WEED MANAGEMENT IN AEROBIC RICE - A REVIEW

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ABSTRACT

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. The promising herbicides in aerobic rice were pre-emergence pretilachlor at 0.45 kg/ha on 5 DAS + hand weeding at 45 DAS and post emergence mixture of fenoxaprop + ethoxysulfuron at 45-60 g /ha + 10-18 g/ha.

Key words: Aerobic rice, Direct seeded, Weed management.

Direct seeded rice: In direct seeded rice crop and weeds emerge simultaneously as a result crop suffers, starting from early period of growth. This in turn reduces the rice yield (Choubey et al., 2001). The key to success in direct sown rice is the availability of efficient weed control techniques (Pandey and Velasco, 2002).

Although labour and water are the major drivers for the shift from CT-TPR to DSR, economic incentives brought about by DSR turn the integration of additional crop intensification are another reason for rapid adoption of DSR in same region. Farmers growing direct seeded rice are however, likely to encounter greater problems related to weed management because of lack of weed suppression by standing water. The transition of direct seeding of rice can therefore only be successful if accompanied by effective weed management practices (Singh et al., 2003). Direct seeding of rice has been tried in the recent past in several countries with both success and failure. Poor seedling establishment, abundance of weeds and lodging are some of the problems associated with and responsible for low productivity of direct-seeded rice (Mahajan et al., 2006).

Growing rice under aerobic environment can reduce water losses to a greater extent. Therefore, it is suggested direct seeding as an alternate planting to reduce the water and labour demand, which will ultimately decrease the cost of production. The productivity of the DSR is often reported to be lower, mainly due to problems associated with weed management (Mann et al., 2007).

Compared to transplanted rice, the weed competition is more severe in direct-seeded rice. The yield losses in direct seeded rice may range from 10 to 100 per cent depending on the type of weed flora, their density and duration of competition. Direct-seeded rice is an alternative to transplanted rice that can help in offsetting the problems associated with puddled transplanting like scarcity of water and labour and deterioration of soil structure (Singh et al., 2008b).

Aerobic rice: Aerobic rice entails the growing of rice in aerobic soil, with the use of external inputs such as supplementary irrigation and fertilizers aiming at high yields (Wang et al., 2002).

Aerobic rice is defined as high yielding rice grown in non puddled and non flooded aerobic soil (Bouman, 2001). Aerobic rice is a new concept of rice culture to decrease water requirements in rice production and is highly suitable for irrigated lowland rice with insufficient rainfall and favorable
uplands with access to supplementary irrigation (Amudha et al., 2009).

Aerobic rice requires less labour than continuous flooded rice and can be highly mechanized (Yogendra, 2009). Aerobic rice is the latest technology that reduces water inputs by growing rice as any other irrigated upland crop (Joshi et al., 2009). The concept of aerobic rice holds promise for farmers in water-short irrigated environments where water availability at the farm level is too low or where water is too expensive to grow flooded lowland rice (Rajakumar, et al., 2009).

Aerobic rice saves 73 per cent water during the crop growth stage compared to flooded condition. In this system the fertilizer losses and the pest and disease incidence are reduced. It is one of the good method of rice growing system where the water is scarce (Sathiya, 2009).

**Constraints in aerobic rice:** Weeds are perceived to be the most severe constraint to this upland aerobic rice production than the conventional production systems, in which weeds are suppressed by standing water and transplanted rice seedlings have a head start over germinating weed seedlings. Nowadays, water scarcity threatens the sustainability of irrigated rice ecosystems and it may no longer be feasible for farmers to undertake wet cultivation and flood fields to ensure good crop establishment and control weeds (Johnson and Mortimer, 2005).

Weed infestation depending up on the situation moderately to severely limits production of upland direct seeded rice. The extent of weed menace is more serious in upland rice than lowland rice mainly due to variations in hydrology and reduction in rice grain yield is ranging from 5 to 100 per cent (Singh et al., 2002). Direct seeded upland rice suffers more from weed problem and consequently yield reduction compared to transplanted rice (Saini, 2005).

Most upland and aerobic rice growers in Asia mechanically weed their crops two or three times per season, investing upto 190 person day’s ha⁻¹ in hand weeding (Roder, 2001). The labour requirement for weeding is a major impediment to the adoption of water saving aerobic rice and for increasing the productivity of traditional upland rice based cropping systems (Zhao et al., 2006).

