Scientific Papers. Series A. Agronomy, Vol. LX, 2017
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

MITIGATE GRAIN YIELD LOSSES OF WHEAT UNDER TERMINAL DROUGHT STRESS BY DIFFERENT NITROGEN APPLICATIONS

Deniz İŞTİPLİLER, Uğur ÇAKALOĞULLARI, Özgür TATAR

Ege University, Faculty of Agriculture, Turkey

Corresponding author email: ozgur.tatar@ege.edu.tr

Abstract

Water and nitrogen are both most limiting factors for plant growth and productivity. Effects of different nitrogen applications on grain yield of wheat under terminal drought stress were investigated in the present study. A field experiment was conducted with a bread wheat cultivar Gönen in two experimental sites characterized by loamy-sand (Menemen) and clay-loam (Bornova) soils. Rainout shelters were used to exclude rain from drought imposed plots during grain filling stage. Gradually decrease in soil moisture content caused significant decrease in grain yield in both experimental sites. However, higher yield were recorded in loamy-sand soils (LSs) than clay-loam soils (CLs) in all treatments. Thousand grain yield and grain number per spike were also decreased due to drought conditions. Similar to grain yield, both parameters were also significantly lower in CLs than LSs. Split nitrogen treatment included flowering stage caused a significant decrease in grain yield because of lower biomass production during earlier development stages. Our findings suggested that higher biomass which could be obtained by high earlier nitrogen application may provide an advantage in wheat production for later drought conditions.

Key words*: drought, grain filling, nitrogen, wheat.*

INTRODUCTION

Global warming, the most obvious and harmful consequence of all human activities, affects most seriously the agricultural production. The estimations demonstrated that, globally, climate-induced reduction in agricultural productivity amounts to 16 % by the 2080s (Cline, 2007). However the United Nations of Food and Agricultural Organization estimates that food demand of world population will increase 70 % in next 40 years and the increase will be more pronounced in developing countries (FAO, 2006).

Wheat is the most important stable food for humans (Curtis et al., 2002) and grown on more land area than any other commercial crops (FAO, 2010). Hence, any reduction in grain yield or quality in wheat production leads to considerable economic losses. Drought as a result of progressively increase in global temperature is regarded as a major restricting environmental factor in wheat production (Acevado et al., 1999). The substantial reduction in wheat production due to drought affected lands has already started to be reported in all around the world. Portugal lost around 60% of wheat production as a consequence of drought in 2005 while economic impact of the drought in 2003 was about € 11 billion in Europe overall (Isendal and Schmid, 2006). Turkey was also adversely affected by low rainfall thus water scarcity in 2008 and wheat production significantly decreased (Ayranci et al., 2010). In consideration of increasing effects of global warming, wheat production is expected to decrease more frequently because of increasing drought-prone areas.

Wheat is more often grown in arid and semi-arid regions of Turkey under rain-fed conditions thus drought is a main limiting factor in production (Yildirim et al., 2009). Most of the rainfall is received between November and April in these regions as Mediterranean countries. Though water scarcity might be experienced during all growth stages of wheat due to unfavorable rainfall distributions, effects of drought markedly increase in post-anthesis and grain filling stages (Ozturk, 1999). These crucial stages of wheat growth are considered as a most important period regarding to yield formation (Acevedo et al., 1999). Drought-inhibited reduction in post-anthesis photosynthesis and remobilization of dry matters to the grain lead to significant decrease in grain yield (Patla et al., 1994; Ercoli et al., 2008).

Nitrogen content of soils in rain-fed production systems is a crucial determinant of grain yield in cereal crops (Abaledo et al., 2008; Cossani et al., 2012). Passioura and Angus (2010) suggested that suitable nitrogen managements in drought-prone environments could be a useful agronomic tool to increase water use efficiency. For instance, nitrogen applications during earlier development stage of plants may lead to better root development and quicker canopy cover thus bigger biomass and lower bare soil evaporation (Borghi, 1999). However, on the contrary, Fischer and Kohn (1966) reported that quicker plant growth in early stages resulted higher transpiration and caused to increase drought risk during later developmental stages.

The purpose of the present study was to understand effects of different nitrogen applications on wheat plants grown under terminal drought stress conditions.

