

[Short Report]

Genotypic Variation in Ability to Recover from Weed Competition at Early Vegetative Stage in Upland Rice

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Abstract: In northern Laos, weeds are a major constraint to upland rice production in slash-and-burn systems. Two experiments were conducted to assess genotypic variation in ability to recover from weed competition at the early vegetative stage. Three traditional and two improved (IR 55423-01 and B6144F-MR-6-0-0) cultivars were grown with or without maize as an artificial weed. Maize was seeded at the same time as rice and removed at 37 d after rice sowing. The two improved cultivars out-yielded the traditional cultivars without weed competition. Larger yield loss due to the competition was associated with longer delay in days to flowering and smaller plant height at 37 d after sowing. The use of B6144F-MR-6-0-0 with high yield potential as well as strong ability to recover from weed competition appears to improve and stabilize rice productivity in this region.

Key words: Improved cultivar, Laos, Recover from weed competition, Slash-and-burn, Traditional cultivar, Upland rice.

In northern Laos, upland rice is typically grown in slash-and-burn systems by resource-poor farmers for subsistence. It yields an average of 1.7 t ha⁻¹ and accounts for about half of the total rice growing area in the region (National Statistical Center, 2004). Weeds are a major constraint to upland rice production (Fujisaka, 1991; Roder et al., 1997). Dominant weed species in this region are *Chromolaena odorata* (L.) King and Robinson, *Ageratum conyzoides* L., *Comelina* spp. *Lygodium flexuosum* (L.) Sw., *Panicum trichoides* Sw., *Corchorus* spp. (Roder et al., 1995, 1997). The farmer relies largely on hand weeding in combination with the use of traditional cultivars with a large stature, which are considered to be strong competitors against weeds (Roder et al., 1996). Improved cultivars with a small stature have not been considered to be feasible since a larger input for weeding and others such as inorganic fertilizer may be required. Consequently, no improved upland rice cultivars have been released in this region (Saito et al., 2007). The labor requirement for weeding is typically 150 d ha⁻¹ and about 50% of the total labor input (Roder et al., 1997; Saito et al., 2006a). Saito et al. (2006a) reported that in the first two months of the rice growing season, the total labor input was 107 d ha⁻¹,

indicating that two persons have to weed continuously during the first two months (average field size is about 1 ha for rice). The two months after rice seeding include a highly critical period for weed competition, when weeds have the greatest effect on rice growth (van Heemst, 1985;



Fig. 1. Delayed weeding due to limited labor availability at farmer's upland rice field in northern Laos (right side). Left side, weeding had yet to be finished. This photograph was taken in Pak Ou district, Luang Prabang province in 2001.

Johnson et al., 2004; Dzomeku et al., 2007). During this period, most farmers generally provide adequate weed control, but sometimes weeding is delayed due to limited labor availability. Fig. 1 shows the effect of delayed weeding on rice growth in farmer's field in this region. When strong competition with weeds happens in rice, flowering is delayed and yield is reduced (Fukai, 1999; Johnson et al., 2004).

One of the options to reduce the negative impact of heavy weed infestation at the early vegetative stage on rice productivity is the use of cultivars with superior ability to recover from weed competition (Fukai, 1999). Ability of crops to recover from weed competition is a function of the ability to maintain high yields despite the severe competition against weeds at the early vegetative stage. Difference in the ability can be shown by the difference in crop yield between plots with and without competition. Genotypic variation of upland rice in competitiveness against weeds has been reported (Kawano et al., 1974; Garrity et al., 1992; Johnson et al., 1998; Dingkuhn et al., 1999; Fofana and Rauber, 1999; Fischer et al., 2001; Koarai and Morita, 2003; Zhao et al., 2006). Most of the previous studies have focused on weed suppression ability during the period from the late vegetative through the reproductive stages. Difference in weed suppressive ability can be determined by assessing weed biomass in plots under weed competition. Rice cultivars that can suppress weeds are often thought to have rapid early growth in height, leaf area and tillers (Kawano et al., 1974; Dingkuhn et al., 1999; Koarai and Morita, 2003; Zhao et al., 2006). However, information is limited on genotypic variation in ability to recover from weed competition at the early vegetative growth of upland rice. To our knowledge, only Dingkuhn et al. (1999), who used maize as an artificial weed, reported the genotypic variation and indicated that crop growth duration and tiller number were related to the ability.

The objectives of this study are, therefore, to assess genotypic variation in ability to recover from weed competition at the early vegetative stage using both traditional and improved cultivars and to examine if improved cultivars differ from traditional cultivars in recovering ability.

