WEED MANAGEMENT IN LOWLAND RICE (ORYZA SATIVA L.) ECOSYSTEM: A REVIEW

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ABSTRACT

Changes in morphological structure of rice varieties and shifting paradigm of cultivation have brought forth marked change in floristic composition of weed flora, weed density and their virulence. These have compounded weed problem further. Yield losses caused by weed species in rice are enormous. With increasing weed density, yield losses are increasing markedly. Several weed management methods viz., cultural, manual, mechanical and chemical methods used for controlling weeds under lowland rice ecosystem were discussed in this review. Each control method has advantages and disadvantages. Weeds have a variable growth habit and life cycles so that no single method can effectively control weeds in all situations. Thus, integrated weed management approach is the urgent requirement for sustainable rice production.

KEYWORDS: Rice, Crop Weed Competition, Weed Management Methods

INTRODUCTION

Rice is the most important staple food in Asia, providing on an average 32% of total calorie uptake (Maclean et al., 2002). Because of growing population, the demand for rice is expected to increase in the coming decades (Pingali et al., 1997). However, to meet this demand the crop should perform to its full potential. Certain factors tend to restrict the crop’s potential performance. Weed competition is one of the major factors responsible for low yield of rice. Competition offered by weeds is most important and it reduces the grain yield up to the extent of 32% (Singh et al., 2007c). Thus, it is important that they are controlled in time to avoid unproductive use of growth factors to enable the crop plant to express fully by utilizing these factors meant for them. Herbicides are effective against weed species, but most of them are specific and are effective against narrow range of weed species (Mukerjee and Singh, 2005). Therefore, appropriate and economical weed management technology is to be developed for the sustainable rice cultivation. Keeping these points in view, this review is focused to crop weed competition and different weed management methods suitable for the lowland rice ecosystem.

WEED SPECTRUM IN RICE

Identification of weeds is the basic step for planning sound weed management programme. Depending upon the weed species, different weed management options are given keeping in view their susceptibility when growing in a crop (Walia, 2006). The dominant grass weed species were Echinochloa crusgalli and Echinochloa colona, sedges were Cyperus iria, C. rotundus and Fimbristylis miliacea and broad-leaved weed species were Ammania baccifera, Marsilia quadrifolia and Potamogeton distinctus under puddled condition of sandy clay loam soil during rainy season. The broad-leaved constituted 34.1 per cent, grasses 42.2 per cent and sedges 23.6 percent of the total weed population under weedy conditions (Singh et al., 2007a). The wet seeded rice was infested with composite weed flora comprising of 51.5% grasses,
30.9% sedges and 17.5% broad-leaved weeds (Ravisankar et al., 2008). Ramachandra (2010) recorded the dominant weed species in transplanted rice as *Echinochloa crus-galli* (L.) and *E. colona* (L.) under grasses; *Cyperus difformis* (L.), *Cyperus iria* (L.) and *Cyperus rotundus* (L.) under sedges and *Eclipta alba* (L.) Hassak and *Ammadia baccifera* (L.) among the broad leaved weeds. Reddy (2010) reported that predominant weed species in the direct seeded rice were *Echinochloa crus-galli* (L.) under grasses; *Cyperus difformis* (L.) and *Fimbristylis miliacea* (L.) under sedges and *Eclipta alba* (L.) Hassak and *Ammadia baccifera* (L.) under the broad leaved weeds.

**CROP WEED COMPETITION**

Crop yield losses due to weeds mainly depend upon their intensity as well as on type of weed flora. There is a linear correlation between yield loss and population of weeds, however, above certain population limits, yield reductions becomes nearly constant due to self competition among weed plants. The greatest loss caused by the weeds resulted from their competition with crop for growth factors viz., nutrients, soil moisture, light, space, etc (Walia, 2006).

