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The effects of lambsquarters (*Chenopodium album*) density and its relative time of emergence on yield and yield components of grain corn (*Zea mays*)

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ABSTRACT

To investigate the effects of lambsquarters density and its relative time of emergence on yield and yield components of grain corn a two year experiment was conducted in 2001 and 2002 growing seasons in the research field of Weed Research Department, Plant Pests and Diseases Research Institute, Karaj. Both experiments were conducted using factorial arrangement of treatments in a randomized complete block design with 3 replications. The treatments were the relative time of lambsquarters emergence (1st year: simultaneously, at 2-3 and 4-5 leaves stages of corn; 2nd year: simultaneously, at 2-3 and 5-6 leaves stages of corn) and lambsquarters density (first year: 2, 5, 10 and 15 plant.m^{-2}; second year: 6.6, 13.3 and 20 plant.m^{-2}). A pure plot of corn was also cultivated to evaluate grain yield of corn in weed free conditions. The results indicated that both treatments had significant effects on grain and biological yields, harvest index, grain number/ear row and row number/ear of corn. Thousand-seed weight was not affected by lambsquarters density. The results also showed that the negative effect of interference period on corn was more than that of density. In conclusion, a delay in lambsquarters emergence and a good management against it at the beginning of the growth season can increase the competitive ability of corn against lambsquarters.

Key words: corn, lambsquarters, competition, yield, yield components.

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Introduction

Although corn is considered as a weed tolerant crop because of its tall height and rapid growth rate, the crop yield loss due to weeds has been reported to be 30 to 90% (Rahman, 1985; Mickelson & Harvey, 1999). The fact that this crop accounts for 22% of total applied herbicides in field crops support the case (Liebman *et al.*, 2001). But the negative environmental impacts lies behind herbicide application and the necessity to reduce these chemicals consumption, has led to an increasing interest in other weed control approaches like increasing crop competitiveness against weeds.

Lambsquarters is among the most important and common broadleaved weeds infesting the corn fields. This weed is a spring annual species belonging to family *Chenopodiaceae* which infests about 40 field crops such as corn, soybean (*Glycine max* L.), and some cereals worldwide (Crook & Renner, 1990; Rashed-mohassel *et al.*, 2001). Lambsquarters is a C_3 photosynthetic pathway species, capable to grow under a vast range of geographical conditions. One of the important characteristics contributes very much to lambsquarters spread is its high potential of seed production. Crook & Renner (1990) reported that every lambsquarters plant can produce more than 72000 seeds. This also contributes in soil seed bank enhancement.

As it was mentioned earlier, enhancement of crop competitiveness is one of the best options to control weeds that attracted much interest in recent weed management strategies. Different studies have shown that crop competitive ability could be enhanced through alteration of weed density and time of emergence (Liebman *et al.*, 2001; Radosevich, 1987; Roush *et al.*, 1989; Booth *et al.*, 2003; Harrison, 1990; Sattin *et al.*, 1997). Becket *et al*. (1988) reported that lambsquarters density at 2 plants per 0.30m of crop row reduced corn yield by 11%. Harrison *et al.* (2001) studied the effect of giant ragweed (*Ambrosia trifida*) density and the relative time of emergence on corn yield loss. They showed that in simultaneous emergence of the crop and weed (at 1.7, 6.9, and 13.8 weed plants m^{-2}) reduced corn yield 18, 46 and 61%, respectively. But with delay in weed emergence to 6-leaf stage of corn, the crop yield loss reduced to 2, 8 and 15%, respectively. In a study performed on lambsquarters interference in soybean, it was revealed that the highest lambsquarters population density along with the latest time of weed removal resulted in the highest soybean yield loss, so that a 10 weeks interference of lambsquarters at 3.2 plants m^{-1} of crop row reduced soybean yield by 20% (Crook & Renner, 1990). Considering 5% as the maximum acceptable yield loss, these researchers reported 5 weeks interference of lambsquarters at 2 plants m^{-1} of crop row or 7 weeks interference at 1 plant m^{-1} of crop row, as the economic damage threshold for soybean. Beilinski *et al*. (2004) found that lettuce (*Lactuca sativa* L.) yield was reduced 39, 50, 59 and 65% from lambsquarters interference for 10 weeks at densities of 2, 4, 8 and 16 plants per 6m of crop row, respectively. In another experiment it was shown that weed interference at 1.7, 6.9 and 13.8 plants m^{-2} under two relative emergence time of weed (simultaneous to (V_E) and at 6-leaf stage (V_6) of corn) reduced corn yield 18, 46 and 61% at V_E and 2, 8 and 15% at V_6 respectively. Massinga *et al*. (2001) reported that corn yield reduced between 11 and 91% from redroot pigweed (*Amaranthus retroflexus* L.) interference at densities between 0.5 and 8 plants m^{-1} of crop row when weed emerged simultaneously to corn. As these researchers found delay in redroot pigweed emergence up to 6-leaf stage of corn caused corn yield reduction between 7 and 35% for the same weed density range. Strahan *et al.* (2000) also reported that *Rottoboellia cochinchinensis* interference resulted in 125 kg ha^{-1} of corn yield loss per every week of weed interference and 33% corn yield loss due to full season weed interference. Agha Alikhani (2001) showed that redroot pigweed density and relative time of emergence significantly affected corn yield and yield components except 1000-seed weight. He stated that corn yield reduced 58, 40 and 19% when pigweed emerged at V_E, 2-3 (V_{2-3}) and 5-6 (V_{5-6}) leaf stages of corn, respectively.

