Stakeholders Dialogue on Strategies for Safe and Sustainable Weed Management

– *A Road Map*

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Preamble

Agriculture is a major source of livelihood for nearly half of the Indian population. The country, despite significant increase in agricultural production, would need to produce more than 400 mt of foodgrains to meet the demand of expected 1.65 billion people by 2050. Among various biotic factors limiting crop productivity, the crop losses due to weeds are quite significant. The crops compete with a large number of species of weeds for space, water, nutrients, and sunlight. Thus, weeds considerably reduce input efficiency and negatively impact farmers' harvest ranging between 10 to 30 per cent, if not managed timely. The ICAR-Directorate of Weed Research (ICAR-DWR), Jabalpur has estimated that the total losses caused by weeds amount to almost $11 billion per annum in just ten major crops in India. The highest loss is caused by weeds (33%), followed by pathogens (26%), insects (20%), storage pests (7%), rodents (6%), and others (8%). Efficient weed management is, therefore, vital both for increasing productivity and farmers' income.

In India, the weeds are primarily managed through manual and mechanical methods which are quite expensive accounting for 20-25 per cent of the total cost of cultivation. With labor becoming scarce and expensive, farmers are finding herbicides as a better alternative. Herbicides constitute more than half of the total pesticides used globally, whereas in India, the share of herbicides is only around 18.0 per cent of the total pesticides, which is quite low compared to insecticides (40%) and fungicides (33.4%) consumption. On the contrary, the trend is quite reverse globally. Further, it is interesting to note that use of herbicides is increasing in the last one decade in India at a much faster pace (15-20% annually).

Existing Constraints and Challenges

The weeds are a major constraint for agricultural production in India. The most prevalent weeds are: *Phalaris, Echinochloa*, weedy rice, *Cyperus, Cynodon*, *Parthenium* in crops*; Parthenium, Lantana, Mikania, Mimosa, Ageratum, Chromolaena, Saccharum and* para grass in non-crop areas; water hyacinth*, Salvinia, Hydrilla,* and *Pistia* in water bodies*;* and parasitic weeds like *Orobanche, Striga, Cuscuta,*

Loranthus, etc. To manage them effectively, the real challenges are: i) inadequate knowledge and awareness among farmers about herbicides, ii) non-availability of farm labor iii) lack of efficient machinery/ mechanical tools, iv) building of herbicide resistance in some weeds, v) poor adoption of integrated weed management practices mainly due to non-availability of effective biocontrol agents/organisms etc. Concerning biological weed control, there is lack of availability and awareness about efficient bioherbicides. Further, though there had been examples of allelopathic effects of a few crops/weed species and some insects/microorganisms which could be used for weed control but then they have not been exploited so far for effective control.

It is quite evident that for effective control of weeds, use of efficient and safe herbicides is imperative. Somehow, both research and development efforts on herbicides in India have lagged behind and thus need to be accelerated. Further, timely availability of quality and cost effective herbicides, besides to some extent the spread of spurious and adulterated herbicides is also an important concern, which must be addressed effectively under the prevailing regulatory mechanisms as per Insecticides Act.

Issues and Options

I. Herbicide Regulations and Management

It is evident that herbicides provide cost-effective weed control. Through their wide window of application, effectiveness on diverse weed flora and timely control of weeds, herbicides reduce labor requirement, increase input-use efficiency and enhance crop yield quite substantially. Moreover, the cost of herbicide application is approximately one-third of the cost of two hand weeding operations. In India, 60 herbicides of different modes of action have so far been registered. Besides, over 700 formulations of herbicides are available in the market. Up to 2016, over 2,000 herbicides belonging to 15 different modes of action were introduced in the global market. In India, over 6,000 tons of herbicides are currently used for weed control, mainly in irrigated crops (about 77% in wheat and rice) and plantation crops (about 10%). Continuous use of herbicides leads to weed flora shifts and development of resistance in weeds. Development of resistance to herbicide isoproturon in *Phalaris minor* in north-west India in the early 1990s had threatened our food security. Somehow, priority registration then of alternate herbicides did restore the situation *albeit* temporarily. The widespread occurrence of *P. minor* populations exhibiting cross and multiple resistance to a host of recommended herbicides is currently an important problem to be dealt with. Moreover, for lack of policy and funding support, the new molecules with effective mechanisms of action may not be available in the near future.

