DOI: 10.17707/AgricultForest.61.1.36

Oner CETIN, Cuma AKINCI [1]

EFFECTS OF DROUGHT ON OPTIMIZING NITROGEN USE OF WINTER WHEAT IN A SEMI ARID REGION

ABSTRACT

Wheat is the most important world crop grown on more of the world's acreage than any other crop in terms of feeding of human. Water and nitrogen (N) are the main limiting factors affecting agricultural production in arid and semiarid regions. Drought originates from deficiency of precipitation which effecting wide areas for temporary periods. However, it is not defined as only water scarcity but also other climate factors such as high temperature and low relative humidity. Effects of drought depend on the phenological stage of the wheat plants. According to a study carried out in this area, the rates of 70 kg N/ha under non-irrigation conditions and 150-170 kg N/ha under irrigated conditions are need as the economic maximum fertilizer nitrogen for wheat. However, in case of drought occurrence, the rate of 120- 130 kg N /ha should be used under irrigated conditions. When there is adequate water throughout grain filling, applied nitrogen boosts yield. When a drought occurs, then extra N may diminish yield. Management of nitrogen is, thus, part of a balanced fertility program. This can lead to increased efficiency and profitability for the growers. Economically amount of nitrogen could be determined using a regression equation showing grain-yield and nitrogen fertilizer relationships under the different climatic conditions. In this article, it is discussed on water and nitrogen relationships, effects of drought under both irrigated and rainfall conditions and the equations showing economically amount of nitrogen for wheat in South-eastern Anatolia Region of Turkey.

Key words: Wheat, irrigation, nitrogen, drought, climatic

INTRODUCTION

Wheat is the most important world crop grown on more of the world's acreage than any other crop in terms of feeding of human. Also it has the highest cropping area in the field crops with about 9.35 million ha grown area in Turkey. It is adapted to a wide range of soil and climate. Climatic factors determine where and to what extend wheat can be grown economically. Climatic conditions

[1] Oner CETIN1 (corresponding author: oner_cetin@yahoo.com, onercetin@dicle.edu.tr); Dicle University, Agricultural Faculty, Dept. of Agricultural Structures and Irrigation, Diyarbakir, Turkey; Cuma AKINCI, Dicle University, Agricultural Faculty, Dept. of Field Crops, Diyarbakir, Turkey.

Paper presented at the 5th International Scientific Agricultural Symposium "AGROSYM 2014".
Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

have a marked influence on growth of wheat as well as on the yield and quality of its grain (Cetin and Ogretir, 2000).

Climate influences plant life in many ways and can inhibit, stimulate, alter or modify crop performance. Its components (temperature, solar radiation, rainfall, relative humidity and wind velocity) independently or in combination, can influence crop growth and productivity (Amgain et al., 2006).

The cultivation of wheat in arid regions is an economically risky undertaking, mainly because of fluctuating rainfall distribution. The effect of pre-sowing rainfall on wheat yields were mainly depend on the rainfall amounts and their distribution from the time the crop has been planted to the tillering stage when rainfall variability is 113-178 % (Lomas and Shashoua, 1973). Yaron et al. (1969) stated that early irrigation on wheat is usually the most efficient, resulting in the highest marginal response in yield.

On the other hand, drought is significantly natural event affecting crop yield and crop cycle life. Drought originates from deficiency of precipitation which effecting wide areas for temporary periods. However, it is not defined as only water scarcity but also other climate factors such as high temperature and low relative humidity (Kayam and Cetin, 2012).

Recently, severe drought has occurred in 2007 in Turkey. This natural event affected agricultural production and hydrological flow. While the wheat production, a basic crop of Turkey, was 21 500 000 tons in the year of 2005, it was 17 234 000 tons in 2007 and 17 782 000 tons in 2008 (TUIK, 2012).