The objective of this study was to investigate the effects of lambsquarters density and relative time of emergence on corn yield and yield components.

Materials and methods

Two field experiments were conducted during 2001 and 2002 growing seasons at the research field of the Weed Research Department (1320 masl, 35º 56′N, 50º 58′E), Plant Pests and Diseases Research Institute, Karaj, to study the effects of different densities and times of common lambsquarters emergence on corn yield loss. The climate of the region is cold and semi-arid with annual rainfall of 240-300 mm and mean annual, absolute maximum and minimum temperatures of 13.7, 41 and -21.7ºC, respectively. The soil type was sandy loam.

The experimental design was a randomized complete block with a factorial arrangement of treatments and replicated three times. The experimental treatments included density (1st y: 2, 5, 10 and 15 plants m^{-2}; 2nd y: 6.6, 13.3 and 20 plants m^{-2}) and the relative emergence time (1st y: simultaneous to (V_E), at 2-3 (V_{2-3}) and 4-5 (V_{4-5}) leaf stages of corn; 2nd y: simultaneous to, at 2-3 and 5-6 (V_{5-6}) leaf stages of corn) of lambsquarters. A weed-free plot was also selected to determine corn yield under no weed competition. In 2002 based on the results of the first year of experiment, higher levels of lambsquarters density were chosen to impose more competition pressure on corn. Also, a later time of lambsquarters emergence relative to the corn was chosen in 2002 for better evaluation of weed effect on the crop. Soil was sampled before tillage operation and was chemically analyzed. According to the chemical analysis results, fertilizers were applied at the rates of 114 kg N ha^{-1} as urea and 112 kg P ha^{-1} as super phosphate for experiment 1 (2001), and 137 kg N ha^{-1} and 110 kg P ha^{-1} (as urea and super phosphate, respectively) for experiment 2 (2002). Also, top dressed urea was applied at the rate of 45 kg N ha^{-1} as urea at 7-8 leaf stage of corn. The soil preparation consisted of fall moldboard plowing (20-25 cm) following by two spring diskings and smoothing with a land lever. Plots were 10 m long and 4 rows spaced 75 cm apart.

The corn cultivar Single Cross 704 was overseeded on 10 and 24 May 2001 and 2002, respectively, with 20cm between holes within rows and finally thinned to one seed of corn per hole at 2-3 leaf stage, giving a potential plant density of 6.6 m^{-2}. Lambsquarters seeds were collected from corn fields infested by this weed in Karaj. Prechilling was applied to break common lambsquarters seeds dormancy, in which seeds were kept 3 months at -2ºC. The weed seeds were sown at high density at the both sides of corn rows, and finally thinned to target densities at 2-3 leaf stage of lambsquarters. Lambsquarters sowing dates were 10 and 25 May and 8 June of 2001, and 24 May, 7 and 17 June of 2002. All other weeds were removed throughout the season by hand every 2 weeks. Furrow irrigation was applied at weekly intervals during the whole growing season.

The crop was harvested manually in September when seeds moisture reduced to 14%. At harvest, the middle 1.5m of the center two rows of each plot (a total area of $3m^2$) were harvested. Grain and biological yields were determined after oven drying for 48h at $75^{\circ}C$. Also, the number of rows per ear, the number of kernels per ear row, 1000-seed weight, ear length, ear diameter, and harvest index were determined. However, in the present paper the discussion has been made only on the yield and primary yield components.

