Dry Matter Contents and Dry Matter Accumulation Rates of Plant Parts of Wheat Under Normal and High Temperature Conditions

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Abstract

Adequate dry matter production of plants is a very important event for producing higher grain yields under high temperature stress. We established a field trial to measure differences in dry matter accumulation of different plant parts of wheat under normal and high temperature conditions. Two temperature regimes were provided by planting at two different times (normal wheat sowing time and quite late time to receive warmer conditions). Also two different irrigation regimes has been applied to distinguish the impact of drought from temperature.

As a result of trials, dry matter content was maximum at lower stem and minimum at flag leaf both at anthesis and maturity. When different growth conditions compared, total dry matter content was lowest at high temperature rainfed conditions except lower leaves at maturity. This value was maximum at normal temperature rainfed condition at anthesis and high temperature irrigated condition at maturity. Instead of existence of enough dry matter for producing high grain yield levels, harvest index was minimum under high temperature irrigated condition. As a result, grain yield was minimum under high temperature irrigated condition (4.65 t/ha). Grain yield was maximum at normal temperature rainfed condition (6.20 t/ha). This indicates an exsistance of a problem other than adequate dry matter production to produce more yield under high temperature conditions.

Keywords: Wheat, High temperature, Heat stress, Dry matter, Yield

Normal ve Yüksek Sıcaklık Koşullarında Buğday Bitki Kısımlarının Kuru Madde İçeriği ve Kuru Madde Birikim Oranları

Özet

Bitkilerin yeterli kuru madde üretimi, yüksek sıcaklık stresi altında yüksek tane verimi elde etmek için çok önemli bir gereksinimdir. Normal ve yüksek sıcaklık koşullarında buğdayın farklı bitki kısımlarının kuru madde birikimindeki farklılıkları ölçmek için bir tarla denemesi kurulmuştur. İki farklı zamanda ekim yapılarak iki sıcaklık rejimi sağlanmıştır (normal buğday ekim zamanı ve daha sıcak şartlar almak için oldukça geç bir zaman). Ayrıca kuraklığın sıcaklıktan etkisini ayırt etmek için iki farklı sulama rejimi uygulanmıştır.

Denemeler sonucunda, kuru madde içeriği hem çiçeklenmede hem de olgunlukta alt sapta maksimum, bayrak yapısında ise minimum olmuştur. Farklı büyüme koşullarının karşılaştırıldığında, toplam kuru madde içeriği, alt yapraklar hariç tüm bitki kısımlarında, yağışa dayalı yüksek sıcaklık koşullarında en düşük olmuştur. Toplam kuru madde içeriği maksimum değere çiçeklenme döneminde yağışa dayalı normal sıcaklık uygulamasında, olgunlukta ise sulamalı yüksek sıcaklık uygulaması ile ulaşmıştır. Yüksek tane verim düzeyleri üretmek için yeterli kuru maddenin varlığı mevcut olsa da, yüksek sıcaklıkta sulanan koşullarda hasat indeksi minimum düzeyde olmuştur. Sonuç olarak, dane verimi de yüksek sıcaklıkta sulanan koşullarda (465 kg/da) minimum olmuştur. Dane verimi yağışa dayalı normal sıcaklıkta maksimum (620 kg/da) değere ulaşmıştır. Bu durum, yüksek sıcaklık koşullarında daha fazla verim üretmek için yeterli kuru madde üretimi gereksinimi dışında bir sorunun varlığını göstermiştir.

Anahtar Kelimeler: Buğday, Yüksek sıcaklık, Isı stresi, Kuru madde, Verim

1. Introduction

High temperature and drought are two important environmental factors limiting crop growth and yield (Barnabas et al. 2008). Heat stress results in linear yield decline in many crops (Hays et al. 2007). Different parts of plant experience different temperature regimes (Monteith and Unsworth, 1990) and many important physiological and biochemical processes in wheat are impaired by heat stress (Wahid et al. 2007). High temperature affects tillering, vegetative growth, dry matter production and grain yield (Boyer and Westgate, 2004), grain weight (Barma, 2005) and grain quality (Gooding, 2003). Heat stress reduces leaf area (Warrington, 1977), the duration of vegetative growth (Saini, 1988), leaf number (Acevedo et al. 1990), leaf and ear photosynthesis (Blum et al. 1994), shoot mass, grain mass and sugar content of grains (Shah and Paulsen, 2003) and affects aging process and plant photosynthesis (Al-Khatib and Paulsen, 1984).

Under optimum temperature, photosynthesis provides up to 90% of the carbohydrates of grains while remobilization responsible for 10–30% (Arduini et al. 2006). Also around 30% of the assimilates of wheat for grain filling sources from flag leaf photosynthesis (Sylvester-Bradley et al. 1990). According to Feng et al. (2014), a significant decrease in the chlorophyll content and photosynthetic capacity of flag leaves of wheat occures during grain filling under high temperature.

