Crop Protection 66 (2014) 80–85

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

The critical period for weed control in dry-seeded rice

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ARTICLE INFO

Article history:
Received 2 May 2014
Received in revised form
24 July 2014
Accepted 13 August 2014
Available online

Keywords:
Critical weed-free period
Weed competition
Weed infestation
Dry-seeded rice
Cultivar

ABSTRACT

The critical crop-weed competition period in a dry-seeded rice system is an important consideration in formulating weed management strategies. Field experiments were conducted in the summer seasons of 2012 and 2013 at the Punjab Agricultural University, Ludhiana, India, to determine the extent of yield loss in two different rice cultivars (PR 114 and PR 115) with different periods of weed interference. Twelve weed control timings were used to identify critical periods of weed competition in dry-seeded rice. PR 114, a long-duration rice cultivar (145 d) having slower initial growth than PR 115 (125 d), was more prone to yield losses. In both years, 100% yield loss was observed where weeds were not controlled throughout the season. In weed-free plots, the grain yield of PR 114 was 6.39–6.80 t ha^{-1}, for PR 115, it was 6.49–6.87 t ha^{-1}. Gompertz and logistic equations fitted to yield data in response to increasing periods of weed control and weed interference showed that, PR 114 had longer critical periods than PR 115. Critical weed-free periods to achieve 95% of weed-free yield for PR 114 was longer than for PR 115 by 31 days in 2012 and 26 days in 2013. Weed infestation also influenced the duration of critical periods. Higher weed pressure in 2012 than in 2013 increased the duration of the critical period of crop-weed competition in that year. The identification of critical crop-weed competition periods for different cultivars will facilitate improved decision-making regarding the timing of weed control and the adoption of cultivars having high weed-suppressing abilities. This will also contribute to the development of integrated weed management in dry-seeded rice systems.

1. Introduction

Food security, among other things, also depends on the ability to increase food production with decreasing water availability. Rice, as a submerged crop, is a prime target for water conservation. In Asia, more than 80% of developed fresh water resources are used for irrigation, about half of which is used for rice production (Dawe et al., 1998). Moreover, about 90% of the world's rice is grown and produced in Asia (FAO, 2009). Rapidly depleting water resources threaten the sustainability of irrigated rice, and hence, food security (Tuong et al., 2004). Thus, a shift toward aerobic rice systems can play a key role in increasing rice production globally without depleting water resources further.

Despite the benefits of these systems, weed infestation continues to be a serious problem in dry-seeded rice (DSR) systems. Aerobic soil conditions and dry-tillage practices, besides alternate wetting and drying, make these systems more conducive for the germination and growth of highly competitive weeds, which cause high grain yield losses (Elliot et al., 1984; Fujisaka et al., 1993). The DSR crop is subjected to greater weed competition for various growth resources—nutrients, light, and space—than transplanted rice, because both crop and weed seedlings emerge at the same time. In DSR systems, weeds can reduce yield by 50–100%, depending on the weed infestation level. Thus, considerable yield increase can be achieved by controlling weeds in these aerobic rice systems (Haefele et al., 2000).

The extent of yield loss varies, depending on cultural methods, rice cultivars, and the weed species associated, their density, and duration of competition. Herbicides are considered to be an economical alternative to manage weeds compared to hand weeding, which becomes costlier and more impractical because of the non-availability of labour during the critical period of weeding. Also, weeds emerge earlier in DSR, starting competition at the early stages of crop growth. Furthermore, weeds emerge in flushes due to the continuous moist condition of the soil. Herbicides applied pre-emergence failed to manage later-emerging weeds, necessitating the use of post-emergence herbicides or hand weeding. The timing of herbicide application or any weed control measure should be

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http://dx.doi.org/10.1016/j.cropro.2014.08.009
0261-2194/

carefully adjusted so as to manage weeds effectively during the critical period of crop-weed competition. Thus, to formulate an effective and economical weed management program for aerobic rice systems, it is essential to establish a critical duration of crop-weed competition and a limit for the acceptable presence of weeds.

The competition offered by the crop can affect the degree of weed control achieved by other methods or herbicides. It has been estimated that enhancing crop competitiveness against weeds could reduce weed control costs by 30% (Sanint et al., 1998). Recently, interest has been increasing in the application of cultural approaches in integrated weed management systems (Mortensen et al., 1998; Gibson et al., 2002; Chauhan et al., 2010). Genetic variations in rice cultivars exist with respect to competitive ability against weeds (Fischer et al., 2001; Haefele et al., 2004). Crop competitiveness may be judged by either crop tolerance (the ability to maintain grain yield in the presence of weeds), weed suppression (the ability to reduce weed biomass and weed seed production), or both (Jannick et al., 2000). Harnessing competitiveness as a weed control measure for DSR may be achieved by focusing on both early vigour as well as traits influencing competitiveness throughout the growth cycle. Rice cultivars with weed-suppressing traits are an important aspect of weed management in DSR. Tall and fast-growing traditional rice cultivars are more competitive with weeds than dwarf cultivars (Kawano et al., 1974). Vegetative vigour, at 2 weeks after seeding, and weed-free yield, accounted for 87% of the variation in yield between cultivars in competition with weeds. These two traits could be efficient means of indirect selection for improving rice yield in the midst of weed competition (Zhao et al., 2006). In a study at Karnal, Haryana, India, *Echinochloa crus-galli* showed higher biomass accumulation and plant height with respect to rice genotype Govind; these were lowest in DRRH-1, indicating differences in rice genotypes in terms of weed-suppressing ability (Dhawan et al., 2003). Such competing varieties may interact with weeds, exhibiting different critical crop-weed interference periods.

