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Nitrogen Contents and Nitrogen Accumulation Rates of Different Plant Parts of Wheat at Anthesis and Maturity Periods Under Normal and High Temperature Conditions

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Abstract

This research was established to evaluate differences in nitrogen contents of different wheat plant parts at anthesis and maturity periods under normal and high temperature conditions. Two temperature regimes was provided by sowing at two different times (normal wheat sowing time and quite late time to receive warmer conditions) and two different irrigation regimes was applied to distinguish the impact of drought from temperature.

Our investigations showed that amount of nitrogen accumulated at flag leaf (at anthesis and maturity), lower leaves (at anthesis and maturity) lower stem (at anthesis and maturity), husk-awn-axis (at maturity), grains (at maturity) and spike (at pre-anthesis, post-anthesis and maturity) was maximum under high temperature conditions.

Maximum nitrogen content was at lower leaves both at anthesis and maturity. Minimum nitrogen content was at lower stem at anthesis and at flag leaf at maturity. If we compare different temperature regimes, nitrogen content was higher at high temperature and lower at normal temperature both for anthesis and maturity at all plant parts except lower stem at maturity. Nitrogen harvest index was reduced both by high temperature and irrigation. Amount of nitrogen at grains was maximum at high temperature- conditions. Nitrogen accumulation rateof whole plant was three times faster at pre-anthesis and two times faster at whole vegetation stage under high temperature regime compared to normal temperature regime.

Keywords: Wheat, high temperature, heat stress, nitrogen content, nitrogen uptake rate

Normal ve Yüksek Sıcaklık Koşulları Altında Buğday Bitkisinin Farklı Aksamlarının Çiçeklenme ve Olgunluktaki Azot İçeriği ve Azot Birikim Oranı

Öz

Bu araştırma, farklı buğday bitki parçalarının normal ve yüksek sıcaklık koşullarında çiçeklenme ve olgunlukta azot içeriğindeki farklılıkları ve değişimi değerlendirmek amacıyla kurulmuştur. İki farklı ekim zamanı (normal buğday ekim zamanı ve daha sıcak koşulların sağlanması için oldukça geç tarihte) ile iki sıcaklık rejimi sağlanmış ve kuraklığın etkisini sıcaklıktan ayırmak için iki farklı sulama rejimi uygulanmıştır. İncelemelerimiz göstermiştir ki bayrak yaprağında (çiçeklenme ve olgunlukta), alt yapraklarda (çiçeklenme ve olgunlukta), alt gövdede (çiçeklenme ve olgunlukta), kavuz-kılçık-eksende (olgunlukta), danede (olgunlukta), başakta (çiçeklenme öncesi, çiçeklenme sonrası ve olgunlukta) biriken azot miktarı yüksek sıcaklık koşullarında en yüksek olmuştur.

En yüksek azot içeriği hem çiçeklenme hem de olgunlukta alt yapraklarda bulunmuştur. En düşük azot içeriği çiçeklenmede alt sapta, olgunlukta bayrak yaprakta bulunmuştur. Farklı sıcaklık rejimleri karşılaştırıldığında azot içeriği hem çiçeklenmede hem olgunlukta yüksek sıcaklık rejiminde yüksek, normal sıcaklık rejiminde düşük bulunmuş fakat, olgunlukta alt sap istisna teşkil etmiştir. Azot hasat indeksi hem yüksek sıcaklık hem de sulama uygulamaları ile düşüş kaydetmiştir. Danenin azot içeriği yağışa dayalı yüksek sıcaklık rejiminde en yüksek bulunmuştur. Tüm bitkinin azot birikim hızı, normal sıcaklık rejimine kıyasla yüksek sıcaklık rejiminde, çiçeklenme öncesinde üç kat, tüm vejetasyon süresince iki kat daha hızlı olmuştur.

Anahtar Kelimeler: Buğday, yüksek sıcaklık, ısı stresi, azot içeriği, azot alım hızı

Introduction

Heat stress effects wheat at different stages of development like, booting, heading, anthesis and reduces grain filling duration (Rane et al., 2007) and grain size and grain yield (Lobell et al., 2012). Nitrogen uptake is active rather than passive in the transpiration system, so the limitations to uptake are the amount of supply and soil dryness (Jamieson and Semenov, 2000). Van Sanford and Mackowen (1986) observed significant differences between lower stem, upper stem and flag leaf at anthesis and maturity in the amount of N uptake. Tahir and Nakata (2005) reported that high temperature significantly affects the distribution of nitrogen at most of the wheat genotypes. Nitrogen increases leaf area, may increase dry matter production by intercepting more sun light (Wilhelm, 1998) and plays an important role in grain filling (Green, 1984).The decline in the rate of grain growth is basicly due to a decrease in the rate of starch accumulation; protein deposition is less temperature sensitive (Bhullar and Jenner, 1985). Remobilization of pre-anthesis stored nitrogen is the primary source of nitrogen for wheat grain, accounting for 65–82% of grain nitrogen content (Edhaie and Waines 2001). Positive correlations observed between grain protein concentration and nitrogen harvest index of wheat (Saint Pierre et al., 2008). N contents at anthesis has a relation with sowing date especially with differences in the number of days from sowing to anthesis (Ehdaie and Waines, 2001). Delaying sowing date results with significant changes in environmental conditions (increases temperatures and diminishes moisture) especially during grain filling (Subedi et al., 2007).

