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Evaluation of Plant Density and Nitrogen Fertilizer on Yield, Yield Components and Growth of Maize

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Abstract: In order to evaluation of plant density and nitrogen fertilizer on yield, yield components and some other traits of Maize (Zea mays) in Ardabil region, Iran, an split-plot experiment based on randomized complete block design was conducted with three replications in 2006. Main- plots were allocated to nitrogen levels (0, 75 and 150 kg ha^{-1}) and sub-plots to plant densities (7, 9 and 11 plant m^{-2}). Results showed that increase in density resulted in increase in yield per hectare and decrease in yield and yield components per plant. Also, increase in nitrogen application led to increase in yield and yield components. With increasing nitrogen level, leaf appearance rate was increased and Phyllochron was decreased. Also, with increasing density, Phyllochron was increased and leaf appearance rate was decreased. The highest leaf appearance rate and the shortest time for Phyllochron was obtained at 7 plant m^{-2} and 150 kg ha^{-1} nitrogen treatment. Vegetative growth period was increased as a result of increase in density and nitrogen. Time of appearance of pollens was decreased with increasing density and at 11 plant m^{-2} and 150 kg ha^{-1} nitrogen, this time was longer than other treatments. Flowering conformity period was decreased with increasing density and nitrogen had no significant effect on this trait and the longest period was related to 7 plant m^{-2} and 75 kg ha^{-1} nitrogen. Totally, with increasing density and nitrogen, yield of Maize was increased.

Key words: Phyllochron · Leaf appearance rate · Flowering conformity period · Maize and Yield

INTRODUCTION

One of the most important factors to gain highest yields in Maize (*Zea mays* L.) is determining appropriate plant density according to the climatic conditions and aspects of planted cultivars. Response of Maize to density is more than row plants. In cereals, more densities lead to low rates of produced seed as a result of competition for light and humidity [1]. With increasing plant density to a definite point, yield is increased and then, even though water and nutrients are not limiting factors, yield is decreased. Main factor of grain yield loss in Maize under high densities has been attributed to sterilization of flowers [2]. Also, decrease in grain number per cob row at high densities has been reported because, this inhibits the light penetration into the canopy and leads to delay in silking and consequently, decrease in produced grains [3]. Nitrogen has positive effect on storage of protein in Maize seed and hence, the rates of this element are effective in its distribution in plant [1]. Soil high fertility or increase in nitrogen application, leads to increase in grain yield and 1000-grain yield [2]. Study of Phyllochron is a suitable method to better realize the plant vegetative growth and helps simulation of plant growth [4]. In addition, it is the basal parameter in predicting plant total leaf number and date of flowering [5]. Tollenaar and Lee [6] defined leaf appearance rate as inverse of Phyllochron. Longnecker and Robson [7] revealed that nitrogen deficit can decrease the leaf appearance rate. Tollenaar and Lee [6] reported that the appeared leaves in Maize were decreased with decreasing available nitrogen. It has been shown that under controlled and field conditions, phenological stage [8], genotype [9] and other environmental conditions, affect Phyllochron. The rate of

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soil compact ability, seeding depth, vernalization, incident radiation and carbon dioxide, affect the leaf appearance rate, as well [10]. Affecting nutrient elements, humidity, incident radiation and plant physiological stages, density can affect the Phyllochron and the leaf appearance rate. Permanent cool season grasses and small seeded cereals, produce one full expanded leaf each 6-10 days if they subjected to favorable conditions while, in Maize and warm season cereals, this rate is each 4-6 days [5]. Low temperatures may lead to delay of length of vegetative growth period, production of crown flower and reduce available nutrients [11, 12].

The aim of this research was to realize effect of different plant densities and nitrogen levels on yield and yield components, the leaf appearance rate and some important phenological stages such as appearance of crown flower and flowering conformity period of Maize.