Since agricultural sector is the most adversely affected sector from the impacts of drought and since approximately 75% of water resources are used in that sector, work and legal arrangements in the issue of drought and its impacts concentrate mostly on agricultural drought. For this reason, a Cabinet decision titled ‘Procedures and principles of combat agricultural drought and of drought management operations’ in 2007 (Kayam et al., 2009).

Drought stress is one of the most important abiotic stresses which can affect the growth of a plant. In cereals like wheat the stress induced due to drought at the stage of grain-filling usually shortens the grain-filling period and reduces the grain-filling rate, eventually reducing grain yield. During seed development, appropriate soil water status is of critical importance for accumulation of starch in grains and thereby formation of grain yield (Mohammadi and Moradi, 2013).

Significant reduction in grain yield as a result of the drought after flowering stage was found. However this reduction was more distinct with lower nitrogen application in the earlier stages (Gevrek and Atasoy, 2012). The negative effect of early drought (before milk stage) on grain yield was more significant than that of late drought (after milk stage) (Ozturtk, 1999).

Effects of drought depend on the phenological stage of the wheat plants. Spikelet and kernel number are affected by water stress occurs during the stem elongation stage (Shpiler and Blum, 1991). Translocation of dry matter to grain is negatively affected by the drought after the flowering stage (Garcia del Moral et al., 2003; Ilker et al., 2011).

In this article, effects of drought on nitrogen use of winter wheat and optimizing nitrogen under the drought conditions are discussed and evaluated.

Effects of nitrogen on wheat under different conditions

Water and nitrogen (N) are the main limiting factors affecting agricultural production in arid and semiarid regions.

Nitrogen is a primary plant nutrient that plays a major role in achieving the maximum economic yields. During the vegetative stage of growth, rapid expansion of the leaves requires large amounts of N and both fruit production and retention are dependent on leaf development and photosynthetic integrity (Oosterhuis et al., 1983). Thus, management of nitrogen is part of a balanced fertility program. This can lead to increased efficiency and profitability for the growers.

According to a research on wheat, durum winter wheat *(Triticum durum L, cv. Balcali-85)* was used and applied N_o(0), N_1(60), N_2(120), N_3(180) and N_4(240 kg N /ha) as nitrogen fertilizer treatments; and I_o (non-irrigated), I_1 (one irrigation at the milk stage), I_2(two irrigations, one at the beginning of heading and one at the milk stage), I_3(three irrigations, one at the booting, the 2nd at the beginning of heading and the 3rd at milk stage) and I_4(three irrigations, the 1st one after sowing, the 2nd one at the beginning of the heading and 3rd one at the milk stage) in the research in Sanliurfa Province of South-eastern Anatolia from 1989 to 1991. Irrigation and nitrogen increased the grain yield of wheat. Generally, grain yield increased as the levels of irrigation and rates of fertilizer nitrogen increased. When normal distribution of the precipitation and drought occurred, only irrigation independently increased grain yield 76 to 136 % and 420 %, respectively. On the other hand, nitrogen independently increased the yield 81-81 % under the normal distribution of the precipitation and 32 % under the drought conditions. However under the same conditions together with irrigation and nitrogen increased the grain yield 198 to 209 and 590 % respectively (Cetin, 1993).

If a drought during especially sowing season occurs, irrigation must be applied absolutely after sowing and supplemental irrigations should be at the beginning of heading and milk stages. In the drought years, the wheat grain yield was determined or limited by amount of irrigation water applied. However, when appropriate amount and proper distribution of the rainfall became together with irrigation, the grain yield was determined or limited by amount of nitrogen fertilizers. For that reason, nitrogen efficiency increased by means of irrigation water and rainfall. The effects of rainfall amount and distribution, temperature, nitrogen and irrigation according to growing stages of wheat on yield were not independent from each other.

