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Effect of crop establishment methods and weed control treatments on weed management, and rice yield

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ABSTRACT

Lower water availability coupled with labor shortage has resulted in the increasing inability of growers to cultivate puddled transplanted rice (PTR). A field study was conducted in the wet season of 2012 and dry season of 2013 to evaluate the performance of five rice establishment methods and four weed control treatments on weed management, and rice yield. Grass weeds were higher in dry-seeded rice (DSR) as compared to PTR and nonpuddled transplanted rice (NPTR). The highest total weed density (225–256 plants m^{-2}) and total weed biomass (315–501 g m^{-2}) were recorded in DSR while the lowest (102–129 plants m^{-2} and 75–387 g m^{-2}) in PTR. Compared with the weedy plots, the treatment pretilachlor followed by fenoxaprop plus ethoxysulfuron plus 2,4-D provided excellent weed control. This treatment, however, had a poor performance in NPTR. In both seasons, herbicide efficacy was better in DSR and wet-seeded rice. PTR and DSR produced the maximum rice grain yields. The weed-free plots and herbicide treatments produced 84–614% and 58–504% higher rice grain yield, respectively, than the weedy plots in 2012, and a similar trend was observed in 2013.

1. Introduction

Rice (*Oryza sativa* L.) is consumed as a staple food by more than half of the world's population. In Asia, the major rice production method used is manual transplanting of seedlings into puddled soil. Puddling, a process of cultivating soil in standing water, consumes a large quantity of water (Bouman and Tuong, 2001). However, human population is increasing at an alarming rate and water resources are depleting. Nowadays, water scarcity is a major concern in many regions of the world, as competition between agricultural and industrial consumption of water resources intensifies and climatic unpredictability increases (Hanjar and Quereshi, 2010; Mahajan et al., 2011, 2012). There is a threat that Asian rice growers will probably have inadequate access to irrigation water in the future (Tuong and Bouman, 2003; Mahajan et al., 2013). The scarcity of irrigation water, therefore, threatens the sustainability of rice production in irrigated environments (Chauhan et al., 2012, 2014b). In addition, the migration of rural labor to urban areas, because of industrialization, causes a shortage of labor during the peak season of transplanting in many regions of Asia (Mahajan et al., 2013; Pandey and Velasco, 2005). This results in delays in transplanting, lower grain yield, and delays in planting of the next crop. Puddling also has deteriorating effects on soil structure, which adversely affect the subsequent nonrice crop (Timsina and Connor, 2001).

Several studies in China (Yan et al., 2010), South Asia (Gupta et al., 2002; Malik and Yadav, 2008), and Australia (Beecher et al., 2006) have revealed that rice can be successfully grown using dry seeding. Dry-seeded rice (DSR) has been developed as an alternative method of rice establishment that reduces labor requirements and other inputs while increasing or maintaining economic productivity and alleviating soil degradation problems (Ladha et al., 2009; Farooq et al., 2011). However, some studies reported a reduction in yield when shifting from puddled transplanted rice (PTR) to DSR using alternate wetting and drying (AWD) water management (Bhushan et al., 2007; Choudhury et al., 2007). The yield reductions were related to the management practices applied and the climatic conditions in the planting site (Belder et al., 2004; Gathala et al., 2006; Kato et al., 2009; Singh et al., 2011).

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DSR can be sown after conventional tillage or under zero-till conditions (Chauhan and Opeña, 2012). Zero-till systems require less labor and fuel compared with conventional tillage systems (Chauhan and Johnson, 2009). The sustainability of DSR, however, is endangered by heavy weed infestations (Chauhan, 2012; Mahajan et al., 2013). Weed control is particularly challenging in DSR systems because of the diversity and severity of weed infestation, the absence of standing water layer to suppress weeds at the time of rice emergence, and no seedling size advantage of rice over the weed seedlings as both emerge simultaneously. In DSR systems, land preparation operations influence weed seed distribution in the soil profile and the comparative abundance of weed species (Chauhan and Opeña, 2012).

The shifts in weed flora composition in agricultural cropping systems have been widely documented. These changes resulted from selection pressures imposed by modifications and innovations in agricultural technologies, which have altered weed habitats to some extent (Haas and Streibig, 1982; Hall et al., 2000). Differences in weed flora also depend on the rice establishment method used. A large number of perennial species [*Paspalum distichum* L., *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L.] as well as annual grasses (*Ischaemum rugosum* Salisb.) and annual sedges [*Cyperus difformis* L. and *Fimbristylis miliacea* (L.) Vahl] were found in conventional-till DSR systems (Timsina et al., 2010). In the same study, less growth of perennial weeds (*C. dactylon, P. distichum*, and *C. rotundus*) and annual weeds (*I. rugosum* and *F. miliacea*) was observed in the zero-till DSR system compared with the conventional-till DSR system. In another study in DSR, *Echinochloa crus-galli* (L.) P. Beauv. appeared after three successive seasons, followed by *Leptochloa chinensis* (L.) Nees (after 10 consecutive seasons), *I. rugosum* (after 14 consecutive seasons), and weedy rice (after 20 consecutive seasons) (Ho, 1996).

