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Weedy rice: an emerging threat

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Rice is the most important cereal crop of India with an area of 44 million ha and production of 103 million tonnes. Being a short statured crop grown during the warm climate in moist and flooded soil condition, rice experiences very severe competition from weeds. They are known to reduce yield production by 15 to 20 % in transplanted and by 50-90 % in direct seeded rice. Traditionally, the important weeds in rice are Echinochloa colona, Echinochloa crusgalli *among grasses,* Monochoria vaginalis *and* Ludwigia parviflora *among broad leaf weeds, and* Cyperus iria, Cyperus difformis *and* Fimbristylis miliacea *among sedges. But with a shift from transplanting to direct seeding of rice due to several reasons including scarcity of water, labour and Green House Gas emissions, weedy rice has emerged as a serious problem. Studies conducted at this Directorate on germination of weedy rice morphotypes (collected from different states of India) from different soil depths revealed varying germination among them. In general, per cent germination reduced with increasing seed burial depths.*

Key words: Management, *Oryza sativa* f. *spontanea* (weedy rice), Weeds

WEEDY rice is a rice biosimilar that has weedy attributes. Indian weedy rice has been reported to be *Oryza sativa* f. *spontanea*, belonging to *indica* group It is the result of introgression between perennial wild rice and cultivated rice and has given rise to a highly variable population of weedy/wild rice forms, including annuals and perennials. It is known by different names in different countries: 'Padi Angin' in Malaysia, 'Lua Lon' in Vietnam, 'Luta' in China, 'Akamai' in Japan, 'Sharea' in Korea, 'Khao Pa' in Laos, ' Khao' in Thailand, and 'Jhor Dhan' in Bangladesh

Infestation of weedy rice

Weedy rice was first documented in the United States of America as red rice and was known to contaminate large areas of rice fields Since then weedy rice has been reported from a number of countries across the globe – Eastern America, South America, South Europe, Mediterranean region, South-East Asia- Japan, China, Vietnam, Thailand, Malaysia, Philippines, Sri Lanka and India.

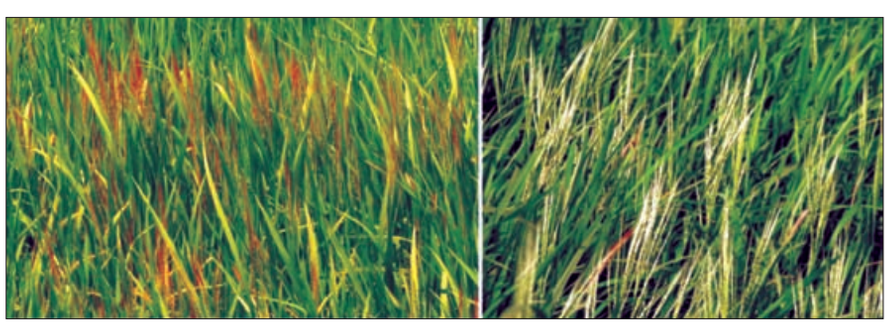


Fig.1. Infestation of weedy rice in farmers' fields

A preliminary survey on weedy rice infestation in Indian rice fields revealed 5 to 60 % infestation in different states whereas it was observed in the range of 11.32 to 44.28 % in cultivators' field of Madhya Pradesh.

In India, weedy rice infestations (Fig. 1) was observed in West Bengal, Andhra Pradesh, Asom, Bihar, Karnataka, Madhya Pradesh, Odisha, Tamil Nadu and Uttar Pradesh. Wild and weedy forms are problematic in Eastern India (Eastern Uttar Pradesh, Bihar, Odisha, Manipur, and West Bengal) and Southern India (Kerala). An infestation of 35 % can cause about 60 % reduction in yield and under serious infestation the yield loss can go up to 75 % or more. Heavy weedy rice infestations result in lodging making mechanical harvesting of rice impossible. This, also forces the farmer to abandon the crop without harvesting it.