Aim of this research is to determine the changes in nitrogen contents and N accumulation rates of wheat under global warming conditions under Mediterranean conditions of Turkey.

Materials and Methods

Research was conducted on research and application fields of University of Cukurova in Turkey in 2003-2004 wheat growing season. Research area is located at 36° 29' North latitude and 35° 18' East longitude at 20 m altitude. Test area is flat with high soil clay content. Adana-99 spring bread wheat cultivar was used in the study. Trial fields were left for fallow in 2002-2003 season. Sowing was done after cultivation of trial area and plots received 500 seeds per m^2. Normal sowing (normal temperature regime-NT) was done on 17 November 2003, late sowings (high temperature regime-HT) was done on 04 March 2004. Interrow distance was 15 cm, plot lenght was 6 m to form 8 lines.

80 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5, 80 kg ha^{-1} K_2O and 5 kg ha^{-1} Zn was given as composite fertilizer (15-15-15+1 Zn) at sowing. In the beginning of tillering (on 27.12.2003 at normal planting, and on 29.03.2004 at late planting) 80 kg ha^{-1} N as ammonium nitrate (26%) fertilizer was given. At stem elongation (for normal planting on 29.01.2004, for late planting on 22.04.2004) 40 kg ha^{-1} N as ammonium nitrate (26%) fertilizer was applied. Irrigation was done with drip irrigation. Lateral interspace was 30 cm and dripper interspace was 50 cm. Soil water was determined by gravimetric measurements made by weekly. Irrigation was done when first 60 cm of the soil profile available water level falls to 60%. Irrigation was carried out to fill the amount of water in the soil profile to field capacity under control of water meter.

Two temperature regimes was provided by planting at two different times (normal wheat sowing time and quite late time (to receive warmer conditions). In order to distinguish the impact of drought from temperature, two different irrigation regimes was applied in both sowing times. The experiment was set up as Randomized Complete Block Design with a split-plot arrangement with four replications where planting time was main plot and irrigation was sub-plot under randomised block design.

Investigations was conducted according to the method described mainly by Bell and Fischer (1994). Used Zadoks Growth Scale to follow plant phenological developments (Zadoks et al., 1974). To determine the amount of N, certain lengths in the middle part of the plots were cut from the soil surface and divided into different plant sections. These different plant parts dried at 70 °C for 48 hours and N content was determined by Khejdal method. The amount of N is determined by the formula "N content = Weight in mg X Percent N / 100". These procedures is applied separately to the samples taken from the plots at anthesis and maturity. For this purpose, during anthesis, spike, flag leaf, the lower leaves, upper stem, lower stem, sterile stem and during ripening grain, husks-awn-axis, flag leaf, lower leaves, upper stem, lower stem, sterile stem was used. The N uptake rate is calculated by dividing the N uptake to relevant vegetation time (emergence-anthesis period or emergence-ripening period). Nitrogen harvest index (NHI) was calculated as grain N/total above-ground N.

Heat regime was main factor, irrigation was sub-factor and trial was established by the randomised block design for the variance analysis of datas. We used MSTAT-C program package forthe analysis. The resulting averages was analysed by LSD. Daily average temperatures under NT regime for 2003-2004 growing season is given in Figure 1.