MATERIALS AND METHODS

This experiment was conducted in research field of Islamic Azad University, Ardabil branch, Ardabil, Iran, in 2006 with altitude of 1350 meter of sea level. Based on the soil test, PH was about 7.7, soil texture was loamy-sand and the depth of soil was 70 cm. This research was arranged as split-plot design based on randomized complete block design with three replications. Main-plots were assigned to nitrogen levels (0, 75 and 150 kg ha^{-1}) and sub-plots to plant densities (7, 9 and 11 plant m^{-2}). Used seed was of single-cross 301 hybrid of Maize. Each sub-plot included five rows each 5 meter spaced 0.75 meter apart. Nitrogen was applied at 7 and 9-leaf stages. In order to measuring yield and yield components, plants of middle rows of each plot in the surface of 2.5 m^2 were harvested. To study Phyllochron, the leaves of there plants of each plot with the length of at least 1 cm, were counted each 3 days. These plants were marked with red stripe during the growth period. The leaf appearance rate was calculated as follows:

$$\text{Leaf appearance rate} = \frac{1}{phyllocron}$$

Some other measurements were done according to Emam and Niknejad [4] included: appearance of crown flower (end of vegetative growth period): while crown flower in 50% plants appeared approximately 10-15 cm among the leaves, appearance of tussle (tussling): while the length of silky fibers in 50% plants reached 5 cm, ending of pollens: while in all plants, pollens were ended and crown flowers were dried (ending flowering), length of vegetative growth period: the time between planting and appearance of crown flower dates, length of flowering conformity period: from appearance of tussle to ending of pollination. Data were subjected to analysis by the SAS software and graphs were drawn using Excel program.

RESULTS AND DISCUSSION

Yield and Yield Components: Results (Table 1) show that at high densities, yield per plant was lower than low densities. This may attributed to competition between plants for getting light, water and nutrient elements which is more obvious at high densities. However, at high densities, grain yield per hectare was higher than low ones. In other words, decrease in yield of each plant at high densities, compensates for more number of plants per unit area. As shown in Table 1, number of grain per row and number of grain per cob, were affected by density and nitrogen so, increase in nitrogen application and decrease in density led to increase in them. Decrease in number of grain per row at high densities has been reported by other researchers [2]. The reason is that with increasing density, incident radiation into the canopy is decreased and delays tussling and hence, causes fewer grains are produced per cob. Also, it seems that increase in density results in increase in competition for gaining nutrient elements, water, etc and causes the fewer produced grains. Hashemidezfouli and Herbert [3] reported increase in number of grain per cob with increasing plant density in Maize, as well. The rows per cob were affected only by nitrogen levels which were increased with increasing nitrogen amounts. Costa *et al.* [13] revealed that with increasing nitrogen levels, number of rows per cob was increased. It has found that increase in density, did not affect the number of rows per cob. In present study, number of cob per plant and 1000-grain weight was not affected by the treatments. Not change in 1000-grain weight has been approved by other researchers [3].

Phyllochron and Leaf Appearance Rate: Phyllochron and leaf appearance rate were affected by density and nitrogen. With increasing plant density, Phyllochron was increased and leaf appearance rate was decreased (Table 2). Low incident radiation into the canopy with increasing density probably is the reason of mentioned values. This result is in accordance with findings of Longnecker and Robson [7]. Increase in nitrogen level had significant effect on Phyllochron and as nitrogen

Table 1: Yield and yield components of Maize under plant density and nitrogen levels

Traits Treatments[1]	Grain yield (ton ha^{-1})	Yield of each plant (gr ha^{-1})	Number of grain per row	Number of row per cob	Number of grain per cob
D1	5.558b*	79.41a	28.55a	-	495.71a
D2	5.817 a	64.64b	26.63b	-	460.59b
D3	5.958 a	54.17c	23.32c	-	403.54c
N1	5.297a	60.43c	23.43b	17.18 c	402.33b
N2	5.801b	66.33b	26.66ab	17.31 b	461.74ab
N3	6.236a	71.45a	278.41a	17.44a	495.79a

*Numbers with the same letter, have no significant difference

1- D1, D2 and D3 are densities of 7, 9 and 11 plant m-2, N1, N2 and N3 are 0, 75 and 150 kg ha-1 nitrogen, respectively.

