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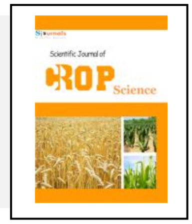

Original article

Effect of nitrogen rates on critical period for weed control and yield of corn (zea mays)

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In order to evaluate the influence of nitrogen (N) rate and weed interference durations on weed dry weight, grain yield, biological yield and harvest index a set of experiments were conducted in the Research Station of the University of Tabriz, Iran, in 2009.The experiment was carried out as split-plot, based on randomized complete block design with three replications. Nitrogen levels (0, 70 and 140 kg/ha) were allocated to main plots and 10 weed interference periods (two sets) to subplots. In the first set, the plots were kept weed-free (from beginning of the growing season) for 14, 28, 42 and 56 days after corn emergence and weeds were allowed to infest the crop, later. In the second set, weed were allowed to infest the crop in the corresponding period and subsequently kept weed free. Results showed that, with increasing weed interference period, grain yield, biological yield and harvest index decreased and weed dry weight increased. Full-season weed infestation decreased grain yield, biological yield. The constructed models showed that in order to prevent a grains yield loss of 5%, weeds must be removed from the field after 9.4, 13.26 and 15.59 days after emergence (DAE), respectively. Corn required 95.33, 87.79 and 80.5 days weed free period to prevent a grain yield loss of 5% under the written nitrogen rates, respectively. An increase in the nitrogen levels enhanced corn tolerance to weed infestation. Furthermore, reductions in the nitrogen level before corn planting may cause the need for more immediate and long period weed control.

1. Introduction

High yielding ability and better quality are considered the 2 main objectives in crop production. In order to achieve these goals, some agronomical principles and methods should be applied. One of the main problems that affect yield and quality of crops is weeds' interference and their competition with the crop (Hager et al., 2002). At present, more money is spent by growers on weed control than other crop inputs. The value of the global pesticide market was $29 billion in 2000, divided approximately between herbicides (48%), insecticides (27%), fungicides (19%) and other products (6%) (CPA, 2002). Thus, maximum yields could not be obtained without controlling weeds. Developing a suitable integrated weed management

(IWM) system requires the precise study of weeds and their interference with crops (Cruse et al., 1995). The critical period for weed control (CPWC) is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses. It is useful for making decisions on the need for and timing of weed control. Determining the CPWC could help reduce yield losses due to weed interference (Knezevic et al., 2002). The CPWC is determined by calculating the time interval between two components of weed interference. These are (1) 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 (2) 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., 2003a; Hall et al., 1992). Studies carried out about the critical period of weed control showed that the duration of CPWC depends on several factors, including cultivars (Seem et al., 2003), climate, weed population density, and dominant weeds in the region (Martin et al., 2001; Seem et al., 2003), crop planting date (Martin et al., 2001), and other factors. Knowledge of critical periods may be used in bioeconomic models to improve the timing of herbicide applications for integrated weed management (Eyherabide and Cendoya, 2002).

Corn (Zea mays L.) is an important crop for Iran and weeds are one of the most important reducing factors in its production in Iran. Therefore, weed control is an important management practice for corn production that should be carried out to ensure optimum grain and forage yield. Studies have been conducted around the world to determine the CPWC in corn, with a range of environmental conditions. Hejazi et al., (2000) reported this period for silage corn in Varamin region, Iran from 5-leaf stage (21 DAP) to 12-leaf stage (38 DAP) at the 5% yield loss. Asghari et al., (2002) showed that CPWC for corn in west of Iran is 5- to 9-leaf stage (26-37 DAE) at the 5% grain yield loss.

2. Materials and methods

2.1. Site description

The field experiments were conducted at the Research Station (latitude 38º15'N, longitude 46º17'E, altitude 1360 m above sea level) of the Faculty of Agriculture, University of Tabriz, Tabriz, northwest Iran, in the 2008-2009 growing seasons. Soil was sandy loam with pH 7.6 and 0.8% organic matter.

2.2. Experimental design

Plot size was 2m×3m, consisting of 4 rows. Corn seeds, cultivar SC704, sown at a spacing of 25 cm within the row spaced 50 cm apart at a density of 8 plants per m2. Sowing dates were 21 May 2009. Naturally occurring weed populations were used in trials.