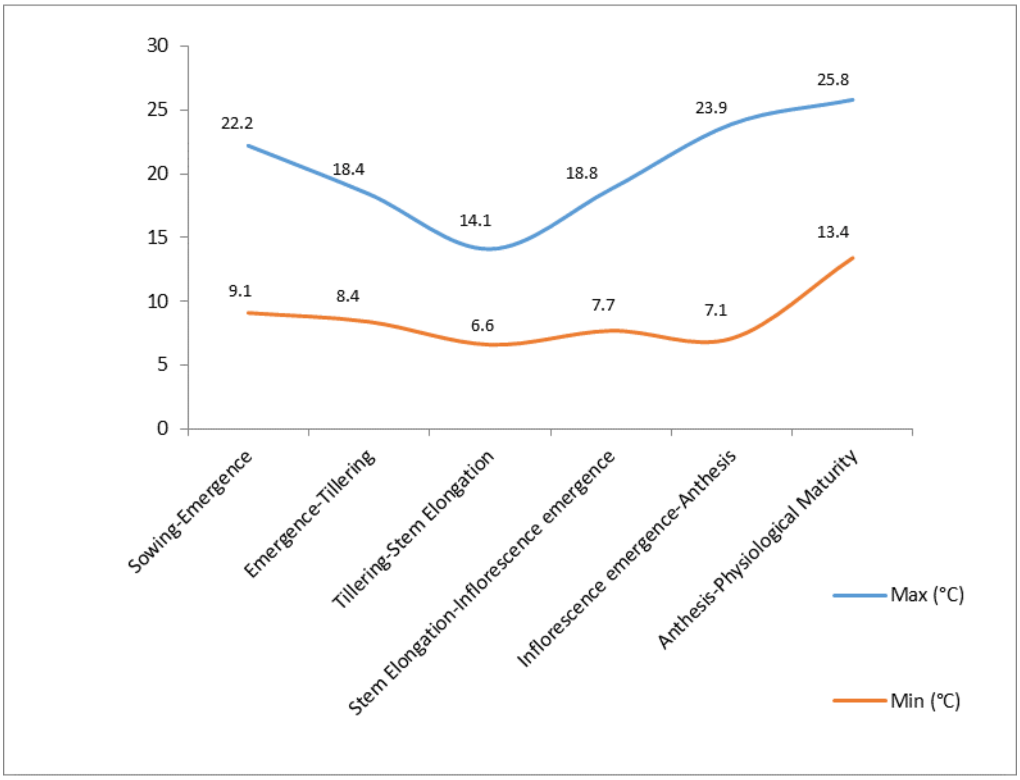

Figure 1. Actual average daily temperatures in different growing periods under NT regime

Daily average temperatures under HT regimefor 2003-2004 growing season is given in Figure 2.

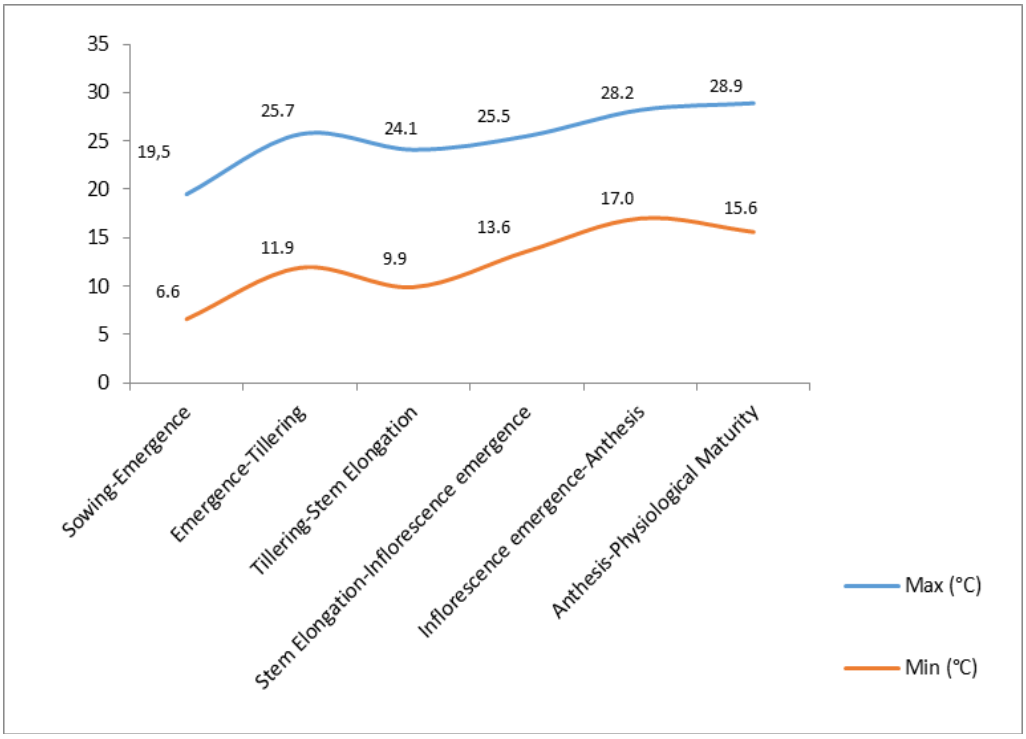

Figure 2. Actual average daily temperatures in different growing periods under HT regime

Amount of water that research area received as precipitation and irrigation in year 2003-2004 under NT regime is given in Figure 3.

