Corn (*Zea mays* L.) yield and nitrogen efficiencies as affected by different nitrogen rates and redroot pigweed (*Amaranthus retroflexus* L.) densities

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(Received: March 12, 2010; Accepted: April 20, 2010)

ABSTRACT

Field experiments were conducted at the Agricultural Faculty research field of the Islamic Azad University, Astara branch (Northwestern Iran) in 2007 and 2008. The main goal was to examine the effects of redroot pigweed density (*Amaranthus retroflexus* L.) on redroot pigweed leaf area index at 50% Corn (*Zea mays* L.) tassel time and corn grain yield, nitrogen recovery efficiency, nitrogen use efficiency and nitrogen utilization efficiency under different nitrogen rates. The experiments were established as split plots arranged in randomized complete block design with three replicates. The main plot was nitrogen rate at four rates 0, 100, 160 and 220 kg N ha^{-1}. The sub plot was redroot pigweed densities, which were considered at four levels 0, 5, 10 and 20 weeds m^{-2} in an extended form to the corn farm. The results indicated that nitrogen application up to 160 kg N ha^{-1} with 5 and 10 weeds m^{-2} did not have any significant effect on leaf area index of redroot pigweed. However, this characteristic increased with the weed density at upper 160 kg N ha^{-1}. Leaf area index of the weed was increased when 220 kg N ha^{-1} was applied, and its amounts in more densities was greater as well. The highest level of redroot pigweed leaf area index, in 20 weeds m^{-2} and application of 220 kg N ha^{-1} was calculated to be 1.82. Corn grain yield, nitrogen recovery efficiency, nitrogen use efficiency were 13.0 t ha^{-1}, 46.2% and 60.5 kg grain/kg N applied, under 160 kg N ha^{-1} in weed-free corn condition. Eventually, it was found that the presence of 5 weeds m^{-2} up to 160 kg N ha^{-1} did not have any significant effect on corn characteristics; however, they were decreased by increasing weed density. The highest decrease was observed when was applied the highest amount of nitrogen under the highest weed density. Although, 20 weeds m^{-2} instead of 10 weeds m^{-2} caused more decrease in corn nitrogen use efficiency, the effect of these weed densities did not have any significant difference, statistically.

Key words: Corn, Competition, Yield, Nitrogen efficiency, Weed.

INTRODUCTION

Nitrogen (N) is a key factor in the production of Corn (*Zea mays* L.) because of its incorporation into many of the key compounds necessary for plant growth[1]. It is most often associated with the establishment of both plant yield and photosynthetic activity[2]. Many researchers[3,4] reported relationship between crops growth, grain yield and dry matter with nitrogen rate. Researches show that Nitrogen Recovery Efficiency (NRE), Nitrogen Use Efficiency (NUE) and Nitrogen Utilization Efficiency (NUtE) were influenced by different N rate application [5,6]. It is reported that NUE in corn cropping systems are only 37% [7], and 33% [8] for cereal crops grown worldwide. If N fertilizer could be managed to reflect differences in the ability of corn plants to capture scarce resources [9], it could lead to a higher NUE in corn cropping systems. Field and year [10] can vary the economic optimum fertilization rates.

In recent decades, weeds are the main problem in crops production, which, on one hand, decrease crops yield and quality; on the other hand, they increase grain production costs about 30%[11].Weed competition can reduce nitrogen uptake and nitrogen content of plants[12]. In agricultural fields, plant competition occurs both inter-specifically and/or intra-specifically to receive incident solar radiation, soil moisture and/or soil nutrients[13]. Kropff [14] explained that the major reason for crops yield loss by weeds was associated with inter-specific competition for limited resources. Competition is based on both resource capture and resource efficiency by each species, which can, in turn, be influenced by the underlying physiology and growth of the species involved[15].

It is well known fact that redroot pigweed (*Amaranthus retroflexus* L.), one of the important weeds in the world cornfields[16] and cornfields in Iran are the main types of weeds that reduce corn yield. According to Hartley & popay's report[17] redroot pigweed decreased corn yield down to 50%. Therefore, having sufficient information about weed competition with crops can play as an important role on weeds management and provides additional information on a number of integrated weed management (IWM) components[18].

The main goals of the present research were to determine the following facts: the interaction of weed density and nitrogen rate on leaf area index of redroot pigweed at corn tasseling time; and the effects of the aforementioned interaction on corn grain yield and nitrogen efficiency forms as well.

