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Critical Period of Weed Control in Winter Canola (*Brassica napus* L.) in a Semi-Arid Region

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Abstract: In order to determine the critical period of weed control in winter canola (*Brassica napus* L. cv. Okapi) an experiment was carried out at research field of Tarbiat Modarres University, Tehran, Iran on 2004-2005 growing season. Fourteen experimental treatments which divided into two sets were arranged in Randomized complete blocks design with four replications. In the first set, the crop was kept weed-free from emergence time to two-leaf stage (V2), four-leaf stage (V4), six-leaf stage (V6), eight-leaf stage (V8), early flowering (IF), 50% of silique set (50% SS) and final harvest (H). In the second set, weeds where permitted to grow with the crop until above mentioned stages. In this study critical period of weed control was determined according to evaluate seed bank emerged weed biomass effect on canola grain yield loss using Gompertz and logistic equations. Result showed a critical time of weed control about 25 days after emergence (between four to six-leaf stages) with 5% accepted yield loss. Therefore, weed control in this time could provide the best result and avoid yield loss and damage to agroecosystem.

Key words: Canola, weed, critical period, grain yield, weed interference, control

INTRODUCTION

Winter canola (*Brassica napus* L.) is one of the main oilseed crops in the world. It received the highest attention of Iran's agriculture policy makers as an alternative crop for self-sufficiency in vegetable oil production. Uncontrolled weed populations can substantially reduce crop yield and farmers rely primarily on herbicides for weed control. Herbicide use is an essential component of successful crop production. However, reducing use of herbicide for weed control may lessen the impact of herbicides on non target organisms, development of weed resistance and ground water contamination. Furthermore, development of weed control strategies that lessens our reliance upon herbicides for weed control may prove to be more cost effective (Hall *et al.*, 1992).

Integrated Weed Management (IWM) involves a combination of cultural, mechanical, biological and chemical methods for effective and economical weed control (Swanton and Weise, 1991). The principle of IWM should provide the foundation for developing optimum weed control systems and efficient use of herbicides. The Critical Period for Weed Control (CPWC) is a key component of an IWM program (Knezevic *et al.*, 2002). This is the period during the life cycling of a crop when it must be kept weed free in order to prevent a specific level of yield loss (Van Acker *et al.*, 1993). Weed presence before and after CPWC should not significantly reduce yields (Martin *et al.*, 2001). Knowledge of the CPWC and its affecting factors are essential for making decisions on the appropriate timing of weed control and in achieving the efficient use of herbicide (Knezevic *et al.*, 2002; Van Acker *et al.*, 1993).

The CPWC is determine by calculation of the time of interval between two separately measured competition components: the critical duration of weed interference, the maximum length of time before early-emerging weeds can grow and interfere with the crop before unacceptable yield loss is incurred and the critical weed-free period, the minimum length of time required for the crop to be maintained weed free before yield loss caused by subsequent emerging weeds is no longer of concern (Knezevic *et al.*, 2002).

Martin *et al.* (2001) indicated that canola must be kept weed-free in most cases until the four-leaf stage of crop (17-38 days after crop emergence [DAE]) and in one early-seeded experiment, until the six-leaf stage of the crop (41 DAE), in order to prevent >10% yield loss. After the four-to six-leaf stage of the canola crop, a few weeds emerged and late-emerging weeds accumulated little shoot biomass. Other research has been shown that an

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infestation of wild mustard could remain in a canola crop until four to six-leaf stages of the crop without causing irrevocable yield loss (McMullan *et al.*, 1994). Blackshaw *et al.* (2002) exhibited four wild radish (*Raphanus raphanistrum* L.) per meter square emerging with canola reduced canola yield 9 to 11%, whereas 64 wild radishes per meter square reduced canola yield 77 to 91%. At 64 wild radishes per meter square, canola yield was reduced 91, 65, 56 and 19% when wild radish emerged 0, 2, 4 and 7 weeks after canola, respectively. Wild radish that emerged 10 weeks after canola did not reduced crop yield. They represented wild radish did not directly reduce canola quality, but if wild radish seed were not separated from canola seed, the amount of erucic acid and glucosinolates will increased above marketable level in some cases.