Characteristics of weedy rice

A conspecific weed, weedy rice is difficult to distinguish from cultivated rice at the vegetative stage. However, there are some



(i) (ii) (iii) (iv)

Fig. 2 (i) Asynchronous maturity in weedy rice panicle, (ii) Shattered grains of weedy rice, (iii) Long awned weedy rice grains with grey-blackish hull, and (iv) Awnless weedy rice with black hull.

distinguishing features of weedy rice (Fig. 2):

Vigorous growth: By and large, weedy rice has superior vegetative growth that makes it more competitive over nearby crop plants. This also implies enhanced utilization of soil nutrients and moisture by weedy rice. Researchers have documented higher nitrogen use efficiency for biomass accumulation in weedy rice.

Taller plants: It is usually taller than its cultivated counterpart, but dwarf morphotypes have also been observed. In Kerela, though most of the variants were tall with 130 to 145 cm height, dwarf plants of 110 cm height, similar to cultivated rice, were also recorded. Also, intermediate and erect plant habits were observed in Indian weedy rice.

Early panicle emergence: Majority of the variants had early panicle emergence compared to cultivated rice. Many variants had days to 50% panicle emergence earlier by 7 days in weedy rice. Early panicle emergence allows earlier grain maturity.

Asynchronous maturity: Grains on the panicle do not mature together, unlike cultivated rice. Some variants even have maturing grains on an emerging panicle [Fig. 2 (i)].

Easily shattering grains: Grains of weedy rice shatter easily and can fall off even in a weak breeze. Seed shattering or seed abscission is an important mechanism for seed dispersal in many wild cereals and is caused due to the formation of abscission zone at the flower-pedicel junction. Swelling and subsequent dissolution of the middle lamella between adjacent cell walls in the abscission layer allows the grains to shatter in *Oryza* [Fig. 2 (ii)].

Presence of awns: Weedy rice may or may not bear awns varying in length and colour. As observed among morphotypes collected from different states of the country, weedy rice grains can be awnless or have awns in range of 1.0 to 7.0 cm. Some variants from Kerela had @wn lengths of approximately 8 cm. Colour of awns of 76 weedy rice morphotypes available at Directorate of Weed Research also revealed variations -they were straw, brown or blackish. [Fig. 2 (iii)].

Variations in grain characters: Though popularly known as red rice, weedy rice in India do not necessarily have a red pericarp or hull. Variants collected from different states reveal different hull colors- straw, brown and blackish [Fig. 2 (iv)]. Pericarp was largely pink to red but a few variants had white pericarp too.

Seed dormancy: Variable dormancy and considerable seed longevity in the soil is another prominent feature of weedy rice that adds to its weediness. The seeds of weedy rice do not germinate immediately after shattering. Scanning electron microscope studies showed that the major reason for dormancy is the impervious hull, blocking the entry of moisture and oxygen to induce germination.

Flowering periods: The flowering period range is generally longer in weedy rice and the florets also remain open longer by an hr.

Ability to hybridize: Weedy rice intermediates can cross with other intermediary forms of rice to give rise to a hybrid swarm. This hybrid population is phenotypically very diverse. In view of this fact, 76 morphotypes, maintained at the research farm of this Directorate were evaluated for their morphological, physiological and phenological attributes. Immense diversity was documented among them. PCA analysis of the quantitative parameters followed by hierarchial analysis revealed that the weedy rice did not cluster based on geographic or agro-climatic zones.

Similarity to rice: This prominent character of weedy rice that makes it difficult to manage persists at the molecular level too. Molecular fingerprinting of Indian weedy rice morphotypes using SSR markers reveals its similarity to both cultivated and wild rice. After molecular analysis, the weedy rice were found to cluster with both cultivated and wild rice; with cultivated rice alone and/or with wild rice alone. Clusters having only weedy rice were also observed.

Tolerance to abiotic stress(es): Initial studies conducted at Directorate of Weed Research revealed ability of weedy rice morphotypes to germinate under anaerobic conditions with 6 cm standing water and seeds below soil surface. On application of more stringent conditions of 15 cm standing water, it was found that 4 of the 99 weedy rice morphotypes germinated by >57%. And the germination percentage decreased rapidly to as low as 3 % with increasing seed depths.

