Impacts of Nitrogen Fertilizer and Plant Density Management on Growth, Dry Matter Remobilization and Yield of Durum Wheat

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ABSTRACT
In order to study the impacts of nitrogen fertilizer and plant density management on growth, dry matter remobilization and yield of durum wheat, Seymareh cultivar, a split plot experiment based on randomized complete block design with three replications was conducted at Agricultural Research Station, Islamic Azad University, Ardabil Branch, Iran in 2009-2010 cropping year. Main plot included three plant densities (300, 350 and 400 seed m$^{-2}$) and sub plots contained four nitrogen levels (0, 70, 140 and 210 kg ha$^{-1}$ N). Results showed that with increasing nitrogen levels, length of the vegetative growth period increased and dry matter remobilization from the plant to grain and its impact on grain yield decreased. Also, the highest length of generative growth and ripening periods and grain yield were obtained using 140 kg ha$^{-1}$ N and excess rates, decreased grain yield. With increasing plant density, all measured traits were increased. On account of increase in remobilization and grain yield, prevent of environmental pollution and decrease in fertilizer application as excess cost, application of 140 kg ha$^{-1}$ N in 400 plant m$^{-2}$ density (with conditions of this research), is recommended.

Keywords: Growth, Remobilization, Plant density, Nitrogen and Durum Wheat.

INTRODUCTION
Nitrogen is the most expensive fertilizer used to raise crop plants (Spiertz, 2010). Growth analysis consists of timing study of biological events, instruments and biological and non – biological causes of this timing and evaluation of them (Lieth, 1974). Wheat reaction to density is more than row plants. In cereals, low rate of seed is produced due to high competition for light and water in higher densities. Amount of N distribution is effective on rate and assignment of it inside the plant (Koochaki and Sarmdnia, 2001). High soil fertility or increase in N application causes the higher plant growth and consequently, seed yield in maize (Sarmadnia and Koochaki, 1995). A reliable portion of the (applied N is lost through leaching and denitrification Jamieson and Semenov, 2000). Increased demand for N fertilizers also raises farm input costs. Therefore, plant breeders need to develop cultivars that can uptake N more efficiently from the soil and partition most of it into the grain. Such cultivars would minimize loss of N from the soil and make more economic use of the absorbed N. Anbessa et al. (2009) observed significant genotypic differences
for vegetative N concentration at anthesis, yet genotypic variation for total N content at anthesis was associated primarily with variation in dry matter. Several authors have reported significant variation for postanthesis N uptake (Fathi, 2005) and in several studies N uptake during grain filling accounted for as much as 50% of the grain N content at maturity (Kada et al., 2005). Several studies have indicated that grain N in wheat primarily originates as a result of translocation from the vegetative parts after anthesis (Hstensteiner and Feller, 2002; Haberle et al., 2008). This translocation is under genetic control but also depends on environmental conditions and can be affected by fertilizer N application (Anbessa et al., 2009).

Ercoli et al. (2008) found that dry matter and nitrogen increased up to maturity when fertilizer was not applied. They concluded that nitrogen in the grain was derived primarily by translocation from leaves and stems rather than by uptake from the soil during the period of grain formation. Improving grain yield and grain protein concentration simultaneously is a difficult task because of the negative relationship often found between these two characters (Charmet et al., 2005; Asseng and Milroy, 2006). Furthermore, the process of dry matter (carbohydrate) and protein accumulation may compete for assimilates and energy (Robert et al., 2001). It has been estimated that two-thirds of the grain N in wheat is derived from assimilated N before anthesis and one-third from assimilation during grain development (Barbottin et al., 2005). Gooding et al. (2005) and Robert et al. (2001) have reported that protein concentration in grain might be improved by selecting genotypes that translocate a higher percentage of N from the vegetative organs to the grain. Positive correlations have been observed in wheat between grain protein concentration and nitrogen harvest index (Saint Pierre et al., 2008).

Density can influence the leaves and shoots by impacting on the nutrient elements. Permanent cool-season grasses and small-seed cereals produce new complete leaves each 6 to 10 days of experience optimal environmental conditions while this time reaches 4 to 6 days in maize and warm-season cereals (Koochaki and Sarmdnia, 2001). Low temperatures may postpone vegetative and flowering period lengths via increase in the required time to leaf emerge and hence, limit the availability of nutrients for plant (MC Williams et al., 1999 and Hill, 2007).