Herbicide rotation and use of herbicide mixtures are good strategies to prevent/ delay the onset of herbicide resistance in weeds. Application of herbicide along with seed and fertilizer under optimum

moisture conditions gives the best results. Mixing compatible herbicides does improve control of specific weed populations, such as 2, 4-D applied with dicamba for broadleaf weeds. Also, tank-mixing of herbicides improves the spectrum of weeds controlled in a single application which saves time and labor. Herbicide combinations also ensure effective control of several weed types at the same time, such as grassy and broadleaf weeds. Herbicides applied alone or in combinations have been regarded as essential options for effective management of weeds in different-ecosystems.

The Central Insecticide Board and Registration Committee (CIB&RC) has given approval for the use of a combination of herbicides having three active ingredients. This is useful in controlling diverse weed flora with a single application, thus saving both cost and time. Presently, 14 combination products of two active ingredients are available for broad-spectrum weed control in major crops like rice, wheat and soybean. However, there is an urgent need to develop and/or introduce new herbicides with higher efficiency and environmental safety. Selective herbicides such as clodinafop, quizalofop, halosulfuron, dicamba, sulfentrazone or 2-4-D are post-emergent herbicides used to target the type of plants to be eliminated, whereas glyphosate, a non-selective systemic and post-emergent herbicide, is widely used to kill perennial weeds. Also, genetic variation for tolerance to herbicides exists in maize, wheat, rice, sunflower, soybean, chickpea, alfalfa, etc. which needs to be exploited to develop herbicide-tolerant cultivars.

The recent notification to ban use of herbicides such as butachlor, 2, 4-D, pendimethalin, glyphosate, etc. has caused major blow to both the farming community and herbicide industry. Glyphosate is a popular herbicide with the farmers and is currently the largest selling product in the country with 30 per cent share. It is used in many wide-spaced crops such as cotton, sugarcane, fruit/plantation crops, etc. In the absence of effective alternative herbicides, such premature ban would create a major setback for our weed management strategy and adversely affect the farmers' income. The industry and the experts strongly feel that banning these herbicides is arbitrary and unscientific and needs to be reconsidered on scientific grounds. The record use of pendimethalin (one of the herbicides listed for banning) in Punjab and Haryana in 2020 saved the crops, thus is a case which needs to be given due attention. The states adopted in a big way the system of direct seeded rice to overcome labor scarcity that happened due to COVID-19 pandemic. Besides, water saving options like growing of direct seeded rice, use of low water requiring crops such as maize, soybean etc., would certainly require enhanced use of herbicides.

Pre-emergent herbicide application is of major concern especially in drylands. There is an obvious need to promote safe use of herbicides by following the principle of '5-R' herbicide stewardship (right kind, right dose based on soil type, right time, right method of application and right place with appropriate nozzle solving many herbicide related problems and resulting in excellent weed control), and creating

awareness among the stakeholders who often resort to faulty/indiscriminate use. The quality of herbicides is also a major concern. There is an urgency for effective regulatory control to test the quality of herbicides, and the sale and marketing of quality products to end-users. Also, there is no significant headway for efficient mechanical weed control. Hence, there is a need for developing efficient power-driven mechanical devices along with other methods as part of an integrated weed management (IWM) strategy.

ICAR- Central Research Institute for Dryland Agriculture (ICAR-CRIDA) has developed a precision planter and raised-bed planter where sowing, fertilizer and herbicide application can be done simultaneously. Such a device is especially suitable for conservation agriculture (CA) ensuring reduction in energy use. Weeds in non-cropped areas particularly in topographies of greater slopes and far from social communities need to be assessed for their carbon sequestration potential and arrest of land degradation. Further, weed control is invariably more expensive in community areas and water lakes.