MATERIALS AND METHODS

A field experiment was conducted in two experimental sites of Izmir-Turkey during 2009-2010 growing season. The experimental sites, Bornova (CLs) and Menemen (LSs), were characterized with clay-loam (pH 7.8 and slightly calcareous) and loamy-sand (pH 7.5) soils respectively. Bread wheat cultivar Gönen (*Triticum aestivum* L.) was used as a plant material. Experimental design was a split-plot arrangement within a randomized complete block design with three replications. Plants were sown 21-22 November 2009 in Bornova and Menemen respectively. Plot sizes were 1.2 x 3 m and row distance were 20 cm for each treatments. Seeding density was 500 seed m^{-2}.

All plants were grown under rain-fed conditions until flowering stage. Then, rain-out shelters were constructed to exclude rainfalls after flowering stage in drought stress treatments (DT) while the control plants (CT) were kept under open field. Total rain amounts were 123.8 and 91.0 mm after the treatment in Bornova and Menemen respectively. Relative water content of the soil in both experimental site and each treatment after stress application were given in Figure 1. The same amount (90 kg/ha) but two different nitrogen applications were applied as a second factor of the experiment. Nitrogen was given in three times: 30 kg ha^{-1} top dressing, 30 kg ha^{-1} at the beginning of stem elongation stage and 30 kg ha^{-1} before flowering stage in N1 treatment. In N_2 treatment, nitrogen was applied two times: 60 kg ha^{-1} at top dressing and 30 kg ha^{-1} at the beginning of stem elongation stage. The fertilizer contained ammonium sulfate was used as top dressing and ammonium nitrate was used in other applications. All treatments received same amount of P_2O_5 (50 kg/ha).

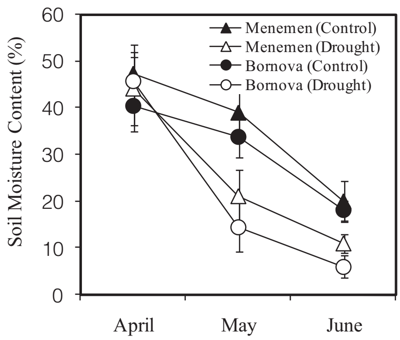

Figure 1. Relative moisture content of the soil under control and drought conditions in Menemen (LSs) and Bornova (CLs), after drought treatments

Plants were sampled and harvested after physiological maturity during second week of June. Yield parameters were determined according to the methods described by Bell and Fischer (1994).

RESULTS AND DISCUSSIONS

Decrease in soil moisture content in stress treatment was more remarkable after April in both locations (Figure 1). Final moister content of the soil in July was 18 % in control plots in both experimental sites while 10 % and 7 % in drought exposed plots in Menemen (LSs) and Bornova (CLs), respectively.

Grain yield of cv. Gönen significantly decreased from 3.0 t ha^{-1} to 2.2 t ha^{-1} as a result of drought conditions during grain filling stage (Figure 2). The nitrogen applications and environmental conditions of experimental sites significantly influenced grain yield of cv. Gönen. Higher grain yield was recorded in LSs (3.1 t ha^{-1}) than CLs (2.1 t ha^{-1}). N_1 treatment caused significantly higher grain yield (2.8 t ha^{1}) than N_2 treatment (2.3 t ha^{-1}) (Figure 2). There was no significant interaction between the experimental factors thus N_2 treatment had always better performance in all conditions.