The critical weed-free period was influenced by crop sowing date relative to the emergence of the weeds. Delayed sowing reduced the length of the critical weed-free period because a few weeds emerged after the late planting date (Martin *et al.*, 2001). The critical period of weed control influenced by the many factors that affect weed interference intensity, including the diversity of weed species, weed density, distribution and emergence periodicity, the nutrient status of the soil, weather and cultural practices (Hall *et al.*, 1992; Swanton and Weise, 1991).

The objective of this study was to determine the critical period of weed control for winter canola in a semi arid region (Tehran west).

MATERIALS AND METHODS

Experiment was conducted at the research field of Agriculture Faculty of Tarbiat Modarres University (35° 42´N, 50° 71´E; 1215 m above sea level) in 2004-2005. This location (West of Tehran Metropolitan) is a represent of a semi arid region. Total annual precipitation in experiment year was 350 mm. Mean daily temperature during growing season varies from 25°C in early fall to -5°C mid winter and 25°C end of spring. The soil texture was sandy loam with pH = 7.4 and less than 1% organic matter. The experiment was arranged in a randomized complete blocks with four replications. Fourteen experimental treatments of divided to two separate groups represent weed control and weed interference duration respectively. In the first set crop was kept weed-free from emergence time to two-leaf stage (V2), four-leaf stage (V4), six-leaf stage (V6), eight-leaf stage (V8), early flowering (IE), 50% of silique set (50% SS) and final harvest (H) [A standardized growth stage scale developed by BASF, Bayer Ciba-Geigy and Hoechst called BBCH decimal system provides an accurate and simplified approach to describing canola growth stages]. In Interference treatments all weed species were allow to grow in canola field till above mentioned growth stages of canola. Both full season weed removal and interference treatments considered to control treatments. Each plot consists of five 4 m rows, spaced 0.3 m apart.

During land preparation in early summer, 300 kg ha^{-1} triple super phosphate fertilizer incorporated to the soil (with mold board plow) followed by disking. One commonly used commercial variety of winter canola (Var. Okapi) was direct seeded in September 22nd, 2004. Canola seedlings thinned at 3 leaves stage to a final population of 650000 plant ha^{-1}. Nitrogen fertilizing divided to three stages involved two-four leaves, end of rosette phase and initiation of grain filling. Field was irrigated to meet crop water requirement (seven times before rosette in autumn and eight times in spring before physiological maturity).

An area of three m^2, corresponding to the central area of the middle two rows of each plot was hand harvested at maturity. Canola was manually threshed and the constant weight before final yield was recorded. The Gompertz Eq. 1 was used to describe the effect of increasing lengths of weed-free period on canola yield (Ratkowsky, 1990; Hall *et al.*, 1992; Martin *et al.*, 2001).

$$Y = Ae^{(-Be^{(-KT)})} \quad (1)$$

where, Y is the yield (% of season-long weed-free plot), A is the yield asymptote, B and K are constants, T is time in DAE (days after emergence) and exp refers to e (the base of the natural logarithm). Also Logistic Eq. 2 was used to describe the effect of increasing duration of weed infestation on the yield of canola (Ratkowsky, 1990; Hall *et al.*, 1992).

$$Y = [(1/De^{[K(T-X)]} + F) + (F-1)/F] \times 100 \quad (2)$$

where, Y is yield (% of season-long weed-free plot), T is the DAE (days after emergence), X is the point of infection (DAE) and D, F and K are constants coefficient (Hall *et al.*, 1992). In order to predict constant coefficients in above functions a mathematical computer program (SIGMA PLOT) was used. According to the curve derived from Gompertz and Logistic equation, the critical length of the weed-free and weed-interference period for canola based on canola days after emergence calculated for specific yield loss levels of 5 and 10%, respectively (Martin *et al.*, 2001).

RESULTS AND DISCUSSION

Field observation was resulted the high variation in weed species and their level of infestation throughout the season. It brings from their difference in ecological and physiological properties. Among fall emerged species, common purslane (*Portulacca oleracea* L.) had produced high density and biomass between weeds in autumn followed by Volunteer wheat (*Triticum aestivum* L.), Redroot pigweed (*Amaranthus retroflexus* L.), Common lambsquaters (*Chenopodium album* L.) and Jimsonweed (*Datura stramonium* L.) respectively (Table 1). In early winter all of summer weeds disappeared except volunteer wheat that was a winter weed. In spring London racket (*Sisymbrium irio*) did appeared but never produce enough biomass because of dense and highly established canola canopy.