The change at rate of leaf initiation effects leaf development, radiation interception and crop growth which increases under high temperature (Loomis and Connor, 1992). Kase and Catsky (1984) informs that high temperature accelerates wheat growth and increases leaf area.

Under high temperature, remobilization of pre-anthesis reserves also becomes important (Tahir and Nakata, 2005). Hot and dry conditions occurring during grain filling reduce photosynthesis rate, limiting the contribution of current assimilates to grain filling (Alvaro et al. 2008).

Heat stress shortens the length of grain filling period independent from day length and vernalisation (Midmore et al. 1982). Rane et al. (2003) indicated that the stem reserves play a significant role in determining grain yield under late sown environment. Carbohydrate storage at stems and remobilization efficiency of reserves for grain development are effective components of grain yield (Ehdaie et al. 2006) and ability of carbohydrate storage in stem is determined by stem weight and stem length (Blum, 1998). Heat stress reduces the rate of assimilate transport from vegetative organs to grains (Plaut et al. 2004). But pre-anthesis high temperature may reduce the negative effects of post-anthesis heat stress on stem reserve carbohydrates remobilization and grain starch accumulation in wheat (Wang et al. 2012). Irrigation may compensate effects of heat stress. When wheat has grown under adequate moisture, transpirational cooling may reduce leaf temperatures to as low as 8°C (Reynolds et al. 1994).

Heat injures sink growth potential, especally during early sink developmental stages (Nicolas et al. 1984). The availability of carbohydrates for floret development is an important factor determining grain number (Abbate et al. 1995) because low availability of carbohydrates may cause floret death (Kirby, 1988). At later developmental stages, stress reduces sink's assimilate absorbtion ability (Dinar and Rudich, 1985). High temperature speeds the assimilation rate and transfer of assimilates from flag leaf to spikes and shortens the grain filling duration (Sofield et al. 1977).

According to Wheeler et al. (1996) and Batts et al. (1997), wheat yield reduces under high temperature. Heat stress reduces grain weight by reduction in grain growth duration (Gebeyehou et al. 1982) and grain growth rate (Viswanathan and Khanna-Chopra, 2001). The grain-filling rate in cereals is dependent on current assimilates from photosynthesis and water-soluble carbohydrates transported to the grain from leaves, stems and ear (Yang and Zhang, 2006). The decrease in the rate of grain growth is basicly sourced from decrease in the rate of starch accumulation; protein deposition is less sensitive to temperature (Bhullar and Jenner, 1985).

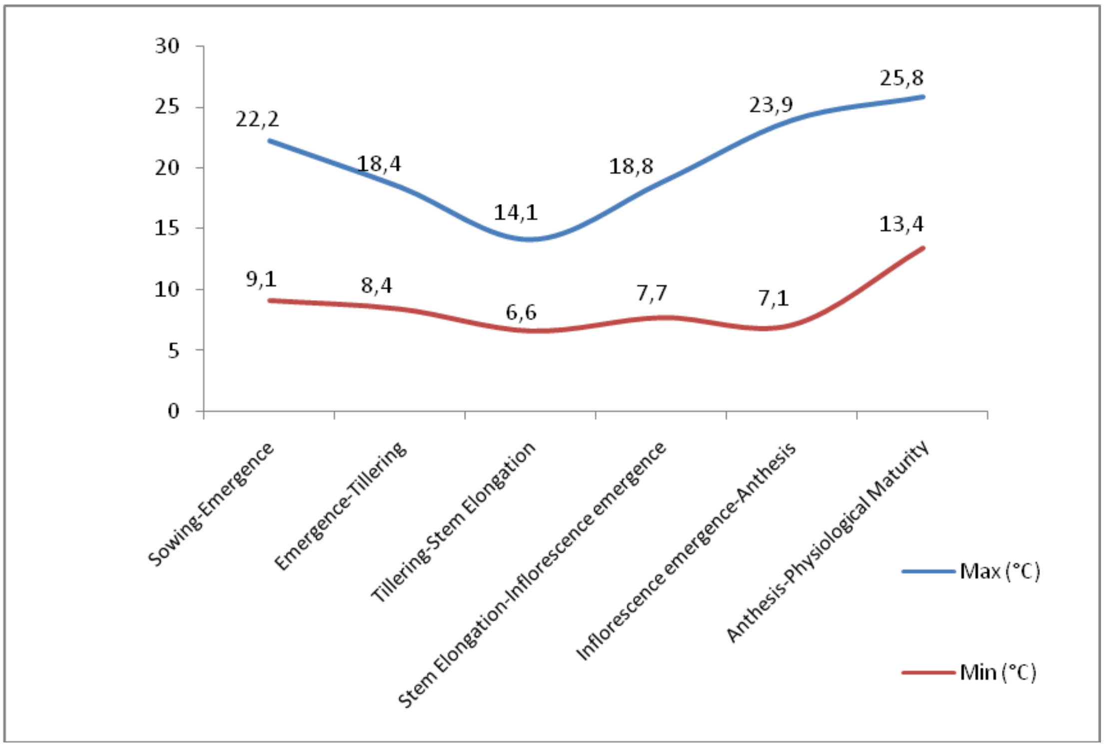
2. Materials and Methods

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. (Ozbek et al. 1974). Adana-99 bread wheat cultivar were used in the study. Trial fields were left for fallow in 2002-2003 season. Sowing was done after cultivation of soil 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.