All data were subjected to analysis of variance using SAS statistical software (SAS Institute, 1996), after verifying the normal distribution about the mean of zero. If the assumptions of variance were not adequately met, data were subjected to an square root transformation. All figures were plotted using Excel software. Because of quantitative nature of lambsquarters density treatment and for more detailed description on the effect of weed density orthogonal comparison was performed (Little, 1981; Petersen, 1977). Linear and quadratic equations were tested to describe the relationship between lambsquarters density and corn yield and yield components. Both regression equations significantly described the relationships. But due to higher coefficient of variation (R^2) of quadratic equation, all aforementioned relationships were fitted to this equation. Data were not combined across years because experimental treatments varied to some extent among the experiments.

Result and discussion

Analysis of variance indicated that lambsquarters density and relative time of emergence had significant effects on corn grain yield in both years of experiment, but there was no significant lambsquarters density by lambsquarters relative time of emergence interaction for this trait (Table 1).

The differences among times of lambsquarters emergence in corn grain yield were significant in 2001 and 2002 (Table 2), with the latest time of lambsquarters emergence (at 4-5 and 5-6 leaf-stages of corn in 2001 and 2002, respectively) showing the highest grain yield. These results indicate that delay in the lambsquarters emergence relative to the crop results in higher amount of corn grain yield. In other words, reduction in interference period of lambsquarters in corn had increased crop grain yield. Mean comparison of lambsquarters density by its relative time of emergence interaction in both years of experiment indicate that increment in lambsquarters density also had significant negative effect on corn grain yield (Fig. 1). As it is observed in Fig. 1, the lowest amounts of corn grain yield in 2001 and 2002 were obtained when corn grew at the highest density and longest interference period of lambsquarters.

These comparisons also revealed that lambsquarters relative time of emergence compared to its density had more effect on corn grain yield. In 2001, corn grain yield at 2 lambsquarters m^{-2} and simultaneous emergence of the weed and crop, was statistically equal to that at 10 lambsquarters m^{-2} emerged at 2-3 leaf stage of corn (Fig. 1). In 2002, the highest amount of corn grain yield was harvested from weed-free check, significantly differed with all other treatments in this respect. Also, within each lambsquarters emergence time, weed density increase caused significant corn yield loss except when weed emerged at 2-3 leaf stage of corn. Moreover, the results of the second year of experiment showed that corn grain yield at 6.6 lambsquarters m^{-2} emerged simultaneously with corn, did not significantly differ that at 20 lambsquarters m^{-2} emerged at 2-3 leaf stages of corn (Fig. 1).

محل قرارگیری جدول ۱ که Landscape است.

The effects of lambsquarters (*Chenopodium album*) density and its relative time of emergence on yield and yield components of grain corn (*Zea mays*)

محل قرارگیری جدول ۲

Our findings are in agreement with those of Bosnic & Swanton (1997), and Cavero *et al.* (1997), who studied the effects of weed density and relative time of emergence on corn grain yield. In contrast, Silbuga & Bandeen (1980) and Beckett *et al.* (1988), found that corn grain yield was not significantly different between 46 and 109 lambsquarters m^{-2}. They attributed this finding to high intraspecific competition in lambsquarters at high density. In the present study, it seems that relative low lambsquarters density has led to low intraspecific competition in lambsquarters, but severe interspecific competition resulted in corn yield loss by increase in weed density.

Figure 2 shows variations in corn grain yield under different lambsquarters density and relative time of emergence in both years of experiment. As it is observed, the highest amount of corn yield loss has occurred at simultaneous emergence of lambsquarters and corn. In both years, the slopes of the regression lines of corn grain yield at different times of lambsquarters emergence on lambsquarters density were sharply negative up to 10 and 12 lambsquarters m^{-2} in 2001 and 2002, respectively. But higher weed densities did not cause further significant corn yield reduction. In fact, increase in lambsquarters density has enhanced intraspecific competition between the corn and the weed so that maximum competition pressure on corn has been imposed at 10 and 12 lambsquarters m^{-2} in 2001 and 2002, respectively. In other lambsquarters emergence times, increase in weed density had caused corn grain yield reduction, although its reductive effect was much lower that that in simultaneous emergence with corn. In fact, delay in lambsquarters emergence had allowed corn to capture resources better than early in the season, thus the yield loss was lower in these treatments. So, it can be concluded that early stages of corn growth are the most critical period of weed control in the crop. Other studies have also shown that the negative impact of weeds on percent corn yield reduction in lower densities is more than that in higher weed densities, especially under longer period of weed interference (Knezevic *et al.*, 1995; Cavero *et al.*, 1997; Massinga *et al.*, 2001).