The experimental design was split-plot, based on randomized complete blocks design with three replications. Nitrogen (urea source) levels (0, 70 and 140 kg/ha) were arranged in the main plots and two sets of weed interference periods in the subplots. In the first set, the plots were kept weed-free from bigining of the growing season to 14, 28, 42 and 56 day after corn emergenced, by hand weeding. In the second set, plots were left weed infested up to the corresponding period and subsequently kept weed free. In each block, 3 experimental plot for pure natural weeds (without crop) as witness for appraise of the potantiol producing weeds, 3 experimental plot was devoted to no weeding from growing season and 3 experimental plot was devoted to weed free from growing season.

Weeds were harvested from one 1 m2 quadrats staggered on each side of the three middles corn rows within each experimental plot. At each harvest weeds were clipped at the soil surface, sorted by species, counted, and dried at 80 °C to constant moisture content to obtain a measure of aboveground dry wee biomass.

2.3. Critical period determination

Yield data of individual plots were calculated as the percentage of their corresponding weed-free plot yields. Nonlinear regression analyses were used to estimate the relative yield of corn as a function of increasing duration of weed interference or as a function of the length of the weed-free period, according to the procedure outlined by Knezevic et al., (2002).

A three-parameter logistic equation (Knezevic et al. 2002) was used to describe the effect of increasing duration of weed interference on relative yield and to determine the beginning of the CPWC for each planting date:

$$Y = C + D/ (1 + \exp (-A + B T)) \qquad [2]$$

where Y is the yield as a percentage of the weed-free control, A and B are parameters that determine the shape of the curve, C is the lower asymptote, D is the difference between the upper and lower asymptotes, and T is days after corn emergence (DAE), which is equal to weed infested duration from corn emergence time until weed removal and control time (Table 1).

The three-parameter Gompertz equation, modified slightly from the proposed form by Hall et al. (1992), was used to describe the effect of increasing duration of weed-free period on relative yield and to determine the end of the CPWC for each planting date:

$$Y = A \exp (-B \exp (-KT)) \qquad [2]$$

Where Y is the yield as a percentage of the weed-free control, A is the upper asymptote, B and K are parameters that determine the shape of the curve, and T is DAE, which is equal to the weed-free period from corn emergence time. Estimated parameters are presented in Table 2.

3. Results and discussion

3.1. Critical timing of weed removal

Beginning of the CPWC was delayed at the 140-kg N ha-1 rate when compared with the 0-kg N ha-1 rate (Fig. 1 and Table 3). Without addition of nitrogen fertilizer, the beginning of the CPWC ranged from 9.42 DAE. At the 140-kg N ha-1 rate, the beginning of the CPWC ranged from 15.59 DAE (Fig. 1and Table 3). The beginning of the CPWC was similar for the 0 and 70-kg N ha-1 rates. These results indicate that an increase in nitrogen applied early in the growing season increased corn tolerance to the presence of weeds even when no yield response to nitrogen was observed.

Table 1
Parameter estimates with standard errors of the three-parameter logistic model used to determine the critical timing of weed removal for three levels of nitrogen application. The model was fit to relative yields of corn (Zea mays L.) (expressed as a percentage of the weed-free control) as a function of increasing duration of weed interference. Refer to text (Equation 1) for model description.

	Parameter estimates				
Nitrogen rate (kg/ha)	**A**	**B**	**C**	**D**	**R2**
0	1.170 (0.288)	0.03 (0.0039)	27.495 (1.595)	95.398 (8.769)	0.999
70	2.641 (0.147)	0.058 (0.003)	31.978 (0.566)	73.218 (1.343)	0.999
140	2.51 (0.478)	0.054 (0.008)	36.336 (1.696)	69.746 (4.38)	0.998

The mechanisms by which the addition of nitrogen reduces negative effects from weeds are not completely understood, but it is likely that nitrogen increased early-season corn growth rates, aiding in more timely corn leaf area expansion and improving the resiliency of corn leaf nitrogen content to the effects of weed interference (Evans 2003b).

Table 2
Parameter estimates with standard errors of the Gompertz model used to determine the critical weed-free period for corn (Zea mays L.) for three levels of nitrogen application. The model was fit to relative yields of corn (expressed as a percentage of the weed-free control) as a function of increasing length of weed-free period. Refer to text (Equation 2) for model description.

	Parameter estimates			
Nitrogen rate (kg/ha)	**A**	**B**	**K**	**R2**
0	102.845 (1.786)	1.203 (0.037)	0.0259 (0.001)	0.998
70	104.663 (9.09)	1.406 (0.214)	0.0264 (0.007)	0.960
140	104.029 (7.349)	1.177 (0.15)	0.0266 (0.006)	0.967

Table 3
The critical period of weed controla (CPWC) for corn (Zea mays L.) at three levels of nitrogen application expressed in days after crop emergence.

