: A scientific validation of indigenous technical on *Ipomoea*

Speaker: Nabanita Chakraborty, ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, India

Dr. Nabanita Chakraborty presented a potential, new application of developing an anti-dandruff compound against the fungal dermatitis agent *Malassezia globosa* using a leaf extract *Ipomoea aquatica* Forssk (Convolvulaceae), a semi-aquatic, tropical weed. *Ipomoea aquatica* is mostly known as a popular edible weed and an important species in in wetland ecosystems. There is considerable evidence from indigenous sources in northern parts of West Bengal, India, that extracts of *Ipomoea aquatica* are good for removal of white flakes (dandruff) in humans. Phyto-chemical analyses of *Ipomoea aquatica* leaf extracts have indicated the presence of phenols, flavonoids and tannins. The research being conducted aims to subject various fractions of the extracts to microbial bio-activity testing, so that the anti-microbial compounds can be determined and isolated. A statistical approach to dose response curve is also being developed for the prediction of desired doses and results.

Concluding remarks

The conclusion of the Symposium was an appreciation that the conflict between humans and weeds will continue, so long as humans modify ecosystems. However, a fresh look at the potential of 'co-existing' with weeds and using them as resources is overdue, given the many possibilities demonstrated. In most cases, up to now, the focus of weed managers has been on managing problematic species in specific situations, rather than on their utilization.

General Recommendations

- Greater emphasis needs to be given on bioherbicides use as they may play crucial role in managing herbicide resistant weeds, invasive and parasitic weed, and responding the need of organic agriculture
- Newer microbial bioherbicides need to be developed
- Conservation agriculture based crop management practices, *viz.* machine transplanting and direct seeding in rice and zero tillage in wheat with appropriate weed management options in rice-wheat systems should be demonstrated more aggressively at farmers' fields
- Dust mulching needs to be promoted to reduce the weed infestation in direct-seeded rice
- Short duration rice cultivars and long duration wheat followed by short duration summer greengram with integrated weed management and maintain crop residues should be adopted for sustaining the productivity of rice-wheat system in South Asia
- Integrated approach of weed management with sustainable intensification is needed to tackle the emerging problem of weed shift and herbicide resistance
- Conservation of biodiversity must be a priority which includes re-diversification of cropping systems, and conservation of weeds to maintain ecological balance at required places
- Human practices need to be monitored including land cleaning, monoculture cropping, overgrazing, introductions of species for short term profit, population explosion and unplanned development *etc*
- Adequate preventive measures need to be taken to stop the spread of weeds
- IWM should be adopted for effective management of problematic weeds
- Transgenic herbicide resistant crops should be adopted for sustainable weed management in the Asian-Pacific region
- Development of new herbicide chemistry is warranted to tackle the problem of multiple herbicide resistance
- Location-specific documentation of weed species and their seeds through quality digital photography for proper weed identification should be taken as pre-requisite for devising a effective weed management strategy
- Maintenance of functional biodiversity should be taken care for sustainable weed management
- More emphasis should be laid on creating strict quarantine facility to prevent the entry of new invasive weeds in South-Asia
- More efforts should be done to introduce bioagents for biological control of alien invasive weeds
- Development of resistant varieties (resistant to pest and herbicides) should be done
- Greater use of agronomic approaches like crop rotation, inter-cropping, shifting of sowing dates should be emphasized
- Sole dependence on herbicides and their excessive use should be avoided
- Precise and regular monitoring of herbicide residues in harvestable parts and soil should be done

Awards

APWSS Young Scientist Awards – 2015

Dr. Bhagirath S. Chauhan, a doctorate in Weed Science from University of Adelaide, South Australia (John Alwright Fellow) holds research interests in weed ecology and biology, herbicide use, integrated weed management systems using agronomic and varietal components and conservation agriculture systems. He has worked as weed scientist in International Rice Research Institute (IRRI) Philippines from 2007-2014. He has published more than 150 articles and book chapters. He is Editor-in-Chief of Crop Protection (Elsevier) and associate editor in many other international journals. He is presently Principal Research Fellow at Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Toowoomba, Queensland 4350, Australia.



