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Critical period for weedy rice control in direct-seeded rice

(Tempoh kritikal untuk mengawal padi angin dalam tanaman padi tabur terus)

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Key words: critical period, direct-seeded rice, Gompertz and Logistic equations

Abstract

On-station trials were conducted in MARDI Seberang Perai in main season 2004/05 and off-season 2005 to determine the critical period of weedy rice control in direct-seeded rice. This period generally consisted of two discrete periods, a critical weed free period and a critical time of weed removal. The Gompertz and Logistic equations were fitted to data representing increasing durations of weed control and weed interference, respectively. In the main season 2004/05, only weedy rice was allowed to grow in association with direct-seeded rice. Other weeds were controlled with selective herbicide applications. In the off- season 2005, mixed weeds including weedy rice were let to grow in association with direct-seeded crop. A period of weedy rice control lasting up to 53 DAS prevented a yield loss of more than 5% in main season 2004/05. However, weedy rice competition could cause 5% yield loss if it allowed to compete with direct-seeded crop until 16 DAS. Therefore, the critical period for weedy rice control was from 16 to 53 DAS. In off-season 2005, to prevent a yield loss of more than 5%, a period of weed free lasting 60 DAS is required and weed competition could cause 5% yield loss if it allowed to compete with direct-seeded crop until 12 DAS. It indicates critical period for weed control under mixed weed infestation from 12 to 60 DAS under 5% yield loss.

Introduction

Weed emergence in relation to crop emergence is an important factor in weed-crop competition. Weeds that emerge along with crop plants have an adverse effect on crop yields. Crop losses due to weed competition vary with the duration of weed infestation of the crops. The crop is likely to experience yield reduction unless weeds are kept free during a part of its growing period. This phenomenon is referred as the critical period of weed competition. Almost all annual crops are susceptible to weed competition during the early stage of development particularly within the first one-third to one-half of the crop life cycle (Mercado 1979). The critical period of weed competition represents the time interval between two separate components (i) the length of time crop must be free of weeds after planting so that weeds do not reduce yield, and (ii) the length of time weeds which emerge with the crop can remain before they begin to interfere with crop growth (Nieto et al. 1968; Tjitrosemito et al. 1989; Hall et al. 1992). Thus, weed control during this period is necessary to avoid considerable reduction in crop yield (Talatala et al. 1983). Furthermore, allowable limit loss in rice growth was

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considered as 20% with allowable period of weed competition of 6 and 9 weeks in flooded direct seeding and machine transplanting, respectively in Korea (Im and Guh 1995).

Previous critical period studies have been phrased the critical period of weed competition or the critical period of weed interference. This terminology suggests that weed competition is restricted to a certain time frame (Cousens 1988). However, the critical period is the optimum time for weed control and is not necessarily the optimum time of most intense interference (Weaver 1984). Perhaps "the critical period of weed control" is more accurate since it describes the duration of weed control measures that must be maintained to prevent the later emerging weeds from interfering with rice yield.

Currently, all rice production areas in Peninsular Malaysia are direct seeded. Seeding with pre-germinated seed is the preferred method and this requires effective water management for good crop establishment. Direct seeding is normally undertaken either by hand broadcasting or using motorised blower.

Currently, weedy rice is a major constraint to direct seeded rice production. The term "weedy rice" refers to easy shattering weedy forms of rice that infest rice fields, and these are particularly problematic in direct-seeded areas (Azmi and Abdullah 1998). While weedy rices are morphologically variable, their close similarity and relation to the cultivated crop necessitates the integration of weed control measures focusing on cultural control measures.

Weed management in direct seeded systems is more critical than transplanted systems as weeds in direct seeded system can emerge at the same time or before the rice plants, resulting in a serious problem of competition. Moreover, the practice of shallow flooding, necessary to enable good establishment of the rice seedlings, also favours weed growth (Johnson et al. 2004). The implementation of an integrated weed management (IWM) system is seen by many weed scientists as means of reducing herbicide use while maintaining crop yield (Swanton and Weise 1991). Part of the concept of IWM is to base herbicide application timing on critical periods and aid in understanding weed population impacts on the crop (Wooley et al. 1993). Appropriate timing of control, whether by the application of herbicides or by other means, represents a substantial opportunity to reduce reliance on herbicide by introducing control at optimum time, rather than repeatedly or prophylactically (Rajcan and Swanton 2001).

The objective of this study was to determine the critical period of weed control in direct-seeded rice especially for weedy rice infested areas in Malaysia. To ensure that results of this study would be broadly applicable to rice growing areas, it was conducted under two situations i.e. weedy rice in competition with direct-seeded rice (main season 2004/05) and a naturally occurring of mixed weed species including weedy rice in competition with direct-seeded rice (off-season 2005). The critical period was defined as days after sowing (DAS).

Materials and methods

Two field studies were conducted from 2004 to 2005 at MARDI, Seberang Perai, Malaysia. These studies were carried out using recommended cultural practices (Anon. 2002). Soil fertility status of experimental site as shown in *Table 1*.