Materials and Methods

A rainfed upland rice experiment was conducted during the 2005 wet season at Northern Regional Agriculture Forestry Research Center (NAFRc, 19° 44' N, 340 m asl.) and farmer's field at Mout village (Mout, 19° 49' N, 325 m asl.) in Luang Prabang province in northern Laos. This province has the highest proportion of upland rice cultivation in the country, with about 70% of the total rice area being used for upland rice. Average annual rainfall is about 1300 mm but is erratic, and about 80% of rainfall

occurs from May to October which is the main growing season. Weather data were recorded in NAFReC, and reported by Saito et al. (2007). During the 2005 wet season, rainfall was adequate for upland rice cultivation without any extended dry spells. In NAFReC, upland rice was grown continuously in the two wet seasons prior to the experiment, while maize was grown in the previous wet season in Mout. Soil chemical properties at both sites were reported by Saito et al. (2007). The chemical analysis of topsoil in the 0 to 15 cm range in NAFReC showed pH (H₂O) of 5.4 (a 1:1 ratio of soil/water), total C content of 13 g kg⁻¹, total N of 1.9 g kg⁻¹, extractable P of 5 mg kg⁻¹ (Bray1) and available N of 17 mg kg⁻¹. The chemical analysis of the topsoil in Mout showed a pH of 6.0, total C content of 12 g kg⁻¹, total N of 1.6 g kg⁻¹, extractable P of 58 mg kg⁻¹ and available N of 14 mg kg⁻¹.

Each trial was conducted on a level area, and the soils were tilled before sowing. Five upland rice cultivars were grown with or without weed competition. Maize (Pacific 984) was used as an artificial weed, following Dingkuhn et al. (1999), since natural weed infestation is generally heterogeneous, as reported by Johnson et al. (1998). Maize was seeded at the same time as rice in order to simulate intense initial competition for resources and place uniform weed competition stress on rice plants, and removed at 37 d after rice sowing (DAS). The experiment was designed with two weed management treatments (with and without competition against maize; main-plot) and five cultivars (sub-plot) in a split-plot design with four replications in each site. The five cultivars included three traditional cultivars from northern Laos (Vieng, Nok, and Makhinsung), one improved cultivar from the Philippines (IR 55423-01) and one from Indonesia (B6144F-MR-6-0-0). Sub-plot size was 2 by 3 m. Rice and maize were planted with a dibble stick as is the traditional practice at a hill spacing of 0.25 by 0.25 m with about six and three seeds in each hill, respectively. Each maize hill was equidistantly about 0.18 m away from the four surrounding rice hills. Planting date was 20–21 May. Fertilizer (N-P-K 40-17-33 kg ha⁻¹) was applied at 30 DAS. Weeds were controlled by hand when necessary.

Tiller number, plant height and total dry matter weight (TDM) were recorded for eight rice hills in each plot at 37 DAS. TDM of maize was measured for the whole plots after removing one border row on each side of the sub-plot. At maturity, grain yields were measured for 2.25 m² (grain yields are reported at 14% moisture). Eight rice hills were randomly sampled from inside the harvested area for the determination of plant height, panicle number, and grain and straw dry weight. Harvest index (HI) was calculated from grain and straw dry weight.

Analysis of variance was conducted on the combined data set across the two sites for grain yield, TDM, HI, days to flowering, plant height, and tiller and panicle number

Table 1. F-ratios for plant height, tiller number and total dry matter weight (TDM) at 37 d after sowing (DAS), grain yield, TDM at maturity, harvest index, panicle number and days to flowering of five cultivars grown in cultivar and weed management experiment conducted at two sites in Laos in 2005.

	Degrees of freedom	Height at 37 DAS	Tiller number at 37 DAS	TDM at 37 DAS	Grain yield	TDM at maturity	Harvest index	Panicle number	Days to flowering
Site (S)	1	28.60**	2.95 ns	22.68**	141.09**	98.60**	0.68ns	47.26**	107.50**
Weed management (T)	1	38.28**	64.87**	310.09**	2.00 ns	51.39**	44.12**	25.13**	6.35*
S × T	1	26.81**	0.09ns	36.30**	3.31 ns	1.32 ns	8.93*	2.06 ns	0.39 ns
Cultivar (C)	4	40.00**	19.84**	4.51**	53.04**	13.71**	28.86**	56.68**	15.85**
C × S	4	2.73*	1.13 ns	3.29*	1.14 ns	3.07*	2.25 ns	3.36*	3.15*
C × T	4	0.33 ns	3.96**	1.79 ns	4.13**	1.94 ns	3.31*	2.94*	4.35**
C × S × T	4	4.21**	1.54 ns	3.12*	1.17 ns	2.08 ns	1.21 ns	0.61 ns	0.46 ns

* indicates significance of the F test at $p=0.05$.