Table 2: Effects of plant density and nitrogen levels on the rate of leaf appearance, Phyllochron and some phenological aspects of Maize

Traits Treatments[1]	Leaf appearance rate (1 day^{-1})	Phyllochron (day)	Appearance of crown flower (day)	Ending of pollens (day)	Flowering conformity (day)
D1	0.279a*	3.998c	68c	85.88b	7.55a
D2	0.274b	4.06b	70.4b	85.66b	5.55a
D3	0.253c	4.4a	72.6a	87.11a	4.33b
N1	0.261c	4.269a	69.5a	86.77a	4.88a
N2	0.265b	4.199b	70.4ab	86.22a	6.00a
N3	0.279a	3.99c	71.1ab	85.66a	6.55a

*Numbers with the same letter, have no significant difference

1- D1, D2 and D3 are densities of 7, 9 and 11 plant m-2, N1, N2 and N3 are 0, 75 and 150 kg ha-1 nitrogen, respectively.

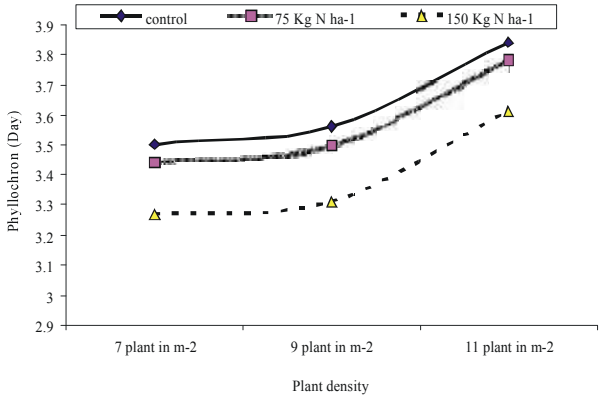

Fig. 1: Effect of plant density and nitrogen level on Maize Phyllochron

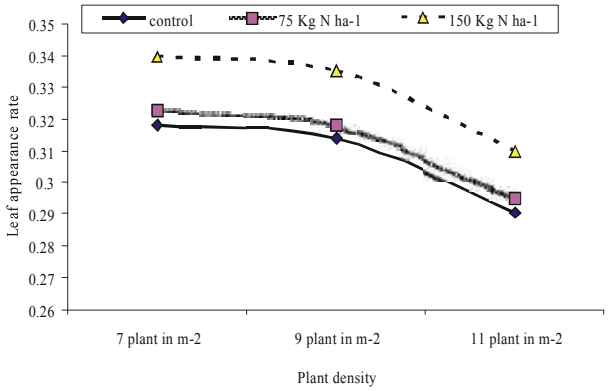

Fig. 2: Effect of plant density and nitrogen level on the leaf appearance rate of Maize

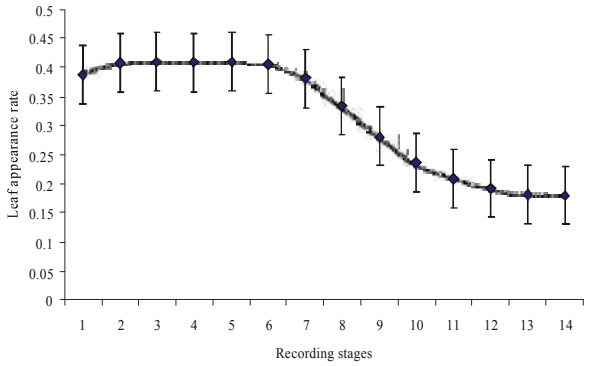

Fig. 3: Trend of the leaf appearance rate changes during the recording stages

was increased, leaf appearance rate was increased and Phyllochron was decreased. The highest Phyllochron was obtained at 11 plant m^{-2} without nitrogen application (Fig. 1), but at 7 plant m^{-2} and 150 kg ha^{-1}, required time to appear sequential leaves was at least. The highest leaf appearance rate of 0.289 leaves per day was observed at 7 plant m^{-2} and 150 kg ha^{-1} nitrogen (Fig. 2). Effect of recording stages ($p<0.01$) and Interaction effects of recording stage × nitrogen level and recording stage × plant density ($p<0.05$) on Phyllochron and leaf appearance rate, showed that at recording stages specially at stages near to the end of vegetative growth period, leaf appearance rate was decreased and Phyllochron was increased (Fig. 3 and Fig. 4).

