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WORKSHOP REPORT

Stewardship guidelines for non-GM imazethapyr-tolerant rice in India

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ABSTRACT

Direct-seeded rice (DSR) is increasingly adopted due to its numerous advantages, including significant savings in water, labour, and time, reduced drudgery, lower production costs, improved soil health, and environmental benefits through reduced greenhouse gas emissions. However, high weed infestation and the emergence of weedy rice remain major challenges limiting its large-scale adoption. Selective herbicides are not available to control weedy rice. A promising solution lies in cultivating herbicide-tolerant (HT) rice varieties in combination with appropriate herbicide application. In India, non- transgenic imazethapyr-tolerant rice varieties such as Pusa Basmati 1979, Pusa Basmati 1985, and CR Dhan 807, along with hybrids SAVA 127 and SAVA 134, have been developed for commercial cultivation. To ensure the long-term sustainability of HT rice technology, strict stewardship guidelines are essential. This paper is an outcome of the deliberations of a workshop on "Stewardship Guidelines for non-GM imazethapyr-tolerant rice in India" organized at IRRI-SARC, Varanasi, on 4 October 2024.

Keywords: Direct-seeded rice, Imazethapyr-tolerant, Intgarted weed management, Non-GM rice, Weed

INTRODUCTION

Rice (*Oryza sativa* L.) plays a major role in sustaining global food and nutritional security, and meets 43% of the calorie requirement of nearly two-thirds of the Indian population (Shankari *et al.* 2023). India produces 137.83 million tonnes of rice from 47.82 million hectares of area with an average productivity of 2.88 t/ha (ASG 2023). By 2050, India needs to produce around 197.40 million tonnes of rice to meet the projected demand by a population of 1.65 billion. This represents an increase of more than 43% compared to current production. There is very limited scope for increasing the area under rice cultivation. With increasing temperature, water scarcity, changes in rainfall patterns, extreme climatic events such as floods and droughts due to global climate change, rice yields may decline significantly. In addition to negative impact on the soil health and water resource, rice cultivation contributes 7–17% to global methane (CH_4) emissions (Liu *et al.* 2022). Therefore, alternative crop establishment and management strategies which require less water, and emit less CH_4 from rice cultivation are urgently needed for sustainable rice production.

Direct-seeded rice (DSR), a resource conservation technology is gaining popularity as a potential alternative to the conventional puddled-transplanted rice (PTR) to reduce labour, water, energy and CH_4 emissions with increased economic returns. Compared to conventional PTR, the DSR has resulted in 76.2% less global warming potential (Tao *et al.* 2016), and 30-38% reductions in CH_4 emissions (Joshi *et al.* 2013). DSR can reduce greenhouse gas emissions by approximately 1.5 to 4.0 tons of CO_2 equivalent (CO_2e) per hectare per season. This translates to 1.5 to 4.0 carbon credits per hectare per season. In addition, DSR matures 7-10 days early and thus facilitates timely sowing of subsequent crops resulting in higher system productivity. Fast depleting water resources and rising labour scarcity have brought a paradigm shift in rice establishment from PTR to DSR in many countries including India. Despite potential benefits of DSR in terms of reducing water requirements and GHG emissions, improving soil health, and increasing resiliency to climate variability, severe weed infestation is a major concern in sustaining the productivity of DSR. If not managed promptly, weeds can reduce DSR yield

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ranging from 15-100%, posing a serious threat to farmers' productivity and food and nutritional security. Unlike traditional transplanting, DSR lacks the early head start advantage and natural weed suppression provided by field flooding.

Weed management by manual and cultural methods is restricted as they are labour-intensive and cumbersome in the context of increasing wages and labour scarcity. The development of new-generation, broad-spectrum pre- and post-emergence herbicides has opened new possibilities for DSR, addressing challenges of labour and water scarcity while providing crops with a critical early weed-free advantage, thus enhancing crop competitive-ness and weed control efficiency. Chemical weed management has largely replaced labour-intensive and physically demanding manual methods, making DSR more practical and economically viable. However, the success of herbicide use in DSR heavily depends on the precise timing of application tailored to specific crop and environmental conditions to ensure effective and lasting weed suppression. Repeated use of selective herbicides for weed management in DSR leads to the evolution of herbicide resistance in weeds. Crop sensitivity limits the application of broad-spectrum herbicides for effective weed management. In addition to complex weed flora in DSR, red rice/ weedy rice (*Oryza sativa* f. spontanea) has become a troublesome weed, causing a potential yield loss of 15 to 100% in DSR (Kumar and Ladha 2011). Weedy rice management in DSR is very difficult due to their morphological and genetic similarity with rice which hinders their targeted control using selective herbicides without injuring the rice crop.