** indicates significance of the F test at $p=0.01$.

ns, not significant.

Table 2. Plant height, tiller number and total dry matter weight (TDM) at 37 d after sowing (DAS), grain yield, TDM at maturity, harvest index, panicle number and days to flowering of five cultivars grown with and without weed competition at two sites in Laos in 2005.

	Height at 37 DAS (cm)	Tiller number m^{-2} at 37 DAS	TDM at 37 DAS ($t ha^{-1}$)	Grain yield ($t ha^{-1}$)	TDM at maturity ($t ha^{-1}$)	Harvest index	Panicle number m^{-2}	Days to flowering
<i>Weed management</i>								
Rice monoculture (without competition)	53	209	0.43	2.86	7.8	0.31	171	104.0
Weed competition	47	140	0.14	2.65	6.0	0.38	150	107.0
LSD(0.05, main weed management effect)	2.3	20.9	0.041	ns	0.62	0.025	9.9	2.84
<i>Rice monoculture (without competition)</i>								
Vieng	53	168	0.36	2.35	6.8	0.30	136	105.1
Nok	58	154	0.43	1.99	6.7	0.27	123	101.4
Makhinsung	60	203	0.55	2.17	7.2	0.26	117	111.9
IR 55423-01	43	236	0.38	4.04	8.9	0.40	218	98.5
B6144F-MR-6-0-0	50	283	0.46	3.76	9.5	0.34	259	103.3
<i>Weed competition</i>								
Vieng	46	134	0.13	2.09	5.7	0.33	130	107.3
Nok	52	115	0.13	2.16	5.0	0.37	109	102.1
Makhinsung	55	135	0.16	2.37	6.0	0.34	125	112.9
IR 55423-01	39	138	0.10	3.16	6.4	0.44	174	109.1
B6144F-MR-6-0-0	44	177	0.16	3.47	6.8	0.43	213	103.4
LSD(0.05, cultivar by weed management interaction effect)	ns	33.3	ns	0.432	ns	0.039	28.3	4.21

(IRRI, 2003), following Gomez and Gomez (1984; page 339-350). In this analysis, we considered the effects of site, cultivar, and weed management fixed, while the effect of replication random. Mean comparison was made using LSD, only when the F test for treatment effect was significant.

Results

The mean grain yields of five cultivars without

competition were 2.23 and 3.49 $t ha^{-1}$ in NAFReC and Mout, respectively. Higher grain yield in Mout was associated with higher extractable soil P, a finding that is consistent with others (George et al., 2001; Saito et al., 2006b, 2007). Height of maize was more than 100 cm at 37 DAS, and much higher than that of rice. TDM of maize at 37 DAS was 2.5 and 3.0 $t ha^{-1}$ in NAFReC and Mout, respectively. There was no significant effect of cultivar on TDM of maize (data not shown).

The effect of site on all the traits evaluated in this study, except for tiller number at 37 DAS and HI was significant ($P < 0.01$). Cultivar by site interaction effect did not reach significance at $P = 0.01$ for all the traits (Table 1); therefore, all the traits were averaged across two sites (Table 2). The effect of weed management treatment reached significance at $P = 0.01$ for all the traits except for grain yield and days to flowering (Table 1). The competition reduced mean plant height, tiller number and TDM at 37 DAS of five cultivars by 11, 33 and 68%, respectively (Table 2). The competition decreased TDM and panicle number at maturity decreased by 23 and 12%, respectively. In contrast, HI increased by 21% with the competition.

