Competitive Interaction of Common Lambsquarters (*Chenopodium album* L.) and Maize (*Zea mays* L.) at Different Time of Emergence and Density

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Abstract

Common lambsquarters (*Chenopodium album* L.) is an important weed of maize fields in Iran. In order to study the effect of common lambsquarters relative time of emergence on single-cross 704 maize (*Zea mays* L.), an experiment was designed with different density levels of the weed. The experimental design was a split plot based on a randomized completed block design with three replications. The emergence time of lambsquarters was considered as main plots with three levels: emergence of the weed 14 days earlier, 7 days earlier than maize and simultaneously with maize. Density of weed was the subplot treatment with six levels: 0, 4, 8, 12, 16, and 20 plants per m^2. The results showed that height and leaf area index of maize decrease with earlier emergence time and increasing density of lambsquarters, so that 14 days earlier emergence of weed at high densities (16 and 20 plants per m^2) led to maximum reduction. In contrast, height and LAI of lambsquarters increased with earlier emergence time especially at high densities. Common lambsquarters was a stronger competitor when emerged 14 days earlier than maize. Maize yield decreased more than 70% in the 7 and 14 days earlier emergence of lambsquarters at high density. Totally, it can be state that relative time of weed emergence compare to its density had maximum effect on maize growth. In addition, controlling lambsquarters before maize emerging at any densities is recommend preventing of maize growth and yield loss.

Keywords: Corn, density, emergence time, interference, leaf area, yield loss

1. Introduction

Common lambsquarters is the most prevalent weed of soybean [*Glycine max* (L.) Merr.] and maize (*Zea mays* L.) cropping systems in the upper Midwest of the USA [3, 6, 9] and it is one of the most competitive annual broadleaf weeds in maize production in Ontario, Canada [15]. Common lambsquarters causes significant yield damage in many cropping systems because of its rapid growth characteristics, competition for nutrients [12, 14], prolific seed production [6], and seed germination, under a wide range of environmental conditions [10, 11]. Weed density is a crucial factor in crop-weed competition. Crook and Renner [5] observed a 20% reduction in soybean yield where lambsquarters was present throughout the entire growing season at a density of four plants m^{-2}. Sibuga and Bandeen [13] found that maize yield reduced by as much as 58% when lambsquarters density reached 277 plants m^{-2}.

The timing of weed emergence relative to crop is important to crop growth and yield. Yield losses are usually high when weeds emerge earlier or at the same time as the crop [1, 2, 7]. Common lambsquarters is known as one of the most troublesome weeds in maize field of Iran. The majority of studies record effects of weeds on yield in the simultaneous emergence time or times after crop emergence, whereas weeds usually cause to yield loss when emerge before crops and interference with crops during the growing season. Therefore, the objectives of this study were to (1) evaluate the importance and influence of earlier emergence time of weed at different densities on maize yield and leaf area index and (2) determine the competitiveness of lambsquarters and its effects on maize yield when emerged at different times and densities.

2. Materials and methods

An experiment was conducted in 2006 growing season at the Agricultural Faculty of Ferdowsi University of Mashhad, Iran. The experiment was a split plot based on randomized complete block design with three replications. Emergence time of lambsquarters as E_1, E_2 and E_3 (emergence of the weeds 14 or 7 days earlier and simultaneously with maize emergence, respectively) were assigned to main plots and density of weed at 6 levels of D_0, D_1, D_2, D_3, D_4 and D_5 (0, 4, 8, 12, 16 and 20 plants m^{-2}) as subplot. Maize seed were planted 1.5 to 2 cm deep in 70-cm between and 20-cm in-row spacing at density of 7 plants m^{-2}. The field was moldboard-plowed, harrowed and cultipacked in the spring to be prepared for planting. Starter fertilizer was broadcasted at a rate of 300-200-200 kg ha^{-1} N-P-K before planting based on local recommendations and was incorporated by cultivation and shallow disking for seedbed preparation. Nitrogen fertilizer was applied three times, 50% before planting, 25% at the six-to eight- leaf stage, and 25% at the ten-to twelve-leaf stage of maize. Based on a pre-test it was determined that emergence took 15 days for lambsquarters and 7 days for maize. We adjusted sowing dates of lambsquarters to achieve emergence 14 and 7 days prior to maize emergence and simultaneously with maize. Common lambsquarters emergence times were based on visual estimates of 50% emerged plants. At the initiation of lambsquarters senescence, five-tagged maize and five plants of lambsquarters near to them were clipped at the soil surface, sectioned, and placed in cloth bags. After measuring plants leaf area with leaf area meter (Delta-T Devices, Cambridge, England), plants were dried to constant weight in an oven for 70 h at 75°C, and dry weights were recorded.

