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Realising Aerobic Rice Potential in India - An Integrated Weed Management Perspective

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A B S T R A C T

Aerobic rice is a new way of cultivating rice that requires less water than lowland rice. Direct sown aerobic rice suffers more due to weed menace as the weeds and rice compete for growth factors together. Achieving higher rice grain yields under aerobic conditions requires better weed management practices. Hence, the aerobic rice should be focused primarily on efficient weed management to make aerobic rice cultivation more efficient in terms of returns on farmer investments and use of water resources. Most upland and aerobic rice growers in Asia manually weed their crops two or three times per season. Both pre- and post-emergence herbicides can be used in aerobic rice fields; however they are effective only if properly used. The application of pre-emergence herbicide like pendimethalin, azimsulfuron, pyrazosulfuron and penoxsulam play significant role in controlling weeds. Similarly, post-emergence bispyribac-Na herbicide also considered to be an alternative/ supplement to hand weeding. There is a need to develop sustainable weed management strategies that will give rice a competitive advantage over weeds. The use of herbicides along with appropriate timing, rotation, and combination needs to be integrated with other cultural approaches which ultimately result into higher productivity in aerobic rice.

Introduction

Rice is the world's most important food and more than half of the world's population depends on rice for food, calories and protein, especially in developing countries. Almost 90 per cent area and production of the world's rice accounted and consumed in Asia. Rice is predominantly grown by transplanting in puddled soil with continuous flooding which provides multiple benefits to rice including reduction in weed population and percolation losses helping in increased availability of nutrients to crop (Sanches, 1973). However, it deteriorates soil physical properties which ultimately affect the growth and productivity of succeeding crops adversely. The increasing cost of labour threatens the sustainability of transplanted rice within the rice-based cropping system. Direct-seeding is cost effective, can save water through rice crop establishment and allows early sowing of wheat (Ladha *et al.,* 2003). All these factors have increased the interest of farmers to shift from the conventional practice of puddled transplanting (TPR) to direct seeded rice (DSR) especially dry DSR. Direct seeded rice (DSR) is a cost effective rice establishment method where dry seed is drilled into the non-puddled soil. This provides opportunities of saving irrigation water by 12-35%, labour up to 60% and provides higher net returns with similar or slightly lower yield of rice (Kumar and Ladha, 2011). Despite multiple benefits of dry DSR, weed control remains one of the major challenges for its success in South Asia (Singh *et al.,* 2008). Weed control is more difficult in dry-DSR than CT-TPR (Conventional puddle transplanting) because of simultaneously emerging rice seedlings with weeds in dry–DSR which are less competitive than 30-35 days old rice seedlings use in CT- TPR. Initial flooding used in CT-TPR is also effective for weed control but it is not same in dry-DSR (Rao *et al.,* 2007). Weeds caused yield loss in direct seeded rice ranging from 14-93 % where as in transplanted rice it is 17- 47 % (Ranjit, 2007). Since the concept of aerobic rice is new growing rice under aerobic conditions on raised beds or flat land would require suitable, effective and economic weed-control methods where development of new improved herbicides for aerobic dry-seeded rice is also needed (Belder *et al.,* 2005). Farmers in many rice growing areas are likely to have only limited availability of irrigation water and in the future it is predicted that in Asia, 17 million ha of irrigated rice areas may experience "Physical water Scarcity" and 22 million ha may have "economic water Scarcity" by 2025 (Bouman and Tuong, 2001). Water scarcity threatens the sustainability of irrigated rice ecosystems since it may no longer be feasible for farmers to undertake wet cultivation. Most upland and aerobic rice growers in Asia manually weed their crops two or three times per season, investing upto 190 person days ha^{-1} in hand weeding (Roder, 2001). It is very environment-friendly but it is tedious, time consuming and highly labor intensive and expensive. In addition, during peak period, the availability of labor is becoming a serious problem by time. Both pre- and post-emergence herbicides can be used in aerobic rice fields; however they are effective only if properly used (Singh *et al.,* 2006a). The application of pre-emergence herbicide like pendimethalin (Bhurer *et al.,* 2013), azimsulfuron (Singh *et al.,* 2009), pyrazosulfuron, penoxsulam (Chauhan and Seth, 2013) and post emergence bispyribac-Na (Khaliq *et al.,* 2012) plays significant role in controlling weeds. To the best of our knowledge, a very few experiments were carried out in this line with a view to evaluating the efficacy of herbicides under field conditions for selecting suitable herbicides and their combinations for sustainable weed control in aerobic rice.

