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RESEARCH NOTE

Modelling rice-weed competition under transplanted ecosystem

Chris John*, Vishram Ram and Ngangbam Pusparani

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ABSTRACT

A field experiment was conducted in the summer of 2021 at the Crop Research Farm of the College of Post-Graduate Studies in Agricultural Sciences, Meghalaya, to determine the extent of yield loss in rice with different periods of weed interference. Twelve weed control timings were used to identify critical periods of weed competition in transplanted rice. Gompertz and Logistic equations were fitted to yield data in response to increasing periods of weed control and weed interference, respectively. The results showed that critical weed-free periods to achieve 95% of weed-free yield ranged from 11 – 57 days after transplanting. Grain yield obtained from a weed control period up to 60 days after transplanting and a weed competition period of 12 days after transplanting were statistically at par with the no-weed competition until harvest plot. Despite registering the highest yields, the plots that were kept weed-free till harvest were less profitable due to the incurred weeding costs. The identification of the critical crop-weed competition period will facilitate improved decision-making regarding the timing of weed control.

Keywords: Critical weed-free period, Growing Degree Days, Mathematical modelling, Transplanted rice, Weed control timing

Weeds are the visible but unspectacular pests, attendance of which may be formidable but effects might not. Despite all recompenses, weeds continue to remain notorious yield reducers that are, in many situations, economically more harmful than insects, fungi or other crop pests. Rice cultivation has always remained significant for food and livelihood security. It is estimated that the demand for rice in India will be 121.2 million tonnes by the year 2030, and 137.3 million tonnes by the year 2050 (Mohapatra *et al*. 2013). In Meghalaya, rice is cultivated in an area of 0.11 million hectares with a production of 0.304 million tonnes and productivity of 2740 kg/ha (DES, 2017-18). Weeds cause severe yield losses in rice (Hosoya and Sugiyama 2017) and seriously harm the ecology and the local economy when they are introduced (Sosa *et al*. 2017). Moreover, weeds vary spatially and temporally and swiftly adapt to new preventive and control tactics, making their control tricky (Sosnoskie *et al*. 2006). The critical period of weed interference and the critical weed-free period are two separately assessed crop-weed competition components that are employed to determine the critical period of crop-weed competition (CPCWC) (Tursun *et al*. 2016).

The field experiment was carried out in the summer of 2021 at the Agronomy farm of the College of Post Graduate Studies in Agricultural Sciences, Umiam, Ri-Bhoi, Meghalaya. It was laid out in a randomized block design with three replications. The treatments consisted of 12 weed control timings (WCT): weedy until 12, 24, 36, 48, and 60 days after transplanting (DAT) and crop harvest; and weed-free until 12, 24, 36, 48, and 60 DAT and crop harvest. The soil of the experimental field was sandy clay loam in texture, moderately acidic (pH 4.97) in nature, medium in available nitrogen (308.5 kg/ha), medium available phosphorus (18.2 kg/ha) and medium in available potassium (175.8 kg/ha). The paddy variety '*CAUS-122*' was used for the study. The recommended dose of NPK, *i.e*., 80:60:40 kg/ha were applied. Weeds were removed by hand according to the treatments and at weekly intervals thereafter.

The Gompertz equation (Knezevic *et al*. 2002) was used to describe the effect of increasing duration of weed free period on yield:

$$y = y_0 + a \times \exp\left[-\exp\left(-\frac{x - x_0}{b}\right)\right]$$

Logistic equation (Smitchger *et al*. 2012) was used to describe the increasing duration of weed interference on yield:

$$y = y_0 + a/\left[1 + abs\left(\frac{x}{x_0}\right)^b\right]$$

where, y: Relative yield (% of season-long weed free yiel d); y_0: Lower limit; a: Upper limit; x_0: Days/

School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences (Central Agricultural University, Imphal), Umroi Road, Meghalaya 793103, India

* Corresponding author email: cjohn3101@gmail.com

GDD giving a 50% response between the upper and lower limit (inflection point); x: Number of days/ GDD calculated after crop emergence; b: Slope of the line at the inflection point (rate of change)

The analysis and interpretation of data was done using the Fisher's protected least significant difference test at $p<0.05$. SigmaPlot 12.5 was used to fit the curves for determining the critical period of crop-weed competition. From the fitted curves, critical periods for 95% of the maximum yield were determined.