Compared with the irrigated condition, wheat N accumulation was significantly decreased at each growth stage under dry land cultivation. Dryland condition decreased the N absorption ratio at anthesis-maturity stage, post-anthesis N accumulation and its contribution to grain N Content (Sun et al., 2010). Nitrogen efficiency of drought-tolerant sib-lines under drought stress was studied in pot experiments to provide knowledge on how to apply efficiently water and nitrogen in arid and semi-arid regions in China. Nitrogen efficiency ratio, nitrogen uptake efficiency, nitrogen use efficiency and nitrogen fertilizer utilization efficiency of a given variety decreased significantly with increasing drought stress. Yaron et al. (1969) stated that early irrigation on wheat is usually the most efficient, resulting in the highest marginal response in yield.

Shia et al. (2014) reported that each drought and irrigation cycle, the severities of drought and N deficiency were immediately alleviated under all treatments following irrigation events.

Optimizing nitrogen use

Nitrogen is an essential plant nutrient that positively impacts on growth and yield when used thoughtfully. However, it must be used in balance with other potential limitations to production, particularly water.

Nitrogen will have little impact on crop yield if other factors present a greater limitation. The most important one of these factors is water and/or irrigation. Water/irrigation or precipitation limitation limited nitrogen used by crops. The yield is, thus, decreased significantly. Other factors affecting nitrogen use are: sowing locally adapted cultivars at the optimum time, ensuring there is a low risk of disease, adjusting soil pH if possible to levels where it presents little or no limitation to growth, ensuring nutrients such as phosphorus, zinc and trace elements are not limiting growth, ensuring there are no subsoil constraints to root growth such as sodicity or trace element toxicity (FAO, 2013).

In order to apply satisfactory amount of nitrogen for each location, it needs to be determined a nominal response curve to N for the location. According to the field experiments, two kind of curve might be obtained. The first is linear curve (Fig. 1A). This curve could be obtained under the insufficient amount of nitrogen on wheat grain yield. However, the second curve (Fig.1B) quadratic or parabolic curve might be used to estimate economical amount of nitrogen on grain yield.

On the other hand, to obtain an economical amount of nitrogen fertilizer, the values given equation in Fig 1B could be used. Thus, it is used the equation given below.

$$Eg = F_f - F_c \cdot b / 2F_c \cdot c$$

Where Eg: Economical amount of nitrogen (kg N/ha), F_f: Price of fertilizer nitrogen ($/N kg), Fc: Selling price of crop ($/kg), b: Liner effect of fertilizer in regression of yield-nitrogen relationship, c: Quadratic effect of fertilizer in regression of yield-nitrogen relationship in the equation in Fig 1B. .

The response curves between nitrogen and grain yield under the different irrigation regimes based on the different experimental years are different in Fig

1B. The effects of climatic conditions such as amount of rainfall and distribution temperature and relative humidity affects significantly grain yield.

Considering the results of the study carried out in South-eastern Anatolia Region of Turkey (Cetin, 1993) grain yields were significantly lower in 1991 compared to those in 1989 and 1990 (Fig 2). The rainfall of 229 mm was occurred during the growing season in 1989 and 52 % of it was at the end of December and 42 % of it was occurred in March.

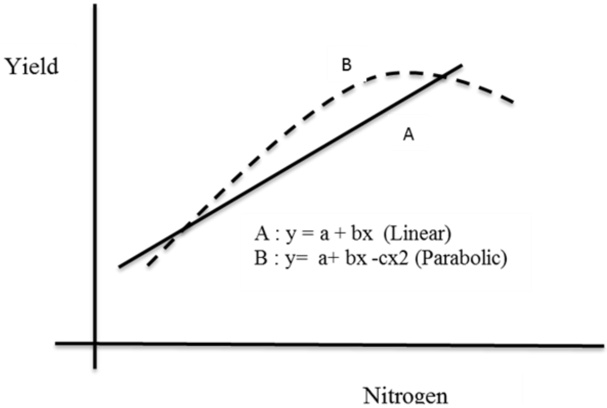

Figure 1. Relationships between nitrogen and grain yield of wheat under insufficient (A) and excessive nitrogen levels (B)

In 1990, the rainfall amount of 327 mm was occurred during the growing season, and 43 % of it was in between end of November and January. However, 42 % of it was in February. In 1991, the rainfall amount of 252 mm occurred during growing season and only 5 % of it were in between the end of November and December. Remaining of it (95 %) occurred in January, February and March. It was, thus, too small and insufficient rainfall amount for germination and development of wheat plants. This situation affected the plants in terms of water deficiency in plots in which were no irrigation after sowing.

