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Effect of tillage systems, seeding rates, and herbicides on weed growth and grain yield in dry-seeded rice systems in the Philippines

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ABSTRACT

In Asia, dry-seeded rice (DSR) production systems are increasing because of water and labour scarcities. DSR can be sown under zero-till (ZT) or after conventional tillage (CONT) operations. In these seeding systems, however, weeds are the main biological constraint. A study was conducted during the wet season of 2012 and the dry season of 2013 at the International Rice Research Institute to evaluate the effect of the tillage systems (ZT and CONT), seeding rate [low seeding rate (LSR) at 50 kg ha^{-1}, and high seeding rate (HSR) at 100 kg ha^{-1}], and weed control treatments (oxadiazon applied as pre-emergence, oxadiazon applied as pre-emergence followed by a commercial mixture of fenoxaprop + ethoxysulfuron as post-emergence at 21–24 days after sowing, and weedy) on weed growth and grain yield in DSR systems. The efficacy of herbicides 14 days after the application of post-emergence herbicide was similar between the tillage systems and between seeding rates. At crop harvest, weed biomass was higher in the ZT plots than in the CONT plots, and higher at LSR than at HSR. At the same time, herbicide applications decreased weed biomass by 73–96%, compared with the weedy plots. Compared with the ZT plots, CONT plots had 9–18% higher grain yield. Similarly, plots sown at HSR had 17–19% higher grain yield than at LSR. Weedy plots had 81–84% less yield than the herbicide-treated plots (3060–3380 kg ha^{-1} in the wet season and 5820–5950 kg ha^{-1} in the dry season).

1. Introduction

Rice (*Oryza sativa* L.) is an important food crop in Asia, where it is grown mainly by manual transplanting of seedlings into puddled soil; intensive tillage in wet conditions referred to as *puddling*, which consumes a large amount of water (Bouman and Tuong, 2001). Water scarcity is a concern in many regions, as competition between industrial and agricultural users of water resources intensifies and climatic variability increases (Alberto et al., 2013; Hanjar and Quereshi, 2010). In the future, Asian rice farmers will likely have limited access to irrigation water (Mahajan et al., 2013; Tuong and Bouman, 2003). Water scarcity, therefore, threatens the sustainability of rice production in irrigated environments (Chauhan et al., 2012a). In many regions of Asia, labour availability for transplanting is also a concern because of increasing wage resulting from migration of labour from rural to urban areas (Mahajan et al., 2013; Pandey and Velasco, 2005).

One approach in reducing labour and water demand is dry seeding of rice, which has been practiced historically in rainfed environments (De Datta, 1986). Dry-seeded rice (DSR) is less labour- and water-intensive, easy and faster to plant, and conducive to mechanization (Chauhan, 2012). DSR can be sown after conventional tillage (CONT) operations or under zero-till (ZT) conditions (Chauhan and Johnson, 2009; Chauhan and Opeña, 2012). ZT systems require less labour and fuel compared with CONT systems (Chauhan et al., 2012b). The sustainability of DSR systems, however, is threatened by heavy weed infestation as these systems are prone to weed competition (Chauhan, 2012; Mahajan et al., 2013). Weed control is particularly challenging in DSR systems because of the diversity of weeds and the severity of infestation; the absence of standing water to suppress weeds at the time of crop emergence; and the absence of a seedling-size advantage between rice and weed seedlings, as both emerge simultaneously.

As mentioned previously, DSR can be grown in ZT or CONT systems. Different tillage operations, however, influence vertical weed seed distribution in the soil profile and the relative abundance of weed species (Chauhan and Johnson, 2009; Chauhan and Opeña, 2012; Froud-Williams et al., 1981). Weeds can reduce grain yield more in ZT systems than in CONT systems. In a recent study,

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Table 1
Effect of seeding rate (HSR 100 kg ha^{-1} and LSR at 50 kg ha^{-1}) and weed control treatments (PRE, PRE fb POST, and weedy) on total weed density before the application of POST and 14 days after the application of POST in the wet season of 2012 (WS12) and dry season of 2013 (DS13).