Dr. Puja Ray obtained her doctorate from Rani Durgawati University, Jabalpur, India, and also served as Rhodes Post-Doctoral Fellow, Rhodes University, South Africa. She has made significant contributions in the field of weed and insect-pest management, activity enhancement of biocontrol agents of weeds, mycoherbicide production and application, insect-pathogen-weed interaction, and non-target impact of microbial and chemical herbicides. She has published more than 25 articles in peer reviewed journals, and received 7 awards at the national and international level. Presently, she is serving as Assistant Professor (Zoology), Department of Biological sciences, Presidency College, Kolkata, India.



Student Travel Grant Awards

As per the recommendations of the committee and approval of the Executive Council of the Indian Society of Weed Science, five Ph.D. scholars have been awarded for students travel grant. These students were entitled for travel expenses and free Registration at the 25th Asian-Pacific Weed Science Society Conference being held at Hyderabad from 13-16 October, 2015. Following five students were awarded with Student Travel Grant.

Ms. N. Viji, Agricultural College and Research Institute, (TNAU), Madurai 625104, TN

Mr. Veeresh Hatti, Department of Agronomy, UAS, GKVK, Bengaluru 560065

Mr. B.S. Gohil, College of Agriculture, Junagarh Agricultural University (JAU), Junagarh 362 001, Gujarat

Ms. Aditi Pathak, Rani Durgawati Vishwavidhyalaya (RDVV), Jabalpur, M.P.

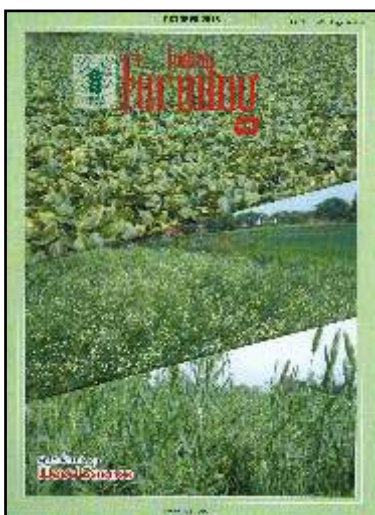
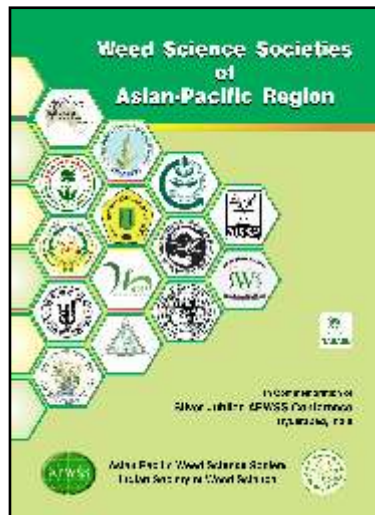
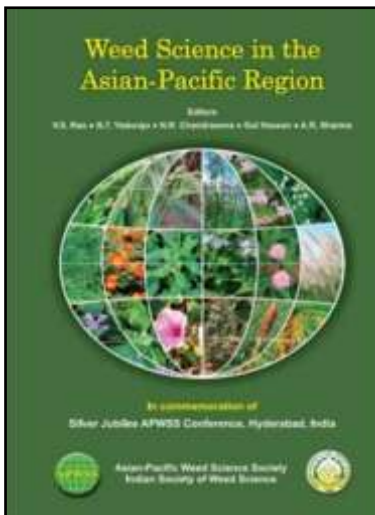
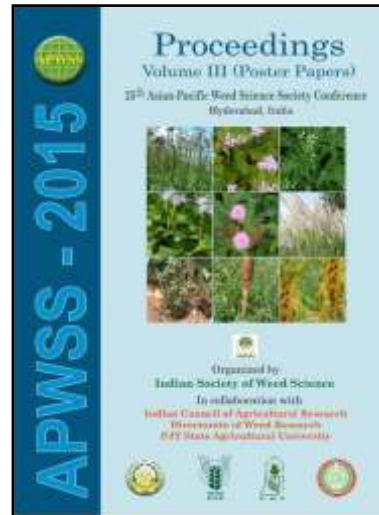
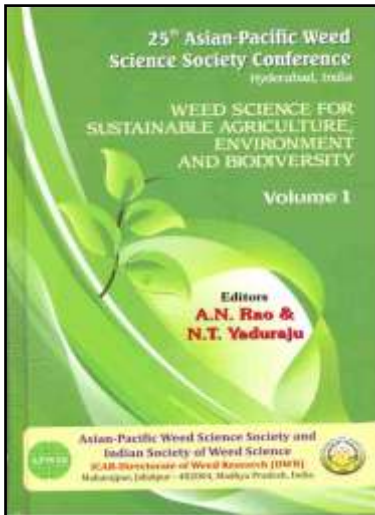
Mr. Sandeep Rawal, CCS Haryana Agricultural University, (CCSHAU), Hisar, Haryana