Herbicides are considered to be an alternative / supplement to hand weeding (Singh et al., 2006). The greatest weed pressure and crop weed competition occur in upland and aerobic rice and least in transplanted irrigated and rainfed lowland rice. However, aerobic systems are subjected to much higher weed pressure than conventional puddled transplanting systems.

Thus, weeds are the most severe constraints to aerobic rice production and timely weed management is crucial to increase the productivity of aerobic rice (Rao et al., 2007). Uncontrolled growth of weeds caused 68% reduction in the crop yield as compared to weed free (Dixit and Varshney, 2008).

**Critical period of crop-weed competition:** The critical period of weed competition is longer for direct-seeded rice (15 to 45 DAS) (Singh et al., 2008b). In aerobic rice cultivation, weed free condition during the initial crop growth period (upto 35 DAS) is critical which has the potential to reduce grain yield drastically (Rajakumar et al., 2010).

For higher yield of spring rice, crop should be kept weed-free during 40 to 120 days (Pandey et al., 2003). First 30 to 60 days after sowing period is considered critical period for crop-weed competition in case of rainfed lowland rice (Moorthy and Sanjay Saha, 2005). In rice weed-free period of 30 days is required to avoid the significant loss in rice yield due to weeds (Sharma, 2007).

**Weed competition on rice:** Weeds are ubiquitous and continues to be an important constraint in crop production. Despite the good effects made in research and extension in the field of weed science.

**Weed competition for nutrients:** The greatest weed pressure and crop-weed competition occur in upland and aerobic rice (Rao et al., 2007). Weed infestation depleted the soil by 24.7 kg nitrogen, 5.8 kg phosphorus and 63.4 kg potassium ha⁻¹ in one season (Sharma, 2007). Ramachandiran et al. (2012a) reported that nutrient depletion by weeds in unweeded condition of aerobic rice showed higher removal of 19.77, 5.28, 16.20 kg NPK ha⁻¹. They also stated that the nutrient uptake by rice in unweeded check was very much reduced by 25.75, 4.13, 35.68 kg NPK ha⁻¹ compared to farmers practice of hand weeding twice.
Nutrient depletion by weeds and nutrient uptake by crop are inversely related. Weeds in wet seeded rice removed significantly higher quantities of N, P and K nutrients due to higher weed population and weed dry matter (Thirumurugan et al., 1998). The combination of manual weeding and chemical weeding significantly reduced the nutrient removal by weeds and maximum N, P and K removal by weeds were recorded under unweeded check (Choubey et al., 1999).

**Weed competition on growth of rice:** Nakayama (1978) observed reduction in plant dry matter of rice from 3.2 to 2.2 g per plant due to weed competition. Rice infested with Echinochloa glabrescens reduced the growth by 12.35 per cent in plant height, 55.3 per cent reduction in leaf area index and 79 per cent in total dry weight of rice (Rao and Moody, 1992). Reduction in crop dry matter due to weeds at various crop growth stages were reported by Johnson et al. (1998). Mishara (2000) have also reported decrease in plant height.

**Weed competition on yield attributes and grain yield of rice:** Gobrial (1981) reported that the weed competition in rice lowered panicle number per unit area by 37 per cent, filled grains per panicle by 13 per cent and test weight by 4 per cent. Rice weed competition decreased the panicle production considerably, perhaps due to less tiller production (Biswas et al., 1992).

Uncontrolled weeds, on an average caused 75.8, 70.6 and 62.6 per cent reduction in grain yield of rice when compared with weeded situation in dry seeded rice, wet seeded rice and transplanted rice respectively (Singh et al., 2005). Weeds posed major problem in rice production due to the prevalence of congenial atmosphere and uncontrolled weeds competed with dry seeded rice and reduced yield upto 30.17 per cent (Singh et al., 2005a). Aerobic soil conditions and dry tillage practices, beside alternate wetting and drying conditions are conductive for germination and growth of highly competitive weeds, which cause grain yield loss of 50-91 per cent (Singh et al., 2006). The extent of yield reduction due to weeds is 50 per cent in direct-seeded upland rainfed rice, 51-74 per cent in rainfed lowland rice, 30 to 35 per cent in direct-seeded puddled rice and 15-20 per cent in puddled transplanted rice (Sharma, 2007).