**Critical Period of Crop – Weed Competition**

During early establishment, the weeds make 20 to 30 per cent of their growth, while the crop makes 2-3 per cent of its growth (Moody, 1990). The competition period up to 45 DAS had the greater impact on yield of wet seeded rice (Govindarasu et al., 1998; Sathyamoorthy and Kandasamy, 1998). Chinnusamy et al. (2000) reported that maintaining a weed free period up to 45 DAT was essential to augment the yield of medium duration rice. Critical period for crop weed competition in rice was up to 40 days after transplanting (Tewary and Singh, 1991; Thapa and Jha, 2002). In rainfed lowland rice, 30-60 days after sowing period was considered as critical period for crop weed competition to avoid grain yield losses (Moorthy and Saha, 2005).

**Nature of Crop - Weed Competition**

Weeds are self-grown and appear simultaneously with crop plant creating severe competition for nutrient, space, moisture and solar energy resulting in low yield of crop. Grassy weeds were heavy competitors with rice crop and were followed by sedges and broad leaved weeds (Umapathy and Sivakumar, 2000). Chauhan and Johnson (2010) stated that when direct seeded rice was grown together with either jungle rice or *Ludwigia* spp, shoot competition reduced the growth and yield of rice more than root competition and rice grain yield was highly correlated with above and below ground biomass of the weeds.

**Nutrient Removal by Weeds**

Weeds usually grow faster than the crop plants and absorb added nutrient more rapidly and in larger quantities than by crops (De Datta and Baltazar, 1996) and thus deprive the supply of nutrients in time to the crop plants. Weeds removed nutrients (N, P and K) eight times higher under direct seeded rice compared to that of puddled transplanting (Singh et al., 2002). Sudhalakshmi et al. (2005) reported that nutrient uptake by weeds was 30 kg N, 10 kg P and 17 kg K per hectare in transplanted rice in clay loam soil of Coimbatore. Puniya et al. (2007b) noticed that the highest loss of nutrients (N 42.07, P 10.00 and K 21.80 kg ha\(^{-1}\)) occurred with unweeded control due to more density and dry weight of weeds in transplanted rice during kharif in silt loam soil of Pantnagar

**Effect of Weeds on Rice Growth and Productivity**

Severe infestation of weeds suppressed the plant height (Bhargavi and Reddy, 1994) increased tiller mortality, decreased shoot and grain production (Srinivasan and Palaniappan, 1994). Singh et al., (2002) observed that maintaining weed free condition till maturity gave significantly higher grain yield due to more panicles m\(^{-2}\) and lower density and dry
weight of weeds. Moorthy and Saha (2005) reported that the losses in grain yield due to weed competition for first 30, 60, and 90 days were 17.7, 11.8 and 5.0 per cent, respectively. Weedy environment throughout the crop growth caused yield reduction to the tune of 57 -61 per cent in case of transplanted rice and 64–66 per cent in case of wet seeded rice in comparison to season long weed free situation (Mukherjee et al., 2008). The unit increase in intensity of monocots, dicots and weed dry weight causes decrease in Pusa Basmati 1 rice grain yield by 2.18, 1.64 and 2.85 q ha⁻¹, respectively during wet season (Singh et al., 2008). Veeraputhiran and Balasubramanian (2010) observed that maintaining weed free condition till maturity produced the grain yield of 7139 kg ha⁻¹ of transplanted rice. The overall effect of crop weed competition is the reduction in the economics as well as biological yield of rice.

**WEED MANAGEMENT METHODS**

**Cultural Methods**

Cultural practices greatly alter the competitive relationship between rice and weeds. Hence, proper agronomic management practices like suitable crop establishment method, efficient fertilizer use and timely weed control have to be planned to attain the target food production (Nagaraju, 1994).

The closely spaced crop effectively smothered the weeds growing under crop canopy by not providing sufficient space for weed growth complemented by restricting sunlight from penetrating downwards (Brar and Walia, 2001). Prasad et al. (2001) stated that transplanting recorded the lowest weed population (63.5 m⁻²) and weed dry weight (24.1 g m⁻²) which was followed by sowing of sprouted seeds in puddled condition and dry drilling of seeds. Francis (2007) found higher weed population (6.58 m⁻²) and weed biomass (12.9 kg ha⁻¹) in SRI than conventional transplanted rice which can be attributed to more inter space area and less population.