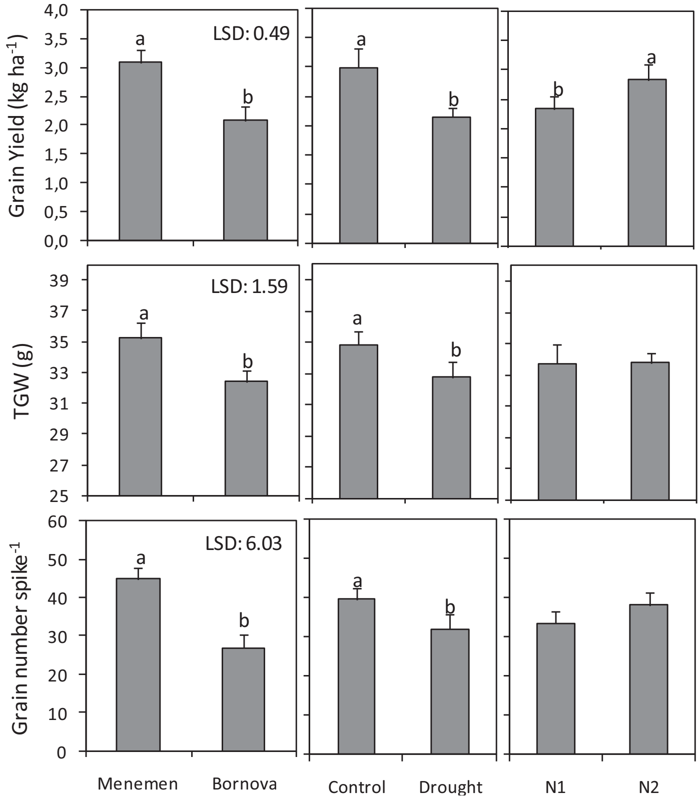

Figure 2. Effects of drought, nitrogen applications (N_1 and N_2) and experimental sites [Menemen (LSs) and Bornova (CLs)] on grain yield (kg ha^{-1}), thousand grain weight (TGW) and grain number per spike of wheat cv.Gönen (P=0.05)

Thousand grain weights (TGW) decreased under drought conditions during grain filling stage (Figure 2). TGW was 34.8 g under control conditions whereas it was 2.0 g lower under drought conditions. On the other hand, grain number per spike (GNS) had same trend with TGW as a response of drought and experimental sites (Figure 2). Relative decrease under drought conditions was 19.1 % in LSs whereas 40.1 % in CLs. Nitrogen application induced relation between biomass production and grain yield of cv. Gonen is demonstrated in Figure 3 whereas Figure 4 shows drought induced TGW and biomass production relation to grain yield.

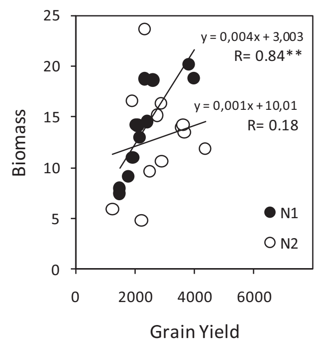

Figure 3. Nitrogen application induced relation between biomass production (g) and grain yield (kg ha^{-1}) of wheat cv.Gönen (* P=0.05, ** P=0.01)

A significant and positive correlation (r = 0.84**) was found between biomass and grain yield in N_1 treatment whereas there was no correlation in N_2 treatment (Figure 3). Higher grain yield was associated with higher TGW under control conditions (r = 0.81**) and more biomass in drought conditions (r = 0.64*). However, there was not any significant link between grain yield and TGW under drought conditions and biomass under controlled conditions (Figure 4).

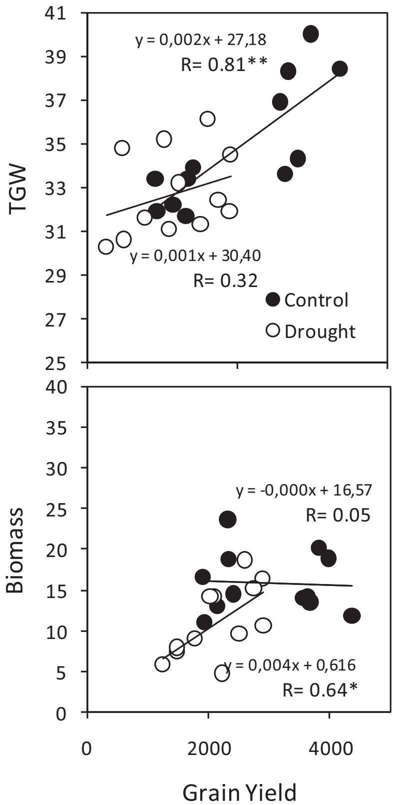

Figure 4. Drought induced thousand grain weight (TGW) and biomass production (g) relation to grain yield (kg ha^{-1}) of wheat cv.Gönen (* P=0.05, ** P=0.01)

Negative effects of drought conditions on grain yield of wheat have been previously reported in several studies (Dodig et al., 2008; Ilker et al., 2011; Tatar, 2011; Aykut Tonk et al., 2011). Acevedo et al. (1999), on the other hand, reported that post-anthesis stage is the most critical stage in terms of drought stress because of dry matter translocation to the grains. A drastic relative decrease (27.9 %) was also recorded in the present study. On the other hand grain yield significantly varied in different experimental sites. Heavy textured, higher calcareous and lower available potassium content of the soil of Bornova (Tatar, 2011) led to lower grain yield production than Menemen. Similar difference between these locations was reported by Altinbas et al. (2004).

N_1 treatment caused significantly higher grain yield than N_2 treatment in both experimental sites. Borghi (1999) demonstrated that earlier nitrogen applications resulted rapid plant development, soil cover by the canopy and better root development in wheat which had the advantage for the later water limited conditions. On the other hand, however, Fisher and Kohn (1966) reported that faster plant growth during earlier stages thus bigger canopy caused higher transpiration and quicker loss of limited water sources. Our data are in agreement with the idea suggested positive impact of earlier application of nitrogen to mitigate higher grain yield losses in wheat.