MATERIAL AND METHODS

Field experiments were carried out at the Agricultural Faculty research field of the Islamic Azad University-Astara Branch, Guilan province, northwestern Iran in 2007 and 2008. The field is located in northwestern Iran (38°252 N, 45°25¹ W, and 20 meters below sea level, average 1300 mm rainfall in 20 years, 30% of which falls between March and September; -6 and 35°C minimum and maximum means of annual temperature, respectively). Soil texture was sandy clay and some soil characteristics were measured at planting time: [PH=7.3, N (%) = 0.11, P_2o_5 (ppm) =9.0, K_2o (ppm) =282, EC (ds/m) = 0.67, and O.C (%) = 1.1]. All of the above mentioned statistics were managed uniformly in a continuous corn system for three consecutive years. Tillage consisted of fall chisel plowing followed by spring disking and harrowing in two years. The experimental designs were as split- plot in randomized complete blocks with three replications, where the main plot was nitrogen rate (0, 100, 160 and 220 kg ha^{-1}) and the sub plot was redroot pigweed densities (0, 5, 10 and 20 weeds m^{-2} ; 0, 3.5, 7 and 14 plants m^{-2} in a corn row, respectively). According to Soil experiments in the north of Iran, the researchers recommended utilizing 100 kg N ha^{-1}, 72 kg P_2o_5 ha^{-1}, and 100 kg K_2o ha^{-1} on the cornfield (The soil with 0.5 to 1.5% organic matter is expected to produce about 9 t ha^{-1}). In such a situation, there were used 350, 150 and 200 kg ha^{-1} of urea, super phosphate triple, and potassium sulfate, respectively. At the planting site, a starter fertilizer (50% N, 100% P_2o_5 and 100% K_2o) was applied. The rest of N was applied at the four-leaf stage of corn.

To start the project, corn S.C.704 (Single cross maize hybrid) was planted on May 10, with the final plant densities of 71400 plants ha^{-1}. Plots were seven rows wide (70 cm spacings) and five meters long. Weed seeds were obtained 6 months before the study from typical weed populations and were dried and conserved in a dark plastic container at 4°C. The weed was hand seeded and incorporated with corn within a 10 cm band on one side of the row. The pigweed seeding thinned by hand at the two-leaf stage of growth to the desired densities. The inner row space outside the 10 cm band was maintained weed free by hand hoeing. In addition, other weeds within the 10 cm band were removed by hand weeding. The field was irrigated before planting and the next irrigation was once a week as needed.

After that, 10 plants of redroot pigweeds from the middle 3 rows of each plot harvested manually at 50% corn tassel time and 10 corns after leaf senescence. One meter was left not harvested at each end of the middle rows. Furthermore, leaf area (LA) for weed was measured using a leaf area meter[1], and leaf area index (LAI) was calculated by dividing the total LA by the ground (m^2) of 10 plants. To record redroot pigweed after sampling and grain yield in corn, samples were oven dried at 110°C for 72 hours and the weights were recorded, and the corn seed yield was adjusted to 14% moisture.

Finally, 100 grams of dried samples were carried to a laboratory to calculate the nitrogen uptake in corn. The wet burning method was used to determine the nitrogen percentage[19]. Then, nitrogen uptake was calculated through the following equation ($Nitrogen\ Uptake_{(gr)} = Dry\ matter_{(gr)} \times Nitrogen\ percentage$), and nitrogen efficiencies were calculated in the following equations[20].

Nitrogen Recovery Efficiency

$$NRE\ (\%) = [(BNY_f - BNY_0) / N_f] \times 100$$

Nitrogen Use Efficiency

$$NUE = (GY_f - GY_0) / N_f$$

Nitrogen Utilization Efficiency

$$NUtE = (DM_f - DM_0) / (BN_f - BN_0)$$

Where:

NRE: Nitrogen Recovery Efficiency (%), NUE: Nitrogen Use Efficiency ($Kg_{grain}\ Kg_N^{-1}$), NUtE: Nitrogen Utilization Efficiency ($Kg_{dry\ matter}\ Kg_{N\ uptaked}^{-1}$). BNY_f: Biomass Nitrogen Yield $_{(nitrogen\ applied)}$, BNY_0: Biomass Nitrogen Yield $_{(nitrogen\ not\ applied)}$, GY_f: Grain Yield $_{(nitrogen\ applied)}$, GY_0: Grain Yield $_{(nitrogen\ not\ applied)}$, DM_f: Dry Matter $_{(nitrogen\ applied)}$, DM_0: Dry Matter $_{(nitrogen\ not\ applied)}$ and N_f : Amount of N applied (all of them in kg m^{-2}).