Transplanted rice recorded the lowest weed count of 3.19 m⁻² and weed dry weight of 2.44 g m⁻² resulting in highest grain yield of 3105 kg ha⁻¹ (Singh et al., 2007a). Further, they reported that the weed intensity and weed dry weight increased with the increase in fertility level and was maximum with application of 120: 60: 60 kg NPK ha⁻¹. Subramanyam et al. (2007) emphasized that intensive puddling with continuous submergence recorded the lowest weed dry weight of 6.63 g m⁻². Chauhan and Johnson (2010) stated that the risks of crop yield loss due to competition from weeds in direct seeded rice was greater than in transplanted rice because the weeds and rice emerge together and farmers are not usually able to use standing water to suppress weeds at the early growth stages of rice.

Dry weight of grasses (6.18 and 8.77 g m⁻²), sedges (3.32 and 4.97 g m⁻²), broad-leaved weeds (1.85 and 2.74 g m⁻²) at 45 and 60 DAS, the N-P-K uptake of 4.09-1.53-4.49 kg ha⁻¹ by weeds at 60 DAS were minimum and the weed control efficiency was maximum (67.02%) in drum seeding method than wet and dry drilling (Singh and Singh, 2010). Reddy (2010) reported that Direct planting system recorded less total weed dry weight (1062 kg ha⁻¹) and nutrient removal by weeds (31:16:52 kg NPK ha⁻¹) over drum seeding. However, weed control efficiency was similar for both establishment methods.

**Manual Weeding**

Hand weeding twice at 20 and 40 DAS was superior to the chemical weed control for all the growth and yield attributes, reflecting the higher grain yield of 2876 kg ha⁻¹ in silty loam and calcareous soil during rainy season (Prasad et al., 2001). Chander and Pandey (2001) observed that hand weeding increased grain as well as straw yields compared to herbicides and weedy check because of frequent elimination of weeds that resulted in the reduced weed competition. Dutta et al. (2005) reported that hand weeding twice at 21 and 42 DAS recorded the highest weed control efficiency and increased grain and straw yield of rice crop.
Manual weeding is very effective but it is tedious, time consuming and expensive in large scale cultivation. Continuous rains in rainy season and unavailability of man power make manual weeding difficult (Puniya et al., 2007a). Pal et al. (2009) opined that hand weeding on 20 and 40 DAT recorded highest grain yield of 5.08 t ha\(^{-1}\) in Gangetic alluvial soil because it gave very little scope to weeds to flourish and to compete with the crop preferably at the critical stage of crop weed competition.

**Mechanical Weeding**

In the recent past weed control is practiced more by chemical means supplemented by hand weeding. In the era of increasing labour scarcity and exploding pollution effects, weed management strategy could be reoriented towards mechanical means for satisfactory fertility and monetary benefits.

Mechanical weeding is accomplished through incorporation of weeds in situ may help in effective recycling of the depleted nutrients which in turn could have augmented the nutrient pool of the rhizosphere together with aeration of the root zone. Rotary weeder was effective in controlling the weeds present in inter row space, but failed to control the weeds in intra row space or those in the vicinity of the crop (Choubey et al., 1998). Uphoff (2002) reported that the mechanical hand weeder pruned some of the upper roots and encouraged deeper root growth. Randriamiharisoa (2002) noticed that the mechanical weeding using rotating hoe with small toothed wheels increased the soil pores so that roots and microbes could more easily gain access to oxygen and also significantly increase the tiller production.