The relationship between lambsquarters density and maize leaf area index was analyzed separately for each time of emergence by using a nonlinear hyperbolic model described by Cousens [4]. Equation 1 was used to describe relationship between lambsquarters density and maize leaf area index:

$$LAI = LAI_{WF}\left[1-\frac{D}{100\left(1+\frac{D}{A}\right)}\right] \qquad (1)$$

Where *LAI* is maize leaf area, LAI_{WF} is estimated leaf area index in weed-free plots, *D* is weed density (plants m^{-2}), *I* is the percent leaf area index loss per unit weed density as *D* approaches zero, and *A* is the percent leaf area index loss as *D* approaches infinity.

The relative leaf area of lambsquarters at the beginning of senescence was determined from Equation 2:

$$L_W = \frac{LAI_W}{LAI_W + LAI_C} \quad (2)$$

Where L_W is lambsquarters relative leaf area, LAI_W is the leaf area index of weed and LAI_C is the leaf area index of maize. The relationship between maize yield loss and weed relative leaf area was determined using Equation 3 [8]:

$$Y_L = \frac{qL_W}{1+(q-1)L_W} \quad (3)$$

Where Y_L is the predicted proportional maize yield loss, *q* is the damage coefficient associated with weed and L_W is the relative leaf area of weed. Another version of the model was derived from the empirical model introduced by Cousens [4]. This model includes an extra parameter for the maximum yield loss caused by weed (*m*) (Equation 4):

$$Y_L = \frac{qL_W}{1+\left(\frac{q}{m}-1\right)L_W} \quad (4)$$

3. Results and discussion

The result of this research showed that earlier emergence time and density of lambsquarters has remarkable effect on maize leaf area index. Maximum maize leaf area index (3) was obtained in the same emerging at low density of weed except of weed free check. In contrast, the lowest LAI (0.4 and 0.3) was observed when maize emergence was delayed 14 days at 16 and 20 plants m^{-2}, respectively (Figure 1). Based on the coefficients of Equation 1, reduction in maize leaf area index per unit weed density as *D* approaches zero at 14 and 7 days earlier emergence of lambsquarters (*I*) was 17.63 and 9.09 percent respectively, while, in simultaneous emergence of weed was 2.71 percent.

These coefficients show that first plant of lambsquarters impose more competition pressure to maize at the earlier emergence time especially in 14 days earlier emergence of weed. Also, maximum reduction in maize leaf area index was obtained at high densities in 14 and 7 days earlier emergence of weed than maize, so that maize leaf area index reduced by almost 100 percent (Table 1). Hence, the time of weed emergence is very important in competition between crop-weed, as earlier emergence of weed would be led to reduction of leaf area index of crop close to 100 percent and consequently the maximum yield loss.

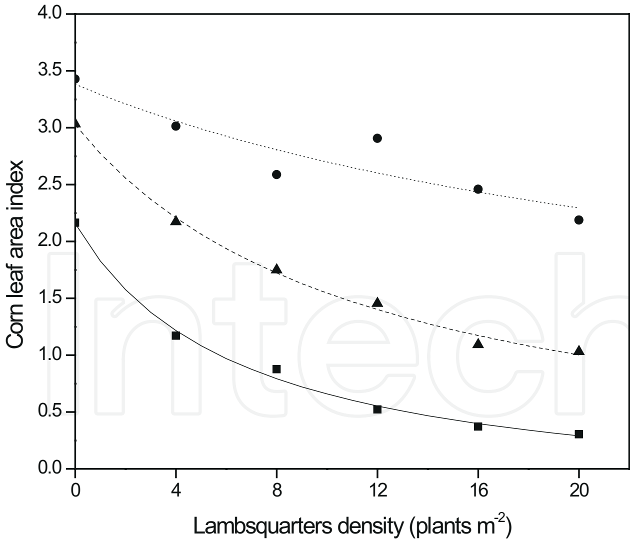

Figure 1. Observed and estimated maize leaf area index at the beginning of lambsquarters senescence as a function of weed density at the 14 days (■), 7 days (▲) earlier emergence of weed and simultaneous (●) emergence time. Regression lines were fitted using Equation 1.