Weed flora composition in aerobic rice

Precise information regarding the prevalent weed flora is highly important for formulating the most suitable weed management programs. The prevalence, germination, and growth of weeds are largely influenced by rice cultivation methods. A number of weed species have been reported to infest aerobic rice systems (Table 1). Moreover, a more difficult-to-control and complex weed flora can be found in rice grown using this method compared with the conventional method (Mahajan *et al.,* 2009). Most of the rice growing areas are located either in subtropical or tropical zones, and hence, are characterized with environmental conditions such as luminosity and high humidity. These weather conditions heavily favour profuse weed growth. Further, the soil in aerobic rice systems is kept moist instead of flooded that favours higher weed germination. Hence, high weed germination as well as weed growth is supported by the climatic conditions under which aerobic rice is grown. Interestingly, the weed species of conventionally flooded rice (CFR) and aerobic rice systems vary certainly (Figure 1). For example, *Trianthema portulacastrum* L. is rarely found in CFR but it grows abundantly and rapidly in growth-conducive aerobic rice systems (Jabran *et al.*, 2012).

Influence of herbicides on yield of crop

Pre – emergence herbicides

In aerobic rice, the grain yield could be increased by 5.5 to 10.4 times and the straw yield by 2.0 to 3.4 times when weeds were effectively controlled (Singh *et al.*, 2005). Oxadiargyl @ 160 g ha^{-1} (Ahmed and Chauhan, 2015), pretilachlor @ 0.75 kg ha^{-1} or pendimethalin 1.00 kg ha^{-1} (Singh *et al.*, 2013), oxyflourfen @ 0.125 kg ha^{-1} (Kathiresan and Manoharen, 2002) and pyrazosulfuron ethyl @ 25 g ha^{-1} (Saha, 2006) are found to be effective in controlling weeds and resulted higher rice grain yield.

Post – emergence herbicides

Post-emergence application of bispyribac-Na 80 g ha^{-1} (Rawat *et al.*, 2012), fenoxaprop-p-ethyl @ 75 g ha^{-1} or cyhalofop butyl @ 100 g ha^{-1} at 15 DAS (Sasikala *et al.*, 2014) and mixture of fenoxaprop + ethoxysulfuron at 30 DAS [36] recorded maximum grain yield at various locations.

Sequential application and mixture of herbicides

Integration of pre-emergence application of pendimethalin 0.75 kg ha^{-1} or oxadiargyl 0.90 g ha^{-1} with post-emergence application of bispyribac-Na 25 kg ha^{-1}, azimsulfuron 20 g ha^{-1} and 2,4-D 0.5 kg ha^{-1} resulted in significant increase in grain yield as compared to pendimethalin 0.75 kg ha^{-1} alone (Walia *et al.*, 2012; Sreedevi *et al.*, 2016).

The combined application of pendimethalin or clomazone as pre-emergence fb bispyribac-sodium as post-emergence or tank-mixture of clomazone + bispyribac sodium effectively controlled weeds and increased the yield (Ghosh *et al.*, 2016).

A compiled report of All India Coordinated Rice Improvement Project revealed that pre + post-emergence application of herbicide was effective in controlling weeds (Table 2) and significantly increased rice yield compared to unweeded and comparable with need based hand weeding (Table 3).

Effect of herbicide toxicity on crop

Phytotoxicity is the capacity of a compound (such as a plant protection product) to cause temporary or long-lasting damage to plants. Phytotoxicity effects may be observed on the crop at emergence or during its growth or may be expressed at harvest.

They may be temporary or lasting. The symptoms may affect the whole plant or any part of the plant (roots, shoots, leaves, flowers) and may be accurately described by figure 2. In practice, in trials for efficacy evaluation of plant protection products, it is unlikely that the most striking symptoms described here will be observed very frequently, for products causing such phytotoxicity would be unlikely to reach the stage of field testing.