Seeding rate	Weed density (no. m^{-2})					
	WS12			DS13		
	PRE	PRE fb POST	Weedy	PRE	PRE fb POST	Weedy
Before application of POST herbicide						
HSR	57	37	195	33	4	726
LSR	16	46	379	48	12	911
LSD (same level of WCT)	77			108		
LSD (same level of seeding rate)	81			127		
14 days after application of POST herbicide						
HSR	57	39	216	35	11	710
LSR	45	36	326	42	18	899
LSD (same level of WCT)	84			169		
LSD (same level of seeding rate)	86			145		

Abbreviations: HSR – high seeding rate at 100 kg ha^{-1}; LSR – low seeding rate at 50 kg ha^{-1}; WCT – weed control treatments; PRE - oxadiazon applied as pre-emergence; PRE fb POST – oxadiazon applied as PRE followed by fenoxaprop + ethoxysulfuron applied as post-emergence.

for example, grain yield in the ZT-DSR weedy check plots was 0.9–1.5 t ha^{-1} less than in the CONT-DSR weedy check plots (Chauhan and Opeña, 2012).

In Asia, manual weeding and herbicides are used to manage weeds, but manual weeding is becoming less popular because of labour scarcity. Herbicide use has therefore increased in DSR systems because it is easy in application, saves on labour, and costs less. The use of single herbicides, however, does not provide effective weed control in DSR systems and may result in shifts in problematic weed species (Chauhan, 2012; Singh, 2008). The adoption of an approach that integrates available weed management practices has been advocated to combat weed problem in DSR systems (Azmi et al., 2005; Chauhan et al., 2011; Mahajan and Chauhan, 2013). An approach that can be integrated with herbicide use is adjusting crop plant population density (Chauhan et al., 2011; Gibson et al., 2002).

Previous research in rice and wheat (*Triticum aestivum* L.) has shown that increased crop seeding rates improve the crop's ability to suppress weeds (Olsen et al., 2005; Zhao et al., 2007). A recent study in the Philippines and India showed that maximum grain yield in the presence of weeds was achieved at 95–125 kg seed ha^{-1} (Chauhan et al., 2011). However, grain yield in weed-free conditions was relatively less affected by seeding rates within the range of 15–125 kg ha^{-1}. Seeding rate was found to affect rice-weed competition in DSR systems, but no literature was available on the integrated effect of tillage systems, seeding rates, and herbicides on weed growth and grain yield in DSR systems.

This study was conducted at the research farm of the International Rice Research Institute (IRRI) to evaluate the effect of tillage systems, seeding rates, and herbicides on weed emergence, weed growth, and grain yield in DSR systems.

2. Materials and methods

2.1. Description of the experiment

A field study was conducted during the wet season (May 2012–September 2012) of 2012 (WS12) and the dry season (December 2012–April 2013) of 2013 (DS13) at the IRRI research farm in Los Baños, Philippines. Soil at the site had a pH of 6.8, sand of 28%, silt of 43%, and clay of 29%. The experiments were arranged in a split–split plot design with tillage systems as the main plots, seeding rates as the subplots, and weed control treatments as the sub–sub plots. The experiment had four replications in each season. The area of each sub–sub plot was 27.3 m^2 (13 m × 2.1 m), and tillage systems were CONT and ZT.

In the CONT plots, two pre-sowing tillage (using a disc-harrow) were done to a depth of 10–15 cm, whereas soil disturbance in the ZT plots was limited to the sowing operation only. Glyphosate at 0.75 kg a.e. ha^{-1} plus 2, 4-D at 0.4 kg a.e. ha^{-1} were applied 3–4

Table 2
Effect of seeding rate (HSR at 100 kg ha^{-1}; LSR at 50 kg ha^{-1}) and weed control treatments (PRE, PRE fb POST, and weedy) on total weed biomass before the application of POST and 14 days after the application of POST in the wet season of 2012 (WS12) and dry season of 2013 (DS13).

Seeding rate	Weed biomass (g m^{-2})					
	WS12			DS13		
	PRE	PRE fb POST	Weedy	PRE	PRE fb POST	Weedy
Before application of POST herbicide						
HSR	2.1	2.0	9.5	2.1	2.2	56.0
LSR	1.7	2.5	13.3	3.2	2.3	70.0
LSD (same level of WCT)	3.3			4.3		
LSD (same level of seeding rate)	3.7			4.5		
14 days after application of POST herbicide						
HSR	6.3	4.3	47.3	2.9	1.5	156.8
LSR	7.4	6.7	82.7	5.8	3.5	211.0
LSD (same level of WCT)	16.3			16.6		
LSD (same level of seeding rate)	16.7			16.9		

Abbreviations: HSR – high seeding rate at 100 kg ha^{-1}; LSR – low seeding rate at 50 kg ha^{-1}; WCT – weed control treatments; PRE – oxadiazon applied as pre-emergence; PRE fb POST – oxadiazon applied as PRE followed by fenoxaprop + ethoxysulfuron applied as post-emergence.