Critical weed-free period: The results of this experiment exhibited that weed-crop competition for radiation capture was too important in four-leaf growth stage of canola. In fall (canola vegetative growth) some species of weeds passed of canola canopy as increasing their height (e.g., Redroot pigweed and Common lambsquaters) and received enough radiation but other weeds grew under the canola canopy (e.g., Hogweed and Volunteer wheat) and competed only for soil water and nutrient.

The critical period of weed interference corresponded directly to reductions in radiation quantity due to weed shading effect (Weaver and Tan, 1983). However, yield losses occurred even in absence of shading and it is likely that water stress also played a role in interference (Weaver and Tan, 1987). In spring the canola canopy height increased (>1 m) as flowering shoots growth (generative growth) and all of the weeds, even were tall, shaded intensively. The growth of late-emerging weeds is generally reduced due to crop shading effect (Weaver and Tan, 1987).

In this experiment weed density increased even though after four-leaf stage. In contrast the weeds single plant weights were consistent. Probably, the canopy closure by canola never can to prevent establishing the weeds but the inter and intra-specific competition (often for solar radiation) after four-leaf stage caused to little biomass accumulation in weeds. Martin *et al.* (2001) reported after four-leaf stage of canola, few weed emerged and those accumulated little biomass and canopy closure by the canola may have prevented weeds from establishing after the four-leaf stage. Minimum weed-free period [minimum length of time after sowing that a crop must be kept weed-free so that later emerging weeds do not reduce yields (Knezevic *et al.*, 2002), obtained 25 days after canola emergence (585 GDD) with 5% yield loss (Fig. 1).

Table 1: Weed average density and biomass in control and interference treatments measured end of fall and early spring

	Canola eight-leaf (40 DAE)		Early flowering (176 DAE)	
Weed species	Density (plant m^{-2})	Biomass (g m^{-2})	Density (plant m^{-2})	Biomass (g m^{-2})
Common purslane (*Purtulaca oleracea* L.)	106	64	0	0
Volunteer wheat (*Triticum aestivum* L.)	8	4	8	11
Redroot pigweed (*Amaranthus retroflexus* L.)	8	4	0	0
Common lambsquaters (*Chenopodium album* L.)	7	8	0	0
Jimsonweed (*Datura stramonium* L.)	2	2	0	0
London racket (*Sisymbrium irio*)	0	0	2	1
Total	131	82	10	12

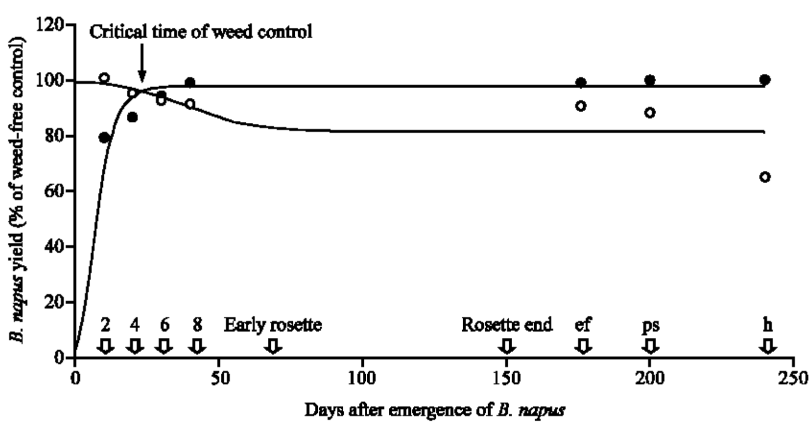

Fig. 1: Canola (*Brassica napus* L.) yield response to increasing length of weed-free period (●) or duration of weed infestation (○) in days after emergence of the crop (DAE). Development stages of the crop, indicated by arrows, were two-leaf (2), four-leaf (4), six-leaf (6), eight-leaf (8), early flowering (ef), pod set (ps) and harvest (h)

Critical timing of weed removal: Based on the results of this study, weeds can remain in canola up to the four-leaf stage (25 DAE) with 5% yield loss. Maximum weed-infested period [maximum length of time that weeds which emerges with the crop can remain before they become large enough to compete for growth resources (Knezevic *et al*., 2002), obtained 25 days after canola emergence (585 GDD) at 5% yield loss (Fig. 1). This means that canola tolerate the early season weeds interference until 25 DAE and repair the weeds damages. Weaver and Tan (1987) reported maximum weed-infested period in field seeded tomatoes varied 5-6 weeks after sowing. Bukun (2004) represented that maximum weed tolerated in early season in cotton was about 100-170 GDD after planting at 10% yield loss level.