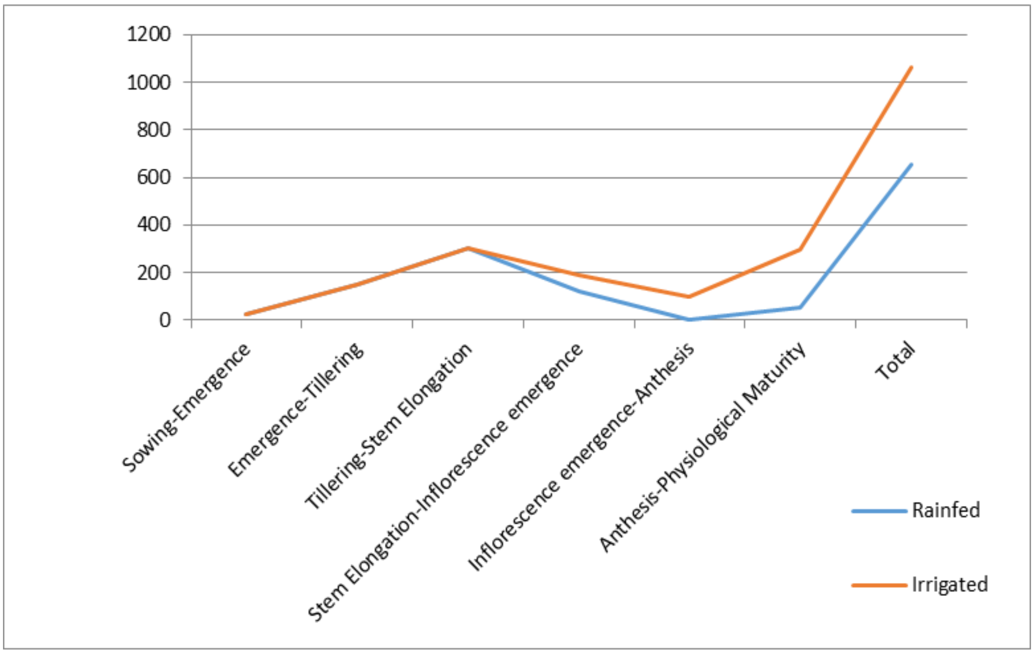

Figure 3. Amount of water research area received under NT regime (mm)

Amount of water that research area received as precipitation and irrigation in year 2003-2004 under HT regime is given in Figure 4.

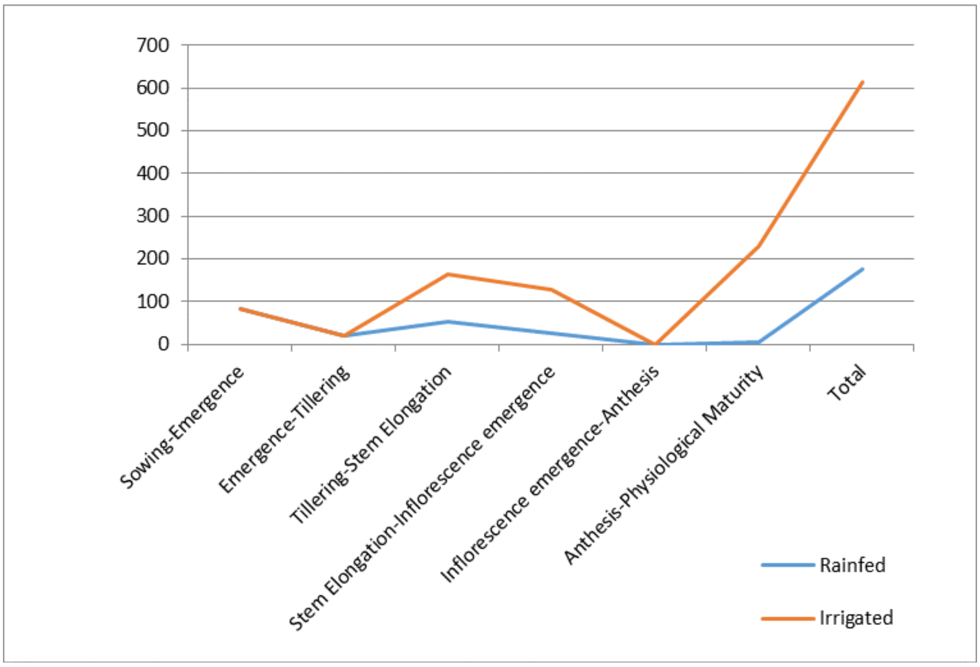

Figure 4. Amount of water that research area received under HT regime (mm)

Results

High temperature drastically reduced the duration of phenological periods except anthesis-maturity period. Phenological durations are given in Figure 5.

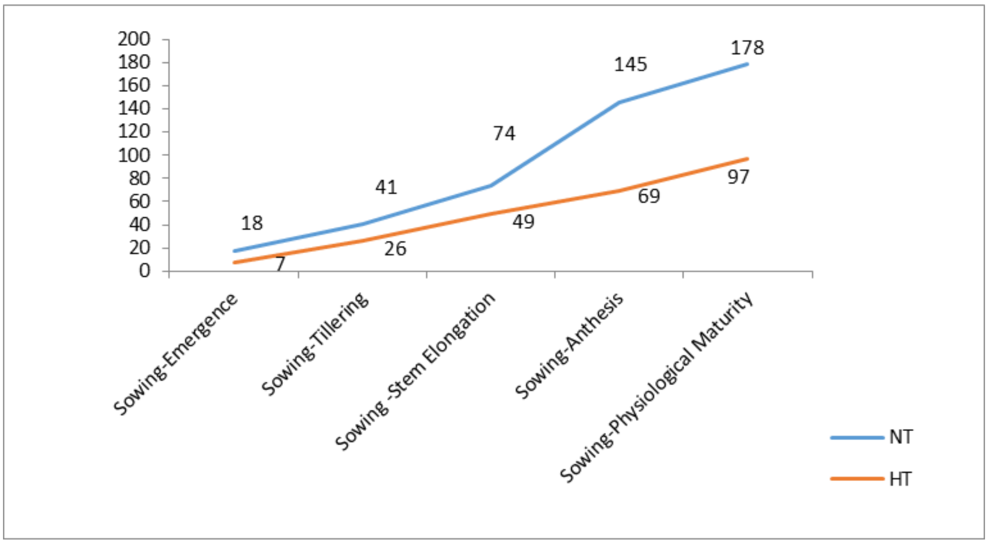

Figure 5. Phenological durations under different temperature regimes (day)

Total vegetation period was 178 days for the NT regime and 97 days for the HT regime. The most affected stages from HT was "sowing-tillering" and "stem elongation-anthesis" periods.