The use of conoweeder resulted in 10 per cent grain yield increase during wet season while the yield increase was only three per cent higher in dry season than conventional method of weeding (Thiyagarajan et al., 2002). Conoweeding alone was found to contribute 17.43 per cent for grain yield when the average grain yield under the conoweeding treatments 3376 kg ha\(^{-1}\) was compared against the average grain yield under hand weeding treatments 2875 kg ha\(^{-1}\) (Sridevi, 2006). The impact of conoweeding in increasing the ammoniacal and nitrate nitrogen content of the rhizosphere soils was evident only at harvest (37.9 ppm) and grain filling stages (49.6 ppm) respectively while at the rest of the stages conoweeding had not set any notable impact on the nitrogen fractions of the rhizosphere soil (Sudhalakshmi et al., 2005).

Mrunalini and Ganesh (2008) opined that the implements like conoweeder that helped to save labour, time and reduced man - days required for weeding from 30 to 10 as they become more experienced in handling the conoweeder implement. Sudhalakshmi et al. (2005) pointed out problems are encountered in incorporation of weeds like *Cynodon* and sedges with underground stolons and rhizomes which result in faster regeneration under mechanical weeding.

**Chemical Method**

Herbicide usage is one of the most labour saving innovations especially in case of the non - availability of labour during peak season (Ampong – Nyarko and Datta, 1991; Moody, 1993). In direct seeded rice, herbicides hold great promise as they can arrest weed growth from the beginning of crop growth. Chemical method of weed control is easy and has been found economical. Wide range of herbicides is available for the management of grassy weeds (pretilachlor, butachlor, anilofos and oxadiargyl) as well as broad-leaved weeds (metsulfuron, chlorimuron, ethoxysulfuron and 2, 4-D). Herbicides recommended against grassy weeds are mostly used as pre-emergence and weeds emerging later in the season often get escaped (Yadav et al., 2008). Many times due to various constraints at farm level, the application of herbicides in the early growth stages is not possible and continuous use of same herbicide might cause resistance in weeds.

Under such situation, the post emergence herbicides may be another option (Puniya et al., 2007a). Saha (2006) reported that sulfonylurea group of herbicides is one of the most important classes of herbicide that has become popular all over the world which represent high level of activity, application flexibility, excellent selectivity and low mammalian
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...toxicity even at very low dose with broad spectrum of weed control. Almix (10% Metsulfuron Methyl + 10% Chlorimuron Ethyl) is an herbicide of the sulfonylurea group for the control of sedges and broad leaf weeds. Application of almix @ 8 g ha\(^{-1}\) at 20 DAT recording highest weed control efficiency of 97.2 per cent for broad-leaved, 21.6 per cent for grasses and 60.0 per cent for sedges and N-use efficiency (59.1 kg grain kg\(^{-1}\) N applied), thereby realizing an increase of 73.1 per cent yield over weedy check in *kharif* rice under temperate conditions of Kashmir valley (Singh et al., 2007b). Pal et al. (2009) found that almix 20 WP @ 4 g ha\(^{-1}\) as post emergence herbicide at 15 DAT was promising in controlling weeds of transplanted rice with best weed control efficiency of 90.44 per cent and gave second highest grain yield of 5.01 t ha\(^{-1}\) which was comparable with hand weeding (5.08 t ha\(^{-1}\)).

Yadav *et al.* (2009) found that bispyribac at 25 g ha\(^{-1}\) applied at 15-25 DAT could be a suitable herbicide for complex weed flora in transplanted rice. The highest weed control efficiency, grain yield and benefit : cost ratio were recorded with sequential application of oxadiargyl 75 g ha\(^{-1}\) and bispyribac-sodium 30 g ha\(^{-1}\) which were at par with HW twice at 20 and 40 DAT in transplanted rice (Kiran *et al.*, 2010).

