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Integrated weed management approach to improve weed control efficiencies for sustainable rice production in dry-seeded systems

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ABSTRACT

Weed management is the major challenge to the success of dry-seeded rice (DSR). A field study was conducted during the dry seasons of 2013 and 2014 at the International Rice Research Institute to evaluate the performance of herbicides combined with mechanical weeding in DSR. The lowest weed density and biomass were found in the treatment oxadiazon followed by (fb) fenoxaprop + ethoxysulfuron fb 2,4-D fb mechanical weeding (MW) at 42 days after sowing (DAS). However, this treatment had similar weed density and biomass to the treatments oxadiazon fb bispyribac-sodium fb fenoxaprop + ethoxysulfuron fb 2,4-D,oxadiazon fb bispyribac-sodium fb 2,4-D, and oxadiazon fb MW (28 DAS) fb MW (42 DAS). The highest weed density and biomass were recorded in the treatment oxadiazon fb MW (28 DAS) and oxadiazon fb 2,4-D. Higher grain yield (5.3–5.8 t ha^{-1}) was produced in the plots that received oxadiazon fb fenoxaprop + ethoxysulfuron fb 2,4-D fb MW(42 DAS) and oxadiazon fb bispyribac-sodium fb fenoxaprop + ethoxysulfuron fb 2,4-D. The results of this study provide sustainable weed management options to farmers growing DSR.

1. Introduction

The aim of dry-seeded rice (DSR) production systems is to make irrigated rice production more sustainable and profitable than transplanted rice systems (Chauhan, 2012; Mahajan et al., 2012; Ahmed et al., 2014). Depending on the season, location, and management practices used, DSR systems can save total labour requirements by 11–66% (Kumar et al., 2009) and irrigation water need by 35–57% (Bhushan et al., 2007; Jat et al., 2009) compared with puddled transplanted rice. However, one factor that hampers the sustainability and profitability of DSR systems is the prevalence and infestation of weeds, thus, efforts are being made to develop effective and sustainable weed management strategies for these systems (Singh et al., 2006; Chauhan, 2012; Anwar et al., 2013).

Manual weeding is the traditional and effective weed control method used in Asia. However, this method is labour intensive, and the recent trend of a shortage of labour and higher wage rate make it less practical. Also, high weed infestation is prevalent in DSR systems, thus, multiple manual weed control operations are needed per season to keep fields completely weed-free (Chauhan and Opeña, 2012; Ahmed and Chauhan, 2014). Therefore, herbicides are considered the most effective and economical weed management tool in DSR systems (Suria et al., 2011; Rahman et al., 2012). Herbicides can be applied as pre-emergence (PRE) or post-emergence (POST), although PRE herbicides are preferred in DSR systems. Different PRE herbicides, including oxadiazon, oxadiargyl, pendimethalin, pyrazosulfuron, pretilachlor, butachlor, and clomazone are now available worldwide and have been reported to provide a fair degree of weed control (Pellerin and Webster, 2004; Chauhan et al., 2012). However, the weed control efficiency of PRE herbicides depends on the soil moisture conditions in the field, application timing, and weed seed bank (Chauhan and Johnson, 2011; Chauhan and Opeña, 2012). PRE herbicides alone are not

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enough to provide season-long weed control in DSR systems (Mahajan and Chauhan, 2013), but they need to be applied to stop the head-start advantage of weeds over rice. The extent of weed control by PRE herbicides varies depending on the herbicides used and the locations of the production system. In the Philippines, for example, the application of oxadiazon, pendimethalin, and pretilachlor reduced weed density by 82, 55, and 70%, respectively, whereas in Bangladesh, the application of oxadiargyl, pendimethalin, and pyrazosulfuron reduced weed density by 70, 51, and 48%, respectively (Chauhan and Abugho, 2013; Ahmed and Chauhan, 2014). Similarly, in India, pendimethalin and pyrazosulfuron reduced weed density by 56 and 50%, respectively (Mahajan and Chauhan, 2013). These studies reported that PRE herbicides can reduce weed density by 50–82%. The weeds that survive even after the application of PRE herbicides and those that emerge later can then be managed either by using POST herbicides or through manual or mechanical weed control measures.

Like PRE herbicides, POST herbicides can also control weeds selectively in DSR systems. As found in different studies, POST herbicides such as bispyribac-sodium, bentazon, fenoxaprop, ethoxysulfuron, penoxsulam, and 2,4-D have been reported to provide effective weed control (Suria et al., 2011; Chauhan et al., 2012; Chauhan and Abugho, 2013). However, most of these POST herbicides are effective only to a specific group of weeds. For example, bispyribac-sodium and penoxsulam were found to be effective on grasses, broadleaved weeds, and sedges; fenoxaprop was effective on only grass weeds; bentazon and ethoxysulfuron were effective on broadleaved weeds and sedges; and 2,4-D on broadleaved weeds (Gopal et al., 2010; Jabran et al., 2012; Mahajan and Chauhan, 2013; Ahmed and Chauhan, 2014).