In India, over 14 crore farmers live in 6.5 lakh villages making it impossible for any individual or organization to reach them. Hence, partnership with the private sector considering available strength and experience is extremely important. Around 6,000 companies have been issued registration, and even for one molecule, there are more than 500 to 1,000 registrations. Also, there is lack of IP protection, as data protection is lacking for 'me-too' registrants, the product is not properly used and thus resistance has been developed against many insect-pests. Also, new molecules are not being introduced mainly for want of data protection facility and enabling policies to promote growth of private sector. Apprehensions and misgivings about herbicide-tolerant crops, negative impacts on biodiversity, gene transfer between wild relatives (particularly in the centres of crop origin), development of super weeds, and health related issues demand effective public awareness campaign at the national level.

Genetically modified crops resistant to non-selective herbicides such as glyphosate have opened up an innovative approach for management of weeds. Introduced in 1996, GM crops are currently (as of 2019) being grown on over 190 mha area globally with 88 per cent area with herbicide tolerant (HT) crops. Glyphosate tolerant (Roundup-Ready) soybean, corn and cotton occupy 82, 30 and 68 per cent of the total cropped area, respectively. In India, the HT tolerant crops like maize and soybean, despite successful field trials, are awaiting the GoI approval for commercial use. Hence, due to lack of policy on the use of GM crops, there is already an illegal cultivation of HT Bt cotton in Maharashtra, Telangana, Andhra Pradesh and Gujarat.

II. Research and Development

Research is mostly centered on enhancing herbicide efficacy. Integrated weed management (IWM) which includes preventative, mechanical,

cultural, chemical and biological methods, is advocated for effective use in crop production systems. Research on herbicides as a tool in weed management has been carried out over the past 4-5 decades and country-wide herbicide recommendations are available for all crops and cropping systems. Knowing the limitations of over-reliance on herbicide use, there has been a concerted effort to include herbicides as a component in the overall IWM strategy. Attempts have been made to integrate herbicide use with tillage, competitive crop cultivars, inter/cover cropping, mulching, and mechanical and manual methods of weed control. Use of herbicides must be made economically and ecologically affordable to farmers by innovatively integrating with other components of IWM. There is a significant scope of growth in herbicide as a component of IWM. The expected concerns related to environmental and ecological impact of HT crops, including the development of super weeds, need thorough investigation.

Biological control is the most suitable option for management of weeds in non-crop areas, grasslands and forestry. Despite intensive efforts by the ICAR-DWR, Jabalpur for over three decades, the control of *Parthenium* with the use of Mexican beetle is far from satisfactory. In Australia, the weed is managed well by employing a large number of biocontrol agents including insects and fungi. The ICAR-National Bureau of Agricultural Insects Resources (NBAIR) and ICAR-DWR should focus on exploring such possibilities. Import and introduction of Smicronyx weevil will be useful for management of *Parthenium*. Introduction of new innovative molecules and sustaining the existing molecules and safe/judicious use are certainly important for sustained and greater use of herbicides.

In view of negative public opinion about GMOs, it would be wise to shift focus on developing HT crops using non-GM approaches such as gene editing (CRISPR/Cas9) technology. The Indian Agricultural Research Institute (IARI), New Delhi has been successful in developing rice cultivars resistant to imidazoline using the non-GM approach. Called as 'clearfield rice technology', this enables control of weedy and wild rice- problematic weeds in some ecosystems using imidazoline herbicides. There is, however, a risk of development of weedy/wild rice resistant to imidazoline herbicides with their repeated use. In this context, the public sector research also needs to be strengthened. It will be good if certified formulations of herbicides are also developed and made available to farmers in India. On the contrary, USA has developed and commercialized several microbials and efforts may be made to import these microbials for use in India.