Crop competitiveness with weeds, exploited through narrow row spacing (Kristensen et al., 2008; Chauhan and Johnson, 2010a), has been reported to decrease the duration of the critical crop-weed competition period (Chauhan and Johnson, 2011). In a recent study, increasing periods of weed interference significantly reduced grain yield in DSR, with a delay of weed control from 14 to 56 DAS resulting in a loss of 47–66 kg grain ha^{-1} day^{-1} (Chauhan and Johnson, 2011). In lowland irrigated rice in the Sahel (West Africa), critical periods for weed control to obtain 95% yield from weed-free plots were estimated to be 29–32 days after sowing (DAS) in the wet season, and 4-83 DAS in the dry season (Johnson et al., 2004). Some studies were conducted on critical weed-free periods in transplanted rice in India, but this important information is still lacking in the context of DSR, the area under which is increasing. Also, selection of cultivars has not been exploited for managing weeds and evaluating their role in decreasing the critical weed-free period in DSR. A study done for the first time was conducted to determine the critical crop weed-free periods for different rice cultivars, which would have significant implications for weed management in aerobic rice systems.

2. Materials and methods

2.1. Description of the experiment

A field experiment was done during the summer seasons of 2012 and 2013 at the Punjab Agricultural University, Ludhiana, India. The soil at the site had pH 7.3, 82.3% sand, 10.6% silt, and 7.1% clay, with available N, P, and K of 182, 13, and 145 kg ha^{-1}, respectively. The experiment was laid out in a split-plot design with two cultivars (PR 114, with 145 d duration; and PR 115, with 125 d duration) in the main plots and 12 weed control timings (WCT) [weedy until 14, 28, 42, 56, and 70 days after sowing (DAS) and until crop harvest; and weed-free until 14, 28, 42, 56, and 70 DAS and until crop harvest] in the sub-plots. The field was prepared by giving four ploughings followed by planking and sowing of rice with a conventional rice seed-drill. Rice was planted on May 29, 2012 and June 6, 2013 at a seed rate of 25 kg ha^{-1} in 20-cm wide rows. P_2O_5, K_2O, and Zn were applied uniformly before the planking operation through the use of diammonium phosphate (DAP), muriate of potash (MOP), and zinc sulphate ($ZnSO_4$) at 55, 42, and 65 kg ha^{-1}, respectively. Nitrogen at 150 kg ha^{-1} was applied through urea in four equal splits at 14, 28, 49, and 70 DAS. The field was surface irrigated immediately after sowing and was kept moist throughout the season; irrigation was stopped two weeks before crop harvest. Weeds were removed by hand hoeing according to the treatments, and at weekly intervals thereafter.

2.2. Data collection

Weeds in the weedy plots, kept for different periods, were sampled from two quadrats of 40 cm $\times$ 40 cm at the time of weed removal (as per the treatment). The same size was used to sample weeds at harvest from the plots that were kept weed-free for different periods (after, Chauhan and Johnson, 2011). Weed biomass (grasses, broadleaved and sedges) was recorded after drying weed samples at 70 °C in an oven for 72 h. The crop was harvested on October 3, 2012 and October 17, 2013. The harvested area for grain yield was 5.4 m^2 during both years. Grain yield was converted to t ha^{-1} and adjusted at 14% moisture content.

2.3. Statistical analyses

The curves for estimating the critical period of crop-weed competition were fitted using SigmaPlot 12.5. The form of the Gompertz equation was used to model the effect of the weed-free period on grain yield, whereas the logistic equation was used to model the influence of weed duration on yield during both years. Critical periods for 95% of the maximum yield were obtained from the fitted curves. Linear regression plots were prepared for the study of the relation between weed biomass of different weed categories and rice grain yield.

3. Results

3.1. Rice grain yield

Weed competition throughout the crop duration resulted in 100% yield loss in both rice cultivars compared to weed-free conditions, in which yield was 6.39–6.80 t ha^{-1} for cultivar PR 114 and 6.49–6.87 t ha^{-1} for PR 115 (data not shown). The Gompertz equation (fitted for increasing period of weed control) and logistic equation (fitted for increasing period of weed competition) accounted for more than 97% of the variation in rice grain yield in both cultivars (Fig. 1; Table 1). The Gompertz equation indicates that the duration of the weed-free period required for a particular level of yield loss was more in cultivar PR 114. Similarly, the logistic equation showed that the length of the period up to which weeds could remain in the crop for a particular level of yield loss would be less in rice cultivar PR 114. This implies that rice cultivar PR 114 will require early weeding, as compared with rice cultivar PR 115. Combining the inference from both the curves in Fig. 1, it was found that for a permissible yield loss of 5%, rice cultivar PR 114 required longer weed-free periods from 11.8 to 83.2 days and 12.9–68.2 days