Accordingly, the symptoms of phytotoxicity will often be inconspicuous, and the researchers will be looking for only a slight expression of the symptoms outlined below:

Fig.1 Major weed flora in aerobic rice

Commelina diffusa

Physalis minima

Chloris barbata

Dinebra retroflexa

Echinochloa colonum

Alternanthera sessilis

Corchorus olitorius

Digera arvensis

Fig.2 Herbicide phytotoxicity symptoms in aerobic rice

Table.1 Common weed flora of the aerobic rice

S.N.	Botanical Name	Family
I.	**Grasses**	
1.	*Echinochloa colonum*	Poaceae
2.	*Echinochloa crusgalli*	Poaceae
3.	*Digitaria sanguinalis*	Poaceae
4.	*Chloris barbata*	Poaceae
5.	*Dinebra retroflexa*	Poaceae
6.	*Eleusine indica*	Poaceae
7.	*Ischaemum rugosum*	Poaceae
II.	**Sedges**	
1.	*Cyperus rotundus*	Cyperaceae
2.	*Cyperus iria*	Cyperaceae
3.	*Cyperus difformis*	Cyperaceae
III.	**Broad leaved weeds**	
1.	*Corchorus olitorius*	Tiliaceae
2.	*Digera arvensis*	Amaranthaceae
3.	*Phyllanthus niruri*	Phyllanthaceae
4.	*Trianthema portulacastrum* L.	
5.	*Acalypha indica*	Euphorbiaceae
6.	*Alternanthera sessilis*	Amaranthaceae
7.	*Commelina benghalensis*	Commelinaceae
8.	*Commelina diffusa*	Commelinaceae
9.	*Merremia emarginata*	Convolvulaceae
10	*Physalis minima*	Solanaceae

Table.2 Suitable pre, post and pre + post-emergence herbicides to control weeds in aerobic rice

S.N.	Pre-emergence		Post-emergence		Pre + Post emergence	
	Dose of herbicides	**References**	**Dose of herbicides**	**References**	**Dose of herbicides**	**References**
1	Pyrazosulfuron ethyl @ 20 to 25 g ha^{-1}	17	Bispyribac-Na 10% SC @ 40 g ha^{-1}	22	Cyhalofop-butyl + Bensulfuron fb Bentazon/MCPA	26
2	Pretilachlor @ 0.75 kg ha^{-1}	18	Cyhalofop-butyl @ (60 to 150 g ha^{-1}	4	Pendimethalin fb Azimsulfuron	27
3	Oxyfluorfen 23.5% EC @ 100 to 400 g ha^{-1}	19	Azimsulfuron @ 25 to 30 g ha^{-1}	23	Oxadiazon fb Bispyribac-sodium @ 45 g ha^{-1} fb 2,4-D	28
4	Pendimethalin @ (1-1.5 g ha-1) and oxadiargyl @ (0.4-0.7 g ha^{-1})	20	Fenoxaprop-p-ethyl @ 47-60 g ha^{-1}	24	Pretilachlor @ 750 g ha^{-1} fb Azimsulfuron @ 35 g ha^{-1}	29
5	Pendimethalin @ (1.0 to 2.0 kg ha^{-1}) and anilofos (0.4 to 0.8 kg ha^{-1})	21	Carfentrazone-ethyl 40 DF @ 20 g ha^{-1}	25	Pendimethalin @ 1 kg ha^{-1} *fb* Bispyribac-sodium @ 35 g ha^{-1}	30

Table.3 Comparative performance of various weed management treatments on Yield of aerobic rice

	2012				2013		
Name of Centres	Unweeded	Need based hand weeding	Pre-+Post-emergence herbicide	Name of Centres	Unweeded	Need based hand weeding	Pre-+Post-emergence herbicide
Chakcha	3.24	5.99	5.78	Bankura	1.26	4.2	3.84
Coimbatore	1.73	3.73	3.52	Dharwad	0.65	6.92	6.14
Dharwad	0	6.23	6.22	Hathwara	1.09	3.26	3.08
Hathwara	1.25	4.52	4.38	Jagdalpur	1.01	1.58	3.40
Kota	1.75	5.23	4.73	Patna-ARI	1.52	4.6	4.33
Patna-ARI	1.06	5.83	5.25	Pusa	1.72	3.78	3.61
Pusa	1.81	4.35	4.17	Varanasi	1.30	3.70	3.68
Vadgaon	1.60	5.58	4.91	Vadgaon	1.53	5.4	5.33