N contents (mg nitrogen per kg dry matter) of flag leaf, lower leaves, upper stem and lower stem at anthesis and maturity is given in Figure 6.

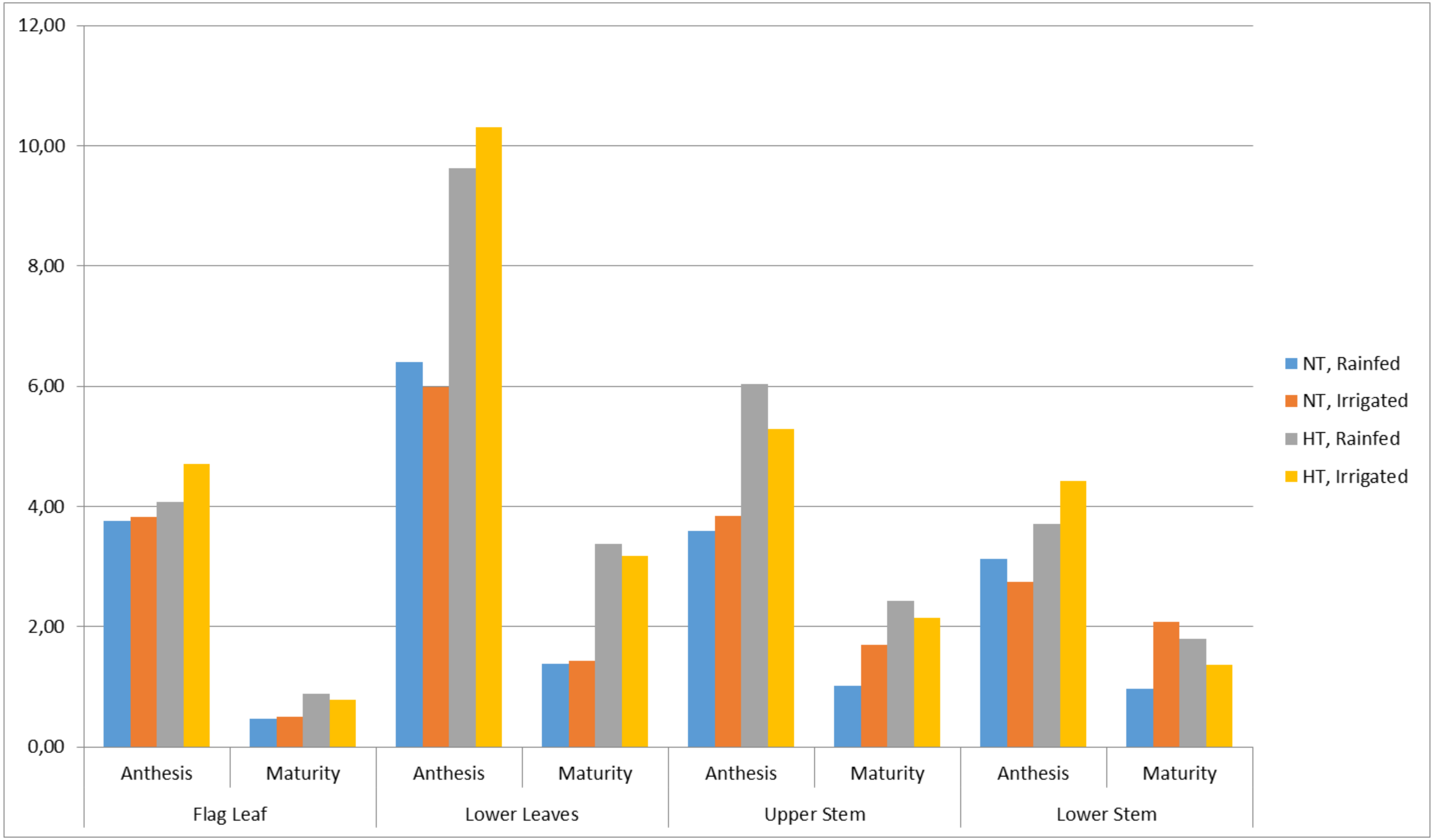

Figure 6. Amount of N accumulated (mg N stem-1) in the flag leaf, lower leaves, upper stem and lower stem at anthesis and maturity

Amount of N accumulated in the flag leaf was increased by HT for both anthesis and maturity. At maturity, there exists approximately 2 times bigger amount of N in the flag leaf under HT rainfed condition compared to NT rainfed.

Amount of N accumulated in the lower leaves was higher under HT for both anthesis and maturity. Amount of N accumulated in the upper stem was increased with HT and was maximum at HT rainfed condition both for anthesis and maturity. Irrigation reduced the amount of N found in upper stems under HT regime opposite of NT both for anthesis and maturity.