These distinguishing features of weedy rice are undesirable and affect the available management strategies (Table 1)

Infestation of weedy rice increases gradually over a period of time. The

Table 1. Undesirable traits of weedy rice.

Traits	Characteristics	Impact
Plant mimicry	Mimics cultivated rice	Difficulty for manual weeding
Herbicide selectivity	Tolerant to rice herbicides	Chemical control is less effective
Height	Taller (140 – 150 cm)	Cause lodging, competitive edge over rice
Grains	Awned/awnless grains, red/ straw-coloured, short grains	Reduce rice quality
Threshability	Earlier flowering, maturity and spontaneous shattering	Increase seed bank in soil
Dormancy	Hull dormancy, variable	Persistence
Seed longevity	Viable in soil for many months	Higher seed bank



Fig. 3. Combine harvesters used to harvest rice are a source of weedy rice contamination

main reason behind its infestation is the available soil seed bank that is increasing due to lack of awareness among farmers. Usually discriminating the tall, vigorously growing weedy rice as rice itself, famers tend to ignore the emerging panicles. These panicles mature and the grains easily shatter, thus increasing the weed seed bank.

Inherent variable dormancy in weedy rices also allows for spread of this menace in famers fields. Seeds of weedy rice do not germinate immediately after shattering. In Kerela, under normal conditions 80% of the seeds on soil surface germinate by around 50 days. It is also seen that half mature seeds germinate earlier than fully mature dried seeds. Also, seeds at the soil surface germinate easily, while those at depths below 2 cm tend to have reduced germination.

Another reason of spread is the use of contaminated seed material for sowing of fields. A common practice among farmers is saving the season's produce as seed for sowing in next season. Another practice is seed trafficking or seed sharing wherein farmers share their seeds for sowing. In both cases, use of contaminated produce can spread weedy rice and infest the fields.

With adoption of technology and use of seeders to sow seeds and combine harvesters(Fig. 3.) to harvest rice crop, the risk of spread of weedy rice is enhanced. Use of machinery in infested fields' contaminates the equipment and when used in another field, it can spread the seeds of weedy rice to that field.

By and large, majority of the farmers use herbicides to manage weeds. But as no selective herbicide is available to manage weedy rice, cultural interventions are the only By and approach left. This is relatively costly and tedious for the farmer, and hence they tend to abandon the infested fields. This, in turn, adds to the problem of increasing infestation.

Farmers have adopted sowing of pre-germinated rice seeds in puddled field conditions to overcome the problem of weedy rice. But preliminary studies revealed ability of weedy rice to germinate under anaerobic conditions, and hence success of this practice is also questionable.

Ways to manage weedy rice

In effort to develop technologies for management of weedy rice, studies were taken up by the Directorate of Weed Research, as well as State Agricultural Universities in the traditional rice growing areas. The main measures to combat increasing weedy rice infestations are represented in Fig. 4 and include: the six different methods and measures all converge to focus on management of weedy rice.

Preventive measures

Prevention is the basic means of reducing weedy rice infestation and can be achieved by sowing certified and clean rice seeds and cleaning the equipments used for rice sowing and harvesting both before and after use. Keeping a check on irrigation water for contaminating seeds can help reduce the chances of spreading infestation.

Depletion of weed soil seed bank

Depleting the soil seed bank can help reduce weedy rice infestations in next cropping season. The management practices that can be adopted are:

Stale seed bed technique: This technique is also named the false seeding technique, is a cultural method commonly applied in rice monoculture for managing weeds. it involves preparation of the seedbed, followed by irrigation. The field is then left idle to allow weed seeds to germinate. The emerging weed seedlings are then destroyed by either mechanical (harrows) or chemical (non-selective herbicides) methods. This technique aims at reducing weed infestations in the same season in which it is done. Staling operations can be repeated for better results.