The effects of lambsquarters (*Chenopodium album*) density and its relative time of emergence on yield and yield components of grain corn (*Zea mays*)

محل قرارگيري شكل ١

محل قرارگيري شكل ۲

The crop yield loss under weed infested condition is also a function of crop yield itself (Sattin *et al.*, 1977). Thus the amounts of crop yield loss agree in most cases with the amount of crop yield. Table 2 demonstrates the amount of corn yield reduction under different times of lambsquarters emergence relative to the crop. As it is observed in table 2, with delays in emergence by lambsquarters, corn yield loss due to weed interference significantly decreased.

Study on variation of percent corn yield reduction at different times of lambsquarters emergence indicated that weed emergence times affected corn yield loss differently (Fig. 2). As Fig. 2 demonstrates, the higher lambsquarters density and interference period in corn, the higher corn yield loss. Strahan *et al.* (2000) stated that *Rottoboellia cochinchinensis* interference resulted in 125 kg/ha corn yield loss per every week of weed interference and 33% corn yield loss due to full season weed interference. In another study, it was shown that higher density and longer interference period of wild proso millet (*Panicum miliaceum*) in corn resulted in greater yield loss (Wilson & Westra, 1991). According to the results of the present study and also the results of similar investigations by other researchers, it can be concluded that weed density and interference period are among the two most important factors determining corn yield loss, although weed interference period effect on yield loss is more than that of weed density.

Biological yield:

Analysis of variance revealed that lambsquarters density, lambsquarters relative time of emergence and the interaction between these two experimental factors had significant effects on corn biological yield and its loss in both years of experiment (Table 1). The effect of relative time of lambsquarters emergence on corn biological yield was similar to that on grain yield, so that by increase in lambsquarters interference period, corn biological yield reduced (Table 2; Fig. 3). Comparison of corn grain yield loss and biological yield loss in both years of experiment indicated more negative effect of lambsquarters interference on corn grain yield (reproductive growth) compared to biological yield. Because weeds create a kind of biotic stress which affects crop growth, the results obtained from the present study is in agreement with those of other studies indicating more negative impact of environmental stresses on the crop reproductive growth (Sarmadnia & Koocheki, 1993; Cavero *et al.*, 1997). Mean comparison of the interaction between lambsquarters density and relative time of emergence on corn biological yield showed that like the grain yield, weed interference period had more negative effect on this trait (Fig. 3). As it is observed in Fig. 3, delaying in the time of lambsquarters emergence up to 4-5 (2001) and 5-6 (2002) leaf stages of corn, resulted in no significant effect of the weed on corn biological yield up to 5 and 6.6 lambsquarters m^{-2} in 2001 and 2002, respectively.

Increase in lambsquarters density resulted in corn biological yield loss in 2001 and 2002 (Fig. 4), with the latest time of lambsquarters emergence (at 4-5 and 5-6 leaf stages of corn in 2001 and 2002, respectively) showing the highest biological yield. On the other hand, the negative effect of lambsquarters density increase on biological yield was more severe under longer periods of weed interference. In other words, the effect of weed density at different periods of interference was not similar (Fig. 4). As Fig. 4 illustrates, the negative effect of lower lambsquarters density on biological yield at simultaneous emergence of the weed and crop was more than that in other times of weed emergence.

Harvest index:

Harvest index is defined as the ratio of the grain weight to the above-ground biomass which reflects the plant ability to partition photosynthates to the reproductive organs. Lambsquarters density and relative times of emergence had significant effect on corn harvest index in both years of experiment, while no significant interaction existed between these two experimental factors for this trait (Table 1). Corn harvest index under different times of lambsquarters emergence relative to the crop showed that with delay in the time of emergence by lambsquarters the harvest index increased (Table 2). As mentioned earlier, the negative effect of weed interference on corn reproductive growth was more than that on vegetative growth. Hadizadeh (1996) attributed the reduction I soybean harvest index by increase in weed interference period to lower partitioning of photosynthates to reproductive organs due to weed infestation.