In Asia, hand weeding and herbicides are used to control weeds, but manual weeding is becoming less common because of labor scarcity and its high cost. The use of herbicides in rice has increased because it saves labor and is less costly, and the herbicides are easy to apply. The use of a single herbicide, however, does not provide effective weed control in DSR because of the complex mixture of weed species (Chauhan, 2012). Previous research showed that cultural practices such as seeding method, land cultivation, and water and fertilizer management affected weed flora and weed infestations in DSR (Moody, 1993; Bhagat et al., 1999; Tuong et al., 2000; Phuong et al., 2005).

There are some aspects of alternative rice establishment technologies that are not yet well-understood, especially in relation to studies addressing a systematic comparison of weed infestation, weed control efficiency, and rice yield in transplanted rice (puddled and nonpuddled), WSR (puddled and nonpuddled), and DSR. We hypothesized that modifications and innovations of agricultural technologies, such as land preparation operations, establishment methods, and weed control methods, have different effects on weed flora composition and rice productivity. Therefore, a study was conducted at the farm of the International Rice Research Institute to evaluate the effect of different rice establishment methods and weed control treatments on weed emergence, weed growth, and rice yield.

2. Material and methods

2.1. Experimental site

Experiments were conducted at a farm at the International Rice Research Institute (IRRI), Los Baños (14′13°N, 121′13°E, 23 m above sea level), Philippines, during the wet season (WS) of 2012 and the dry season (DS) of 2013. The soil at the site was clay loam with 0.9% organic carbon and 6.1 pH (Sudhir-Yadav Evangelista et al., 2014).

2.2. Experimental design

The experiment was laid out in a split-plot design with three replications. Five rice establishment methods in the main plots and four weed control treatments in the subplots were evaluated in both seasons. The rice establishment methods involved a combination of tillage treatments (puddled or dry tilled) and planting methods (transplanting or direct seeding) as follows: (1) PTR (20 × 20 cm), (2) nonpuddled transplanted rice (NPTR) (20 × 20 cm), (3) surface-seeded rice on puddled soil using a drum seeder (wet-seeded rice, WSR), (4) surface-seeded rice on nonpuddled soil using a drum seeder (nonpuddled wet-seeded rice, NWSR), and (5) DSR in dry cultivated soil. The four weed control treatments were (1) pretilachlor (600 g a.i. ha^{-1} in DSR and 300 g a.i. ha^{-1} in other establishment methods) applied at two days after sowing (DAS) in DSR and two days after transplanting (DAT) in transplanted rice followed by fenoxaprop plus ethoxysulfuron (0.045 kg a.i. ha^{-1}) tank mixed with 2,4-D (0.5 kg a.i. ha^{-1}) at 21 DAS/DAT, (2) pretilachlor (600 g a.i. ha^{-1} in DSR and 300 g a.i. ha^{-1} in other establishment methods) followed by fenoxaprop plus ethoxysulfuron (0.045 kg a.i. ha^{-1}) at 21 DAS/DAT, (3) weedy, and (4) weed-free. In the weedy plots, weeds were not removed. However, weed inflorescences were removed to avoid addition of weed seeds in the seed bank. In the weed-free plots, weeds were controlled using weed control treatment (1) plus hand weedings, whenever needed.

2.3. Crop management

Prior to the 2012 WS experiment, the land was dry cultivated using a twin-axle tractor with discings followed by two passes of a tractor-mounted rotavator. For the puddled treatments, the soil was irrigated three days before puddling (three passes) using a power tiller. The test variety used in this study was NSIC Rc222 (IR154), a short duration (110 d) variety. DSR was sown on 17 May 2012 (2012 WS) and 2 December 2012 (2013 DS). The rice seeds were sown at 45 kg ha^{-1} with a 4-wheel tractor-drawn seed drill at a row spacing of 20 cm and depths of 1–2 cm. For all establishment methods except DSR, the seeds were soaked in water for 24 h. The seeds were then incubated for 8-10 hours prior to sowing by a drum-seeder on puddled (WSR) and nonpuddled soil (NWSR), and on the seedbed for raising nursery for the transplanted treatments. The 17-day-old seedlings were transplanted at 20 cm × 20 cm geometry on well-puddled soil.

All treatments received a basal fertilizer application (30 kg P ha^{-1} as single super phosphate, 30 kg K ha^{-1} as muriate of potash, and 15 kg Zn ha^{-1} as zinc sulphate) prior to the last cultivation/puddling. Nitrogen in the form of urea was applied at 200 kg ha^{-1} in four splits at 15, 31, 45, and 60 DAS/DAT. Urea was applied on the soil when there was no standing water. Immediately after broadcasting of urea, irrigation was applied. The herbicides were applied with a knapsack sprayer having a delivery of about 320 L ha^{-1} of spray solution through a flat fan nozzle at a spray pressure of 140 kPa.

The soil was kept near saturation from sowing to 21 DAS in the direct-seeded plots, while it was kept under flooded conditions (2–3 cm) from transplanting to 8 DAT in the transplanted plots. The plots were then kept under AWD conditions and irrigation was applied when soil water tension had increased to 10 kPa at 15 cm soil depth, at an average of three replications.