Best Poster Presentation Awards

Nine 'Best Poster Awards' were given for the excellent poster presentations made by participants.

Publications

Following publications were released during the 25th APWSS conference



Glimpses



Lighting of lamp in the Inaugural Session by the dignitaries



Welcome address by Dr. A.R. Sharma, Organizing Secretary, APWSS and Secretary, Indian Society of Weed Science



Address by Chief Guest, Professor P. Appa Rao, Vice Chancellor, University of Hyderabad



Address by Guest of Honour, Dr. D. Rama Rao, Director, ICAR-NAARM, Hyderabad



Dr. A.N. Rao, newly-elected Secretary, APWSS felicitating Dr. Steve Adkins



Release of publications during the inaugural ceremony



Release of publications during the inaugural ceremony



Congregation of delegates outside the Auditorium after inaugural ceremony



Group photo of delegates in front of main Auditorium



Drs. V.S. Rao (USA), Nimal Chandrasena (Australia), Peter Michael (Australia), Dr. N.T. Yaduraju (India), Anis Rehman (New Zealand), Steve Adkins (Australia), Hiroshi Matsumoto (Japan) and A.N. Rao (India) (Left to right) during the Silver Jubilee Commemoration function



Dr. Anis Rehman addressing gathering during the Silver Jubilee function



Release of book "Weed Science in the Asian-Pacific Region" during the Silver Jubilee function



Dr. V.S. Rao delivering plenary lecture on "Transgenic herbicide resistant crops for sustainable weed management in the Asian-Pacific region: Perspectives and alternatives"



Delegates interacting during tea break



Dr. Ian Heap delivering plenary lecture on "Herbicide resistance: A global overview"



Delegates in the main Conference Hall



Delegates interacting during poster sessions



A view of dinner Hall



Dr. Zahid Ata Cheema (Pakistan) interacting with Dr. A.R. Sharma



Dr. Murray Scholz presenting farmer's perspective on weed management under conservation agriculture



Dr. K. Dhilepan presenting paper in the symposium on biological control of Weeds



Dr. Michael J. Widderick presenting paper on Integration of alternative chemical and non-chemical approaches for weed management



Dr. N.T. Yaduraju and Dr. Prasanta Bhowmik family along with other delegates



Handing over of APWSS flag by the outgoing President Dr. N.T Yaduraju to Dr. Hiroshi Matsumoto, President-designate, 26th APWSS Conference, Kyoto, Japan



Dr. Steve Adkins, Past President, APWSS, Dr. N.T. Yaduraju, current President, APWSS and Dr. Hiroshi Matsumoto, President-designate, 26th APWSS Conference with Executive Committee members of the Indian Society of Weed Science and the Weed Science Society of Japan



Dr. A.R. Sharma, Organizing Secretary, APWSS proposing vote of thanks during the closing ceremony

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