Pre (Pendimethalin 30 EC @ 1 kg ha^{-1} (3-4 DAS) + Post (Bispyribac- sodium (10% SC) @ 35 g ha^{-1}(15-20 DAS) (DRR Progress report, 2012-13) [40]

Table.4 Crop phytotoxicity rating using 0 to 10 point scale

Rating	Crop phytotoxicity symptoms	Remarks
0	No injury, normal	None
1	Slight stunting injury or discoloration	
2	Some stand loss, stunting or discoloration	Slight
3	Injury more pronounced but not persistent	
4	Moderate injury, recovery possible	
5	Injury more persistent, recovery possible	Moderate
6	Near severe injury, no recovery possible	
7	Sever injury, stand loss	
8	Almost destroyed, a few plants surviving	Severe
9	Very few plants alive	
10	Complete destruction	Complete
		(Source: Rao, 1986) [41]

Table.5 Effect of weed management practices on benefit cost ratio of aerobic rice

Net return (Rs/ ha)	B:C ratio	References
21,954	1.30	55
28,281	2.25	56
21,019	2.15	14
10,940	1.77	57
9,459	1.98	58
57,063	2.3	59

Delay in emergence

Thinning

Number of seedlings
Number of panicles

Delay

In reaching various growth stages
In emergence of inflorescences
In ripening of grain

Inhibition

Reduction in number of tillers

Discolouration of leaves

Paler or darker green
White leaves

Necrosis of leaves

All kinds of deformations of the leaves, the stems or the inflorescences

May be noted

Curling or other deformations of the leaves

Alteration in habit

Length or deformations of the stem

Deformations of the inflorescences (e.g. Double or forked ears, additional spikelets)

Failure of normal booting and inflorescence emergence

Effects on yield

Total grain yield in kg ha^{-1}

Grain weight per hill

1000 grain weight

Seed grading

Further crop phytotoxicity can be rated in the following manner (Table 4).

The application timing of pre-emergence herbicides in aerobic rice needs to be adjusted so as to minimize the damage to rice crop (Matloob *et al.,* 2015). The higher grain yield (1805 kg ha^{-1}) was obtained with the application of Mon-46992 @ 2.5 ha^{-1} 12-14 DAS. Crop phytotoxicity was observed at 10 days after spraying with Mon-46992 applied either at 3.75 or 5.0 liter ha^{-1} of herbicide. Toxic effects were not observed after 20 to 30 days of the treatment. Weed control was better with the higher doses of Mon 46992 irrespective of the time of spray (Raikar *et al.*, 2009). A high rate of oxadiargyl applied at 150 g ha^{-1} caused seedling mortality in rice in anaerobic conditions but not in aerobic conditions (Gitsopoulos and Froud-Williams, 2004). The increased rate of bispyribac-Na controlled weeds more effectively than the recommended rate; however, grain yield was slightly decreased, which could be due to the phytotoxicity of the increased rate of bispyribac-sodium (Chauhan and Johnson, 2011). Pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS showed phyto-toxicity rating of 5 at 10 DAS and 4 at 20 DAS and no toxicity before harvest (Kathiresan and Manoharen, 2002). There was no phytotoxic effect of bispyribac-sodium at any of the doses (15, 20 and 25 g ha^{-1}) on direct seeded rice crop (Singh *et al.*, 2014). Pendimethalin rates higher than the recommended rate (800 g ha^{-1}) effectively controlled weeds but resulted in lower crop yield due to phytotoxicity (Ahmed and Chauhan, 2015). An increase in bispyribac-sodium rate from 30 to 50 g ha^{-1} increased weed control efficiency by 7%; however, it decreased plant density and biomass by 19%

and 14%, respectively (Rao and Ratnam, 2010). Therefore, the application of an appropriate herbicide rate is very important in achieving adequate weed control and in reducing crop phytotoxicity (Harding *et al.*, 2012).

Integrated weed management in aerobic rice

Weed management must aim at reducing the weed population to a level at which weeds occurrence has no effect on farmer's economic and ecological interests. By using different appropriate management practices against weeds, farmers have more options for controlling weeds, thereby reducing the possibility of escapes and weed adaptation to any single weed management tactic.