Effect on yield attributes of rice

A synergistic effect was observed on the various yield attributes with decreasing duration of crop weed interference (**Table 1**). The maximum number of grains per panicle was reported from the plot kept weed-free until harvest (65.6), whereas, the lowest number of grains per panicle (42.1) was observed from the full-season weed competition plot. The treatments registered no significant difference on 1000-grain weight.

Effect on grain yield of rice

The weed-free set of plots recorded yields ranging from 2.07 to 4.01 t/ha, whereas, the weedy set of plots recorded yields ranging from 1.77 to 3.79 t/ha. Maximum grain yield (4.01 t/ha) was registered with no weed competition. But grain yield obtained from weed control period up to 60 DAT (3.91 t/ha) and a weed competition period of 12 DAT (3.79 t/ha) were found to be statistically at par with the weed-free in the harvest plot. The plot kept weedy throughout the growing period recorded a 56% reduced yield as compared to the plot which was kept weed-free throughout its growing period. Puddled transplanted rice production systems possess higher yield potential than direct-seeded rice (DSR), primarily owing to the protection from weeds during the early stages of growth (Choudhary *et al.* 2008).

The plot kept weed-free until harvest recorded the highest harvest index (41.24%), which was statistically at par with the plot kept weedy up to 12 DAT harvest and the plot kept weed-free up to 60 DAT. Conversely, the plot kept weedy throughout the growth season recorded the lowest harvest index (20.34%), however, it was statistically at par with the plot kept weedy up to 60 DAT and the plot kept weedy up to 12 DAT. This decline may be from a decrease in economic yield relative to the biological yield of rice.

Economics

The benefit: cost ratio differed across treatments. It was found that keeping the plots weed-free until 60 DAT gave statistically par profitability as the plots that were kept weed-free unti harvest (**Table 1**). Albeit with highest yields, the completely weed-free plot was not the most profitable due to the costs incurred in continuous weed removal. This reinforces the importance of realizing a critical period for weed management.

Estimation of rice yield loss and critical period for weed control

The Gompertz equation accounted for about 95%, whereas the logistic equation accounted for more than 60% of the variation in rice grain yield (**Table 2**).

Table 1. Rice yield and yield attributes as influenced by divergent weedy and weed-free regimes

Treatment	No. of grains/panicle	No. of panicles/m^2	Test weight (g)	Grain yield (t/ha)	Harvest index (%)	B:C ratio
Weedy up to 12 DAT	63.3ef	276.3e	26.63a	3.79f (5)	39.87e	1.11bc
Weedy up to 24 DAT	60.2ef	242.7cde	25.97a	3.33def (17)	34.84cde	1.05bc
Weedy up to 36 DAT	52.5cd	192.3abc	25.23a	2.64bcd (34)	27.45abc	0.91abc
Weedy up to 48 DAT	48.9bc	163.3ab	25.13a	2.20abc (45)	23.74ab	0.82ab
Weedy up to 60 DAT	45.2ab	140.7a	25.43a	1.96ab (51)	20.54a	0.74a
Weedy up till harvest	42.1a	129.0a	24.41a	1.77a (56)	20.34a	0.71a
Weed-free up till harvest	65.6f	292.3e	26.83a	4.01f	41.24e	1.17c
Weed-free up to 12 DAT	47.3abc	151.0ab	24.44a	2.07abc (48)	21.38a	0.83ab
Weed-free up to 24 DAT	49.9bc	181.0ab	24.90a	2.49abc (38)	26.83ab	0.90abc
Weed-free up to 36 DAT	58.4de	211.0bcd	25.13a	2.90cde (28)	31.45bcd	0.97abc
Weed-free up to 48 DAT	61.6ef	257.0de	25.78a	3.52ef (12)	36.31de	1.10bc
Weed-free up to 60 DAT	64.0ef	284.6e	26.73a	3.91f (2)	39.39e	1.20c
LSD (p=0.05)	6.09	58.19	2.39	1.32	7.34	0.27