Rouging: It is the practice of removing the panicles of weedy rice (Fig. 4). This has to be done as and when panicles emerge to avoid shattering of seeds. Removal of the panicle prevents increase in weed soil seed bank.



Fig. 4. Methods to manage weedy rice.

Drying the panicles of standing weedy rice: It is observed that weedy rice ear heads/panicles can be selectively dried



Fig. 5. Labourers rouging out weedy rice

without affecting rice plants by direct contact application (DCA) using wick applicator (Fig. 5) with glufosinate ammonium at 15 %, paraquat dichloride at 15 % or glyphosate at 10-15 % concentration of the formulated product (Fig. 6). This technique reduces the soil seed bank so as to get a relatively weedy rice free crop in the subsequent years. The technique is faster, economic and less labour intensive than rouging operation.

Burning of straw: Though a practice banned in many states of India, burning of straw is an age old method to kill weed seeds present on soil surface. Weedy rice seeds that have shattered to the ground get killed during straw burning and, in turn, the seed soil bank is reduced. Partially burnt seeds, however, are induced to germinate because of break in hull dormancy. But, these seedlings can get destroyed in subsequent land preparation methods.

Soil solarization: This is as an advanced, non-chemical, field technology for management of weeds where the soil surface is covered with thin, transparent polyethylene films of 19 to 25 micro-meter, which allows sunlight to pass through and heat up the soil to temperatures that are lethal to many of these pests, including weeds. This technique can be practised in the warmest months for duration of 4 to 6 weeks. However, this can be adopted as a management strategy only in rice nurseries, considering the practical difficulties and the possible environmental problems from large scale use of plastic.

Cultural methods L: This method include non-chemical means of weed control by working on crop sowing time and spatial arrangement, crop genotype choice, cover crops (when used as living mulches), intercropping, and crop fertilization. In the absence of effective selective post-emergence chemical control, techniques to minimize weedy rice infestations should necessarily focus on lowering the chance of emergence of weedy rice seedlings at crop establishment, and preventing subsequent return of seed to soil from surviving plants at maturity.

Crop rotation: It is an age old, preventive method to ward off crop associated and mimicry weeds. Different crops bring about different cultural practices, which act as a factor in disrupting the growing cycle of weeds. This causes a break in the continuing cycle of growth of weeds and increasing abundance of the problem species. Wherever possible, a crop sequence consisting of rice and other upland crops e.g soybean in Madhya Pradesh, can prevent the build up of weedy rice population when compared with the continuous rice-rice sequence.

Soil tillage: The primary objective of tillage is providing a good tilth to soil. It also helps manage weeds by breaking the life-cycle of already germinated weeds when soil is upturned. Besides, weed seeds at the soil surface are buried down and cannot geminate in that season. Deep tillage during land preparation is suggested in fields infested with weedy rice. Tillage during stale seed bed technique can also be done to remove germinated weed cover.

Water management: In direct sown, wet seeded rice, where the field has to be kept drained for few days after seeding to facilitate germination and establishment; water management may not be very successful. In transplanted rice, however, water management is very effective as continuous flooding can be provided. So wherever possible transplanting is recommended at least for few seasons to manage weedy rice in severely infested areas.

Hand weeding: This type of weeding of weedy rice, though expensive, time consuming and tedious is sometimes carried out, in small fields where the works are done by the farm family. Though impractical up to 30 to 40 days after crop emergence, hand weeding is still practised in crops above 60 days of soweing.

Use of pigmented varieties: Traditionally, farmers grow purple pigmented rice varieties in fields



Fig. 6. Direct contact application of herbicides using wick applicator



Fig. 7. Weedy rice (green) in a field of purple colored rice

infested with weedy rice. The purple crop helps them distinguish between green weedy rice and sown purple crop rice for efficient rouging (Fig. 6). Farmers in Karnataka have been using the purple coloured rice, Dambersali, every fourth year in rice fields for managing weedy rice. Though a practical and feasible method to manage weedy rice, lack of high-yielding pigmented rice varieties prevents the wide adoption of this technique.