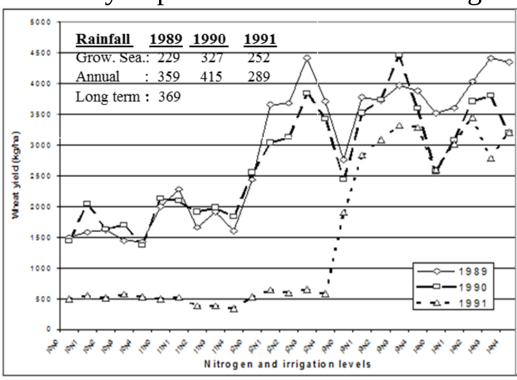

Figure 2. Effects of rainfall distribution on wheat yield under the same irrigation and nitrogen treatments for different experimental years (Cetin, 1993).

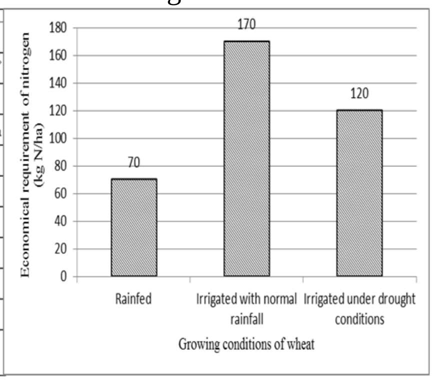

Figure 3. Effects of drought on economical requirement of nitrogen in Southeastern Anatolia Region of Turkey (Cetin 1993).

Due to water stress during the sowing stage in 1991, the seeds of wheat could not sufficiently germinate and young plants also could not properly develop and the root system and parts of stem were weak as entering winter season. Also, the tillering was weak (Cetin and Ogretir, 2000).

Considering the results of this study, as the economic maximum fertilizer nitrogen, the rates of 70 kg N/ha under non-irrigation conditions and 150-170 kg N/ha under irrigated (one at the beginning of heading and one at the beginning of milk stages) conditions can be recommended. However, in case of drought occurrence, the rate of 120- 130 kg N /ha may be used under irrigated conditions (Fig. 3). Drought or limitation of the rainfall limits use of nitrogen and its positive effects on grain yield. (Cetin, 1993; Cetin and Ogretir, 2000).

CONCLUSION

Insufficient precipitation and irrigation water are limited during the growth period of wheat, so it is very important for the growth of crop and the formation of grain yield to fertilize and irrigate in the dry-period.

When there is adequate water throughout grain filling, applied nitrogen boosts yield. However, when a drought occurs, then extra N may diminish yield. If management decisions or the environment seriously limited early growth, N applied late may not compensate for low yield potential. An adequate plant stand must first be established to make it worthwhile applying N during later growth.

A yield increase would normally be expected in wheat yield from this small amount of N fertilizer, but the weather complicated the response. All crops were exposed to a hot, very dry period from immediately preceding anthesis and into early grain filling so their soil water reserves were significantly depleted. Water, not N, became the major constraint to yield.

In the case of dry years winter wheat production cannot be maintained at satisfactory level. Nitrogen use efficiency is also lowered and this increases the probability for nitrogen loss to ecosystems and also to negative economic results in winter wheat production.

If the farmers get information and/or data about climatic and drought, the farmers should be avoided full fertilization as occurred normal amount of rainfall and distribution. The farmers should be, thus, used yield-response curve pertaining each region to get an economical yield.