Combined analysis of data was performed using PROC GLM of SAS software[21] after Bartlett's test. The nitrogen rate and weed density were treated as fixed effects, but the year was considered as a random effect. Duncan's new multiple range test (DMRT) was used to compare the means (α=5%) and graphs were drawn by Sigma Plot software ver. 11.0

RESULTS

Total rainfall amounts were 1157 and 855 mm per year, respectively, in 2007 and 2008. Rainfall distribution in plant growth season was not very different in two years. Yearly average temperatures were close in two years, around 16ÚC, and monthly average temperature in two years did not vary a lot (Table 1).

Combined analysis showed significant interactive effects of nitrogen amount and weed density on leaf area index (LAI_w) of pigweed at corn tassel time, corn grain yield (GY_c), corn nitrogen recovery efficiency (NRE) ($pd \leq 0.01$) and nitrogen use efficiency (NUE) ($Pd \leq 0.05$). Besides, the effect of nitrogen rate, weed density and their interactive effect on nitrogen utilization efficiency were not significant, and the corn produced average 74.1 kg dry matter /1 kg nitrogen up taken.

Leaf area index (LAI_w) of redroot pigweed without nitrogen application using 5, 10, 20 weeds m^{-2} was 0.46, 0.86 and 1.17, respectively. The increase of nitrogen application up to 160 kg N ha^{-1} did not have any significant effect on pigweed leaf

Table 1: Monthly rainfall and mean temperature in growing season of 2007 and 2008

Month	Temperature (ºC)		Rainfall (mm)	
	2007	2008	2007	2008
May	15.3	17.0	73.3	54.0
June	23.5	21.1	27.6	22.7
July	24.5	24.6	26.2	18.0
August	26.7	26.4	5.0	2.0
September	24.4	24.7	92.4	88.0

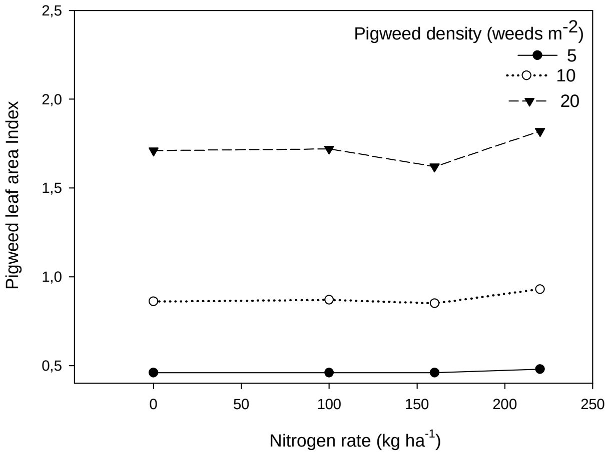

Fig. 1: Relationship between redroot pigweed leaf area Index (LAI_w) and nitrogen rates in different weed densities

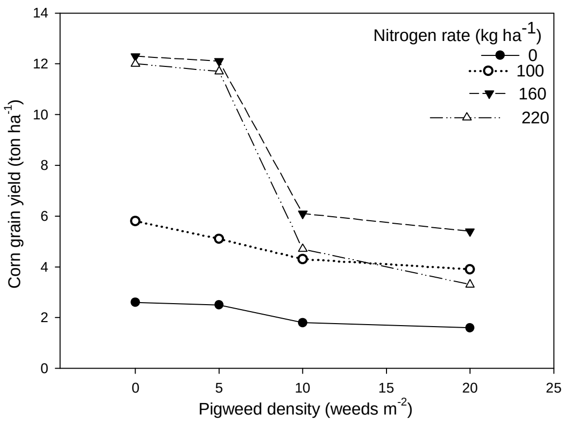

Fig. 2: Relationship between corn grain yield (GY_c) and pigweed densities in different nitrogen rates

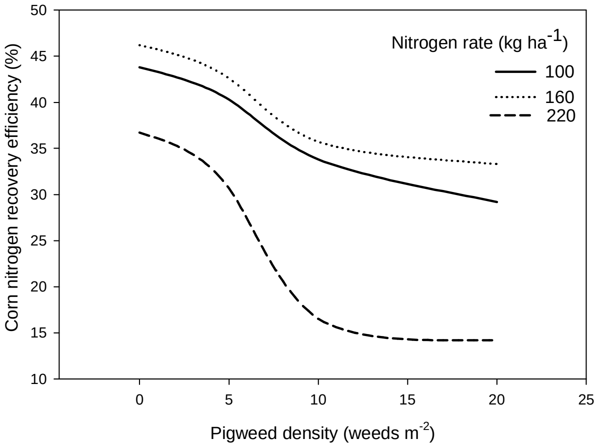

Fig. 3: Relationship between corn nitrogen recovery efficiency (NRE) and pigweed densities in different nitrogen rates

area index at all weed densities, but it was increased by 4.4, 8.2 and 6.4%, respectively, when 220 kg N ha^{-1} was applied. The highest pigweed Leaf area index was 1.82 in 20 weeds m^{-2} applying 220 kg N ha^{-1} (Fig. 1).