*Within the same columns, means followed by different letters are significantly different at the 0.05 probability level, according to DMRT; Values in parenthesis showing per cent decrease in grain yield over the plot kept weed-free until harvest

Table 2. Parameter estimates for the four-parameter Gompertz and Logistic model fitted to Rice grain yield (% of weed-free yield) in 2021 with their respective R^2 values

Treatment	Regression parametes				R^2
	b	y_0	A	x_0	
Weedy[a] (Based on DAT)	2.67	37.16	62.10	34.35	0.9992
Weed-free[b] (Based on DAT)	34.97	39.20	100.17	38.15	0.9988
Weedy[a] (Based on GDD)	2.79	38.39	60.86	419.89	0.9991
Weed-free[b] (Based on GDD)	403.67	40.16	94.92	461.49	0.9991

b: the slope of the line at the inflection point; y_0: the lower limit; a: the upper limit; x_0: the growing degree days giving a 50% response between the upper and the lower limit; R^2: Regression coefficient; [a:] Logistic equation; [b:] Gompertz equation

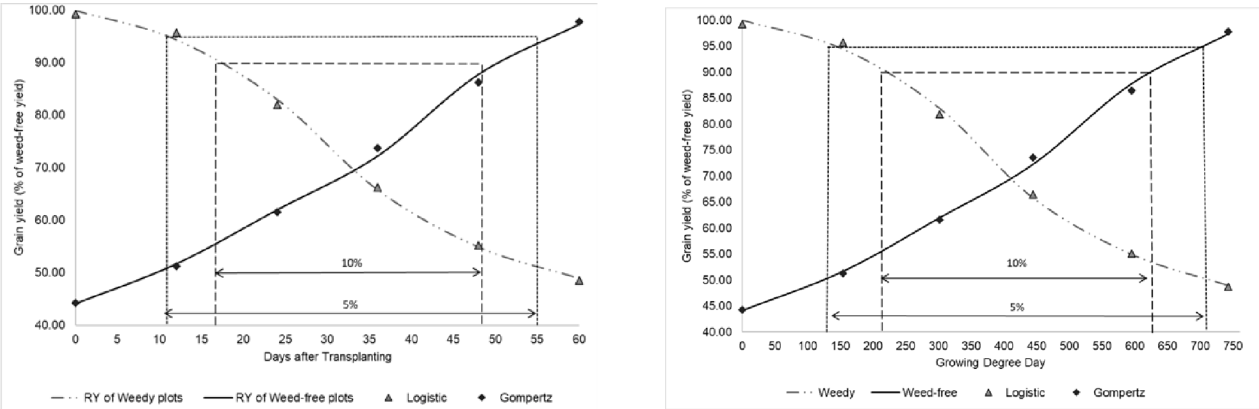

Figure 1. Critical period of rice-weed competition (a) DAT basis, (b) GDD basis

AYL (%)	CPCWC		
	DAT	GDD	CGS
Onset of the CPCWC			
5	11	140	First tillering stage
10	17	217	Active tillering stage
Culmination of the CPCWC			
5	57	704	Booting stage
10	50	620	Heading stage

Table 3. CPCWC in rice in Ri-Bhoi, Meghalaya in 2021 expressed in GDD, DAT and corresponding crop growth stage (CGS)

Based on the 5% acceptable yield loss (AYL), the onset of the CPCWC in rice was 140 GDD, suggesting the initiation of weed control at 11 DAT (**Figure 1a**), in accordance with the Logistic equation. Similarly, the end of CPCWC in rice was 704 GDD (**Figure 1b**), which corresponded to 57 DAT, as simulated by the Gompertz equation (**Table 3**). Based on the 10% AYL, the onset of the CPCWC in rice was 217 GDD, *i.e.*, 17 DAT and the end of CPCWC in rice was 620 GDD, which corresponded to 50 DAT.

Thus, it may be concluded that weeds must be controlled within the period of 11 to 57 DAT and 17 to 50 DAT in rice to avoid 5 and 10% grain yield losses, respectively. The results of this study also dispense guidelines to rice growers for making decisions with respect to the weed competition period during which it is of economic importance to execute weed control measures in rice.

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