

Prospects of herbicide-tolerant rice

under Indian perspective

Sanjoy Saha¹, Sushmita Munda² and Hemant Kumar Jangde³

National Rice Research Institute, Cuttack (Odisha) 753 006

Rice varieties with herbicide tolerant genes would allow farmers to use herbicide which is more environment-friendly than those in current use while simultaneously allowing better management of weeds. Herbicide tolerant rice offer rice farmers a vital tool to control broad-spectrum of weeds. It provides farmers flexibility to apply herbicides only when needed, to control total input of herbicides and to use herbicides with preferred environmental characteristics. The main objectives for the development of herbicide tolerant-rice are to control the weed flora associated with rice, especially of wild and other weedy rice species and also to provide an alternative tool for the management of weeds that have already evolved resistance to particular herbicides, especially grassy weeds like Echinochloa spp. It, furthermore, allows for the substitution of some of the currently used herbicides by other non selective herbicides having less detrimental effect to the environment like Glyphosate, Glufosinate etc.

Key words: Herbicide tolerant, Prospects, Rice

RICE (*Oryza sativa* L.) is an important staple food grown in 150 million ha, constituting nearly 11% of the world's cultivated land. It is the primary food for most of the Asians and over 90% of the world rice is produced and consumed in Asia. Scarcity of labour particularly during peak period of transplanting and increase in labour wages resulting from migration of labour from rural to urban areas aggravated the problem of transplanted rice which is the normal practice in Asian rice farming. One of the approaches in reducing labour and water demand is direct seeded rice. The sustainability of direct seeded rice systems, however, is threatened by heavy weed infestation as these systems are prone to weed competition. Weed control is particularly challenging in this system because of diversity of weeds and the severity of infestation; absence of standing water to suppress weeds at the crop emergence; alternate wetting and drying conditions; and the absence of a seedling-size advantage

between rice and weed seedlings, as both emerge simultaneously, causing grain yield losses of 50 to 91%. Weedy rice is another newly emerged problem in direct-seeded rice systems that infest rice fields in most of the rice growing areas in the tropics, Americas, Caribbean and South and South-east Asia. For farmers, it becomes a difficult-to-control, aggressive weed that increases the costs of production, reduces yield, lowers the market value of their crop, and where not controlled properly, can render the infested land unfit for rice production.

The use of the technology of herbicide-tolerant rice may have labour-saving benefits of conventional chemical control without the concomitant risks of phyto-toxicity. The herbicide tolerant-transgenic rice could be used efficiently to overcome weed menace in direct-seeded rice and thereby promote conservation agriculture. It could tolerate up to 1% of commercial roundup, which is five-

fold more than the usual dose used to kill weeds under field conditions. Herbicidal control of weedy rice is facing difficulty due to the genetic similarity of weedy and cultivated rice. The herbicides Ordram™ (molinate: S-ethyl hexahydro-1-H-azepine-1-carbothioate) and Bolero™ (thiobencarb: S-[(4-chlorophenyl) methyl] diethylcarbamothioate) may be feasible to partially suppress weedy rice. However, no herbicide that actually controls weedy rice currently is used in cultivated rice because of the simultaneous sensitivity of existing rice cultivars to such herbicides. The problem of weedy rice can be tackled by the introduction of herbicide-tolerant varieties which allow the selective post-emergence control of weedy rice infestation. The introduction of herbicide-resistant clearfield rice (IMI rice), a mutant developed by radioactive bombardment of a conventional rice plant, made selective control of weedy rice possible with the use of imazethapyr

and imazamox. Adoption of herbicide-tolerant rice may offer the rice farmers a vital tool for controlling broad-spectrum of weeds. It provides rice grower the flexibility to apply herbicides only when needed, and to use preferred.

Development of herbicide tolerance rice

Three herbicide-tolerant systems were developed in rice which include imidazolinone, glufosinate, and glyphosate-tolerant rice varieties. Glufosinate- and glyphosate-tolerant rice were developed through transgenic technologies and convey resistance to these broad-spectrum, non-selective herbicides. Imidazolinone-tolerant rice was developed through chemically induced seed mutagenesis and conventional breeding and conveys resistance to the imidazolinone group of herbicides. The imidazolinone herbicides control weeds by inhibiting the enzyme acetohydroxy acid synthase, also called acetolactate synthase. Acetohydroxy acid synthase is a critical enzyme for the biosynthesis of branched-chain amino acids in plants. Through mutagenesis and selection, several variation in Acetohydroxy acid genes conferring imidazolinone tolerance were discovered in plants, and were used to evolve imidazolinone-tolerant rice (*Oryza sativa*), wheat (*Triticum aestivum*), maize (*Zea mays*), oilseed rape (*Brassica napus*) and sunflower (*Helianthus annuus*). These were developed in crops, using conventional breeding methods and commercialized as Clearfield* crops since last two decades. Due to a single target-site mutation in the AHAS gene may confer tolerance to AHAS-inhibiting herbicides, so as to make it possible technically to develop the imidazolinone-tolerance trait in many crops.