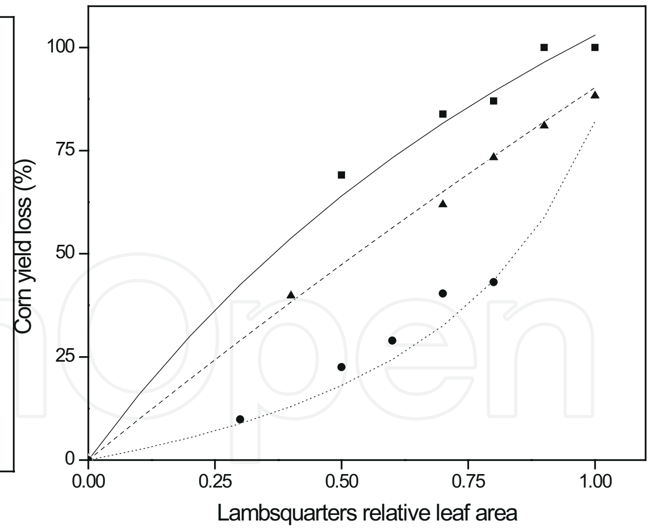

Figure 2. Relation between estimated yield loss in maize and relative leaf area of lambsquarters at the initiation of weed senescence for the 14 days (■), 7 days (▲) earlier emergence of weed and simultaneous (●) emergence time. Common lambsquarters densities were zero, 4, 8, 12, 16 and 20 plants m^{-2}.

Lambsquarters relative time of emergence	Weed-free maize leaf area index	Parameter estimates [a]			
		LAI_{WF}	I	A	R^2
	—	—	%	%	—
E_{-14} [b]	2.16	2.15 ± 0.05	17.63 ± 2.23	100 ± 7	0.99
E_{-7}	3.03	3.02 ± 0.06	9.09 ± 1.11	100 ± 9.44	0.99
E_0	3.42	3.38 ± 0.21	2.71 ± 2.31	78 ± 10.09	0.84

[a] **LAI_{WF}**, represents predicted weed-free leaf area index ± SE of maize; I, represents leaf area index loss ± SE as weed density approaches zero; A, represents leaf area index loss ± SE at high weed densities. The coefficient of determination (R^2) describes the fit of each model to the observed data.

[b] **E_{-14}**, E_{-7} are 14 and 7 days earlier emergence and E_0 is the same emergence of this weed with maize, respectively.

Table 1. Observed weed-free maize leaf area index and rectangular hyperbola parameter estimates for the first, second and third lambsquarters emergence times as a function of weed density.

Relative damage coefficient indicated that lambsquarters in 14 days earlier emergence was a stronger competitor than maize, so that at this time of emergence, *q* was larger than one (1.64 and 1.3 for one and two parameter model, respectively) and a convex curve is found above the diagonal line. In contrast, this coefficient was smaller than one (0.28 and 0.04) for both parameter model and a concave curve is found under the diagonal line (Table 2 and figure 2). Hence, lambsquarters was not good competitor when emerged simultaneously with maize and crop was the stronger competitor. Coefficients also showed that maize and weed had equals competition ability at the 7 days earlier emergence, but maximum yield loss (*m*) was obtained at high densities showing that emerging lambsquarters in this time and 14 days earlier than maize was led to yield reduction by 75 and 79 percent, respectively (Table 2).

These results show that crop yield would be reduce more than 70%, when weed emerged earlier than crop even though competitiveness of crop is the same as weed. Hence, this weed should be controlled in the earlier emergence time to prevent greater yield loss and in the same emerging time to prevent more plants of weed reaching reproductive growth and developing seed bank.

Model	**Parameter estimates [a]**			
	Lambsquarters relative time of emergence	**q**	**m**	**R^2**
One-parameter model	E_{-14} [b]	1.64 ± 0.27	—	0.99
	E_{-7}	1.1 ± 0.62	—	0.92
	E_0	0.28 ± 0.15	—	0.93
Two-parameter model	E_{-14}	1.3 ± 0.14	0.79 ± 0.89	0.99
	E_{-7}	0.83 ± 0.3	0.75 ± 0.27	0.92
	E_0	0.04 ± 0.23	0.15 ± 0.83	0.93

[a] **q,** represents the damage coefficient associated with lambsquarters; m, represents the maximum yield loss caused by weed. The coefficient of determination (R^2) describes the fit of each model to the observed data.

[b] **E_{-14},** E_{-7} are 14 and 7 days earlier emergence and E_0 is the same emergence of this weed with maize, respectively.

Table 2. Estimated parameters obtained from maize yield loss as a function of the relative leaf area of the lambsquarters for the first, second and third emergence times.

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