Integrated weed management (IWM) is a science-based decision-making process that coordinates the use of environmental information, weed biology and ecology, and all available technologies to control weeds by the most economical means, while posing the least possible risk to people and the environment. IWM through application of pre-emergence application of pendimethalin 1 kg ha^{-1} followed by 2,4-D 1 kg ha^{-1} at 25 DAS followed by HW 45 days after sowing resulted best alternative for manual hand weeding practices higher yield, higher net return per unit investment and controlling weeds effectively in dry direct seeded rice (Bhurer *et al.*, 2013).

Higher weed control efficiency and lower weed index was recorded with Bensulfuron methyl + Pretilachlor (6.6 GR @ 0.06 + 0.60 kg ha^{-1}; a pre-mix formulation) + one inter cultivation at 40 DAS (Sunil *et al.*, 2010). Pre-emergence application of pendimethalin at 1.0 kg ha^{-1} followed by mechanical weeding with single type sweep weeder at 45 DAS followed by single wheel hoe at 45 DAS and both proved more remunerative than HW twice at 25 and 45 days (Chinnusamy *et al.*, 2009). Pre-emergence applications of either butachlor + 2,4-D (1.5 + 0.5 kg ha^{-1}) or thiobencarb + 2, 4-D (1.5 + 0.5 kg ha^{-1}) or anilofos + 2, 4-D (0.4 + 0.5 kg ha^{-1}) followed by one HW at 25 DAS were effective ways to minimize weed competition and enhance grain yield of direct dry seeded rainfed upland rice (Singh *et al.*, 2006b).

Pre-emergence application of pendimethalin 1.0 kg ha^{-1} fb bispyribac 25 g ha^{-1} + readymix chlorimuron + metsulfuron 4 g ha^{-1} at 30 DAS fb one HW at 60 DAS, recorded significantly lower weed density, weed biomass and higher WCE of 82% at 60 DAS (Ganie). Use of pendimethalin 1 kg ha^{-1} (pre-emergence) fb azimsulfuron 35 g ha^{-1} at 15-20 DAS + one HW at 40 DAS proved to be most effective in minimizing the weed density, dry weight and weed persistence index (0.08 and 0.04) and in enhancing the weed control efficiency (72.04% and 76.77%) also maximum grain yield, straw yield and biological yield (Singh and Singh, 2014).

Suitable date of sowing and variety are changing with early sowing (5 June - 3 July) showed higher productivity and hybrid showed superior performance than high yielding varieties by manipulating these two factor higher productivity of aerobic rice can be attained with reduced water requirements (Indian institute of rice research progress report of crop production, 2014).

Hybrids and long duration high yielding varieties are found to have better weed suppressing ability and registered lower weed population and biomass during the season (Indian institute of rice research progress report of crop production, 2015). Integrated weed management not only reduce weeds, increase yield but also more profitable (Table 5).

Future scope of weed management in aerobic rice

Mechanical weed control

Dry direct seeded rice is grown in rows as well as broadcast. Therefore, mechanical weed control is not very common, as its scope is limited to row-seeded crops. In addition, mechanical weeders require an optimum soil-water condition to work efficiently and effectively. However, mechanical weeding (*e.g*., using a star weeder, finger weeder, wheel hoe, or cono weeder) in conjunction with pre-emergence herbicide applications can be used as an effective tool in IWM in DSR. Mechanical weeding could be more effective in situations in which continuous rains or dry spells may reduce the effectiveness of post-emergence herbicides. Mechanical weeders can also help to reduce overall herbicide use. However, there is a need to evaluate the labor requirements and economics in relation to chemical control.

Weed-competitive rice genotypes

The use of weed-competitive genotypes is the key requirement in developing weed management strategies in any crop (Mahajan and Chauhan, 2013). The use of such genotypes might help reduce selection pressure, herbicide use, and labor costs. Weed competitiveness has been attributed to a crop's ability to tolerate and suppress weeds (Jannink *et al.*, 200). Increased crop competitiveness against weeds could lower the cost incurred in weed control by up to 30% (Sanint *et al.*, 1998). Weed suppression ability of the crop can be judged in terms of a reduction of weed biomass production, while weed tolerance is the ability of a genotype to maintain its yield under weedy conditions. Weed tolerance can be determined only for genotypes with the same weed-suppressing ability and yield potential. A strong weed-suppressing ability does not necessarily mean a high yield advantage if the potential yield is low (Zhao *et al.,* 2006). A competitive genotype might help in limiting the dose of herbicides by suppressing weed emergence and growth. Therefore, the development and use of weed-competitive genotypes in DSR systems would provide a safe and environmentally friendly tool for weed management with less use of herbicides in the agro-ecosystem.