Glyphosate competes the substrate phosphoenolpyruvate with strongly at the EPSPS enzyme-binding site in the chloroplast, resulting in the inhibition of the shikimate pathway. Essential aromatic amino acids tryptophan, tyrosine, phenylalanine and other important plant metabolic products are products of the shikimate pathway resulting relatively

slow down the MOA and physicochemical characteristics of glyphosate at the vital growing points before phyto-toxicity occurs. Plants killed by glyphosate herbicide by blocking the EPSPS enzyme, the enzyme involved in the biosynthesis of aromatic amino acids, vitamins and many secondary plant metabolites. There are several ways by which crops can be modified to be glyphosate tolerant. One strategy is to incorporate a soil bacterium gene that produces a glyphosate-tolerant form of EPSPS. Another way is to incorporate a different soil bacterium gene that produces a glyphosate degrading enzyme.

Glufosinate inhibits glutamine synthetase, an enzyme that catalyzes the conversion of glutamate plus ammonium to glutamine as part of nitrogen-metabolism. Glufosinate herbicides contain the active ingredient phosphinothricin, which kills plants by blocking the enzyme responsible for nitrogen metabolism and for detoxifying ammonia, a byproduct of plant metabolism. Crops modified to tolerate glufosinate contain a bacterial gene that produces an enzyme that detoxifies phosphinothricin and prevents it from doing damage. By using the above three mechanisms, work is going on to develop herbicide-tolerant rice to overcome the problem of grassy weeds particularly weedy rice in rice environment.

Relevance of herbicide tolerant-rice

Herbicide-tolerant rice will give growers more options for managing mixed weed flora including problem weeds like *Echinochloa* spp. and weedy and wild rice, without the concomitant risk of crop loss due to phyto-toxicity. The availability of herbicide-tolerant rice varieties would enable early-season weed control and promote DSR systems (ZT or bed-planting) by reducing the need for flooding to control weeds. Compared to other conventional herbicides used in rice, glyphosate and glufosinate are considered environmentally benign. Glyphosate is strongly adsorbed to the soil and there is a negligible threat of residual effects on

succeeding rotational crops. These herbicides can be used as post-emergent and therefore their rates can be adjusted to the actual weed pressure. Compared to conventional herbicides, the technology also provides a broader time frame for herbicide applications and therefore alleviates some of the usual time pressure for rice farmers. However, for season-long and broad-spectrum weed control, appropriate herbicide programme need to be developed for herbicide-tolerant rice in relation to the time of application, dose, herbicide mixture, and integration of non-chemical methods to ensure the long-term benefits of herbicide-tolerant rice technology.

Todate, research is conducted with either glufosinate-resistant or IMI-rice. In glufosinate-resistant rice, two applications of glufosinate at 0.42 kg ai/ha early post (2–3 leaf rice) and just prior to flooding provided almost 100% control of wild rice (*O. sativa*) and excellent season long control of *E. crusgalli* and *Brachiaria platyphylla*. The results showed that glufosinate-resistant rice had excellent potential in providing broad-spectrum weed control in DSR. However, primary direct effect of herbicide-tolerant transgenic-rice adoption is on the cost structure. There may be reduction in herbicide material and application costs but the cost of transgenic seeds are likely to be increased. It will be costlier than that of conventional seed because companies that sell transgenic varieties typically charge a premium to recoup their research investment costs. Another important aspect is that the herbicide-tolerant rice crops are not engineered to increase yields; rather, they are designed to prevent yield losses arising from weed infestation. The imidazolinone herbicides have proved to be effective against weedy rice and other rice weeds when applied twice at 70 kg a.i. ha⁻¹ before flooding and one application of imazamox (45 g a.i. ha⁻¹) during mid-season to control weedy rice and other weeds. Research work at this Institute indicated that there was no emergence of any weed seeds up to 20 days of pre-sowing application of imazethapyr at 100 g

a.i. ha⁻¹. However, all the seeds of herbicides-tolerant rice emerged at this application dose with 8 days of sowing. It was also observed that pre-sowing application at 100 g a.i. ha⁻¹ fb post-emergence application (21 days after emergence (DAE)), of herbicides-tolerant rice at 40 g a.i. ha⁻¹ suppressed the weeds that emerged later. No phyto-toxicity symptom on herbicide-tolerant rice was recorded even at high dose of post-emergent application of imazethapyr (21 DAE) at 140 g a.i. ha⁻¹.