Amount of N accumulated in the upper stem was higher under HT for both anthesis and maturity compared to NT. N content at upper stem was maximum at HT-rainfed anthesis observation.

For lower stems, amount of N accumulated in the lower stem is lowest at anthesis but highest at maturityunder NT irrigated condition. The amount of nitrogen found in husks-awn-axiswas linearly increased both by HT regime and irrigation (Figure 7).

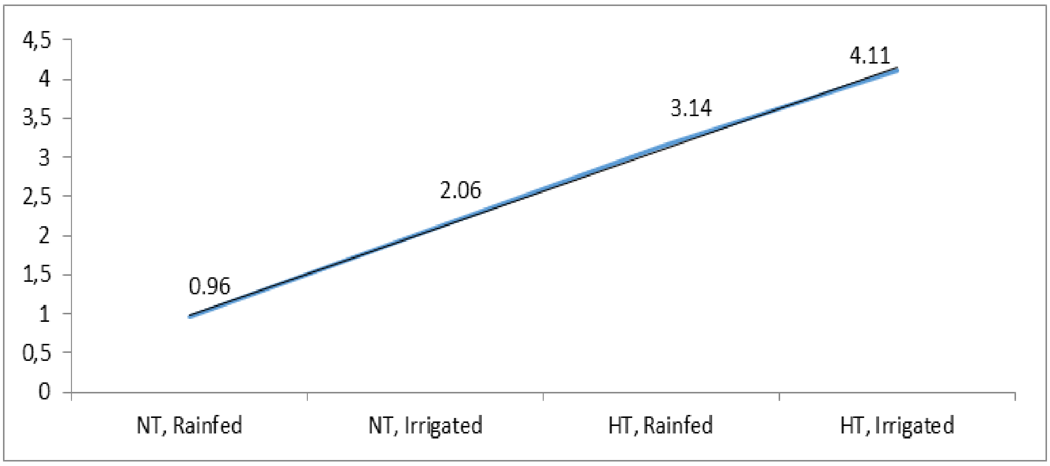

Figure 7. Amount of N accumulated in the husks-awn-axis (mg N stem^{-1}) at maturity

Amount of N accumulated in the spikes at anthesis is increased by HT but reduced by irrigation (Figure 8).

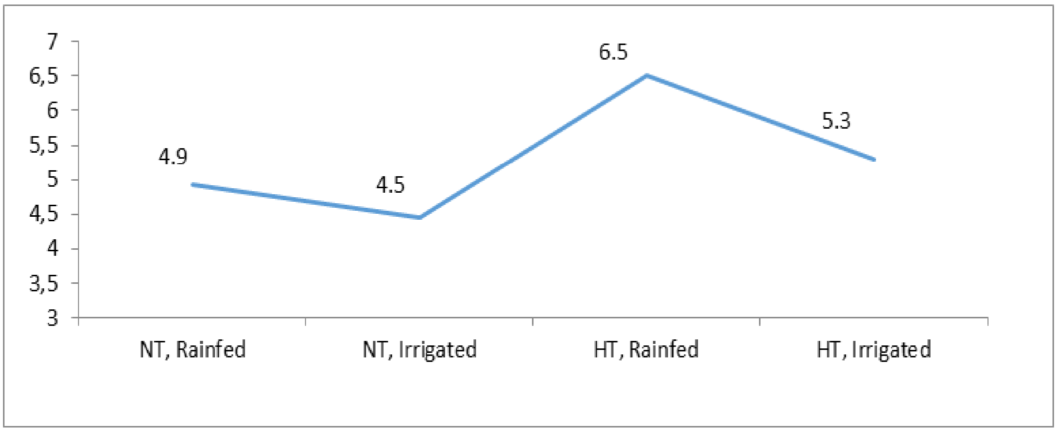

Figure 8. Amount of N accumulated in the spike (mg N spike^{-1})

Amount of N accumulated in the grains at maturity was maximum at HT, and irrigation had no significant effect under this condition (Figure 9).

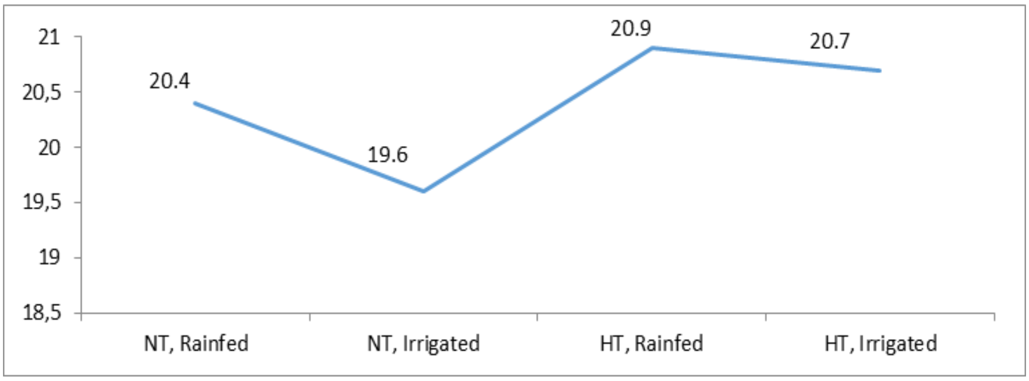

Figure 9. Amount of N accumulated in the grains at maturity (mg N spike^{-1})

Amount of N accumulated in plant at maturity was maximum at HT irrigated condition and minimum at NT rainfed condition (Figure 10).

