AGRIEAST 2015 (10) P. 6-10
Research Article

# Critical period of weed control in radish (*Raphinus sativus* L.)

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## ABSTRACT

*A field study was carried out at Crop Farm of the Eastern University of Sri Lanka to determine the critical period for weed control and the effects of weed interference in radish in the regosols of the Batticaloa District. An increasing series of the duration of weed interference and length of the weed-free periods were imposed weekly from 0 to 40 days after emergence (DAE). The beginning and the end of CPWC were based on 5, 10 and 20% acceptable yield loss levels (AYL), which were determined by fitting logistic and Gompertz equations to relative yield data, representing increasing duration of weed-interference and weed-free periods. The critical period for weed control increased to 31 days, starting at 7 days and ending at 38 days, at 5% yield loss level. At 10% and 20% yield loss levels, the CPCW decreased to 12 and 8 days respectively, starting at 18 DAE and ending at 30 DAE, and beginning at 13 DAE and ending at 21 DAE, respectively.*

**Key words:** Critical period, gompertz equation, logistic equation, weed interference, weed management

## Introduction

Radish is an edible, quick growing root vegetable. It looks like turnips with a pungent smell. The young tender tuberous roots can be eaten as a raw vegetable and added to cooked dishes or served as a whole. It contains glucosinolates (s-containing), a cancer-fighting compound that shield the cells from the genetic mutations and also helps to obliterate cancerous cells (Health Benefits of Radishes, 2013). It gives vitamin C and dietary fiber. Vitamin C controls the blood cholesterol levels while dietary fiber controls blood sugar and cholesterol, and inhibits constipation. They are the good source of folates, vitamin $B_6$, riboflavin, thiamin and minerals such as iron, magnesium, copper and calcium.

Heavy application of pesticides led to higher incidence of cancer in the Batticaloa District. Hence, one of the ways to reduce the cancer is by encouraging the cultivation of vegetables like radish among the farmers. In Sri Lanka, radish is the only crop that can be grown in all agro-ecological regions round the year if sufficient moisture is provided (Department of Agriculture, 2002). However, farmers do not show any interests on the cultivation of this crop due to weed problem.

Weeds compete for growth resources such as light, space and nutrients, and reduce the quality and quantity of yield of any crop. Competition affects the shape, size, and function of competing species. Therefore, weeds should be controlled in time in order to prevent the yield loss and income. Roush and Radosevich (1985) perceived that crop biomass is the easiest and quickest method to evaluate species competition while Spitters and Kramer (1986) reported that the biomass has the direct link with the absorption of limiting resources. Therefore, it can be used as an appropriate index for the assessment of the competition effects on the crop growth.

Weed competition is usually calculated by the amount of crop yield loss due to the competition of weed species. The degree of weed competition is influenced by weed community, crop, environment and periods of crop and weed co-exist (Pitelli, 1985).

Critical period studies can be used to regulate weed control tactics and to explore the nature of weed-crop relations (Weaver and Tan, 1987). The critical period for weed control (CPWC) is the span of time that the crop must be retained weed-free in order to prevent yield losses to a certain extent (Weaver and Tan, 1983, Evans *et al*., 2003 and Zimdahl, 2004). Swanton and Weise (1991) and Knezevic *et al*. (2002) recognized the CPWC as the main component of a successful integrated weed management (IWM) program. The CPWC is assessed by calculating the time period between two components of weed interference. These are; the critical weed interference period or the maximum length of time during which weeds emerging soon after crop planting can coexist with the crop without causing unacceptable yield loss, and the critical weed-free period or the minimum length of time required for the crop to be maintained weed-free before yield loss caused by late emerging weeds is no longer a concern (Evans *et al.,* 2003 and Hall *et al.,* 1992). It also identifies the most favourable time periods for the optimum integrated weed management (IWM) program (Swanton and Weise, 1991).

Many studies have determined the maximum acceptable yield loss (AYL) level between 2.5 and 10% (Knezeic *et al*., 2002). The AYL can be adjusted. However, it depends on various factors such as the cost of weed control and the financial gain ((Knezevic *et al*., 2015). This perception is closely related to the use of weed thresholds (Dawson, 1970) as the length of time that a crop can tolerate weed competition before yield loss goes beyond the cost of control. Even though studies on CPWC have been reported universally in diverse crops in varying environments, however, studies on CPWC on radish are scarce. Due to the lack of information on the competitive ability of weeds in radish, the present study was initiated to determine the effects of timing of weed removal and duration of weed interference on radish in the regosols of the Batticaloa District.

## Materials and Methods

A field experiment was conducted at the Crop Farm, Faculty of Agriculture, Eastern University, Sri Lanka during the period of April to June 2013 (Latitude of $7^0$ 43'N and the longitude of $81^0$ 42').