The results showed a non-linear relation between the increase in the redroot pigweed density and a decrease in corn grain yield (GY_c), nitrogen recovery efficiency (NRE) and nitrogen use efficiency (NUE). Nitrogen application in comparison to non-nitrogen application caused an increase in corn grain yield, but it decreased as weed density increased (Fig. 2). In weeds-free corn condition, the corn grain yield was produced in 2.7, 5.8, 13 and 12.8 t ha^{-1}, respectively when 0, 100, 160 and 220 kg N ha^{-1} were supplied; however, in the presence of 5 to 20 weeds m^{-2} these amounts decreased by 3.7 to 56.1%. The highest amount of corn grain yield was 13 t ha^{-1} under weeds-free conditions by applying 160 kg N ha^{-1}. It is worth mentioning that an increase of nitrogen application up to 220 kg N ha^{-1} did not have any significant effect on it, but increases in weed density decreased corn grain yield.. In the present of 10 weeds m^{-2}, corn grain yield reduced by 30.8, 25.9, 50.4 and 60.8%; respectively as compared to weeds-free corn cultivation applying 0, 100, 160 and 220 kg N ha^{-1}. This reduction was 38.5, 32.8, 56.1 and 72.5%, respectively, under 20 weeds m^{-2} condition.

The highest corn nitrogen recovery efficiency was observed as 46.2% where 160 kg N ha^{-1} was applied in weeds-free corn cultivation, but decreased when more fertilizer was utilized (Fig. 3). Corn nitrogen recovery efficiency with nitrogen application of 100 and 220 kg N ha^{-1} was 43.3 and 26.7%, respectively, in weeds-free corn cultivation. Presence of five weeds m^{-2} didn't have any significant effect on corn nitrogen recovery efficiency, but the density of 10 weeds m^{-2} decreased corn nitrogen recovery efficiency by 22.8, 22.7 and 55.1%, and the 20 weeds m^{-2} density decreased corn nitrogen recovery efficiency by 33.3, 29.9 and 61.3% with nitrogen application of 100, 160 and 220 kg N ha^{-1}, respectively.

The lowest and the highest corn nitrogen use efficiency, namely, 32.5 and 60.5 kg grain production/1kg nitrogen application was observed through applying 100 and 160 kg N ha^{-1} in weeds-free corn cultivation, and it amounted to 42.7 kg grain production/1kg nitrogen application in the field applying 220 kg N ha^{-1} (Fig. 4). However, Weed density up to five weeds m^{-2} did not have any significant effect on corn nitrogen use efficiency at 160 kg and 220 kg N ha^{-1} levels. Presence of 10 weeds m^{-2} resulted in the highest reduction in corn nitrogen use efficiency and the amounts of decrease were 55.7 and 69.6% at 100, 160 and 220 kg N ha^{-1} relative to the control (weeds-free corn), respectively.

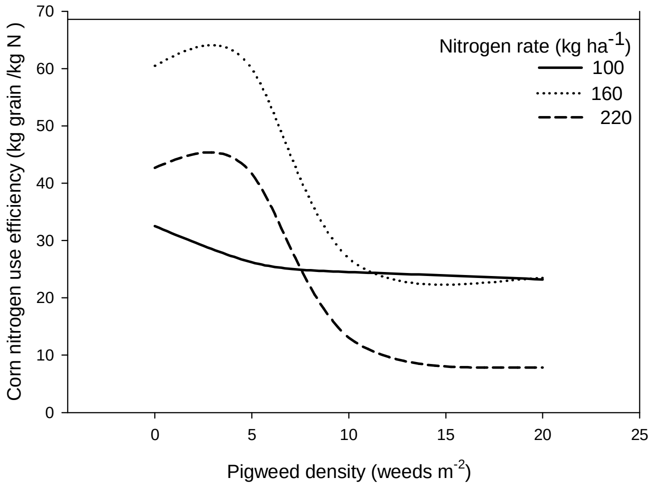

Fig. 4: Relationship between corn nitrogen use efficiency (NUE) and pigweed densities in different nitrogen rates

Once 20 weeds m^{-2} were present, corn nitrogen use efficiency decreased, though it did not have any significant effect with a density of 10 weeds m^{-2}.