Development of machineries/tools suitable to small farms is to be given high priority. The advanced technologies such as ICTs, artificial intelligence (AI), machine learning, sensors, and image processing have been found to have immense potential in weed management. Machines capable of identifying weeds in the crop field and removing them selectively either pulling them physically, or through laser beams, or spraying with herbicides need to be developed. The prototypes of self-driven robotic weeders are also being tested in

many countries. The 'sense and spray' technology, which is commercially available in some countries needs to be adopted as it reduces herbicide requirement by 75 per cent thus saving money and reducing the herbicide load in the environment substantially. The rise of digital farming and dense geospatial data will enable prediction tools for the occurrence and spread of different weeds and herbicide resistance within fields and across landscapes. Weed omics will further contribute to better define these prediction tools.

The Dialogue

In view of above, the Trust for Advancement of Agricultural Sciences (TAAS), a neutral Think Tank, the Natural Resource Division of Indian Council of Agricultural Research (NRM-ICAR), ICAR-Directorate of Weed Research (ICAR-DWR), Jabalpur and the Indian Society of Weed Science (ISWS), Jabalpur jointly organized a virtual "Stakeholders Dialogue on Strategies for Safe and Sustainable Weed Management: A Way Forward" on 9 December, 2020. The major objectives of the Dialogue were to: i) discuss possible ways to avoid losses due to weeds and their efficient management, ii) suggest strategy for safe and sustainable use of herbicides and weed management; and iii) discuss policies on herbicide use and regulatory systems, including proposed ban of certain herbicides. A total of 61 participants/stakeholders (and 63 observers across the country) on one platform from the Central and State Governments, ICAR, State Agricultural Universities (SAUs), CGIAR Centers, scientific institutions, and private sector dealing with herbicides deliberated holistically science-based farmer-centric strategy on 'Issues to Actions' on weed management towards a sustainable food, nutrition and environmental security.

During the dialogue, in-depth discussions were held on constraints and challenges, herbicides regulations and management for sustaining farm productivity, banning of herbicides, research and innovation for development of herbicides, developing herbicide resistant crop varieties including transgenics by incorporating resistant genes from various sources, enhanced use of bioherbicides, enabling policies and understanding the industry's perspective. It was strongly felt that there is an urgent need to develop a clear **'Road Map'** for disruptive innovation in the field of chemical herbicides through greater investment in R&D, both by public and private sector.

The Road Map

A holistic approach with multi-disciplinary, multi-locational and multi-institutional involvement would be imperative to effectively tackle future weed problems. Decades of efficient chemical weed control have led to a rise in the number of herbicide-resistant weed populations, with a few new herbicides with unique modes of action to counter this trend and often no economical alternatives to herbicides in crops with large acreage. If these challenges are addressed appropriately and the new emerging trends in technology and innovation are well adopted, sustainable

weed management will be ensured in future. The emergence of natural products leads to discovery of new herbicides and biopesticides suggesting that new modes of action can be discovered, while genetic engineering provides additional options for manipulating herbicide selectivity and creating entirely novel approaches to weed management. Selective and non-selective use of herbicide is extremely important. Only red triangle herbicides are to be banned and certainly not those in other color triangles. A Road Map based on discussions related to IWM practices, managing weeds through judicious use of herbicides, developing bio-control measures, using biotechnological tools for managing weeds, monitoring alien invasive weeds, and developing techniques for managing weeds in conservation agriculture (CA), was suggested for safe and sustainable use of herbicides in agriculture, along with science-based herbicide related policies and regulatory systems, and a mechanism to gradually phase out certain herbicides. The salient recommendations that emerged as a result of in-depth discussion are given below:

Recommendations

I. Herbicide Regulations and Enabling Policies

1. There is an urgency to expedite the present registration process of herbicides, especially to ensure the availability of new and safe molecules much faster. Also, use of herbicides needs to be promoted as post-emergence application for controlling broad-leaved weeds in pulses (chickpea and lentil) and oilseeds (rapeseed-mustard) and also for controlling grassy weeds in standing crops of pearl millet, sorghum and other small millets. Similarly, the re-registration of herbicides (after 10 years of registration) be based on critical review and with reference to human/environmental health.