Table 1. Soil fertility status of experimental site

Parameter	
pH	4.73
Organic carbon	1.06 %
Nitrogen	0.18 %
Soluble phosphorous	7.90 ppm
Cation Exchange Capacity (%)	8.42 me %
Ex potassium	0.20 me %
Ex sodium	0.45 me %
Ex calcium	2.08 me %
Ex magnesium	1.00 me %

Critical period of competition between weedy rice and direct-seeded rice

This study was conducted during main season 2004/05. Weeds were removed at different intervals in the crop according to two ranks of treatments. One set of plots consisted of weedy rice plants which was allowed to grow in direct-seeded rice culture for 0, 10, 20, 40 and 50 DAS, after which the plots were kept free of weedy rice until harvest *(Table 2)*. Another set consisted of plots that kept fully free from weedy rice for 0, 10, 20, 40 and 50 DAS, and then weedy rice was allowed to grow until harvest. Rice variety MR 219 was used at seeding rate of 100 kg/ha. Pre-germinated rice seeds were sowed in row at a spacing 25 cm x 25 cm in well-puddled soil to ensure better establishment and facilitate manual weeding for each treatment. Prior to this, weedy rice seeds were incorporated at a rate of 2,000 kg/ha into the soil in each plot 3 days before sowing.

A completely randomized design was employed. Plot size was 5 m x 5 m. During the first 10 DAS, water level was kept as low as possible to create good condition for weedy rice germination and crop growth. Other weeds were removed by application of a combination of cyhalofop-butyl + bensulfuron at 10 DAS followed by 2, 4-D amine at 25 DAS.

Critical period of competition between mixed weeds and direct-seeded rice

The study was repeated in the same site during off-season 2005 where mixed weeds including weedy rice were allowed to compete with direct-seeded rice. Similar treatments, growth measurements and crop care as in main season 2004/05 were practised in this season.

Statistical analysis

Gompertz and Logistic equations were fit to the yield data, expressed as a percentage of the unweeded control, for increasing length of weed free period and increasing duration of weed interference, respectively. The equations were fit using the nonlinear regression technique described by Hall et al. (1992). The Gompertz and Logistic curves were fit separately for each planting season i.e. main season 2004/05 and off-season 2005. The critical weed free period and the critical time of weed

Table 2. Treatments for critical period of weed competition study

Day after sowing (DAS) in competition					
0–10 DAS	11–20 DAS	21–30 DAS	31–40 DAS	41–50 DAS	Until harvest
Weedy rice or mixed weed in competition with rice followed by weed free					
//////////	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++
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Weed free followed by weedy rice or mixed weed in competition with rice					
++++++++++	//////////	//////////	//////////	//////////	//////////
++++++++++	++++++++++	//////////	//////////	//////////	//////////
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++++++++++	++++++++++	++++++++++	++++++++++	++++++++++	++++++++++

//////// Weedy rice competition
++++ Weedy free (manual weeding)

removal were calculated by substituting rice yields, expressed as percentage of control, into Gompertz and Logistic equations, respectively. Yield loss levels of 5% and 10% were chosen arbitrarily. The equation with the highest coefficient of determination (r^2) value was judged to be the most appropriate.

Results and discussion

Critical period

Past studies have determined the critical period using Duncan multiple range test or LSD (Harris and Ritter 1987). Regression analysis has been suggested as a more appropriate and useful means of determining the critical period (Cousens 1988). Regression analysis could be used to determine critical periods based on a maximum allowable yield loss. In this study, the Gompertz equation suggested by Cousens (1988) was used to fit the length of the weed control period and yield data. On the other hand, the Logistic equation was used to represent the influence of increasing duration of weed interference on yield. Researchers have used 2–5% yield reduction as the threshold point for defining the onset of the critical period of weed removal (Van Acker et al. 1993; Knezevic et al. 1994). In this study the weed free and weedy intervals were based on days after sowing.

Study in main season 2004/05 showed that the critical time of weedy rice removal, based on a more than 5% yield loss level, ended 15.9 DAS and the critical time of weedy rice free period occurred at 53.0 DAS *(Figure 1* and *Table 3)*. On the other hand, the critical time of weedy rice removal based on a 10% yield loss level, ended 22.4 DAS and the critical time of weedy rice free period occurred at 42.1 DAS. These results are in agreement with earlier findings, critical period for barnyard grass *(Echinochloa crus-galli)* control from 15–30 DAS (Azmi 1990) but some crop species can be more competitive towards weeds than others (Aldrich 1987).