DISCUSSION

Kropff & Van laar[22] believed that excess weed in crops field causes worry and influences the results of the two plants competing. Results showed that by an increase in redroot pigweed density, its leaf area index increased as well. This trend existed at all nitrogen application rates. The rate of leaf area index states the ability of plant canopy to capture the photosynthetically photon flux density (PPFD); therefore by an increase in LAI, the rate of photosynthetically active radiation (PAR) might be decreased for corn, and consequently the speed of photosynthesis goes down. As a result, grain yield and corn dry matter would decrease. Rajcan & Swanton[23] also confirmed these results. The more nitrogen applied, the higher the redroot pigweed LAI_w became and the same situation was found at all nitrogen levels. Utilizing 220 kg N ha^{-1} had the highest influence on redroot pigweed LAI_w. In all quantities of nitrogen, the presence of 5 weeds m^{-2}, redroot pigweed LAI_w was less than 0.5, but by the presence of 10 and 20 weeds m^{-2}, redroot pigweed LAI_w was 1.0 and more than 1.0, respectively (Fig. 1). Oliver [24] believed that weed is considered as a crop rival when weed leaf area index is at least 1.0 during the competition. It could be concluded that without dry matter and grain yield reduction, redroot pigweed is able to compete with five weeds m^{-2}.

Corn GY_c decreased by the presence of 5 to 20 weeds m^{-2} and 3.7 to 56.1%. In Hartley & Popy's [17] experiment, pigweed decreased corn grain yield up to 50% in comparison with the weeds-free condition. They considered this reduction in receiving the light because of corn competing with redroot pigweed. Kenzevic *et al.* [25] reported less than five weeds m^{-2} as the threshold of density for annual broad leaf weeds for corn. The results in this research indicated that presence of five weeds m^{-2} does not have any significant effect on corn GY_c. The ability of redroot pigweed competitiveness grew by an increase in inter-specific competition, and then corn GY_c decreased by an increase in weed density. Applying more than 160 kg N ha^{-1}, corn GY_c did not increase because of high pigweed LAI_w (Figs. 1 & 2). Di Tomaso [26] believed that at high levels of soil nutrition, weeds are able to compete more with crops.

The highest corn NRE was 46.2% when 160 kg N ha^{-1} were applied for sole corn cultivation. Corn could uptake 73.9 and 80.7 kg N ha^{-1} when applying 160 and 220 kg N ha^{-1}, respectively, which points out that in 220 kg N ha^{-1} treatment, the highest portion of nitrogen in soil was not absorbed. Zemenchilk & Albrecht [27] found that the effect of fertilization rates on NRE was significant. According to previous findings in this paper, the highest corn GY_c was observed when 160 kg N ha^{-1} was applied (Fig. 2). These findings can be attributed to more nitrogen absorption and more nitrogen recovery efficiency at this level of nitrogen fertilizer. The researcher also found out that not only the corn NRE would be decreased with the increase of weed presence; the rate of this reduction was high when more nitrogen was used in the field as well, because pigweed was a more powerful competitor for corn at higher levels of soil nutrition. In Cathcart & Swanton's [28] report, an increase of up to 200 kg N ha^{-1} increased the rate of nitrogen uptake in upper biomass of the plant in comparison to the control sample.

NUE indicates the rate of the economical grain yield of the crop according to the units of nitrogen used in the form of a fertilizer in fields. The highest corn NUE was at 160 kg N ha^{-1} for weeds-free corn cultivation. By applying 1.0 kg N ha^{-1} of nitrogen in the form of a fertilizer, 60.5 kg grain of corn can be produced at 160 kg N ha^{-1} level. We also figured out that the rate of pigweed growth and corn production were the highest and the lowest rate at 160 kg N ha^{-1}, respectively (Figs. 1 & 2). Therefore, high corn NUE at this level of N fertilizer can be related to effects of N using in corn growth and grain yield. Corn NUE decreased at upper 160 kg N ha^{-1}. Paolo & Rinaldi [5] and Sinebo *et al.* [6] reported that NUE was reduced by an increase in nitrogen application.

Although at all levels of nitrogen application, corn NUE reduced as a result of weed density growth, the rate of this decrease was high by an increase in nitrogen application due to broadening of leaf area and expansion of pigweed biomass at high degrees of nitrogen usage. This caused an increase in inter-specific competition, which in turn caused the corn NUE to reduce. Bauman [29] reported that inter-specific competition resulted in a reduction in nitrogen use efficiency in crops. He believed that the effect of inter-specific competition with higher use of nitrogen cannot be cancelled, but this competition might be accelerated. The present research found the same results.

Sources of Materials

[1]LI-300 leaf area meter, LI - COR Inc, 4308 Progressive Avenue, Lincoln, NE 68504.

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