2. Product efficacy work done by various ICAR institutes should be considered for grant of label expansion, subject to the establishment of maximum residue limit (MRL) data wherever applicable. For this purpose, there is need to establish an expert committee involving representatives of DoAC, ICAR, CIB&RC and the private sector organizations working on herbicides to collate all available research findings and to develop recommendations for approval of new herbicides. Also, there is an urgent need for harmonization of MRL standards for individual herbicides across the globe.

3. An urgency is evident to have a transparent National Policy on GM Crops, based mainly on scientific considerations. GM herbicide tolerant crops used widely for weed management in several countries could also be promoted in India. In this context, release of both HT maize and HT soybean appears to be fully justified. In fact, India seemed to have lost almost a decade as well as an opportunity to harness higher productivity. Therefore, it will be in the national interest if the GoI takes

an early decision to allow use of herbicide tolerant GM crops to increase both productivity as well as farmers' profitability. Also, herbicides need to be included in the "National Agrochemical Policy", as already recommended in the Proceedings of Pesticide Management Dialogue organized by the TAAS in July 2020. Further, it will be desirable to have a 'Status Paper' on future potential of herbicides in India, encompassing the entire gamut of weed management, such as availability of different herbicides, the level of their toxicity and future possibilities of research for innovation, development and extension.

4. An early decision by the GoI to put in place a mechanism for sale of quality herbicides exclusively by the trained professionals, setting of accredited laboratories in different eco-regions for testing herbicide efficacy, their bioefficacy including residue retention, and the quality testing to safeguard against supply of spurious/expiry date herbicides would help much faster growth of herbicides in India. Also, safeguard mechanisms to protect the farmers against adverse effects of herbicides handling would be desirable, including capacity building and public awareness.

5. Creation of an enabling environment for the private sector participation to accelerate growth of herbicide use will be in larger national interest and in line with the GoI initiative of '*Atmanirbhar Bharat*'. In this regard, data protection shall have to be ensured to facilitate introduction of new molecules. Also, proper guidelines need to be put in place for the introduction of microbials with proven safety record so as to promote environment friendly products required for enhancing organic agriculture. Special efforts are needed for establishing public-private partnership in a mission-mode in specific areas such as: i) herbicide application techniques, ii) safe handling of herbicides, iii) safe disposal of used herbicide containers, iv) combating herbicide poisoning, and v) establishment and use of first aid facilities. Public-private partnership could also help in promoting private extension for plant protection.

6. Non-chemical methods like robots for mechanical weed control, flaming and solar-energy based microwave generating devices are being experimented successfully in advanced countries. Use of such devices also needs to be promoted in India through custom-hire centers. Similarly, there is need to promote the use of power-driven mechanical devices in row-planted crops along with other methods as part of an integrated weed management strategy. Weed control through power-driven weeders including tractor-driven inter-row weeders in wide row spaced crops like maize, cotton, sugarcane, chickpea, mustard, soybean, etc. is required to be promoted, for which needed equipments could be subsidized.

7. There is an urgency to have a technical review of recent notification to

ban seven herbicides, including the notification for restricted use of glyphosate. The sudden ban on herbicides without required technical justification and suitable alternatives may adversely affect both the farmers and the Indian pesticides Industry. The recent directive on "Glyphosate use or any other product use by PCO" also needs to be reviewed on a scientific basis as well as practical feasibility for implementation.

8. There is need to generate data on adverse effects of herbicides under Indian conditions rather than relying on studies conducted in other countries. Also, a proper mechanism of consultative process involving key stakeholders to justify product utility and performance, before suggesting any herbicide ban or restrictions will be desirable to ensure transparency of the system involved.

9. Use of new technologies and innovation in weed management will have to be given priority attention. Appropriate policies and guidelines for the use for unmanned aerial vehicles (UAV) for pesticide spray need to be developed. For this, a separate approval mechanism for UAV based products would be highly desirable.