Impact/risk of herbicides tolerant-rice

Herbicides-tolerant -rice has the potential to improve the efficiency of weed management and facilitate adoption of resource conservation technologies. However, several important risks associated with herbicides-tolerant rice should be examined before its widespread adoption. The greatest risk in the commercialization of herbicides tolerant crops is the potential for transfer of the gene conferring the herbicides tolerant trait to related wild and weedy relatives. This could lead to increased weediness or invasiveness. Gene transfer between cultivated and wild or weedy rice is known to occur and existing scientific literature confirms that herbicides tolerant genes can move from herbicides tolerant rice to wild and weedy relatives forming hybrids. The likelihood of such gene transfer is especially high in India, where cultivated rice and its relatives are symmetrically distributed and their flowering times overlap. Such gene flow can impact crop invasiveness, fitness of wild species, and the loss of native biodiversity.

There is great concern about its sustainability of IMI rice because of the potential evolution of herbicide-tolerant weedy rice populations either via gene flow from IMI rice to weedy rice or increased herbicide selection pressure on the weed. An out-crossing between IMI herbicide-resistant rice and weedy rice is discovered in Arkansas. Therefore, IMI rice should not be planted in two growing seasons in a row to ensure

the longevity of this technology. Additional reduction of the weed can be achieved using herbicides with different action mechanisms or with cultural and mechanical weed control means. Crop or rice cultivar rotation has an important role in preserving the usefulness of IMI. In glyphosate-resistant crops, optimal weed control often requires sequential applications with glyphosate, and the timing relative to weed emergence is important. When glyphosate is sprayed 2-3 times annually at high rates it imposes a high selection pressure on the weed flora. In 5-8 years this may cause shifts in weed composition towards species that naturally tolerate glyphosate and other herbicides may be needed to control these weeds. Furthermore, it may become difficult to control volunteer crop of rice in subsequent years in rice-based cropping sequence.

While adopting genetically modified crops, farmers may also face a number of constraints, namely: seed-saving in herbicide tolerant -rice is illegal, the cost of seed or of fees for technology agreement is high, and fewer suppliers provide the input for crop production. Furthermore, if the herbicide-tolerant crop readily cross-pollinates with adjacent non-genetically modified crops, it raises questions both about property rights of these unintentionally resistant plants and threshold levels of genetically modified seed in harvests from non-genetically modified crops. Further more, public concern over genetically modified food may lead to demands for the segregation of genetically modified crops from non-genetically modified crops. Thus, the potential of this technology, however, is assessed prior to introduction and is also monitored after the crop is planted. This indicates that in the absence of herbicide applications, genetically modified herbicide-tolerant crops are not likely to be invasive in agricultural fields or in natural habitats than their non- genetically modified counterparts.

Recommendations to use herbicide tolerant-rice

- Continuous rotation of herbicide tolerant -rice should be avoided. If wild rice is present at harvest, herbicide tolerant -rice should not be grown in the following season.
- Sowing should be done early enough to avoid synchronous pollination and minimize out-crossing potential.
- The leaves and ditches should be free from wild/weedy rice.
- Rouging should be done to remove wild/weedy rice plants.
- The rice fields after harvest should be flooded to promote germination of weeds/ volunteer rice.
- If wild/weedy rice is present at harvest, ratoon rice crop should be avoided.

SUMMARY

Herbicides-tolerant rice has a great potential in the simplification of weed management. It must be emphasized that the risk from herbicide-tolerant rice should be carefully evaluated prior to releasing the herbicide-tolerant rice into a cropping system, especially when the herbicide-tolerant rice possess weedy characters or may outcross to related weeds. In commercially grown herbicide-tolerant rice, precautions need to be taken in the management strategies to prevent the development of naturally-resistant weeds. Many have concerns that genetically modified herbicide tolerant rice would bring reduction of biodiversity, and then affect the balance of agro-ecosystem; and exogenous gene of genetically modified herbicide-tolerant rice would escape to cultivated rice, weedy rice and its wild relatives through gene flow. To meet people's demand of food and ensure safety to people and environment, the research about the possible effects of genetically modified herbicide-tolerant rice on biodiversity is urgent and important.

¹Principal Scientist (Agronomy), ²Scientist, ³Ph.D. Scholar, Corresponding authors' e-mail: ssahacri@gmail.com

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