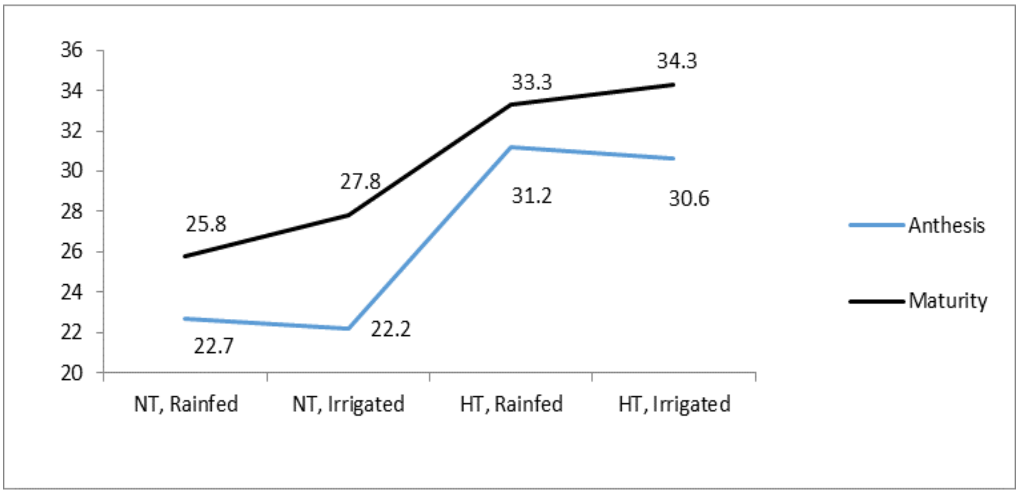

Figure 10. Amount of N accumulated at whole plant at anthesis and maturity (mg N stem^{-1})

Percentage of N accumulated at anthesis compared to maturity at whole plant was higher for HT; and was maximum at HT rainfed condition (Figure 11).

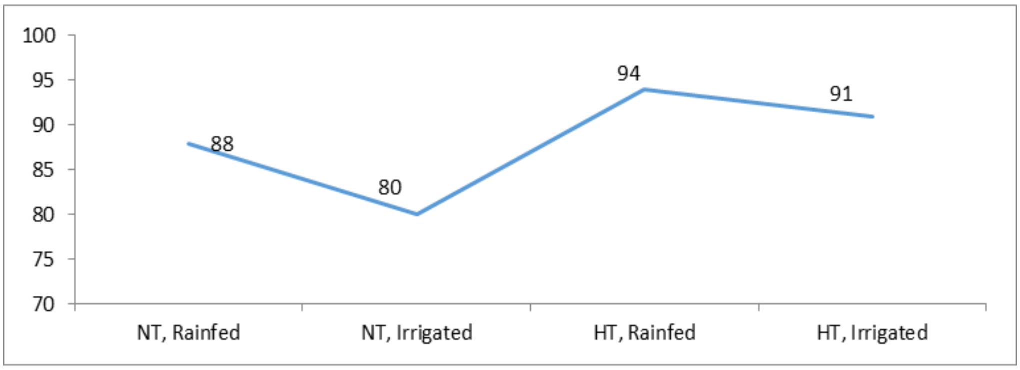

Figure 11. Percentage of N accumulated at anthesis compared to maturity for whole plant (%)

N uptake rate of spikes was higher at HT compared to NT during pre-anthesis, post-anthesis and whole vegetation duration (Figure 12).

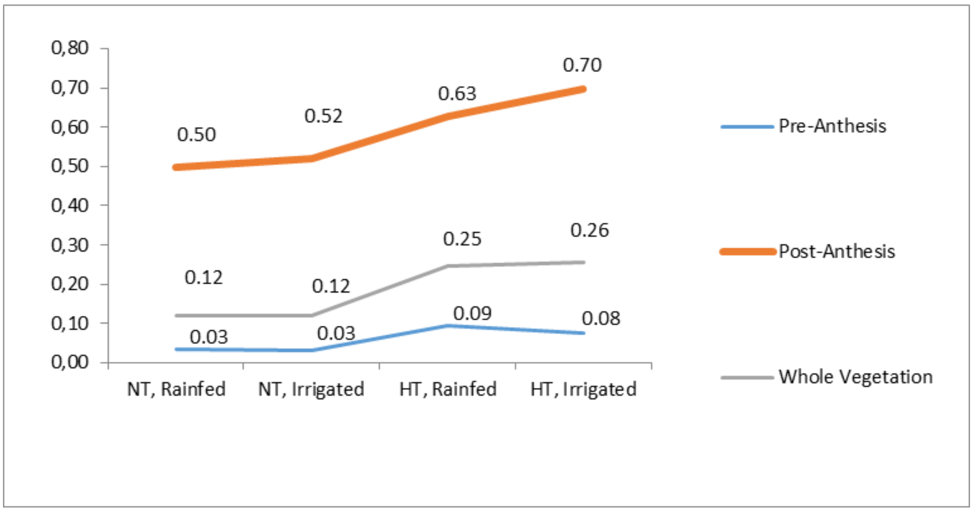

Figure 12. Average rate of N accumulation in the spike (mg day^{-1}).