II. Herbicides for Improving Productivity – An Industry Perspective

10. As new molecules with new modes of action are likely to take time, it is imperative to retain already released herbicides and use them more judiciously and efficiently. In some countries, parasitic weeds have been controlled successfully through the use of herbicides. Such herbicides need to be imported for testing their efficacy and eventual use in India. Similarly, import, testing and fast track registration (even ad hoc) of bioherbicides should be our current priority for high level policy decision and implementation.

11. The effective weed management strategy in future should address: i) focus on season long weed management rather than critical period of weed management concept, ii) use of nano-encapsulated formulations for slow and steady release for season long weed control, iii) use of drones for herbicide spray for quick and more area coverage (5 minutes for one hectare spray), and iv) deactivating/degrading the left over (residual) herbicides with the help of nanoparticles.

12. Greater attention is needed at the Government level to promote safe use of herbicides following the '5-R' principle of herbicide stewardship (right kind, right dose based on soil type, right time, right method of application and right place with appropriate nozzle solving many herbicide related problems and resulting in excellent weed control), and creating awareness among the stakeholders, especially the farmers to avoid both faulty and indiscriminate use. Efforts need to be made to reduce the herbicide load in the soil

through integrated approach around conservation agriculture (CA), soil type, organic matter content, stage of weed growth, use of adjuvant and proper herbicide application technology. Awareness among farmers on weeds, safe herbicide use, and integration of other mechanical/ cultural methods, including zero-till/ no-till needs to be ensured.

13. Artificial intelligence is an emerging area that can certainly help in effective weed management. Weed populations need to be mapped through remote sensing mechanisms, viz., spectroradiometer, weed seeker, unmanned aircraft vehicles like drones, etc. enabling precise herbicide release on the targeted weeds. Hence, required expertise needs to be developed by training youth (both men and women) seeking the support of both public and private institutions.

14. To overcome the concern of harmful chemicals, the industry is already laying greater attention on developing biobased herbicides, which offer a clean solution for weed control, including the weeds that have developed herbicide resistance. Somehow, relatively low price of chemical herbicides is a deterrent for the growth of bioherbicides. Hence, concerted efforts are needed to develop cheaper bioherbicides. Also, policy consideration to subsidize these by the Government will help in accelerating the growth of bioherbicides in India.

15. The role of industry in production and promoting the use of herbicides in India through in-house production will be in line with Government policy of '*Atmanirbhar Bharat*'. Hence, a concerted effort by the private sector will greatly benefit the farmers and promote national agricultural growth faster. Also, the import of new molecules and use of combination herbicides will be highly beneficial. Further, greater thrust on use of safe herbicides will be much beneficial to the farmers. For this, adoption of herbicide rotation must be practiced to avoid herbicide resistance.

16. It will be desirable if the herbicides are sold by the trained youth having good scientific knowledge and requisite formal training. In this context, building skills of youth to provide custom-hire services for plant protection to the farmers is urgently needed. Obviously, pesticide industry could play an important role in using resources available under corporate social responsibility (CSR). Also, senior/retired weed scientists/ experts could be employed to train youth and act as mentors/advisors to promote safe use of herbicides in line with the adoption of IPM strategy at the national level. Thus "paid service providers" and "paid extension agents" will ensure proper pest/weed management at farm level. They may also be authorized to have an eye on market/sellers to avoid to a greater extent the practice of sale and use of poor quality or spurious herbicides.

III. R&D for Weed Management

17. There is also need for intensifying research on the discovery of new herbicides with new modes of action in public-private partnership (PPP) mode. Development of suitable technologies to tackle crop-weed competition due to increased atmospheric CO_2 concentration and subsequent global warming is an emerging challenge to be addressed through intensification of research.

18. Greater thrust for IWM research in future needs to be given on: i) enhancement of herbicide efficacy, ii) assessment of on-farm losses caused by weed; iii) weed ecology, iv) interdisciplinary approach for R&D, v) on-farm assessment of available IWM options, and vi) need for knowledge-based decision-making tools. In view of the diversity of weed flora in different agro-ecosystems, appropriate technological support for weed management under organic farming, natural farming, hill farming and rainfed agriculture shall have to be provided.