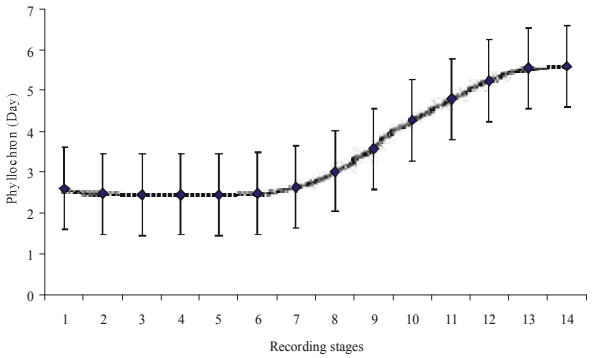

Fig. 4: Trend of Phyllochron changes during the recording stages

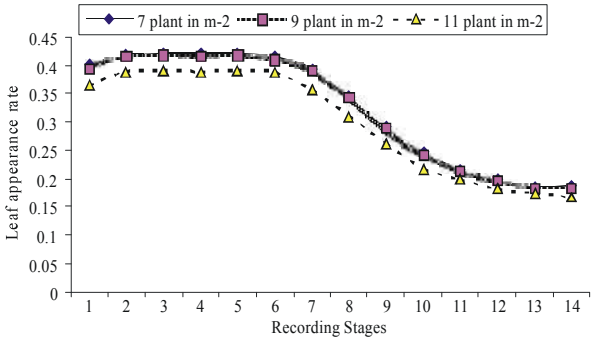

Fig. 5: Effects of plant density and recording stages on trend of the leaf appearance rate changes of Maize

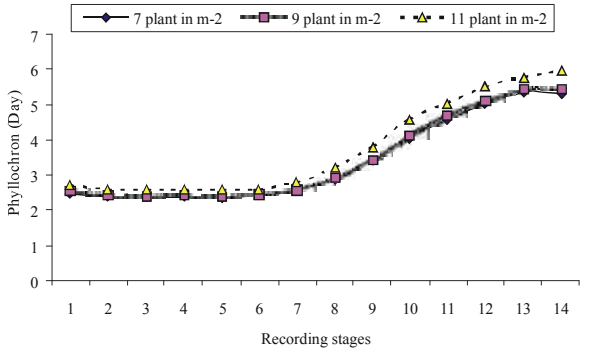

Fig. 6: Phyllochron changes as affected by plant density and recording stages

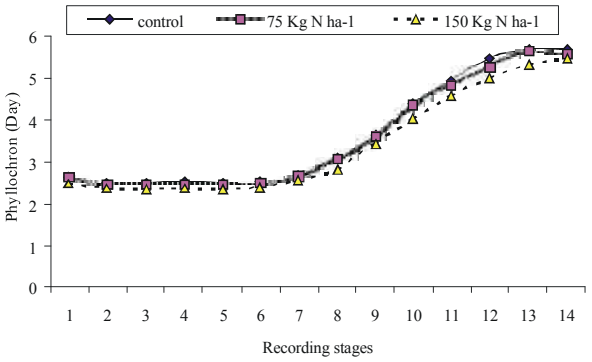

Fig. 7: Phyllochron changes of Maize as affected by nitrogen level and recording stages.

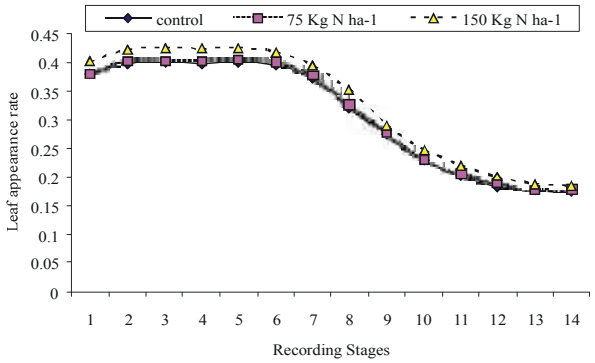

Fig. 8: Leaf appearance rate changes of Maize as affected by nitrogen level and recording stages.