	Nitrogen level (kg/ha)		
	0	**70**	**140**
Maximum duration of weed infestation	9.42	13.26	15.59
Minimum duration of weed-free	104.75	101.15	96.09
Length of critical period (day)	95.33	87.89	80.5

a Based on a 5% acceptable yield loss level.

3.2. Critical weed-free period

The ending time of the critical weed-free period was obtained as 104.75 DAE for the 0-kg N ha-1 rate and 96.09 DAE for the 140-kg N ha-1 rate, the critical weed-free period was shorter for the 140-kg N ha-1rate (Fig. 1 and Table 3).

Analysis of variance revealed significant effects of different durations of weed interference on weed dry weight, grain yield, biological yield and harvest index. However, nitrogen levels were not significant effect for these traits (Table 4).

Non-significant effect of nitrogen on the dry weight of weeds shows that, with increasing of nitrogen levels weeds have not been able to significantly use of excess nitrogen in order to increase their dry weight. Similar results were reported by Shafagh-Kolvanagh and et al. (2008). The highest weed dry weight production was obtained from weed-infested until harvest (weedy control).

Grain yield decreased significantly with increasing length of weed interference duration and decreasing length of weed-free period (Table 5). The maximum corn grain yield (970 g m-2) was obtained with the control treatment (full season weed-free) and minimum grain yield (323 g m-2) was obtained for the full-season weed interference treatment. Weed infested conditions for the entire growing season led to 67% reduction in grain yield, as compared with full season weed-free control treatments. This yield reduction is related to the lower amount of available nutrients, light, and water for the crop plants.

Biological yield and harvest index increased with increasing levels of nitrogen and length of weed-free period and decreased with decreasing levels of nitrogen and length of weed-free period (Table). The maximum and minimum biological yield was devoted respectively to weed-free control (2247.98 g/m2) and weedy control (1061.26 g/m2) treatments, however there was no significant difference between the full season weed-free control and Weed-infested for 14 DAE (Table 5).