Herbicide–resistant genetically modified rice

Herbicide resistant (HR) rice technologies have the potential to control a wide range of weeds including grasses, broad-leaved and sedges which cause serious problems in lowland rice, including problematic weeds like *Echinochloa* spp. and weedy rice (Rodenburg and Demont, 2009). The ability to control problem weed species efficiently makes HR rice an attractive technology and farmers may rapidly adopt it in many cases. Three HR systems have been developed in rice: imidazolinone, glufosinate and glyphosate -resistant varieties (Gealy *et al.*, 2003). Glyphosate and glufosinate are considered as relatively environmentally benign and, as post-emergence herbicides, the application rates can be adjusted to the weed population, and the technology has wider herbicide application time window compared to conventional technologies. Despite the possible advantages of HR options, there are concerns regarding the likelihood of gene flow from HR rice to wild and weedy rice species. In India, *O. sativa f. spontanea* is considered as weedy species in cultivated rice. In Eastern India (*e.g*. Eastern Uttar Pradesh, Bihar, Odisha, Manipur, and West Bengal) and Southern India, wild and weedy relatives are common and gene flow may occur from HR rice to these species (Kumar *et al.*, 2008). The reliance on HR technology for effective weed control in rice will depend thus on careful introduction and management.

Exploration of potential bio-agents

In some developed countries several bio-control agents have been used successfully in specific situations. In India also few attempts have been made for application of some fungal pathogen and insect bio-control agents over rice weeds. However, very low abundance of these bio-control agents at specific situation has resulted in failure of wider application and commercial success. In lowland rice *Ludwigia parviflora* was reported to be completely defoliated in lowland transplanted rice by Halticid beetle (Mukhopadhyay and Duary, 1999) indicating its potentiality as a bio-control agent against the weed. The possibilities of such bio-control agents should be explored by identifying natural enemies through auto-ecological studies of major weeds in lowland rice.

Developing allelopathic rice and C_4 rice

Some rice lines or wild rice species have been found to be allelopathic and can inhibit the growth of some weeds like barnyard grass and broad-leaf weeds (Olofsdotter *et al.,* 1995). A number of compounds such as phenolic acids, fatty acids, phenylalkanoic acids, hydroxamic acids, terpenes and indoles have been identified as potential rice allelochemicals. The momilactone B secreted from rice seedlings appears to be the major contributor to the allelopathic activity of rice crops at least against barnyard grass (Kato-Noguchi, 2013). Similar attempts may be made in India and rice cultivars are to be screened for their allelopathic potentials. Rice scientists are aiming for a second Green Revolution by developing a C_4 rice through traditional breeding or transgenic methods (Gunawardana, 2008). At present rice being a C_3 plant is less competitive than C_4 weeds like *E. crusgalli* and *C. rotundus*. A C_4 rice will be more competitive against weeds, more efficient in photosynthesis and will yield high even with less water, since water requirement of C_4 plants is much lower than that of C_3 plants (Baltazar and Johnson, 2013).

Dry direct seeded rice systems are increasing in several Asian countries because of labor and/or water shortages. However, weeds are the most important biological constraint in these production systems. The successful adoption of dry direct seeded rice systems in farmers' fields will mainly depend on the solutions available to manage weeds. Herbicides are a possible solution to manage weeds in Dry direct seeded rice, but the sole use of herbicides cannot provide effective and season long weed control. In addition, a weed control method focusing entirely on herbicides is no longer ecologically sound, economically feasible, and effective against the diverse weed flora in dry-direct seeded rice. Therefore, there is a need to develop sustainable weed management strategies that will give rice a competitive advantage over weeds. The use of herbicides (appropriate timing, rotation, and combination) needs to be integrated with other cultural approaches, such as the use of weed-competitive cultivars, optimum sowing time, the use of stale seedbed practices, the use of a high seeding rate and narrow crop row spacing, appropriate fertilizer and water inputs and their application method/timing, mechanical weeding, etc., to achieve effective, sustainable, and season-long weed control in dry direct seeded rice systems.

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