Development of herbicide-tolerant (HT) rice varieties is one of the feasible and practical long-term solutions for sustainable weed management in DSR. With the advent of HT rice varieties, the spectrum of chemical weed control can be further exploited for flexibility in the timely application of herbicide and a wide-spectrum weed control including weedy rice without injuring the rice and the subsequent crops in rotation. Developing effective stewardship guidelines for HT rice utilization, creating awareness among farmers, crop rotation and integrating it with other weed management practices can help in realizing the fullest potential of HT rice varieties without any harmful effects on the environment and biodiversity.

Benefits of HT-rice technology

Herbicide-tolerant rice technology will facilitate the adoption of resource-efficient and cost-effective direct seeding of rice. Some of the key benefits of HT-rice include:

- Improved weed control with greater flexibility and reduced risk of crop phytotoxicity, especially for problematic weeds of DSR including weedy rice.
- Replacement of currently used herbicides with more efficient herbicides in controlling broad-spectrum weeds with better environmental profiles.
- New options to control weeds that have evolved resistance to currently used herbicides.
- Better crop establishment, more efficient use of nutrients and moisture, and higher crop yields.

Imazethapyr-tolerant HT rice techno-logy in India

India has introduced imazethapyr-tolerant HT rice varieties and hybrids, but their regulatory status remains contentious. Indian Council of Agricultural Research (ICAR)-Indian Agricultural Research Institute (IARI), New Delhi has developed and released two non-genetically modified (non-GM) HT Basmati rice varieties (Pusa Basmati 1979 and Pusa Basmati 1985). These varieties were developed through mutation breeding by altering the acetolactate synthase (ALS) gene, enabling tolerance to the herbicide imazethapyr. These varieties are particularly suited for DSR cultivation, offering benefits such as reduced water usage and labour requirements. Similarly, ICAR-CRRI Cuttack has also developed non-basmati rice variety '*CR Dhan 807*' tolerant to imazethapyr (Kar *et al.* 2024, ICAR-DWR 2025).

In addition, two HT rice hybrids (SAVA 127 FP and SAVA 134 FP) are being commercially cultivated by the rice growers. Some other companies are also working on development of non-GM HT rice varieties and hybrids (Dubey *et al.* 2022, Hubli 2022). This technology has been commercialized to address weed management challenges including management of weedy rice in DSR and to facilitate the transition from PTR to DSR.

STEWARDSHIP GUIDELINES

Stewardship guidelines for non-genetically modified (non-GM) imazethapyr-tolerant rice in India emphasize responsible use of herbicides to prevent the evolution of herbicide-resistant weeds and maintain crop productivity while minimizing environmental impact. Proper stewardship is crucial to ensure this technology's long-term viability and sustainability. Therefore, it is essential to develop and implement stewardship guidelines for imazethapyr-tolerant HT-rice technology that balances productivity gains with sustainability and risk mitigation.

A workshop was organized jointly by ICAR-DWR, Jabalpur, ICAR-IARI, New Delhi and IRRI, Philippines, on 1st December 2024 at ISARC, Varanasi, bringing together bureaucrats, researchers, industry representatives, and progressive farmers. During the workshop, all stakeholders shared their insights and experiences. Researchers and industry experts presented key findings, while farmers contributed practical perspectives from the field. From these discussions, several general and specific points emerged regarding the adoption and implementation of imazethapyr-tolerant HT rice technology.

For the longer-term use and sustainability of imazethapyr-tolerant HT rice technology it is important to implement the following stewardship guidelines.

Imperative requirement: Imazethapyr use should be limited to imazethapyr-tolerant rice varieties only.

1. **Integrated weed management program:** To achieve effective and sustainable weed management with imazethapyr-tolerant rice technology and to avoid/delay resistance evolution in weeds, the integrated weed management program given below is to be followed:

Herbicide program: Follow the label recommendation and integrate non-ALS herbicides in the herbicide program of imazethapyr-tolerant rice as given below:

Imazethapyr early post-emergence (12-14 days after sowing (DAS) or 2-4 leaf stage of weed) followed by imazethapyr as post-emergence at 25-30 DAS.

(or)

Recommended pre-emergence herbicides (pendimethalin, pyrazosulfuron, pretilachlor + pyrazosulfuron, pyrazosulfuron + pendimethalin, pendimethalin + penoxsulam, *etc*.) (apply within 3 days of sowing, if DSR is established in dry followed by irrigation, whereas under Tar-Watter DSR, apply immediately after sowing) followed by post-emergence application of imazethapyr at 18-20 DAS.