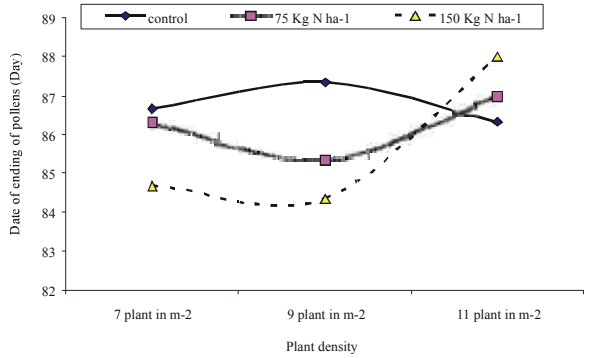

Fig. 9: Effects of plant density and nitrogen level on date of ending of pollens of Maize.

Interaction effect of density × recording stage on trend of changes of leaf appearance rate and Phyllochron revealed that with increasing plant density, leaf appearance rate was decreased, Phyllochron was increased and these changes were more obvious at the end of vegetative growth period (Fig. 5 and Fig. 6). As show in Fig. 7 and Fig. 8, with increasing nitrogen level, required time to appear sequential leaves was lower and leaf appearance rate was higher and this trend after eight's recording was more obvious.

Date of Appearance of Crown Flower (Vegetative Growth Period): Vegetative growth period of Maize was affected by density and nitrogen (Table 2). Long *et al.* [14] observed that with increasing each plant (over the favorite rate), date of appearance of crown flower was delayed one day. Results showed that different densities ($p<0.01$) and nitrogen levels ($p<0.05$) had significant effects on mentioned trait. The longest and shortest vegetative growth period was observed at 11 and 7 plant m^{-2} densities, respectively.

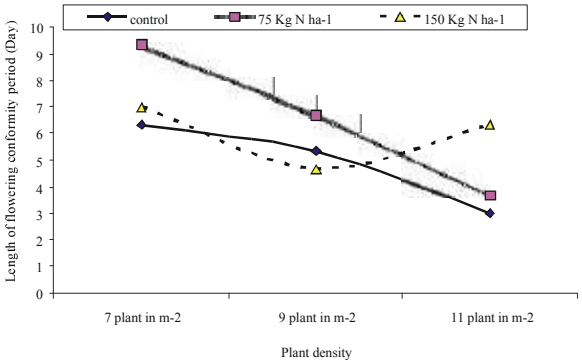

Fig. 10: Effects of plant density and nitrogen level on the length of flowering conformity period of Maize.

Also, with increasing nitrogen levels, this period was increased and the longest one was obtained using 150 kg ha^{-1} nitrogen. However, statistically, there was no significant difference among 75 and 150 kg ha^{+} nitrogen application on this aspect (Table 2).

Date of Ending of Pollens and Flowering Conformity: Effect of plant density on date of ending of pollens was significant ($p<0.05$). Mean comparisons (Table 2) showed that with increasing density, this date was delayed. However, statistically there is no significant difference among 7 and 9 plant m^{-2} densities (Table 2). Interaction effect of nitrogen level × plant density showed that at 11 plant m^{-2} and 150 kg ha^{-1} nitrogen, time of drying crown flower (ending of pollens) was higher than other treatments (Fig. 9). With increasing plant density, length of flowering conformity period was decreased (Table 2). In this work, time of flowering conformity was not affected by nitrogen levels, but interaction effect of nitrogen level × plant density was significant ($p<0.05$) and the highest conformity period was observed in treatment of 7 plant m^{-2} and 75 kg ha^{-1} nitrogen (Fig. 10).

CONCLUSIONS

Generally, it can be said that increasing plant density, caused yield increase per hectare and yield and yield components per plant. Also, increasing nitrogen levels led to increase in yield and yield components. Increasing plant density resulted in lengthening Phyllochron and decrease in leaf appearance rate and vice versa. With increasing plant density, vegetative growth period was longer and flowering conformity period was shorter. It should be said that Phyllochron and leaf appearance rate are of the traits used in plant growth modeling.

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