### Experimental site

The experimental site falls in the $DL_2$ agro-ecological region. The mean annual rainfall ranges from 1600 mm to 1970 mm and temperature varies from 25 to 32 $^0$C. The major soil type of the field is sandy regosol.

### Experimental plot

The land was ploughed upto a depth of 30-40 cm to provide fine tilth. Beds were made with the dimension of 3 $m^2$ and separated by 0.5 m boundaries. The radish variety "Beeralu rabu'' seeds were sown in the bed at a spacing of 30 cm x 10 cm. All the cultural practices except weeding were carried out in accordance with the Department of Agriculture (Department of Agriculture, 2002).

### Experimental design

The experimental design was randomized complete block (RCBD) with three replications. Weedy and weed-free treatments were imposed. In weedy treatment, weeds were allowed to interfere with radish from emergence until 10, 20, 30 and 40 days, after which weeds were removed and plots were maintained weed-free throughout the experiment. In weed-free treatment, plots were maintained weed-free from emergence until 10, 20, and 30 and 40 days, after which weeds were allowed to remain throughout the experiment. Also, season-long weedy and season-long weed-free plots were maintained.

Natural weed populations were used in this experiment. The most common weed species were *Amaranthus* spp., *Digitaria* spp., *Eleusine indica*, *Setaria* spp. and *Cyperus rotundus*. Weed biomass was determined by removing the weeds from each plot by hoes and dried at 80$^0$C for a period of 48 hours and then the weight was measured. Crop yield was evaluated by measuring tuber yield.

Relative yield from individual plots was calculated as the percentage of their corresponding weed-free plot yields. Nonlinear regression analysis was used to estimate the relative yield of radish as a function of rising duration of weed interference or as a function of the length of the weed-free period, according to the procedure outlined as reported by Knezevic *et al*. (2002).

**Statistical analysis**

A logistic equation, modified slightly from the equation proposed by Hall *et al*. (1992), was used to determine the effect of increasing duration of weed interference on relative yield of radish and to determine the beginning of the critical weed-free period of radish:

$$RY=\left[\left[\frac{1}{(D\,\mathrm{x}\exp[K\,\mathrm{x}(T-x)]+F)}\right]+\left[\frac{(F-1)}{F}\right]\right] \mathrm{x}\ 100 \ ...\text{(Eq 1)}$$

$-1)\Big]\times 100$ ... (Eq. 1)

Where, RY is the relative yield (percent of season-long weed-free yield), *T* is the duration of weed interference measured from the time of radish emergence in DAE, *x* is the point of inflection in DAE, and K is the parameter that limits the curvature of the function, and F is the lower asymptote - expected proportion of yield loss for the longest period of time of weed competition.

The Gompertz model was used to predict the relationship between the increasing duration of weed interference on yield under increasing length of the weed-free period (Hall *et al*., 1992 and Knezevic *et al*., 2002). The model has the following form

$$Ry = a \times \exp(-b \times \exp[-k \times T]) \ \dots \text{( Eq. 2)}$$

Where, *Ry* is the relative yield (% season-long weed-free yield), *a* is the theoretical maximum or asymptote yield, *b* is the yield when time equals to zero and *k* represents the slope and *T* is the length of the weed-free period after crop emergence (planting) in days.

The logistic equation was used to determine the beginning of the CPWC, and the Gompertz equation was used to determine the end of the CPWC for acceptable yield loss levels of 5%, 10%, and 20%. The goodness of fit was studied in terms of minimum mean square error (MSE) and maximum $R^2$. All the statistical analysis were performed by using SAS and SPSS statistical software.

## Results and Discussion

Radish yield response to increasing duration of weed infested period or weed- free period was adequately described by the regression models with $R^2$ values of 0.98 and 0.97 respectively. A logistic model was fitted to relative yields of radish (expressed as a percentage of the weed-free control) as a function of increasing duration of weed interferences (days) (Table 1). The entire parameters estimate in logistic model were significant ($p<0.05$).This provides sufficient evidence to conclude that the parameters of the logistic model were not equal to zero and relative yield and duration of weed interference were significant. In addition, Gompertz model revealed that relative yields of radish (expressed as a percentage of the weed-free control) as a function of increasing duration of the weed-free period (days). The entire parameters estimate in Gompertz model were significant ($p<0.05$). This further confirmed that the parameters of Gompertz model were not equal to zero and relative yield and duration of weed interference were significant.

**Table: 1 Parameter estimations for the logistic and Gompertz equations for relative yield**

| Logistic | | | | Gompertz | | |
|---|---|---|---|---|---|---|
| C | F | D | X | A | B | k |
| 0.2388 | 1.3112 | 0.6306 | 14 | 100.2 | 1.2936 | 0.835 |

The length of the CPWC in radish was 31, 20 and 8 days with 5, 10 and 20% acceptable yield loss levels (AYL), respectively. The onset of the CPWC was 7 DAE at 5% AYL. Further 10 DAE and 13 DAE at 10 and 20% AYL, respectively (Figure 1).