REFERENCES

Amgain, L.P., Devkota, N.R., Timsina, J., Singh, B. (2006). Effect of clımate change and CO_2 concentration on growth and yield of rıce and wheat in Punjab: simulations using CSM-CERES-Rice and CSM-CERES-Wheat models. J. Inst. Agric. Anim. Sci. 27:103-110

Cetin, Ö. (1993). Effects of different amount of water and nitrogen and water consumption on winter wheat. Cukurova Uni. Institute of Sciences, Soil Science Department, PhD. Thesis, Adana, Turkey (in Turkish)

Çetin, Ö. Öğretir, K., (2000). The Effects of rainfall distribution and temperature changes under different irrigation and nitrogen levels on winter wheat. International

Conference: Present and Future Requirements for Agrometeorological Information, 11-15/09/2000, Poznan. POLAND (ISBN 83-85176-92-6), 55-68.

FAO, (2013). Optimizing Nitrogen use on the farm. http://www.fao.org/docrep (30.12.2013).

Garcia del Moral, L.F., Y. Rharrabti, D. Villegas and C. Royo. (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). Effects of post anthesis drought on certain agronomical characteristics of wheat under two different nitrogen application conditions. Turkish Journal of Field Crops, 17 (1):19-23

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

Kayam, Y., Cetin, O. (2012). The Impacts of drought and mitigation strategies in Turkey. 5th International Scientific Conference on Water, Climate and Environment. BALWOIS 2012 - Ohrid, Republic of Macedonia - 28 May - 2 June 2012

Kayam, Y., Üner, K., Acar, O.A., Şen, S., Beyazgül, M. (2009). Drought management applications in Turkey: Problems and new approaches for effective risk management of drought. Soil and Water Resources Research Institute, Menemen, Izmir, Turkey.

Lomas, J., Shashoua, Y. (1973). The effects of rainfall on wheat yields in an arid region. Plant response to climatic factors. Proc. Upprala Symp.

Mesic, M., Basic, F., Kisic, I., Zgorelec, Z., Vukovic, I. (2010). Influence of drought in 2003 on winter wheat yield and nitrogen use efficiency. American Geophysical Union, Fall Meeting 2010, abstract #GC23C-0931

Mohammadi, H., Moradi, F. (2013). Effects of plant growth regulators on endogenous hormones in two wheat cultivars differing in kernel size under control and water stress conditions. Agriculture & Forestry, Vol. 59. Issue 4: 81-94, Podgorica

Oosterhuis, D.M., Chipamaunga, J., Bate, G.C. (1983). Nitrogen uptake in field-grown cotton. I. Distribution of in plant components in relation to fertilization and yield. Exp. Agric. 19:91-101.

Özturk, A. (1999). Effects of drought on grain yield and growth of winter wheat. Tr. J. of Agriculture and Forestry, (23) 531-540.

Shia, J., Yasuorb, H., Yermiyahuc, U., Zuoa, Q., Alon Ben-Galc, A. (2014). Dynamic responses of wheat to drought and nitrogen stresses during re-watering cycles. Agricultural Water Management 146 (2014) 163–172

Shpiler, L. Blum, A. (1991). Heat tolerance for yield and its components in different wheat cultivars. Euphytica 51:257-263.

Sun, M., Gao, Z., Yang, Z., He, L. (2012). Absorption and accumulation characteristics of nitrogen in different wheat cultivars under irrigated and dryland conditions. Australian Journal of Crop Science. 6(4):613-617

TUIK, (2013). Basic statistics. Area and production of cereals and other crop products. www.tuik.gov.tr (08.01.2014)

Yaron, B., Danfors, E., Vaada, Y. (1969). Irrigation in arid zones. Stocholm, Department of lands improvement and drainage; school of surveying, Royal Institute of Technology.(Report 3.2b, p. 231-235)