Singh et al. (2008a) reported loss of 38-92 per cent of grain yield in aerobic rice due to weed competition. Yield losses as high as 46 per cent caused by weeds was reported in direct seeded rice (Arunvenkatesh and Velayatham, 2010). Ramachandiran (2012b) reported that grain yield was reduced by 66.47 per cent of aerobic rice in unweeded check.

**Weed management practices**

**Effect of herbicides on weed growth**

**Pre-emergence herbicides:** Application of pyrazosulfuron at 20 g a.i., ha$^{-1}$ recorded better control of weeds at early stages of crop growth which coincided with critical period of crop-weed competition (Lakshmi et al., 2006). Pyrazosulfuron ethyl at 25 g ha$^{-1}$ applied on 10 DAS was most effective in curtailing the weeds up to 95.6 per cent (Saha, 2006).

Application of pretilachlor at 0.75 g a.i., ha$^{-1}$ showed better control of weeds at early stages of crop growth which coincided with critical period of crop-weed competition (Lakshmi et al., 2006). Pre-emergence application of pretilachlor with safener at 500 g a.i., ha$^{-1}$ effectively controlled grassy weeds (Singh et al., 2008b). Pretilachlor at 0.75 kg ha$^{-1}$ significantly reduced the total weed population and weed dry matter production resulting in higher weed control efficiency (Payman and Singh, 2008). Pretilachlor-S at 0.45 kg a.i., ha$^{-1}$ as pre emergence with one hand weeding on 30 to 35 DAS registered higher weed control efficiency (Arunvenkatesh and Velayatham, 2010).

Oxyfluorfen at 0.1 kg ha$^{-1}$ as pre-emergence most effectively controlled all types of weeds and recorded lowest dry weight of weeds (Gosh and Singh, 1986). Singh et al. (2005a) reported that Panicum maximum population was reduced most effectively by oxyfluorfen application. Pre emergence application of Oxyfluorfen 23.5% EC at 400 g ha$^{-1}$ recorded lower weed density, dry weight and higher WCE at 20 and 40 DAS in rice (ARWR, 2011).

**Post-emergence herbicides:** Post-emergence application of cyhalofop- butyl at 80 g ha$^{-1}$ was found effective in controlling Echinochloa colona (Choubey et al., 2001). Cyhalofop-p-butyl at 120 g ha$^{-1}$ could be used as post-emergence spray for the control of grassy weeds (Singh et al., 2008b).
Bispyribac sodium gave the highest weed control and reduced weed density (Hussain et al., 2008). For the control of sedges including Cyperus rotundus and broadleaved weeds, post-emergence application of azimsulfuron at 25 to 30 g a.i., ha^{-1} was effective in direct seeded rice (Singh et al., 2008b). Post-emergence application azimsulfuron suppressed the late emerged weeds effectively (Murali et al., 2010). Effective weed control and improved grain yields with Ethoxysulfuron were earlier reported in transplanted rice (Bhowmick and Ghosh, 2002). Ethoxysulfuron at 18 g a.i., ha^{-1} and 2, 4-D at 500 g a.i., ha^{-1} effectively controlled broadleaf weeds and sedges (Mann et al., 2007).

Ethoxysulfuron gave the highest weed control and reduced weed density (Hussain et al., 2008). Fenoxaprop-ethyl at 50 g ha^{-1} could be used as post-emergence spray for the control of grassy weeds (Singh et al., 2008b). Broad-leaved weeds were effectively controlled by 2, 4-D at 0.5 kg ha^{-1} (Singh et al., 2005a).

Herbicide mixture: Pyrazosulfuron ethyl + molinate had comparatively better weed control efficiency (Saha, 2005). The weed frequency, density and abundance were highly affected by fenoxaprop-ethyl + ethoxysulfuron at 45+10 g a.i., ha^{-1} applied at 15 DAS (Katiyar and Kolhe, 2006). Tank mixture of fenoxaprop + ethoxysulfuron at 50+18 g a.i., ha^{-1} effectively controlled both grassy and broadleaved weeds when applied as post emergence between 18 to 21 DAS (Singh et al., 2008b).