All the traits studied significantly varied among the cultivars (Table 1). The effect of cultivar by weed management interaction was significant ($P = 0.01$) for tiller number at 37 DAS, grain yield and days to flowering, whereas the effect of cultivar by weed management by site interaction did not reach significance at $P = 0.01$ for all the traits except for plant height at 37 DAS. In both weed management treatments, traditional cultivars had higher plant height at 37 DAS than improved cultivars, and IR 55423-01 had the lowest plant height (Table 2). B6144F-MR-6-0-0 had the largest tiller number at 37 DAS, followed by IR 55423-01. Makhinsung and B6144F-MR-6-0-0 had larger TDM at 37 DAS than the other cultivars in both weed management treatments. Tiller number of two improved cultivars at 37 DAS was more affected by the competition than three traditional cultivars since the absolute loss of tiller number due to the competition was larger in improved cultivars than traditional cultivars (98–106 vs. 34–68 m^2). In contrast, absolute loss of height and TDM of rice at 37 DAS was not largely different among five cultivars. Grain yields with and without competition ranged from 2.09 to 3.47 $t ha^{-1}$ and from 1.99 to 4.04 $t ha^{-1}$, respectively (Table 2). The two improved cultivars out-yielded three traditional cultivars in both weed management treatments. The absolute yield losses of cultivars with weed competition ranged from -0.20 to 0.88 $t ha^{-1}$ (minus value means that grain yield was higher in competition than in control). IR 55423-01 had the largest absolute yield loss among cultivars tested.

The two improved cultivars constantly had heavier TDM, and higher HI, and panicle number at maturity than the traditional cultivars across two weed management treatments (Table 2). Days to flowering with and without competition varied from 102.1 to 112.9 and from 98.5 to 111.9 DAS, respectively. Makhinsung had the longest growth duration in both weed management treatments. Except for this cultivar, there was no large difference in days to flowering among cultivars in control. Delay in flowering of all five cultivars with competition relative to that without competition varied and ranged from 0.1 to 10.6. Flowering of IR 55423-01 was most-delayed.

Discussion

In this study, there was genotypic variation in ability to recover from weed competition at the early vegetative stage: IR 55423-01 had the largest absolute yield loss among the five cultivars under the same magnitude of weed pressure, which could be guaranteed by the fact that there was no significant effect of cultivar on TDM of maize. A distinct difference between this cultivar and the other cultivars was its small height at 37 DAS and great delay in growth (days from sowing to flowering). These may suggest that smaller rice plants (IR 55423-01) could have been covered with maize earlier and consequently longer, and suffered more from the competition in this study. Although there have been no reports on genotypic variation in the delay of growth due to weed competition in rice, the delay in flowering by weed competition has been reported (Fukai, 1999). The delay in flowering by weed competition could be due to the effect of the competition for light, water, and nutrients, although we can not identify which factors strongly affect the delay in this study. Water stress and low nutrient availability have been reported to cause delay in flowering in rice, and cultivars differed in the response of flowering time to water or nutrient availability (Boonjung and Fukai, 1996; Wonparasaid et al., 1996; Fukai, 1999). For competition for light, Nakano (2000) reported that 95% shading for 16-34 d at the early vegetative stage delayed heading by 4-11 d and reduced the number of spikelets per panicle and grain filling percentage. Although there is such information from previous studies, attention should be focused on elucidating the mechanisms of genotypic variation in the delay in flowering due to weed competition at the early vegetative stage, and the relationship between the delay and yield loss. The length of delay in flowering may be useful as a visible indicator of damages by weed competition if such a relationship is validated.

Dingkuhn et al. (1999) indicated that short growth duration and low tillering ability were associated with inferior ability to recover from weed competition. This is in contrast with our study, which showed that IR 55423-01 possessing inferior recovering ability had similar growth duration (days to flowering) to the other cultivars except Makhinsung, and all traditional cultivars with low-tillering ability had superior recovering ability than IR 55423-01 with high-tillering ability. Furthermore, B6144F-MR-6-0-0 showed a loss of tiller number at 37 DAS due to the weed competition similar to that in IR 55423-01, but it had superior recovering ability than IR 55423-01. The reason for these contrasting results could be due to different cultivars used, and establishment methods used for rice (they planted three to four rice seeds and thinned to two plants per hill, while we planted about six seeds and did not thin) and maize (they planted maize in replacement of

some of the rice hills, while we grew it between rice hills).

B6144F-MR-6-0-0 had grain yield similar to IR 52423-01 without weed competition and yield stability similar to three traditional cultivars across two weed management treatments. Good performance of this cultivar without weed competition in this study confirms a finding of previous study in northern Laos (Saito et al., 2006c, 2007). These results are in contradiction with Dingkuhn et al. (1999), who reported that low-yielding *O. glaberrima* cultivars produced higher yields than high-yielding *O. sativa* cultivars when they were grown with maize at the vegetative stage.

In summary, genotypic variation in ability to recover from weed competition at the early vegetative stage existed among the cultivars tested in this study. The use of improved cultivar B6144F-MR-6-0-0, which not only had high yield potential but also had ability to recover from weed competition, appears to improve and stabilize rice productivity in this region, where weed is one of the major constraints to upland rice production and traditional cultivars are still dominant.

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