19. There is an urgent need to intensify research on integrated weed management in rainfed cropping systems as well as in conservation agriculture (CA).

20. Breeding for herbicide tolerant and herbicide resistant transgenic crop varieties shall be intensified using resistant genes from various sources. Further, intensification of research to develop bioengineered plants for better nutrient mining, herbicide tolerance and weed suppression is highly justified, requiring additional funding support to ICAR to initiate an inter-institutional and inter-disciplinary network at the national level.

21. In-depth study is needed on design and development of energy-efficient weeding tools (for smallholders); sensor-based weeding tools and spraying equipments; small scale floating-cum-submerged weed harvester and dredgers. Also, there is need to develop nano-capsules/ nano-herbicides for slow release to ensure season long weed control, use of nano-biosensors for quick detection and quantification of herbicide residue in soil and crops, use of drones for herbicide application, socio-economic impact assessment, and the development of weed management portal for knowledge dissemination.

22. Biological control is an economical and practical option for the management of invasive weeds in forests, pastures and non-crop areas. There is an urgent need to promote research on biocontrol of major weeds and also introduce proven biocontrol agents from other countries. In Australia, *Parthenium* is being effectively managed by a consortium of 4-5 biocontrol agents. In fact, similar strategy can be tested and adopted in India. The ICAR-DWR in collaboration with ICAR-NBAIR could possibly introduce useful biocontrol agents from abroad and test them under varying agro-ecologies.

23. Continuous refinement of weed management technologies is essential to cut down crop production costs in the light of ever-changing socioeconomic conditions of the farmers and international trade policies. The rapid expansion of weedy rice infestation, evolution of herbicide resistant weeds, introduction of alien invasive weeds, lack of low-cost environment-friendly weed management technologies for water bodies and dryland farming systems are some of the burning issues requiring urgent attention.

24. Use of herbicides is rapidly increasing and hence the residue hazards and other environmental issues related to herbicides need to be suitably addressed. Since herbicide residue estimation through analytical method is tedious and time consuming, there is a need to develop sensors for *in situ* detection and quick quantification of herbicide residues.

25. Looking at the global trend and the national needs, greater emphasis on research and development (R&D) for better weed management is urgently needed. An IWM strategy around cultural, mechanical, biological and chemical methods would require much accelerated efforts at the national level. In this context, both ICAR and SAUs need to promote the use of safe herbicides, critical for increasing agricultural productivity while ensuring health and environmental security. Hence, a national 'Mission on Weed Management' is fully justified and thus be created under ICAR at the earliest possible.

TECHNICAL PROGRAM

WEBINAR (Wednesday, 9th December, 2020; 15.00-18:30 hrs)

Chair **:**	RS Paroda, Chairman, TAAS	
Co-Chair **:**	SK Chaudhari, DDG (NRM), ICAR	
3.00-3.40 PM	**Opening Session**	
3.00-3.05 PM	Welcome	JS Mishra, Director ICAR-DWR
3.05-3.15 PM	Setting the Context	SK Chaudhari, DDG (NRM), ICAR
3.15-3.30 PM	Opening Address	T Mohapatra, DG ICAR
3.30-3.40 PM	Chairman's Remarks	RS Paroda, Chairman TAAS
3.40-4.40 PM	**Technical Session: Status of Weed Management Research, Development and Policies**	
3.40-4.00 PM	Research and Development on Weed Management- Status and Challenges	Sushil Kumar, President, ISWS
4.00-4.20 PM	Herbicides for Sustaining Farm Productivity- An Industry Perspective	Anil Kakkar, Vice-Chairman, CropLife India
4.20-4.40 PM	Herbicide Regulations and Enabling Policies	SK Chaudhari, DDG (NRM), ICAR
4.40-5.40 PM	**Panel Discussion on Future Road Map**	
	Moderator **:** ML Jat ***Panelists*** **:** • SK Malhotra, Agriculture Commissioner, GoI • Samundar Singh, President, International Society of Weed Science • Rajvir Rathi, BayerCrop Science • BS Sidhu, Commissioner Agriculture, Govt. of Punjab • S Bhaskar, ADG (Agronomy), ICAR • RG Agarwal, Chairman, Dhanuka Agritech Ltd. • AR Sharma, Director Research, RLBCAU • Ajay Kumar, Corteva Agriscience • Gita Kulshreshtha, Ex Principal Scientist, Agricultural Chemicals, IARI	
5.40-6.10 PM	**General Discussion**	
6.10-6.25 PM	**Concluding Session**	SK Chaudhari and RS Paroda
6.25-6.30 PM	***Vote of Thanks***	Bhag Mal, Secretary, TAAS