Because of the complex weed flora infesting DSR systems, applications of a single POST herbicide often provide suboptimal weed control. Many authors suggested that a single PRE herbicide followed by a single POST herbicide hardly provides satisfactory yields in DSR systems mainly because of the narrow spectrum of herbicide activity (Suria et al., 2011; Chauhan, 2012; Chauhan and Opeña, 2012). For instance, compared with season-long weedy plots, the application of a PRE herbicide followed by a POST herbicide increased rice grain yield by 48–56% in Malaysia (Suria et al., 2011), by 60–82% in Bangladesh (Ahmed and Chauhan, 2014), by 76–84% in the Philippines (Chauhan and Opeña, 2013), and by 80–86% in India (Singh et al., 2006). Therefore, in some situations, a PRE herbicide followed by a POST herbicide followed by one hand-weeding is considered the best weed management option in DSR systems (Mahajan and Timsina, 2011; Anwar et al., 2013; Chauhan and Abugho, 2013).

The availability of agricultural labour is decreasing day by day in Asia, making it difficult in the future to find labourers for hand weeding. Therefore, to eliminate the need for hand weeding, weed control in DSR systems needs the intensive use of herbicides, which is made very possible by the increase in the number of POST herbicides available or by the use of sequential applications of POST herbicides (Rahman et al., 2012; Chauhan et al., 2013; Mahajan and Chauhan, 2013). The strategy of using a mixture of two or more herbicides with different modes of action for weed control has been widely advocated for weed resistance management (Gressel and Segel, 1990; Powles et al., 1997; Friesen et al., 2000; Diggle et al., 2003). Commercial mixtures of herbicides are now available in the market and different compatible herbicides can also be mixed in a tank before application (Lagator et al., 2013).

Although herbicides are essential in DSR systems, the intensive use of herbicides may cause environmental hazards and may result in the evolution of resistant weeds (Karim et al., 2004; Powles and Yu, 2010). Therefore, researchers need to find ways on how to reduce the unwarranted environmental hazards posed by the use of herbicides and how to eliminate labour-intensive manual weeding in DSR systems. One possible option may be to combine herbicide use with mechanical weeding, so that the sole reliance on herbicides or on labour can be minimized. There is very limited literature, however, on the effect of the use of herbicides combined with mechanical weeding on weed management in DSR systems. Therefore, this study was conducted to evaluate the effect of using sole and sequential application of herbicides and mechanical weeding on weed control and rice yield in DSR systems.

2. Materials and methods

Field experiments were conducted during the dry seasons of 2013 (DS13) and 2014 (DS14) at the rice fields of the International Rice Research Institute (IRRI), Los Baños, Philippines to evaluate the effect of using a combination of chemical and mechanical weed control on weed growth and rice grain yield in a DSR system. Soil at the experiment site had a pH of 6.8 and contained organic carbon of 1.02%, available K of 1.13%, available P of 37 mg kg^{-1}, sand of 27%, silt of 44%, and clay of 29%. The experimental site had been under a rice monoculture system for several years.

The field was dry cultivated using a rotavator and then levelled using a steel leveller drawn by a four-wheel tractor. The crop was sown with a 4-wheel tractor-mounted seed-drill at a distance of 20 cm row spacing and a depth of 1–2 cm. The crop was planted on 12 and 19 December in DS13 and DS14, respectively. The rice variety used in the experiments was ‘Rc222’ with a seed rate of 50 kg ha^{-1}. P_2O_5 and K_2O, each at the rate of 40 kg ha^{-1}, were applied before last land preparation. N, as urea, was applied after crop emergence at 180 kg N ha^{-1}in four equal splits, that is, 45 kg N at 14 days after sowing (DAS), 45 kg N at 30 DAS (early tillering), 45 kg N at 60 DAS (panicle initiation), and 45 kg N at 80 DAS (at the start of flowering). The field was surface irrigated immediately after sowing and then as required by the crop.

The weed control treatments used in the study are shown in Table 1. The herbicides were applied using a multi-nozzle (8) boom sprayer that delivered 320 L ha^{-1} of spray solution. Mechanical weeding was done using a rotary weeder in standing water conditions. The experiments in both seasons were arranged in a randomized complete block design with three replications, with the area of the unit plot measuring 24 m^2 (6 m $\times$ 4 m).

The efficacy of the herbicides was evaluated at 28 DAS (before the application of 2,4-D and MW), at 42 DAS (14 d after 2,4-D application and before the second MW), and at start of flowering in rice. At each date, two quadrates of 40 cm $\times$ 40 cm were placed randomly in each plot, and weeds were collected from each quadrate. The collected weeds were clustered by groups (i.e., grass,

Table 1
Weed control treatments used in the study.

Weed control treatments	Dose	Application time
	g ai ha^{-1}	Days after sowing
Oxadiazon fb 2,4-D	750 fb 500	1 fb 28
Oxadiazon fb bispyribac-sodium fb 2,4-D	750 fb 30 fb 500	1 fb 14 fb 28
Oxadiazon fb bispyribac-sodium fb fenoxaprop + ethoxysulfuron fb 2,4-D	750 fb 30 fb 45 fb 500	1 fb 14 fb 21 fb 28
Oxadiazon fb mechanical weeding	750	1 fb 28
Oxadiazon fb mechanical weeding fb mechanical weeding	750	1 fb 28 fb 42
Oxadiazon fb fenoxaprop + ethoxysulfuronfb 2,4-D fb MW	750 fb 45 fb 500	1 fb 21 fb 28 fb 42

Abbreviations: fb, followed by.