As Fig. 5 illustrates, the effect of lambsquarters density on corn harvest index was less negative compared to relative times of lambsquarters emergence. As is observed in Fig. 5, in 2001 when lambsquarters emerged simultaneously with corn, the crop harvest index was significantly affected while this effect was not significant at the second and third times of lambsquarters emergence. In 2002, almost the same results were obtained. Comparison of corn harvest index between 2001 and 2002 showed that this trait was affected by year of experiment, so that in total corn harvest index in 2001 was higher than 2002 (Fig. 5). This can be attributed to the higher effect of year of experiment on grain yield compared with biological yield (Fig. 2, 4, 5). Cavero *et al*. (1997) also reported that jimsonweed

(*Datura stramonium* L.) interference reduced corn harvest index significantly, although the difference was significant only in one of the years of experiment.

Yield components:

Primary yield components in corn are population density, the number of rows per ear, the number of kernels per ear row, and 1000-seed weight. In the present study because corn population density was constant, variation in corn grain yield could be analyzed in terms of variation in the other three yield components. Analysis of variance revealed that relative time of lambsquarters emergence had significantly affected corn yield components (Table 1). As observed in Table 2, reduction in lambsquarters interference period had resulted in significant increase in the number of rows per ear and the number of kernels per ear row. Cavero *et al*. (1997) also reported similar result for the number of kernels per ear when jimson weed interference period increased in corn.

Results also indicated that the number of kernels per ear was more affected by weed interference period compared with the number of rows per ear (Table 2). Mickelson & Harvey (1999) stated that environmental stresses and resource limitation after fertilization do not affect the number of rows per ear, but the number of kernels per ear row deeply. Comparison of the results of the present study with those of Mickelson & Harvey (1999) indicated that maximal stress by lambsquarters on corn occurred at anthesis, caused further negative effect on the number of kernels per ear row due to weed.

Significant differences were observed in the number of rows per ear, and the number of kernels per ear row under different lambsquarters density (Table 1). As Fig. 6 shows, increase in lambsquarters density had caused reduction in the number of rows per corn ear, although the amount of reduction was a function of relative time of lambsquarters emergence, i.e. when lambsquarters emergence delayed up to 4-5 (2001) and 5-6 (2002) leaf stages of corn, increase in lambsquarters density could not significantly reduce the number of rows per ear, while simultaneous emergence of the weed and crop resulted in severe loss in the number of rows per ear in corn (Fig. 6).

محل قرارگيري شكل ٣

The effects of lambsquarters (*Chenopodium album*) density and its relative time of emergence on yield and yield components of grain corn (*Zea mays*)

محل قرارگيري شكل 4

محل قرارگيري شكل 5

The effects of lambsquarters (*Chenopodium album*) density and its relative time of emergence on yield and yield components of grain corn (*Zea mays*)

محل قرارگيري شكل 6

Thousand-seed weight is an index which shows the crop sink demand during seed filling period that might be increased or decreased by omitting environmental stresses (Gelavi, 2002). In the present study, the effect of relative time of lambsquarters emergence was significant for 1000-seed weight in both years of experiment. Lambsquarters density also significantly affected this trait only in 2002 but not in 2001. The interaction between these two experimental factors was not significant for this trait in both years (Table 1). As table 2 indicates, increase in lambsquarters interference period had caused increment in corn 1000-seed weight in 2002. This can be attributed to the source-sink relationships. Overall results indicate that increase in lambsquarters interference period in corn, had caused reduction in the number of kernels per ear and as a result the number of kernels per corn plant. So, 1000-seed weight increase observed in 2002 may be due to compensation for the lower seed number associated with increase in weed interference period. Comparison between corn seed number loss and leaf area index loss agrees with this finding. In 2001, the reductions occurred in the sink (seed number) and the source (leaf area) were almost similar, but in 2002, by increase in weed interference period the amount of seed number loss was greater than leaf area loss in corn (data not shown). Mickelson & Harvey (1999) believe that although source limitation can be resulted in seed weight reduction but the proportion of sink to source is more important in this case. These researchers also believe that environmental stresses occuring after fertilization and seed formation have more effect on crop seed weight. Malik *et al.* (1993) also stated that increase in weed interference period in bean (*Phaseolus vulgaris* L.) resulted in greater 100-seed weight.

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