In subsequent season (off-season 2005) weedy rice together with other weeds were allowed to compete with direct-seeded crop. Results showed that length of the weed free period to prevent more than a 5% yield loss ranged from 12 DAS to 60 DAS *(Figure 2*

Table 3. Effect of time of weed removal on yield of direct seeded rice and number of weedy rice panicles/m^2

	Main season 2004/05		Off-season 2005
Schedule of interference (days)	Yield (kg/ha)	Number of weedy rice panicles/m^2	Yield (kg/ha)
Weed infested			
10	3090	0	4655
20	2785	0	4090
30	2589	0	3520
40	2290	0	2358
50	2115	0	2178
120	914	382.0	1348
Weed free			
10	2216	174.9	1422
20	2695	15.5	2687
30	3077	5.0	3224
40	3823	0	3713
50	3863	0	4592
120	4055	0	4885
SE (N = 4)	307.8	–	616.9
5% LSD	885.7	–	887.51

Table 4. Maximum weed competition and minimum weed free period for weedy rice competition in direct-seeded rice from regression equation based on two stages of estimated yield loss

Maximum weed competition		Minimum weed free period	
Main season 2004/05		**Main season 2004/05**	
5% yield loss	10 % yield loss	5% yield loss	10% yield loss
16 DAS*	22 DAS	53 DAS	42.1 DAS
Off-season 2005		**Off-season 2005**	
12 DAS	17 DAS	60 DAS	51 DAS

DAS = Days after sowing

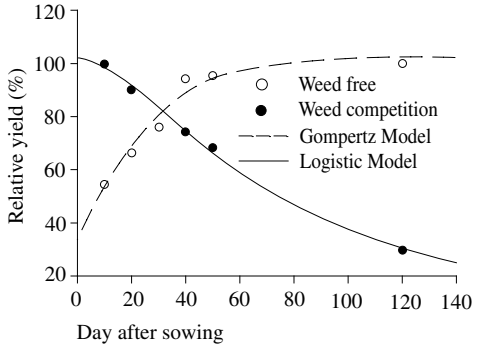

*Figure 1. Critical period of weedy rice competition in direct-seeded rice, main season 2004/05, MARDI Seberang Perai. {Logistic Y = 102.1/(1+abs(x/72.3458)^1.71), R^2 = 0.99 ; Gompertz Y = 102.0478*exp(-exp(-(x-2.1268)/19.2429)), R^2 = 0.96}*

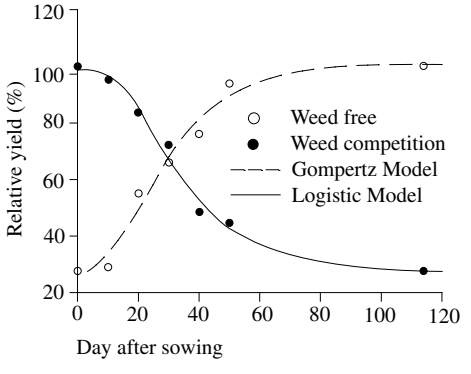

*Figure 2. Critical period of weedy rice competition in direct-seeded rice, off-season 2005, MARDI Seberang Perai. {Logistic Y =25. 5775+73.0068/(1+abs(x/33.4854)^2.9315 , R^2 = 0.99; Gompertz Y = 24.7806+75.9474*exp(-exp(-(x-21.7007)/15.2657)), R^2 = 0.99.}]*

and *Table 3)*. On the other hand, weed free period to prevent more than a 10% loss ranged from 17 DAS to 51 DAS *(Table 4)*.

Conclusion

There is a critical period from approximately 12–16 to 53–60 DAS, during which weedy rice removal during critical period will prevent more than 5% rice yield loss provided other weeds can be controlled by selective early post-emergent herbicides applied at the onset of critical period. Preferably these herbicides would control the weeds other than weedy rice throughout the critical period. If pre-emergence herbicide being used and applied before onset of critical period, this herbicide must have residual activity to control the weeds at least until mid-stage of the critical period. The differences in critical period at 5% and 10% yield loss in both seasons indicate that recommendation for weedy rice control in direct seeded rice have to be made with respect to level of weedy rice infestation, and seasonal basis as weed growth patterns were different in each season.

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Abstrak

Kajian mengenal pasti tempoh kritikal bagi mengawal padi angin dalam amalan tabur terus telah dijalankan di stesen MARDI Seberang Perai selama dua musim berturut-turut (musim utama 2004/05 dan luar musim 2005). Tempoh kritikal ini terdiri daripada dua komponen penting iaitu tempoh kritikal tanaman perlu bebas daripada rumpai, dan tempoh kritikal rumpai boleh bersaing dengan tanaman tanpa menjejaskan hasil tanaman. Data tempoh bebas daripada rumpai dan tempoh persaingan rumpai yang diperoleh dianalisis menggunakan persamaan Gomperzt dan Logistic. Pada musim utama 2004/05, kawalan terhadap rumpai menggunakan racun herba selektif dilakukan bagi membenarkan hanya padi angin sahaja yang bersaing dengan tanaman. Manakala pada luar musim 2005, rumpai lain bersama padi angin dibiarkan tumbuh dan bersaing dengan tanaman padi. Kawalan padi angin sehingga 53 hari lepas tabur (HLT) didapati sudah mencukupi bagi mengelakkan pengurangan hasil sebanyak 5% pada musim utama 2004/05. Manakala persaingan padi angin sehingga 16 HLT akan menyebabkan pengurangan hasil sebanyak 5%. Ini bererti tempoh kawalan padi angin pada tahap toleran 5% hasil adalah daripada 16 hingga 53 HLT. Bagi mengelakkan pengurangan hasil lebih daripada 5% pada luar musim 2005, kawalan rumpai bersama padi angin hanya perlu dilakukan pada 12 HLT sehingga 60 HLT.

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