List of Participants

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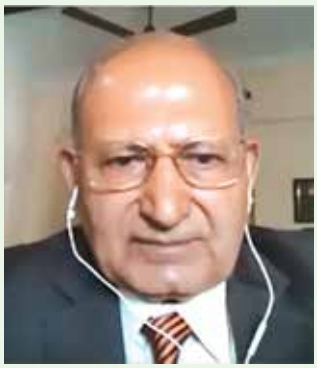







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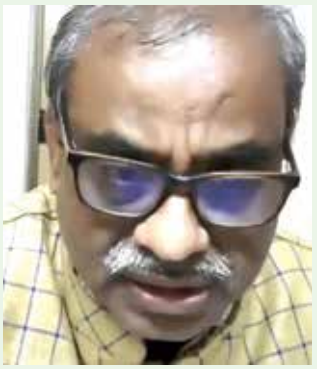


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- A Road Map on Stakeholders Dialogue on Current Challenges and Way Forward for Pesticide Management, September, 2020.
- A Road Map on Stakeholders Dialogue on the Indian Seed Sector, June, 2020.
- A Road Map on Policy Framework for Increasing Private Sector Investments in Agriculture and Enhancing the Global Competitiveness of Indian Farmers, December, 2019.
- Crop Biotechnology for Ensuring Food and Nutritional Security – Strategy Paper by Dr J.L. Karihaloo and Dr R.S. Paroda, December, 2019.
- National Dialogue on Land Use for Integrated Livestock Development –Proceedings and Recommendations, 1-2 November, 2019.
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- Urgency for Scaling Agricultural Innovations to Meet Sustainable Development Goals (SDGs) – Strategy Paper by Dr R.S. Paroda, April, 2019.
- Tenth Foundation Day lecture on "Can India Achieve SDG 2 – Eliminate Hunger and Malnutrition by 2030" by Dr Prabhu Pingali, Professor in the Charles H. Dyson School of Applied Economics and Management at Cornell University, January 24, 2019.
- Motivating and Attracting Youth in Agriculture - Strategy paper by Dr R.S. Paroda, November, 2018.
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- Strategy for Doubling Farmers' Income - Strategy Paper by Dr R.S. Paroda, February, 2018.
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- Proceedings and recommendations of "Foresight and Future Pathways of Agricultural Research through Youth", March 1-2, 2013.
- Special lecture delivered at Indian Seed Congress 2013 on "Indian Seed Sector: The Way Forward" by Dr. R.S. Paroda, February 8, 2013.
- The Seventh Foundation Day Lecture on "Ensuring Food and Nutrition Security in Asia: The Role of Agricultural Innovation" by Dr. Shenggen Fan, DG, IFPRI, January 11, 2013.
- Proceedings and Recommendations of Global Conference on "Women in Agriculture", March 13-15, 2012.
- Proceedings of Farmers' Led-Innovation, December 23-24, 2011.
- Recommendations of Stakeholders' Interface on GM Food Crops, May 19, 2011.
- Intensive Efforts Needed for Food and Nutrition Security - Strategy Paper by Dr. R.S. Paroda, November, 2009.
- Imperatives of Global Climate Change for Agricultural Research in Asia-Pacific - Strategy Paper by Dr. R.S. Paroda, November, 2009.
- Proceedings and Recommendations of Brainstorming Workshop on "Emerging Challenges before Indian Agriculture - The Way Forward", March 6, 2009.

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