Critical period of weed control: Critical period of weed control obtained with combination of both critical timing of weed-removal and weed-free period as Logistic and Gompertz models curves. Knezevic *et al.* (2002) described three relationships that can exist in critical studies. The first is when the critical weed-free period is of longer duration than the critical timing of weed-removal; the crop must be kept free of weeds between these timings to prevent yield loss. In the second relationship, the crop must be kept weed-free for the same duration that a weed infestation can be tolerated (i.e., the critical weed-free period and the critical timing of weed removal are equivalent in term of developmental stage or days after crop emergence (DAE). In this situation, yield loss will be avoided if weed control is performed at this one critical time. The third relationship exists when the critical timing of weed removal is longer than the critical weed-free period. In this case, yield loss will not occur if weeds are controlled at any point between these critical stages.

In this experiment, the critical weed-free period and the critical timing of weed removal are equivalent in days after crop emergence. Therefore, the critical time of weed control that occurred on 25 DAE (between four-to six-leaf stages) and a time weed control is enough for avoid yield loss. However, if we had not performed any weed control, canola yield loss will reduces just 7% because of lack the powerful canola competitor species in experiment field. The coefficient for the equations which defined the critical period of weed control are listed in Table 2 and 3.

Martin *et al.* (2001) showed when there were high levels of weed pressure, weed removal prior to the four-leaf stage (17-38 DAE) of spring canola was not required to prevent yield loss >5% and that canola growth and development are sufficiently plastic at the four-leaf stage to recover yield potential after weeds are removed. After CPWC, shading by the crop will normally prevent the establishment of late-emerging weeds, or the crop might tolerant the reduced competitiveness of these weeds (Martin *et al*., 2001).

Table 2: Parameter estimates for Gompertz equation and standard error*

Year	A	B	K	R^2
2004	97.67	3.81	0.23	96.58

* Y = Aexp (-Bexp(-KT); Y = Yield (% of season-long weed free corn); A = Asymptote (% of season long weed-free corn); B, K = Constants; T = Time from emergence (days)

Table 3: Parameter estimated for the logistic equation and standard error*

Year	X	D	K	F	R^2
2004	9.07	0.46	0.082	5.37	95.8

* Y = ((1/(Dexp(K(T-x))+F))+((F-1)/F))100%; Y = Yield (% of season-long weed-free corn); T = Time from emergence; x = Point of infection (days); D, F = Constants

Hall *et al.* (1992) represented the beginning of the CPWC varied from 3-to 14-leaf stages of corn (*Zea mays* L.) development and the end of CPWC was less variable and ended on average at the 14-leaf stage. He suggested weed interference reduced corn leaf area by reducing the expanded leaf area of each individual leaf and accelerating senescence of lower leaves. Bukun (2004) reported the beginning of CPWC in Cotton, (*Gossypium hirsutum* L.) ranged from 100 to 159 GDD and the end from 1006 to 1174 GDD, depending on the weed species and density. Ngouajio *et al.* (1997) showed the CPWC beginning in Common bean (*Phaseolus vulgaris* L. [cv. Maringue]) occurred emergence to first trifoliate and end of second trifoliate leaf to pod filling stages of bean. He offered the CPWC in bean was less than 25 days at 5% yield loss.

Practical implication: The development of any IWM (integrated weed management) system requires knowledge of the behavior of weeds in the agro ecosystem, including possible effects on crop yields (Amador-Ramirez, 2002). Knowledge of CPWC and morphological changes occurring in the crop may provide useful information upon which to base future weed control recommendation (Hall *et al*., 1992). The result of this study suggests that weeds must be controlled during the four-to six-leaf of canola in growing season to prevent yield loss and utilize the post emergence herbicide with less survival in CPWC will be useful for weed control in canola.

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