# Opportunities to improve cultural approaches to manage weeds in direct-seeded rice

Bhagirath S. Chauhan and David E. Johnson
International Rice Research Institute, Los Baños, Philippines
Corresponding author: b.chauhan@cgiar.org

**Summary** Weeds are a major constraint to rice production in direct-seeded systems as they increase production costs and cause yield loss. Herbicides are widely used but, with the threat of herbicide resistance and a scarcity of new molecules, interest has increased in cultural approaches, based on understanding of weed biology, within integrated weed management programs. Approaches include use of stale seedbed techniques, tillage practices, making the crop more competitive with the use of competitive varieties, narrow crop row spacing and high crop seed rate, use of crop residue as mulches, and optimum time and depth of flooding. There is also scope to integrate herbicides with cultural practices to improve the sustainable use of herbicides. Strategies to manage weeds in direct-seeded rice should emphasise making the crop more competitive and reducing the competitiveness of weeds by delaying emergence or suppressing weed growth.

**Keywords** Direct-seeded rice, crop residue, cultural approaches, weed management.

## INTRODUCTION

Farmers are moving from transplanting of rice to direct seeding in many Asian countries in response to rising production costs, and labour and water shortages. Risks of crop yield losses due to weeds are, however, much greater, because in direct-seeded rice the rice seedlings have no size advantage over weeds and standing water is usually absent in the early stages of crop establishment. Herbicides are widely used in direct-seeded rice although the evolution of herbicide resistance, scarcity of new herbicide molecules, weed population shifts, and increased costs may limit the herbicide options available to farmers in the future. This has increased interest in the use of cultural approaches, based on understanding of weed biology, in integrated weed management programs.

## APPROACHES

**Stale seedbed technique** Weeds germinating during the crop growing season could be reduced by encouraging weed seeds to germinate by giving light irrigations before land preparation and then killing the seedlings by non-selective herbicides or tillage operations. Information on the effectiveness of these 'stale seedbed' methods is, however, very limited in the literature on direct-seeded rice.

**Tillage practices** Soil cultivation influences the vertical distribution of weed seeds in the soil profile, and this distribution affects seedling establishment due to factors such as seed dormancy, longevity and predation, and the potential of a seedling to emerge from a given depth (Chauhan and Johnson 2010b). A recent study showed that seedling emergence of several weeds, including awnless barnyard grass (*Echinochloa colona* (L.) Link) and southern crabgrass (*Digitaria ciliaris* (Retz.) Koel), was greater in rice sown under zero-till conditions than after dry tillage (Chauhan and Johnson 2009). This was possibly due to the small seed size of these species preventing emergence from the deep burial that occurs with conventional tillage system, and also that these species require light for germination. If a large weed seed bank accumulates on the soil surface after continuous zero-till, the option of deep tillage to bury weed seeds below the maximum depth of emergence could be used as a tool to suppress weed growth. Such a "rotation" to deep tillage would only be effective if it does not bring to the surface large quantities of seeds buried in the previous deep tillage event. To be able to predict this, it is necessary to understand the longevity of the seeds in the soil seed bank.

**Competitive varieties** The competitive ability of rice is often associated with traits related to light interception and is correlated with height, leaf area index, specific leaf area, droopy leaves and early tiller production (Rao *et al.* 2007). Namuco *et al.* (2009) suggested that easily measurable traits, such as leaf area and dry matter of rice seedlings at an early stage, are correlated with weed competitiveness and therefore, could be used as an indirect tool for screening of rice varieties for competitiveness against weeds. Earlier Zhao *et al.* (2006) reported that vegetative vigour scored at 2 weeks after seeding and weed free yield accounted for 87% of the variation in yield between varieties in competition for weeds, and these two traits could be an efficient means of indirect selection for improving rice yield in competition with weeds.

**Row spacing and seed rate** Impacts of weed competition could be reduced by optimising crop plant density and arrangement. Narrow row spacing and increased plant population can increase a crop's ability to compete with weeds for light. Studies have demonstrated the benefit of decreased row spacing on reduction in weed biomass and early season canopy development in other crops, such as maize (Mashingaidze *et al.* 2009) and soybean (Hock *et al.* 2006). However, limited information is available on this aspect in direct-seeded rice in Asia. Seedlings of awnless barnyard grass and barnyard grass (*E. crus-galli* (L.) Beauv.) emerging during the first month of the crop growing season had greater biomass and seeds in direct-seeded rice planted at 30 cm rows than at 20 cm rows (Chauhan and Johnson 2010a). In this study, rice grain yield was also greater in narrow rows than in wider rows.