Movement of photosynthetic substances from the sources to sinks or consuming places depends on both the production of these matters and sinks capacity that may result in the yield loss if there is no balance between them. While source potential for assimilates decreases, contribution of the components moving again to the seeds, increases (Barzegari and Postini, 1998). All vegetative organs may refer to sink, at least in part of their growth period reserving photosynthetic substances. As there is close relation between photosynthesis and amount of reserved matters in plant so, changes in the environmental conditions which affect photosynthesis, may influence making and replacement of the soluble carbohydrates. For example, if produce of photosynthetic matters restricted to high density and shading, remobilization of stem reserves increases to compensate for photosynthesis decline (Hashemi Dezful and Marashi, 1994). Uhart and Andrade (1995) suggested that decrease in soluble carbohydrates remobilization as a result of shading, may be attributable to growth decrease and lower physiological demand for assimilates. Part of seed carbohydrates of maize is supplied via remobilization from stem (Mc Cullough et al., 1994). Main sources for carbon in plants include current photosynthesis in leaves and other green organs such as stems, spikes and...
awns. Also, this involves remobilization of stored matters in vegetative parts prior to anthesis (Borras et al., 2004). Przulj and Momcilovic (2003) showed that among barley plants, some cultivars under optimal conditions, lost a large amount of their reserve substances stored in vegetative parts from flowering to ripening, indicating that substantial part of dry matter prior to flowering is assigned to other sinks except seeds.

The aim of this work was to evaluate impact of N and plant density on growth, dry matter remobilization and yield in Durum wheat (Seymareh cultivar) in Ardabil regain of Iran.

**MATERIALS AND METHODS**

In order to study impacts of nitrogen fertilizer and plant density management on growth, dry matter remobilization and yield of durum wheat, Seymareh cultivar, in Ardabil regain, a split plot experiment based on randomized complete block design with three replications was conducted at Agricultural Research Station, Islamic Azad University, Ardabil branch, Iran in 2009-2010. Main plot included three densities (300, 350 and 400 seed m$^{-2}$) and sub-plots contained four nitrogen levels (0, 70, 140 and 210 kg ha$^{-1}$ N). To determine soil chemical and physiological property of the site, sampling was carried out from the depth of 0-30 cm. Results of the soil analysis has been shown in Table 1.

After surface sterilization, seeds were planted at the depth of 3-4 cm in rows with a distance of 15-20 cm apart. Sub-plots included 10 growing rows each 4 meters at which different densities were adjusted by changing distances between the seeds. The first irrigation applied after planting and the rest was used depending on the environmental circumstances and plant requirements. Weed control was done mechanically and chemically (2-4-D). One third of N trait was applied pre-planted and the rest, as top dress in spring at stem elongation stage (Kazemi, 1999). The following growth and developmental periods were (Emam and Niknezhad, 2005):

- Length of the vegetative period: from planting to 50% flowering.
- Length of the reproductive period: from flowering to physiological ripening (beginning of 50% plants yellowish).
- Length of the ripening periods: from planting to beginning of plants yellowish.

To evaluate the rate of remobilization and its contribution in seed yield, amount of transferred of dry matters into the seeds from pre–earring to physiological ripening stages was measured. So that, at pre–earring, some alike plants in main rows of each plot, were marked and from earring to physiological ripening, three plants in three or four day intervals were taken from each plot.

Harvested plants then separated into stem, leaf and root and after drying (in oven at 75°C for 72 hour to constant weight) were weighed and eventually, dry matter remobilization and other traits, were calculated (Niu et al., 1993; Papakosta and Gagianas, 1991). In following equations, respiratory drop has not been considered and supposed that respiration in this work is same for the environmental conditions. Ehdaie and Wanies (1996) have accepted such suggestions in evaluation of genetic variation and dry matter remobilization in wheat.

\[
M \ D_m \ A_p \ H - D_m \ A_p(ES) = D_mR(S) \ P_r
\]

Where: \(M\) = Maximum, \(D_m\) = Dry matter, \(A_p\) = Aerial parts, \(H=\) Harvest \(A_p(ES)\) = Aerial part except seed, \(R_S\) = Remobilization into seed, \(P_r\) = physiological ripening.

Remobilization (seed yield) = dry matter transferred into seed / seed yield×100

At the end of plant growth, while they ripped completely, crop of the 1.5 m$^{-2}$ from each plot was clipped, placed in the bags
and transferred to the laboratory for yield measurement.