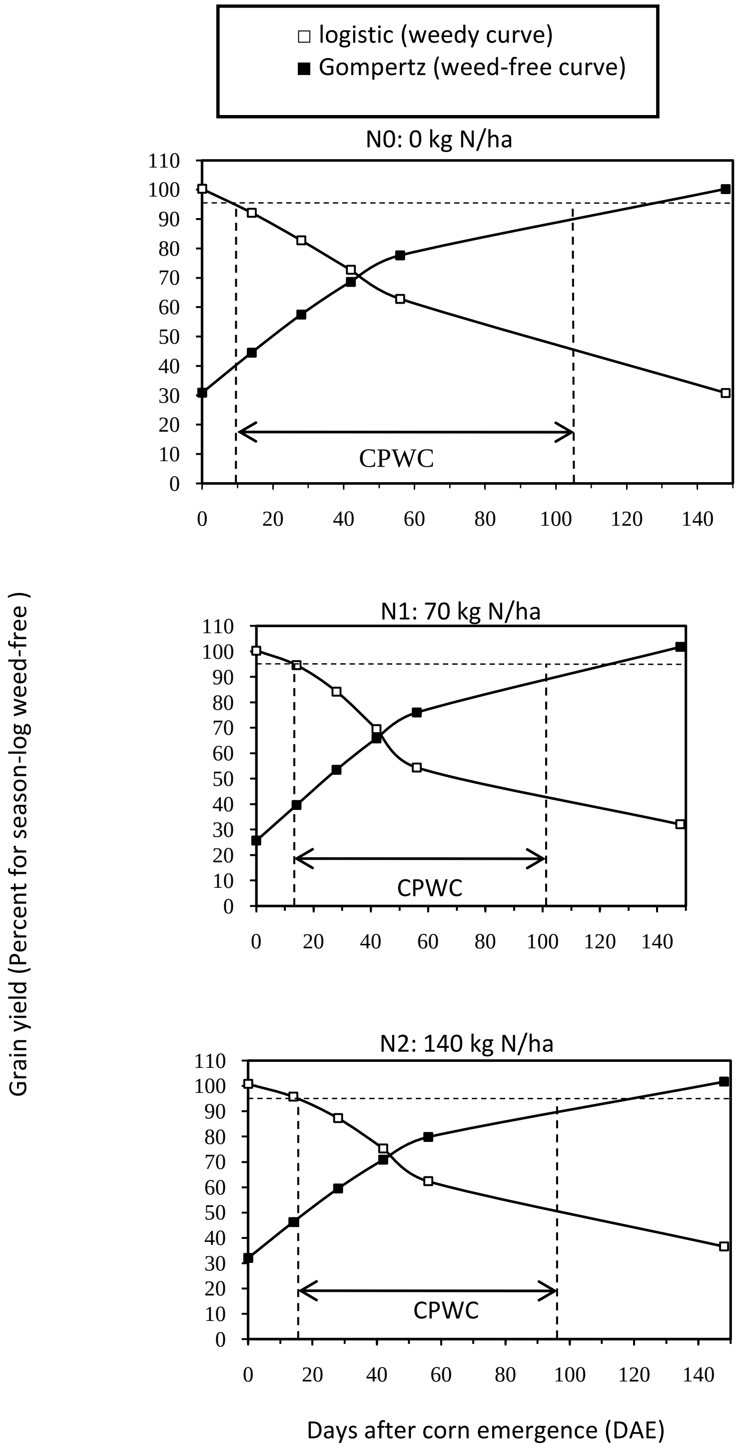

Fig. 2. Corn (Zea mays L.) grain yield (Y) expressed as a percentage of the weed-free control as a function of increasing duration of weed interference (■) or length of weed-free period (□) for three rates of nitrogen application. Solid lines predicted from fitting the three-parameter logistic model, weedy curve, and the Gompertz model, weed-free curve, are used to determine the beginning and end of the critical period for weed control (CPWC), respectively. Refer to Tables 1 and 2 for parameter estimates and Equations 1 and 2 in the text for model explanation. Horizontal dashed lines indicate the 5% acceptable yield loss level used to determine both the beginning and end of the CPWC, whereas vertical dashed lines indicate the DAE, which produce a model solution of 95% Y.

Weed infested conditions for the entire growing season led to 53% reduction in biological yield, as compared with full season weed-free control treatments.

This yield reduction is associated with increasing of weed infested duration, lower amount of available nutrients, light, and water for the crop plants and other resources among Space in weeds competition.

Table 4
Analysis of variance for the effects of different nitrogen levels and period of weed interference on several corn characters.

Mean squares					
Source of variation	**DF**	**Weed dry weight**	**Grain yield**	**Biological yield**	**Harvest Index**
Replication	2	3736.39	585572.64*	1854611.58*	331.72*
Nitrogen level (N)	2	4149.42	92013.75	628535.01	10.04
Ea	4	10412.66	51080.15	261619.71	40.60
Period of weed interference (P)	9	97545.97***	420502.68***	1257836.94***	220.10***
N*P	18	5067.58	3085.41	65719.97	20.78
Eb	54	4563.94	9826.50	47493.91	17.83
CV (%)		47.53	14.71	12.45	11.36

*, ** and *** significant at p<0.05, p<0.01, and p<0.001, respectively.

Table 5
Mean values of the traits under different nitrogen levels and period of weed interference for corn.

Treatment	**Weed dry weight (g/m2)**	**Grain yield (g/m2)**	**Biological yield (g/m2)**	**Harvest Index**
Nitrogen level (N kg/ha)				
0	132.82a	617.46a	1599.35a	36.58a
70	155.45a	675.97a	1765.87a	37.24a
140	138.18a	728.16a	1887.69a	37.74a
Mean	142.15	673.86	1750.97	37.19
Period of weed interference (P)				
Weedy control	321.92a	323.06f	1061.26g	30.18f
Weed-free for 14 DAE	228.57bc	396.96f	1362.07f	28.44f
Weed-free for 28 DAE	161.25d	528.60e	1503.78ef	34.77e
Weed-free for 42 DAE	109.67de	652.85cd	1654.44e	38.84bcd
Weed-free for 56 DAE	47.93ef	807.48b	1924.79c	40.36abc
Weed-free control	0.00f	970.42a	2247.98a	43.04a
Weed-infested for 14 DAE	43.62ef	926.36a	2178.64ab	42.58ab
Weed-infested for 28 DAE	82.77e	823.49b	2036.37bc	40.22abc
Weed-infested for 42 DAE	168.09cd	711.90c	1865.45cd	37.90cde
Weed-infested for 56 DAE	257.68ab	597.50de	1674.95de	35.52de
Mean	142.15	673.86	1750.97	37.19

Different letters indicate significant differences at p<0.05 and * Data transformed.

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