Method of cultivation: Weedy rice infestations are higher in upland rice followed by wet seeded rice, and least in transplanted rice. Growing rice by the conventional method of puddling and transplantation helps reduce weedy rice infestation and also reduce its seed bank. Also, line sowing instead of broadcasting facilitates removal of weedy rice.

Mechanical control: In farmers' field with severe weedy rice infestation, farmers have switched over to line sowing using a drum seeder. This facilitates removal of weeds using mechanical weeders like cono weeder, as practised by the farmers of Kuttanad in Alleppey district of Kerala.

Chemical control: Studies conducted to modify the time and method of application of herbicides to effectively control weedy rice without affecting cultivated rice gave promising results.

Pre-sowing surface herbicide application of herbicides: Surface application of oxyfluorfen 0.2 kg/ha three days before sowing in a thin film of standing water in the field managed weedy rice. After three days, when water in the field has evaporated, pre-germinated seeds of cultivated rice can be broadcast. Since rice seeds are sown above the herbicide treated soil layer, they germinate without any phytotoxic efect, while, the seedlings which emerge below the treated layer (including weedy rice) are killed by the herbicide. To take care of the slight reduction in the germination of the crop, it is advisable to increase the seed rate by 10%.

Genetic engineering: Weedy rice, being biochemically similar to cultivated rice, cannot be killed selectively by any herbicide. However, genetically modified rice resistant to the imidazolinone group of herbicides has been developed and released under the name 'Clearfield' to manage the problem of red rice. This genetically modified (GM) rice was crossed with popular rice cultivars of Malaysia and the resulting hybrids were grown. Records document an increase in rice production since adoption of 'Clearfield' rice hybrids in Malaysia. However, due to ability of weedy rice to naturally hybridize, there are now reports of imidazolinone resistant weedy rice from Malaysia.Another option is to develop genetically engineered rice for herbicide resistance e.g. against glyphosate, and use it to manage weedy rice. But, because of the possibilities of outcrossing and development of herbicide tolerant weedy rice, this approach is not feasible.



(i) (ii)

Fig 8. Use of weedy rice straw (i) for compost making (ii) as mulch in wheat crop climate change and weedy rice

Uses of weedy rice

Weedy rice, being biochemically similar to rice, is edible and can be consumed by human beings. Also, the rouged out plants can be used as raw material for compost preparation. Dried straw of weedy rice can also be used for compost [Fig. 8 (i)] and can also be used as mulch. Weedy rice straw was used as mulch in wheat crop at Directorate of Weed Research, [Fig. 8 (ii)].

It is speculated that weedy rice will be more problematic in forthcoming regime of climate change. The effect of climate change (enhanced temperature, enhanced CO_2 and a combination of both in comparison to ambient conditions) on a morphotype of weedy rice, a wild rice and cultivated rice studied till maturity revealed significant effect on root parameters both at early and near maturity stages. Differences in effective tillers, panicle length, grains per panicle and yield per plant were observed. An important observation was that elevated temperature and CO_2, in combination, delayed panicle maturity in all rice morphotypes studied.

SUMMARY

The menace of weedy rice (*Oryza sativa* f. *spontanea*) has risen globally during the last decade. Being a natural introgression between wild and cultivated rice, weedy rice bears intermediary characters and a weedy nature. The important, distinguishing and undesirable traits of weedy rice include easy shattering of seeds, variable seed dormancy, high seed persistence in soil and high nitrogen use efficiency. Hull induced dormancy and high soil persistence favour staggered germination of weedy rice in infested cropped field. Being a biochemical mimicry weed, no selective herbicide is available to manage weedy rice. Preventive measures like use of clean/ certified seeds, clean machinery and irrigation water; cultural methods like stale seed bed technique, crop rotation, repeated tillage etc. can help manage it and reduce the weed seed bank. An indispensable measure is the need to create awareness about weedy rice among farmers and our scientific fraternity.

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