Data were subjected to analysis by SAS, graphs were drawn in Excel and mean comparisons were done using Duncan’s multiple range test software at 5% probability level.

RESULTS AND DISCUSSION

Length of the vegetation growth period

Length of the vegetative growth period was affected by plant density, N level and N level×plant density interaction. Results showed that there were significant (P<0.01) difference between N levels, plant densities and their interactions on the length of the vegetation growth period. The highest and lowest rates were observed in 400 and 300 seed m⁻², respectively. As a result of N increment, this period was increased so that, the highest rate was achieved using 210 kg ha⁻¹ N. With increasing N amount and plant density, this period was prolonged (Table 2). Based on the graph resulted for the interaction effect, treatment of 400 seed m⁻² with no N (Control) resulted the lowest period (Figure 1). Excess rates of N by enhancing growth of aerial parts, prolongs this period (Jamaati-e-Somarin et al., 2009a). Also, Jamaati-e-Somarin et al. (2009b) reported the same results. Lang et al. (1986) found that by each plant more than optimum density, vegetative growth period delayed one day than normal, which is in accordance with our results.

Table 1. Results of the soil analysis

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Saturation percent</th>
<th>Electrical conduction (ds/m)</th>
<th>pH</th>
<th>Neutral matter</th>
<th>Organic carbon (%)</th>
<th>Total N (%)</th>
<th>Phosphorus (ppm)</th>
<th>Potassium (ppm)</th>
<th>Soil texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>48</td>
<td>2.66</td>
<td>7.8</td>
<td>4.8</td>
<td>0.97</td>
<td>0.103</td>
<td>4.8</td>
<td>460</td>
<td>Sand 31 Silt 41 Clay 28 Loam -clay</td>
</tr>
</tbody>
</table>

![Figure 1. Length of the vegetative growth period as affected by N and plant density.](image-url)
Figure 2. Length of the reproductive growth period as affected by N and plant density.

Figure 3. Length of the ripening period as affected by N and plant density.

Figure 4. Rate of dry matter remobilization into grain as affected by N and plant density.
Figure 5. Contribution of dry matter remobilization in grain yield as affected by N and plant density.

Figure 6. Grain yield as affected by N and plant density.

Length of the reproductive growth period

Results showed that N levels and interaction of N levels x plant densities had significant (P<0.01) effect on length of the time for this trait was achieved in control (Table 2). In treatment of 300 seed m\(^{-2}\) and control for N levels, the lowest, and in the 400 seed m\(^{-2}\) and 140 kg ha\(^{-1}\) N, the highest reproductive growth period. Plant density did not show such effect. It was observed that usage of N up to 140 kg ha\(^{-1}\), increased this period but beyond this, reproductive growth period was decreased. The shortest period length was observed (Figure 2). As with the findings of the researchers about decreasing reproductive growth period as a result of higher densities, it seems that in
lower densities, branches tend to grow higher and consequently, amount of absorbed photosynthetic active radiation is increased and in turn, resulted in the enhancement of photosynthetic efficiency. Eventually, this leads to the fast flowering (Lang et al., 1986). Since, reproductive period is initiated with flowering, it seems that with increasing plant density, length of the reproductive growth period would increase. Jamaati-e-Somarin et al. (2009b) reported the same findings, as well.

Length of the ripening periods

Only the measures of plant density and interaction of N level × plant density were significant (P<0.01) for the length of the ripening period and there was no significant difference for N treatments. Increase in plant density prolonged this period so that, plant densities of 300 and 400 seed m$^{-2}$ caused the shortest and longest periods, respectively (Table 2). For interaction effect, it was observed that with increasing plant density and N level, this period was prolonged so that, by application of 140 kg ha$^{-1}$ N and 400 seed m$^{-2}$ the longest, and without N application (Control) and density of 300 seed m$^{-2}$, the lowest period was gained (Figure 3). Increase in N application appears to be use cause of plant growth increment and consequently, delays in plant density and ripening.

The finding is in accordance with Jamaati-e-Somarin et al. (2009b).

Rate of the dry matter remobilization into seed

Results revealed that there was significant (P<0.01) differences among N levels, plant densities and their interaction for the rate of dry matter remobilization into seeds. Mean comparisons showed that the rate of dry matter remobilization was increased with increasing plant density and decreased with increasing N application (Table 2). Hokmalipour (2006) and Hokmalipour et al. (2007) reported increase and decreased in this trait with increasing plant density and N application, respectively.