**Integrated Weed Management**

The growing concern that using the same method of weed control continuously may lead to a build up of weed species tolerant to the weed control method used. This leads to the development of integrated weed control methods (Datta, 1981). Several indirect and direct methods can be combined to control weeds effectively and reduce the total cost of weed control in a given situation (Ampong-Nyarko and Datta, 1991). Vijayakumar *et al.* (2006) found that a combination of 14 days old seedlings planted at 25 cm x 25 cm spacing with alternate wetting and drying method of irrigation and conoweeding produced taller plants of 109 cm, LAI of 7.69 and total dry matter of 12,012 kg ha\(^{-1}\).

Pretilachlor with safener at 500 g a.i. ha\(^{-1}\) applied at 3 DAS/DAT and chlorimuron + metsulfuron at 4 g a.i. ha\(^{-1}\) applied at 21 DAS/DAT followed by hand-weeding at 35 DAS/DAT could effectively control all the weeds (Singh *et al.*, 2008). Reddy (2010) reported that application of pretilachlor + safener @ 0.45 kg ha\(^{-1}\) on 3 DAS and conoweeding on 45 DAS recorded higher weed control efficiency of 86.7 per cent which lead to highest grain yield of 6,216 kg ha\(^{-1}\) in direct seeded rice. Combination of stale seedbed technique with pre-emergence spray of herbicides or with hand weeding or concurrent growing of green manure crops will give better control of weeds and better grain yields (Sindhu *et al.*, 2010).

SRI planting (25 cm x 25 cm) with two way rotary weeder weeding thrice at weekly interval starting from 15 DAT and absolute control without fertilizer recorded lower weed parameters and nutrient removal by weeds. Whereas, SRI planting (25 cm x 25 cm) with two way rotary weeder weeding thrice at weekly interval starting from 15 DAT in association with recommended dose of fertilizer (150:50:50 kg NPK ha\(^{-1}\)) + 12.5 t FYM ha\(^{-1}\) + *Azophosmet* (seed and soil application) + PPFM (foliar spray) at active tillering, panicle initiation and at 50% flowering stage registered higher growth characters, nutrient uptake, yield attributes and grain yield (Sridevi, 2011). Babar and Velayutham (2012) observed that application of pretilachlor at 0.75 kg a.i. ha\(^{-1}\) as pre-emergence + 4 times conoweeding from 10 DAT at 10 days interval was found to be more effective in controlling weeds (95.7-99.5% WCE) under System of Rice Intensification (SRI).

**ECONOMICS OF DIFFERENT WEED MANAGEMENT PRACTICES**

Hand weeding is laborious and generally more expensive. The weed control cost is maximum for hand weeding (two hand weeding at 30 and 45 DAT) and the lowest for chemical weed management (Hasanuzzaman *et al.*, 2007). Khare and Jain (1995) reported that rotary weeder attained the highest net profit because of less cost of cultivation and thus resulted in the highest value of B: C ratio of 1.90 in sandy loam soil during wet season at Jabalpur.
Almix 20 WP @ 4g ha⁻¹ as post emergence herbicide at 15 DAT in transplanted rice resulted in highest B: C ratio of 1.41 and maximum net return of `21,802 in comparison to hand weeding (Pal et al., 2009). The maximum net returns of `35813 and benefit: cost ratio of 1.63 were obtained with almix 8 g ha⁻¹ in kharif rice under temperate conditions of Kashmir valley (Singh et al., 2007b). Reddy (2010) reported that pre emergence application of pretilachlor + safener @ 0.45 kg ha⁻¹ on 3 DAS + conoweeding on 45 DAS recorded the gross return of `65,961 ha⁻¹, net return of `46,793 ha⁻¹ and B: C ratio of 3.4 and was comparable with pretilachlor + safener @ 0.45 kg ha⁻¹ on 3 DAS + motorized weeding on 45 DAS during wet season.

CONCLUSIONS

Weeds are one of the major constraints to the successful cultivation of rice. Therefore, appropriate and economical weed management technology is to be developed for the sustainable rice cultivation. The adoption of any one method of weed control, whether cultural, mechanical, or chemical, may not provide effective weed control in rice. Therefore, an integrated strategy of weed management is needed for the sustainable rice production.

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