A wealth of data pointed out that drought lead to decrease thousand grain weights (TGW) and finally reduction in grain yield (Mollasadeghi et al., 2011; Ozturk, 1999). However, decrease in TGW as a result of lower dry matter translocation to grains has been perceived as a main reason in grain yield reduction under drought conditions during grain filling stage (Garcia del Moral et al., 2003; Tatar, 2011). Present findings also suggested that decrease in grain yield under drought conditions and different sites could be mainly attributed to decrease in TGW.

Miralles and Slafer (1999) stated that grain number per spike (GNS) is determined earlier than flowering stage in wheat. Gholami and Asadollahi (2008), however, reported that GNS was also affected by drought conditions after flowering stage. The similar reduction in the present study could be explained by pollen sterility due to drought effects during flowering stage. On the other hand, effect of experimental sites on GNS might be perceived as a result of better growth conditions in Menemen in terms of soil properties.

Despite the nitrogen effects on grain yield was significant, both TGW and GNS did not significantly differ under two different nitrogen applications (Figure 2). Figure 3 indicates nitrogen application induced relation between biomass production and grain yield of cv. Gonen. Since the biomass production was restricted by the lower nitrogen amount during earlier growth stages in N_1 treatment, grain yield of plants were determined mostly by biomass production (r = 0.84**). However, earlier nitrogen applications resulted in higher biomass production which had no correlations with grain yield in N_2 treatment. Madeni et al. (2012) reported that nitrogen application during flowering stage reduced negative effects of drought during grain filling stage. In the present study, similar to the results of Gevrek and Atasoy (2012), split application of nitrogen (N_1) included flowering stage had no positive effects on grain yield under drought conditions. Drought induced TGW and biomass production relation to grain yield were demonstrated in Figure 4. The results indicated that grain yield under control conditions mostly correlated with TGW (r =0.81**) whereas biomass production (r =0.64*) under drought conditions. Therefore, it might be suggested that wheat plants could better adapt to drought stress during grain filling stages by higher biomass production as a result of higher earlier nitrogen applications.

CONCLUSIONS

In conclusion, it could be suggested that water limited conditions during grain filling stage led to drastic decrease in grain yield in wheat which is mainly depends on a reduction in TGW and GNS. Plants were more productive because of favorable soil properties of Menemen (LSs) than Bornova (CLs) Location. Split nitrogen treatment included flowering stage caused a significant decrease in grain yield because of lower biomass production during earlier development stages. Therefore, we may propose that higher biomass which could be obtained by earlier nitrogen application may provide an advantage for later drought conditions.

ACKNOWLEDGEMENT

The data presented in this paper is the part of PhD. Thesis of Ozgur Tatar. This study financially supported by Ege University (Scientific Research Project No: 2009ZRF064).

REFERENCES

Abaledo L.G., Savin R. Slafer G.A., 2008. Wheat Productivity in The Mediterranean Ebro Valley: Analyzing the Gap Between Attainable and Potential Yield With a Simulation Model. European Journal of Agronomy, 28: 541-550.

Acevedo E.H., Silva P.C., Silva H.R., Solar B.R., 1999. Wheat Production in Mediterranean Environments. In: Satorre E.H. and Slafer G.A. (ed.). Wheat: Ecology and Physiology of Yield Determination. Binghamton, New York, USA: Food Products Press. p. 295–331.

Altinbas M., Tosun M., Yuce S., Konak C., Kose E., Can R.A., 2004. Effects of Genotype and Location on the Grain Yield and Some Quality Traits in Bread Wheats (*T.aestivum* L.). Journal of Ege University Faculty of Agriculture, 41: 65-74.

Aykut Tonk F., Ilker E., Tatar O., Recber A., Tosun M., 2011. Effects of different rain amount and distributions on bread wheat yield. Journal of Ege University Faculty of Agriculture, 48: 125-130.

Ayranci R., Sade B., Soylu S., 2010. Drought stress and some approaches in drought tolerant bread wheat improvement. In: Symposium on Prevention of Desertification. Corum, Turkey. p: 194-204.

Bell M.A., Fischer R.A., 1994. Guide to plant and crop sampling: measurements and observations for agronomic and physiological research in small grain cereals, Wheat Special Report CIMMYT, No: 32.