N uptake rate of whole plant at pre-anthesis stage under HT is approximately 3 times higher than NT (Figure13).

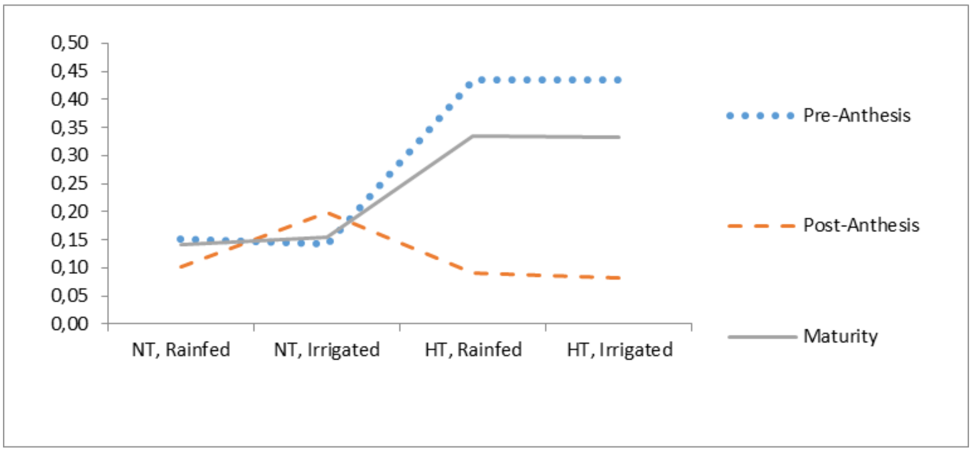

Figure 13. Average N accumulation rate for whole plant (mg day^{-1})

Irrigation had no significant effect on N uptake rate of plant under HT condition at all periods. Post-anthesis N uptake rate of whole plant was highest under NT irrigated condition.

Nitrogen harvest index reduced both by HT and irrigation (Figure 14).

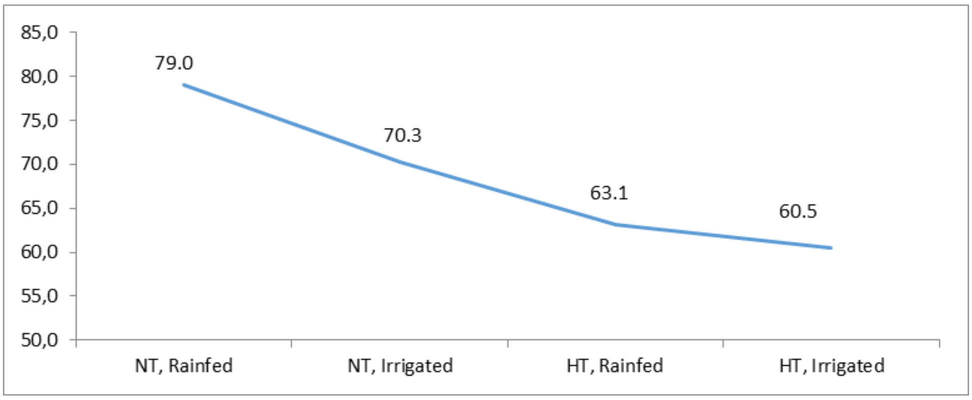

Figure 14. Nitrogen harvest index

Discussion

Our investigations showed that high temperature (late sowing) shortened all phenological periods except anthesis-maturity period but increased the amount of nitrogen accumulated in whole plant both at anthesis and maturity. Hussain et al. (2012) reported in a study carried out on wheat that the period between sowing and booting decreased with delayed sowings. Amount of nitrogen accumulated at flag leaf (at anthesis and maturity), lower leaves (at anthesis and maturity), lower stem (at anthesis and maturity), husk-own-axis (at maturity), grains (at maturity) and spike (at pre-anthesis, post-anthesis and maturity) was maximum under high temperature. Meichen et al., (2016) reported similarly that late sowing increases the nitrogen content, nitrogen accumulation and protein content in stem leaf and grain of winter wheat.

Maximum N content of plant parts was at lower leaves both at anthesis and maturity and minimum at lower stem and flag leaf at maturity. On the heat regime basis, N content at plant parts was higher at HT and lower at NT both for anthesis and maturity except lower stem at maturity. Nitrogen harvest index was reduced by high temperature regime and irrigation. Amount of nitrogen at grains was maximum at high temperature-rainfed conditions. Nitrogen accumulation rate for whole plant was 3 times faster at pre-anthesis and 2 times faster at whole vegetation stage at high temperature regime compared to normal temperature.

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