Application of fenoxaprop + (chlorimuron + metsulfuron) on 30 DAS recorded the lowest grass and broadleaved weed density, total weed dry weight and highest weed control efficiency (Ramachandiran, 2012b). Fenoxaprop at 0.06 kg ha^{-1} mixed with ethoxysulfuron at 0.015 kg ha^{-1} as post emergence showed the highest weed control efficiency (Tiwari et al., 2010).

Sequence application of herbicides: Herbicides when applied in sequence effectively controlled both grass and broad-leaf weeds. Cyhalofop-butyl at 120 g ha^{-1} on 15 DAS followed by 2, 4-D at 1.0 kg ha^{-1} on 20 DAS and 2, 4-D at 1.0 kg ha^{-1} on 15 DAS followed by cyhalofop-butyl at 120 g ha^{-1} on 20 DAS were at par with each other and recorded significantly lower total weed dry weight and higher weed control efficiency (Saini, 2005).

Singh et al. (2005a) reported that combination of pre-emergence application of pendimethalin at 1.0 kg ha^{-1} and post-emergence application of 2, 4-D at 500 g ha^{-1} recorded highest rice grain yield and weed control efficiency. Singh et al. (2008a) reported that in aerobic rice system pretilachlor with safener at 500 g a.i. ha^{-1} applied 3 DAS / DAT followed by chlorimuron + metsulfuron at 4 g ha^{-1} applied 21 DAS / DAT followed by hand weeding at 35 DAS / DAT could effectively control all the weeds.

Application of pertilachlor fb 2, 4-D (0.75 fb 0.5 kg ha^{-1}) was most effective in lowering the weed density of grassy and non-grassy weeds and their dry weight with higher WCE of 84.23 per cent (Singh and Singh, 2010).

Effect of herbicides on growth and yield of crop
Pre- emergence herbicides: Application of oxyfluorfen at 0.125 kg ha^{-1} registered the highest Leaf Area Index, dry-matter accumulation, number of productive tillers and grain yield (Kathiresan and Manoharan, 2002). The higher efficacy of pyrazosulfuron-ethyl at 25 g ha^{-1} for improving the productivity of wet direct-sown summer rice was reported by Saha, (2006).

Pyrazosulfuron ethyl (25 g ha^{-1}) applied at 10 DAS was most effective for higher rice grain yield (Saha, 2006). Pre emergence application of pyrazosulfuron at 20 g ha^{-1} recorded higher grain yield. The grain yield of rice was higher under pre emergence application of Oxyfluorfen 23.5 per cent EC at 250 g ha^{-1} (ARWR, 2011).

Post - emergence herbicides: Ethoxysulfuron at 18 g ha^{-1} and 2, 4-D at 500 g ha^{-1} were effective in realizing higher rice grain yield (Mann et al., 2007). Bispyribac sodium and ethoxysulfuron registered higher paddy yield (Hussain et al., 2008). Application of bispyribac Sodium 10% SC at 30 g ha^{-1} recorded higher grain yield (Rao et al., 2009).

Sequence application and mixture of herbicides: Cyhalofop-buty1 at 120 g ha^{-1} (15 DAS) followed by 2, 4-D at 1.0 kg ha^{-1} (20 DAS) and 2, 4-D at 1.0 kg ha^{-1} (15 DAS) followed by cyhalofop-buty1 at 120 g ha^{-1} (20 DAS) being at par with each other significantly recorded higher number of panicles m^{-2} panicle length, grains panicle^{-1} and 1000 grain weight due to reduction weed biomass and higher weed control efficiency (Saini, 2005).
Butachlor at 1.25 kg/ha as pre plant surface application + brown manuring + 2, 4-D at 0.50 kg/ha at 40 DAS recorded highest grain yield of 4.30 t/ha (Maity and Mukherjee, 2009). Pre-emergence application of pendimethalin at 0.75 kg ha\(^{-1}\) followed by post-emergence (25-30 DAS) application of bispyribac sodium 25 g ha\(^{-1}\) or azimsulfuron at 25 g ha\(^{-1}\) produced 61.7 and 42.1 per cent higher yield, respectively (Walia et al., 2009).