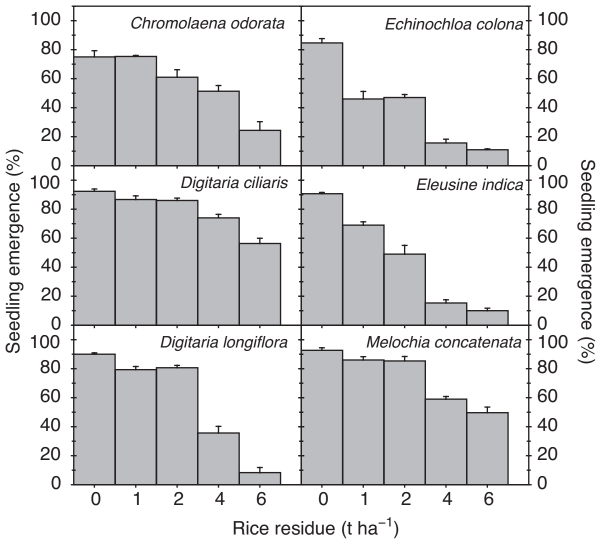


**Figure 1.** Effect of crop residue amount on percent seedling emergence (± standard error of mean) of six weed species (Chauhan and Johnson 2010b).

Increased seed rate in direct-seeded rice, especially dry seeded, helps to suppress weed growth and to compensate for poor crop establishment. In a recent study, increased seed rate from 100 to 300 seeds m$^{-2}$ resulted in a significant increase in rice yield and a decrease in weed biomass, whereas a further increase in seed rate (500 seeds m$^{-2}$) did not improve yield or weed suppression (Zhao *et al.* 2007). Similarly, in Malaysia, the grain yield of rice increased with increases in seed rate from 20 to 80 kg ha$^{-1}$ in a direct-seeded field infested with weedy rice (Azmi *et al.* 2000). Recent studies in the Philippines showed that grain yield of an inbred variety increased with increases in seed rate from 15 kg ha$^{-1}$ to 75 to 100 kg ha$^{-1}$ in weedy condition; however, yields remained similar at these rates in weed-free conditions (B.S. Chauhan and D.E. Johnson unpublished data).

**Crop residue** Crop residues on the soil surface, as mulch, can influence germination and emergence of many weeds by altering the physical and chemical environments surrounding the seeds. The environmental factors include lower soil temperatures, shading, physical obstruction provided by mulch itself, allelopathy and toxic microbial products. The impact of crop residues on weed emergence, however, depends on the quantity and allelopathic potential of the residue and the weed species.

In the Philippines, seedling emergence of several weed species has been reported to be influenced by rice residue (0 to 6 t ha$^{-1}$) although the extent of the response varied between weed species (Figure 1). In India, a mulch of previous wheat crop residue at 4 t ha$^{-1}$ reduced annual and broadleaved weed densities in dry-seeded rice compared with no mulch (Singh *et al.* 2007).

Addition of crop residues can reduce seedling emergence of several weed species, but the quantities required to cause a substantial reduction in weed densities may be greater than those normally found in fields after harvest. Seed-drills, such as the Turbo Happy seeder and rotary-disc, are capable of seeding into loose residue of up to 6 t ha$^{-1}$. It will be important, however, to balance the quantity of residue required to suppress weeds with quantities that will not hinder rice emergence in direct-seeded systems.

**Flooding** Rice is more tolerant of flooding than many weed species and the differential response between rice and associated weeds enables the use of flooding as a widespread intervention against weeds. The timing, duration and depth of flooding are critical to the effective suppression of weed growth. Better exploitation of the differences between rice and weeds in their tolerance of early flooding could enable more effective weed management through more precise timing and depth of flooding.

Recent studies showed that continuous flooding to a depth of 2 cm compared with 0 cm greatly reduced emergence of several weed species (Figure 2a). Intermittent flooding (2 days out of 7 days for 28 days), however, was effective only when flooding depth increased to 10 cm. Flooding caused a more pronounced effect on seedling dry matter than seedling emergence (Figure 2b). Intermittent flooding to a depth of 10 cm reduced weed dry matter by about 90% compared with no flooding, while only 2 cm of continuous flooding suppressed weed growth to the similar level.

Flooding after hand weeding or herbicide application could largely prevent the subsequent growth of weeds and reduce the need for further weeding. In situations where farmers have limited water supply, early rather than later flooding would make best use of water to control weeds effectively. As currently used rice varieties are not tolerant to germination under anaerobic condition, flooding in direct-seeded rice is usually applied only after crop emergence. By the time fields are flooded, weeds may have already emerged and will be difficult to manage by standing water. The availability and use of rice varieties tolerant to anaerobic germination will provide an additional means to suppress weed germination and growth during crop establishment.