(or)

Imazethapyr early post (12-14 DAS or when weeds are 2-4 leaf stage) followed by post-emergence application of a non-ALS herbicide at 25-30 DAS or when weeds are 3-5 leaf stage if needed.

Note: In presence of diverse weed flora including some weeds which are not controlled by imazethapyr, either go with pre-emergence (pendimethalin, pyrazosulfuron, pretilachlor + pyrazosulfuron, pyrazosulfuron + pendimethalin, pendimethalin + penoxsulam, *etc.*) followed by imazethapyr or tank mix application of imazethapyr with a non-ALS herbicide as post-emergence. Always use the herbicides as recommended dose, time, and method of application as per the label claim. Use flat-fan nozzle for herbicide application.

- Avoid spray drift reaching the neighbouring non-HT rice and other crops susceptible to imazethapyr.
- Maintain good soil moisture during and following imazethapyr applications to get full efficacy.
- Use recommended pre-emergence/post-emergence herbicide(s) with alternate mode of action (non-ALS herbicides), as appropriate for comprehensive weed management.
- Scout for any leftover weeds and remove them manually before they set seeds.
- Follow stale seedbed technique to reduce the potential population density of weeds including weedy rice and volunteer rice from the previous season.
- Maintain irrigation channels and bunds free of weedy rice.
- Do not apply imazethapyr on non-HT/ conventional varieties in neighbouring field.
- Do not flood the field at the time of imazethapyr application.
- Apply uniformly all across field without escapes.

2. **Use quality seeds (certified/ truthfully labelled) as per the seed standards:** Farmers should use quality seeds of imazethapyr-tolerant varieties/ hybrids from authentic sources. In case of imazethapyr-tolerant hybrids, fresh seeds must be purchased from authorized sources every season.

3. **Gene flow risk management:** Following guidelines need to be adhered to minimize inadvertent gene flow into wild/ weedy rice.

I. In weedy/wild rice affected areas, make two applications of imazethapyr, one as early post-emergence at 12-14 DAS or at 2-3 leaf stage of weeds followed by second application at 25-30 DAS or when weeds are at 3-5 leaf stage to avoid any escape of weedy/wild rice plants.

II. Ensure rouging out escaped weedy/wild rice plants if any, by hand weeding before seed setting.

III. Weed stage should not cross 2-3 leaf stage at the time of application.

4. Avoid continuous use of imazethapyr tolerant-rice varieties in the same field: The sustainability of the technology depends on limiting the over-exposure of weeds to the herbicide. Therefore, it is recommended not to cultivate imazethapyr-tolerant rice for more than two consecutive growing seasons in the same field. Rotate imazethapyr-tolerant rice with conventional rice. Continuous use of imazethapyr-tolerant rice enhances the risk of faster resistance development in weeds and gene flow to weedy rice in weedy rice affected areas.

5. Minimize carryover effects on succeeding crops: Succeeding crops such as wheat and field peas could be taken up after imazethapyr-tolerant rice. However, for other succeeding crops that can be grown after the harvest of imazethapyr-tolerant rice, consult nearby SAUs/ ICAR institutions.

6. Recommended management of volunteer rice plants: Any of the following alone or in combination can minimize the problem of volunteer rice. These practices minimize other weed problems also.

- Stale seedbed approach may be adopted to reduce the potential population density of volunteer rice from the previous season. This practice also reduces the density of other weeds including weedy rice.
- Wherever feasible it is recommended to grow greengram/ blackgram as a catch crop or green manure crop during summer before seeding rice. By doing so, most of the volunteer rice get killed during land preparation for rice.
- Wherever feasible, it is recommended to grow a crop other than rice after two years of imazethapyr-tolerant rice and ensure use of non-ALS herbicides.

7. Capacity building of stakeholders: Technology providers and public institutes should organize following capacity building activities:

- Organize regular comprehensive training/ capacity building programs and awareness raising activities on Stewardship involving all stakeholders (researchers, farmers, input dealers, extension officers of KVK/FPOs/SHGs, industry personnel, *etc*.).
- Technology providers to develop resource/ training materials and knowledge products as per the target groups.

8. Herbicide resistance monitoring committee

A committee for Herbicide Resistance Monitoring (HRMC) under the leadership of ICAR-Directorate of Weed Research with participation from public institutions such as ICAR institutions, SAUs, CGIAR institutions, and private organizations may be formulated to monitor the adherence of stewardship guidelines and the development of herbicide resistance, if any in areas where herbicide-tolerant rice cultivars are grown.

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