Fenoxoprop at 0.06 kg ha\(^{-1}\) mixed with ethoxysulfuron at 0.015 kg ha\(^{-1}\) as post emergence produced significantly higher grain yield (Tiwari et al., 2010). Ramachandiran and Balasubramanian (2012) reported that growth parameters of rice such as plant height, LAI, number of tillers m\(^{-2}\), SPAD value (Chlorophyll) of leaves and DMP of aerobic rice were enhanced by post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS. They also recorded yield attributes such as number of panicles m\(^{-2}\), number of filled grains panicle\(^{-1}\) and test grain weight were increased which inturn resulted in higher grain yield, straw yield.

**Effect of herbicide toxicity on crop:** Though some phytotoxic symptom on rice crop was observed by application of oxyflourfen at 0.125 kg ha\(^{-1}\), the crop recovered and grown as normal crop (Kathiresan and Manoharan, 2002). No phytotoxic effect was observed on rice crop due to various rates of fenoxoaprop-p-ethyl + ethoxysulfuron (Katiyar and Kolhe, 2006). There was no visible phytotoxicity symptoms observed on rice as well as on fallow crop with application of bispyribac sodium 10 per cent SC at 30 g a.i., ha\(^{-1}\) (Rao et al., 2009).

The result on phytotoxicity rating taken on 7 and 10 days after application of herbicide showed that there was slight yellowing of rice crop at the initial stage at higher dose of azimsulfuron 50 DF application. But the yellowing recovered by 10 days after application (Sakthivel et al., 2009). As per the reports of ARWR (2011) crop phytotoxicity was observed with pre emergence application of oxyflourfen at 300 g ha\(^{-1}\). Toxicity symptoms of oxyflourfen was observed at the early stages of rice crop which recovered later (Ramachandiran, 2012c).

**Effect of hand weeding:** Amongst several weed management techniques practiced in rice cultivation, manual weeding appears to be the most effective method by keeping the crop under near-weed free situation for a considerable period of time (Ghosh, 2005).

Though manual weeding is the general practice adopted by the farmers, it is becoming, more and more cost prohibitive and caused drudgery (Saha et al., 2005). Hand weeding at 20 and 40 DAS recorded the maximum rice grain yield (Laskar et al., 2005).

According to Lakshmi et al. (2006) hand weeding twice on 20 and 40 DAS was found to be superior weed control in dry sown rice. They also recorded higher crop growth parameters, yield attributing characters, grain yield (5444 kg ha\(^{-1}\)) and straw yield (5759 kg ha\(^{-1}\)) in dry sown rice. The highest grain yield was recorded with two hand weeding treatment (Singh et al., 2005b). Two hand weeding one as early as possible (10-15 days after sowing) and the second 25-50 days later are generally sufficient in upland rice field (Sharma, 2007). Highest weed control efficiency of 65.52 per cent was recorded with two hand weeding at 30 and 45 DAS (Payman and Singh, 2008).

**Effect of weed management practices on economics of rice:** The benefit: cost ratio was more in integration of weed management practices oxyfluorfen at 0.20 kg ha\(^{-1}\) + hand weeding (Laskar et al., 2005). The highest net benefit was obtained by the application of bispyribac sodium followed by Fenoxaprop (Hussain et al., 2008).

Butachlor at 1.25 kg/ha as pre plant surface application + brown manuring + 2, 4-D at 0.50 kg/ha at 40 DAS recorded highest net return (Rs 21954 /ha) and B:C ratio of 1.30 (Maity and Mukherjee, 2009).

They also stated that the lower net return (Rs. 15993) and benefit: cost ratio (0.68) obtained in farmers practice were because of more man days that was required for hand wedding at 15, 30 and 50 DAS resulting in considerable increased cost of cultivation. Pre emergence pretilachlor (S) 0.45 kg ha\(^{-1}\) on 3 DAS fb azimsulfuron 50 DF 35 g ha\(^{-1}\) on 20 DAS + hand weeding 45 DAS recorded higher gross return and net return (Murali et al., 2010).

Application of pretilachlor + safener at 0.5 kg ha\(^{-1}\) was remunerative in direct seeded rice as it had higher net return of Rs. 9459 ha\(^{-1}\) and benefit:
cost ratio of 1.98 (Upasani et al., 2010). Application of fenoxaprop + ethoxysulfuron on 30 DAS registered higher gross return (Rs. 50915 ha\(^{-1}\)), net return (Rs. 28281 ha\(^{-1}\)) and B:C ratio (2.25) (Ramachandiran et al., 2012d).

REFERENCES