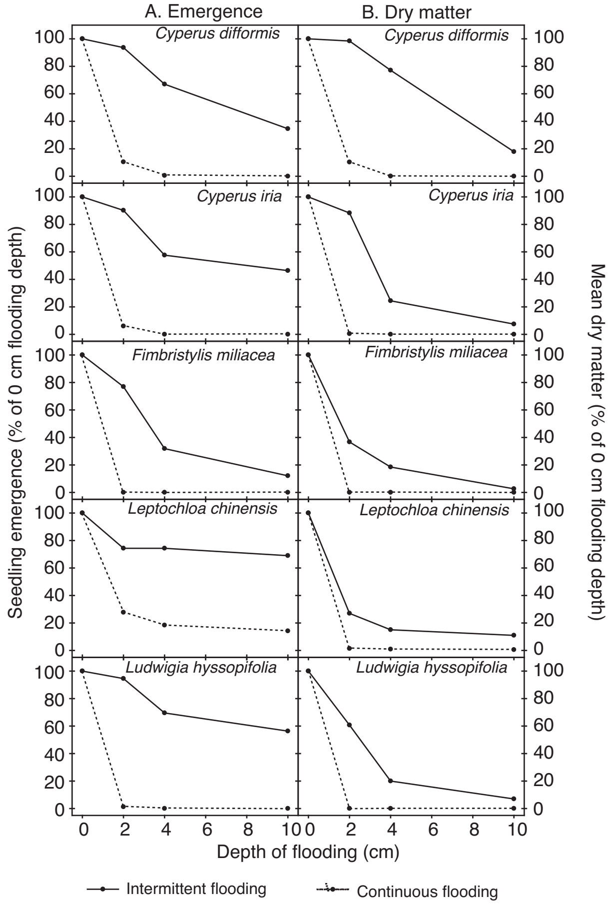


**Figure 2.** Effect of flooding depth and duration (intermittent: 2 days out of 7 days for 28 days, and continuous: for 28 days) on (a) seedling emergence and (b) mean dry matter of five weed species (Chauhan and Johnson 2010b).

**Herbicides** Herbicides are a major tool for weed management in direct-seeded rice, and their use is likely to increase further with rising labour costs. Herbicide use becomes even more important when weeds and rice emerge simultaneously in direct-seeded system, and some of the weeds have morphological similarity to rice. Pendimethalin, oxadiazon, bispyribac sodium, azimsulfuron, pretilachlor, fenoxaprop and propanil are among those herbicides used in direct-seeded rice. However, a single application of any herbicide is unlikely to be effective in controlling weeds. Herbicides should, therefore, be integrated with other cultural management practices to retain them for sustainable and continuous use in the future. In irrigated systems, for example, herbicide application followed by flooding could suppress subsequent growth of weeds. Rice cultivars that can germinate under anaerobic conditions could help in reducing herbicide use, water pollution and weed growth.

Improving strategies to manage weeds in direct-seeded rice will enable the crop to be more competitive and reduce the competitiveness of weeds by delaying their emergence and suppressing growth. Future research in direct-seeded rice needs to be focused on the integration of appropriate agronomic practices with herbicide application timing and weed-suppressive ability of cultivars in order to improve effectiveness of weed management approaches.

## REFERENCES


Azmi, M., Abdullah, M.Z., Mislamah, B. and Baki, B.B. (2000). Management of weedy rice (*Oryza sativa* L.): the Malaysian experience. *In* 'Wild and weedy rice in rice ecosystems in Asia – a review', eds B.B. Baki, D.V. Chin and M. Mortimer, pp. 91-6. (International Rice Research Institute, Los Baños, Philippines).

Chauhan, B.S. and Johnson, D.E. (2009). Influence of tillage systems on weed seedling emergence pattern in rainfed rice. *Soil and Tillage Research* 106, 15-21.

Chauhan, B.S. and Johnson, D.E. (2010a). Implications of narrow crop row spacing and delayed *Echinochloa colona* and *Echinochloa crus-galli* emergence for weed growth and crop yield loss in aerobic rice. *Field Crops Research* 117, 177-82.

Chauhan, B.S. and Johnson, D.E. (2010b). The role of seed ecology in improving weed management strategies in the tropics. *Advances in Agronomy* 105, 221-62.

Hock, S.M., Knezevic, S.Z., Martin, A.R. and Lindquist, J.L. (2006). Soybean row spacing and weed emergence time influence weed competitiveness and competitive indices. *Weed Science* 54, 39-46.

Mashingaidze, A.B., van der Werf, W., Lotz, L.A.P., Chipomho, J. and Kropff, M.J. (2009). Narrow rows reduce biomass and seed production of weeds and increase maize yield. *Annals of Applied Biology* 155, 207-18.

Namuco, O.S., Cairns, J.E. and Johnson, D.E. (2009). Investigating early vigour in upland rice (*Oryza sativa* L.). Part I. Seedling growth and grain yield in competition with weeds. *Field Crops Research* 113, 197-206.

Rao, A.N., Johnson, D.E., Sivaprasad, B., Ladha, J.K. and Mortimer, A.M. (2007). Weed management in direct-seeded rice. *Advances in Agronomy* 93, 153-255.

Singh, S., Ladha, J.K., Gupta, R.K., Bhusan, L., Rao, A.N., Sivaprasad, B. and Singh, P.P. (2007). Evaluation of mulching, intercropping with *Sesbania* and herbicide use for weed management in dry-seeded rice (*Oryza sativa*). *Crop Protection* 26, 518-24.

Zhao, D.L., Atlin, G.N., Bastiaans, L. and Spiertz, J.H.J. (2006). Cultivar-weed competitiveness in aerobic rice, correlated traits, and the potential for indirect selection in weed-free environments. *Crop Science* 46, 372-80.

Zhao, D.L., Bastiaans, L., Atlin, G.N. and Spiertz, J.H.J. (2007). Interaction of genotype × management on vegetative growth and weed suppression of aerobic rice. *Field Crops Research* 100, 327-40.