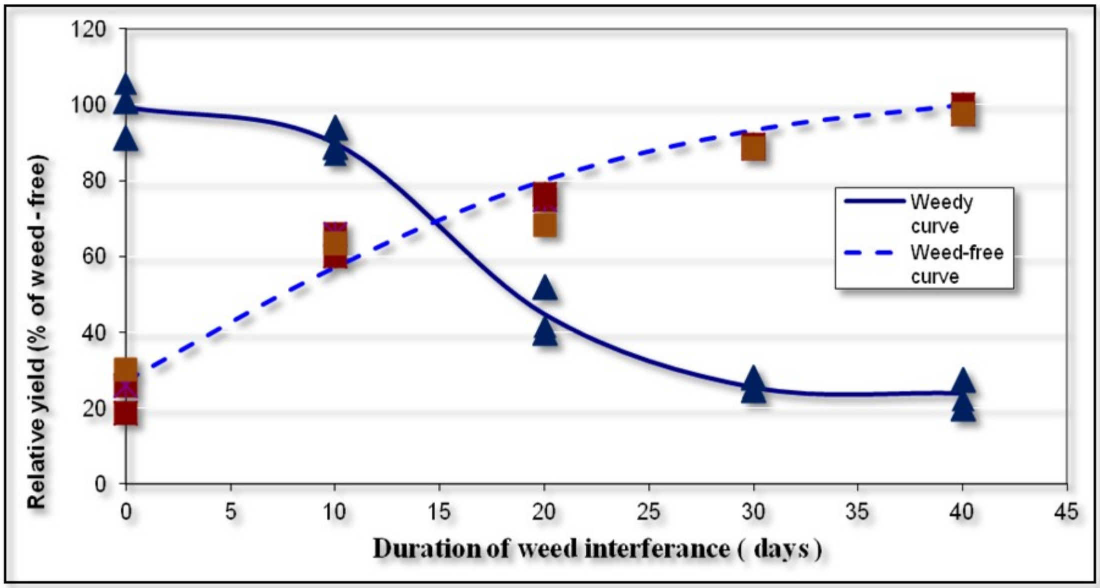


Figure 1. Effect of weed interference on total yield of radish. Increasing duration of weed interference (■) fitted curves as calculated by the logistic equation; increasing weed-free period. (▲) fitted curves as calculated by the Gompertz equation. Dots represent observed data.

From a weed management standpoint, weed control should, therefore, start one week after crop emergence to avoid a yield loss of more than 5%. The CPWC for AYL of 5, 10 and 20% ended at 38 DAE, 30 DAE and 21 DAE (Table 2).

**Table: 2 The critical period of weed control (CPWC) was calculated from Logistic and Gompertz equations**

| AYL | Beginning of CPWC (DAE) | End of CPWC (DAE) |
|---|---|---|
| 5% | 7 | 38 |
| 10% | 10 | 30 |
| 20% | 13 | 21 |

(AYL) expressed as days after emergence (DAE)

As the length of weed existence increased, the tuber yield lessened. This might be due to the competition of the weed species with radish and their total biomass. The differences in yield losses were also due to the intensity of weeds and their infestation on radish plants. However, studies on CPWC in radish were not reported earlier in elsewhere and the yield loss in radish due to weed competition was greater and this will be a foremost constraint in the cultivation of radish.

The duration of the weed-free period indicated that radish is vulnerable to the weed competition up to 3-4 weeks after planting and weed control is necessary in order to prevent the unacceptable yield loss. There is no evidence to support this finding. CPWC gives useful information to the producers and the best time for controlling the weeds (Norsworthy and Oliveira, 2004). But, CPWC fluctuates with the location, time, and crops. It also showed that long CPWC in radish results in the severe competition of weeds. If the weed population is high, necessary care should be taken to protect the radish from weed competition immediately after the emergence of the seedlings. To avoid the cost involved in controlling the weeds and reduce the herbicide damage on the environment, one or two hand weeding can be adopted.

## Conclusion

Weed control is one of the most important factors that determine the crop yields. The weed-free period during early growth stages assures the seedlings to follow the normal growth and development and achieve maximum yield potential. During this period, crop seedlings strengthen their advantage over later emerging weeds and this reduces the amount of weed competition for growth resources.

In radish, the critical period of weed control for 5% yield loss, starts with 7 DAE and ends in 38 DAE. Therefore, pre-emergence or pre-sowing and post-emergence herbicides can be applied to avoid higher yield losses and this would depend on the density of weeds. The post-emergence herbicide can be applied at the second week after sowing and the field should be kept weed free for 5 or 7 weeks. The post-emergence herbicide application can also be coupled with 1-2 hand weeding to reduce the cost and herbicide damage on the environment.

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