Borghi B., 1999. Nitrogen as determinant of wheat growth and yield, Wheat Production in Mediterranean Environments. In: Satorre E.H. and Slafer G.A. (ed.). Wheat: Ecology and Physiology of Yield Determination. Binghamton, New York, USA: Food Products Press. p. 67-84.

Cline W.R., 2007. Global warming and agriculture: impact estimates by country, Washington, D.C., Center for Global Development, p: 250.

Cossani C.M., Slafer G.A., Savin R., 2012. Nitrogen and Water Use Efficiency of Wheat and Barley Under Mediterranean Environment In Catalonia, Field Crops Research, 128: 109-118.

Curtis B.C., Rajaram S., Macpherson H.G., 2002. Bread Wheat Improvement and Production, *FAO* Plant Production and Protection Services. Rome, Italy. No:30.

Dodig D., Zoric M.D., Knezevic S.R., King G., Surlan-Momirovic, 2008. Genotype x environment interaction for wheat yield in different drought stress conditions and agronomic traits suitable for selection, Australian Journal of Agricultural Research, 59: 537-545.

Ercoli L., Lulli L., Mariotti M., Masoni A., Arduini A., 2008. Post-anthesis dry matter and nitrogen dynamics in durum wheat as affected by nitrogen supply and soil water availability, European Journal of Agronomy, 28: 138-147.

FAO, 2006. Prospects for food, nutrition, agriculture and major commodity groups, World agriculture: Towards 2030/2050, Interim Report of Global Perspective Studies Unit, Food and Agriculture Organization of United Nations, Rome, Italy.

FAO, 2010. Statistical Year Book-2010, Statistic Division of Food and Agriculture Organization of the United Nations, Rome, Italy.

Fischer R.A., Kohn G.D., 1966. The Relationship of grain yield to vegetative growth and post-flowering leaf area in the wheat growth under conditions of limited soil moisture, Australian Journal of Agricultural Research, 17: 281-295.

Garcia del Moral L.F., Rharrabti Y., Villegas D., Royo C., 2003. Evaluation of grain yield and its components in durum wheat under Mediterranean conditions: an ontogenic approach. Agronomy Journal, 95: 266-274.

Gevrek M.N., Atasoy G.D., 2012. Effect of post anthesis drought on certain agronomical characteristics of wheat under two different nitrogen application conditions. Turkish Journal of Field Crops, 17: 19-23.

Gholami A., Asadollahi A.P., 2008. Improving wheat grain yield under water stress by stem hydrocarbon reserve utilization. Pakistan Journal of Biological Science, 11: 2484-2489.

Isendahl N., Schmidt G., 2006. Drought in the Mediterranean: WWF policy proposals, A WWF-World Wide Fund for Nature Report, July, Germany.

Ilker E., Tatar O., Aykut Tonk F., Tosun M., 2011. Determination of tolerance level of some wheat genotypes to post-anthesis drought, Turkish Journal of Field Crops 16: 59-63.

Madani A., Makarem A.H., Vazin F., Joudi M., 2012. The impact of post-anthesis nitrogen and water availability on yield formation of winter wheat. Plant Soil and Environment, 58: 9-14.

Miralles D.J., Slafer G.A., 1999. Wheat development, In: Satorre E.H. and Slafer G.A. (ed.). Wheat: Ecology and Physiology of Yield Determination. Binghamton, New York, USA: Food Products Press. p. 13-43.

Mollasadeghi V., Valizadeh M., Shahryari R., Imani A.A., 2011. Evaluation of drought tolerance of bread wheat genotypes using stress tolerance indices at presence of potassium humate. American Eurasian Journal of Agricultural and Environmental Science, 10: 151-156.

Ozturk A., 1999. The effect of drought on the growth and yield of winter wheat. Turkish Journal of Agriculture and Forestry, 23: 531-540.

Palta J.A., Kobata T., Turner N.C., Fillery I.R., 1994. Remobilization of carbon and nitrogen in wheat as influenced by postanthesis water deficits. Crop Science, 34: 118-124.

Passioura J.B., Angus J.F., 2010. Improving productivity of crops, in water-limited environments. Advence in Agronomy, 106: 37-75.

Tatar O., 2011. Physiological regulation of drought stress related with yield components of some wheat cultivars, PhD. Thesis, Ege University, Izmir.

Yildirim M., Akinci C., Koc M., Barutcular C., 2009. Applicability of canopy temperature depression and chlorophyll content in durum wheat breeding, Anadolu Journal of Agricultural Science, 24: 158-166.