Treatment of 400 seed m$^{-2}$ and control caused the highest rate of remobilization was achieved and in higher rates of N along with the decrease in plant density, it was declined, remarkably (Figure 4). The same results also have been reported by Schussler and Westgate (1991) in maize as plant density was increased. Jones and Simmous (1988) believe that remobilization is increased if plant density, shading and demand for sink are incensed. In this work, likely high density has been led to the higher dry matter remobilization due to shading and increase in competition within the plants.
Contribution of the dry matter remobilization in seed yield

Plant density and interaction of N level×plant density significantly (P < 0.01) affected contribution of dry matter remobilization in seed yield. Effect of N application was significant (P<0.05) on this trait. Dry matter remobilization reached from 15.39% in density of 300 seed m$^{-2}$ to 26.3% in density of 400 seed m$^{-2}$. Such trend was observed by decreasing N application (Table 2). For the interaction effect, the highest value was gained without N application in the highest density of 36.17%. With increasing N levels and decreasing plant densities, decline of this trait was observed (Figure 5). Hokmalipour (2006) and Hokmalipour et al. (2007) have reported the same results. Reserved matters prior to flowering, contributed to seed filling up to 90% with an average of 20 to 40% (Rahimian and Zand, 1998). Yoshida (1972) has reported this value up to 50%.

Grain yield

Results showed that there was significant (P<0.01) difference between N levels and interaction of N level×plant density on grain yield. Plant density did not show significant effect, however, the highest and lowest grain yield was obtained from densities of 400 and 300 seed m$^{-2}$, respectively. With increasing N levels grain yield was increased so that, the highest yield was observed using 140 kg ha$^{-1}$ N while, other N levels statistically grouped in the same class and increase in N amount more than 140 kg ha$^{-1}$, led to yield loss. With increasing N amount up to 140 kg ha$^{-1}$ along with the plant density, the highest seed yield was achieved (Table 2). Hokmalipour (2006), Hokmalipour et al. (2007) and Jamaati-e-Somarin et al. (2008 and 2009b) have reported the same results. For the interaction effects, it was found that in treatment of 140 kg ka$^{-1}$ N and density of 400 seed m$^{-2}$, the highest seed yield was resulted (Figure 6). Mazaheri (1994) reported that increase in N application leads to yield increase. Cuomo et al. (1998) found that increasing plant density, increases grain yield. Hamidi and Dabbagh Mohammadinasab (1995) illustrated that in maize in higher plant densities, anthesis and tassel initiation take place in a long period of time from each other and consequently, number of produced seeds per plant is decreased due to lower pollination but this decrease is compensated for the higher number of plants per unit area. Mengel (1992) described that the first effect of N application in the field, is to increase the size and number of leaves per plant. By incensing number of mature leaves, N cause photosynthesis to increased relative to respiration, and hence, yield is increased but in excess rates, over the optimum range, expanding of the vegetative parts

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Vegetative growth period (DAP)</th>
<th>Reproductive growth period (DAP)</th>
<th>Ripeing period (DAP)</th>
<th>dry matter remobilization to grain (mg)</th>
<th>Contribution of dry matter remobilization in grain yield (%)</th>
<th>Grain yield per area (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant density (plant m$^{-2}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>300</td>
<td>180.25b 60.00a</td>
<td>240.25b 133.06b</td>
<td>15.39b</td>
<td>873.21a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>350</td>
<td>184.25ab 58.83a</td>
<td>243.08ab 196.08a</td>
<td>21.82a</td>
<td>878.03a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>185.16a 60.75a</td>
<td>245.95a 219.27a</td>
<td>26.30a</td>
<td>888.20a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen levels (kg ha$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>179.33c 57.55c</td>
<td>236.88a 230.22a</td>
<td>24.16a</td>
<td>835.04b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>183.11b 59.00bc</td>
<td>242.11a 135.83b</td>
<td>15.90b</td>
<td>845.28b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>184.44ab 63.33a</td>
<td>247.77a 187.74ab</td>
<td>22.47a</td>
<td>986.15a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>186.00a 59.55b</td>
<td>245.55a 177.41b</td>
<td>22.14a</td>
<td>852.79b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Numbers with the same words in each column, have no significant differences to each other (P<0.05)
highly occurs. Therefore, number of leaves placed in the shadow is increased, the ratio of photosynthesis to respiration is decreased, and loss assimilates transferred into the seeds and more matters consumed by these leaves (Emam and Niknezhad, 2005).

REFERENCES