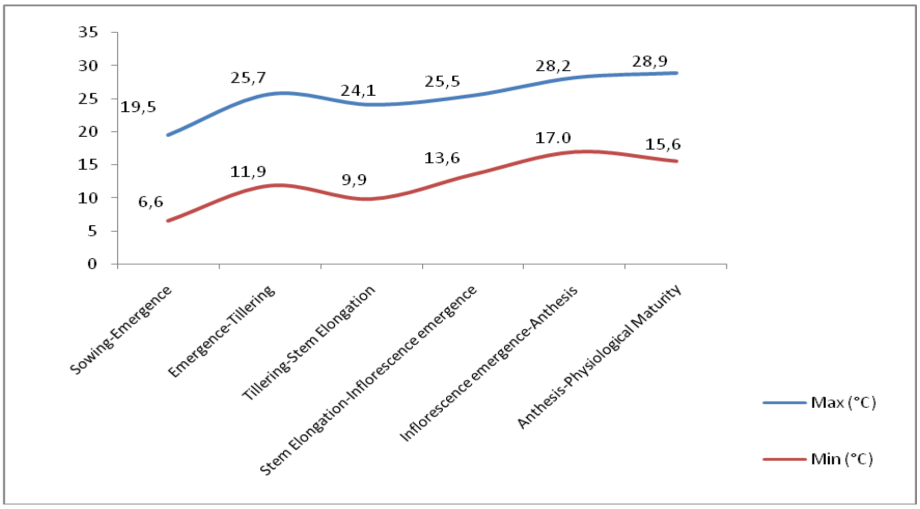
Daily average temperatures under NT regime for 2003-2004 growing season are given in Figure 1.

Figure 1. Actual Average Daily Temperatures in Different Growing Periods Under NT Regime



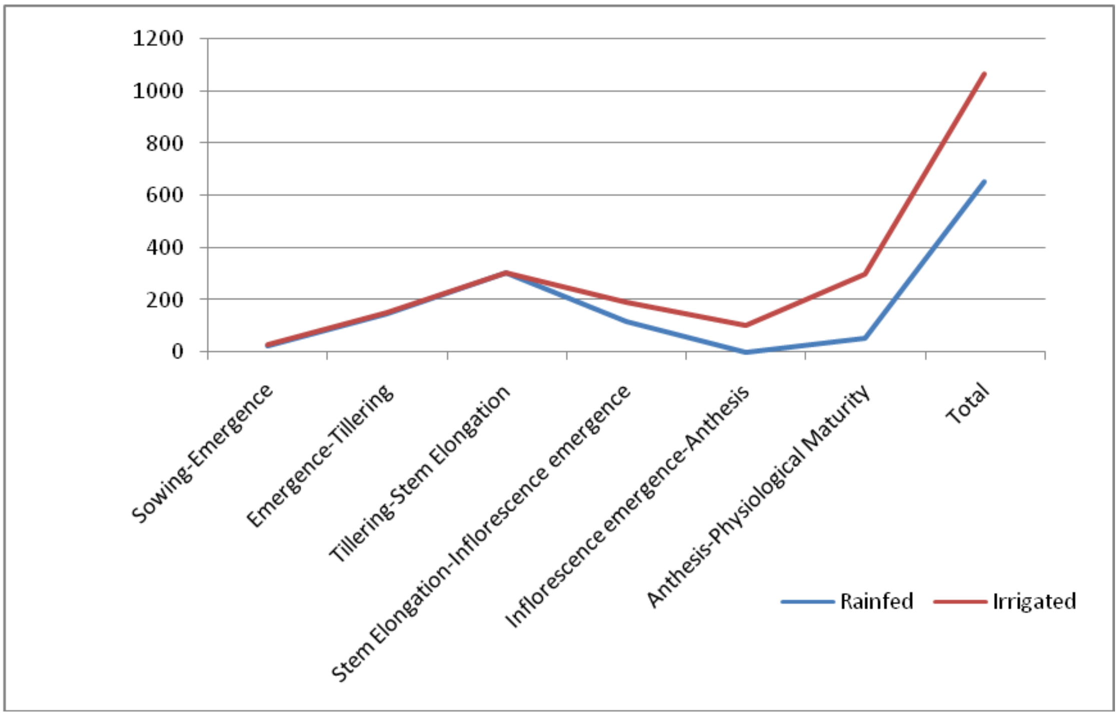
Daily average temperatures under HT regime for 2003-2004 growing season are given in Figure 2.

Figure 2. Actual Average Daily Temperatures in Different Growing Periods UnderHT Regime



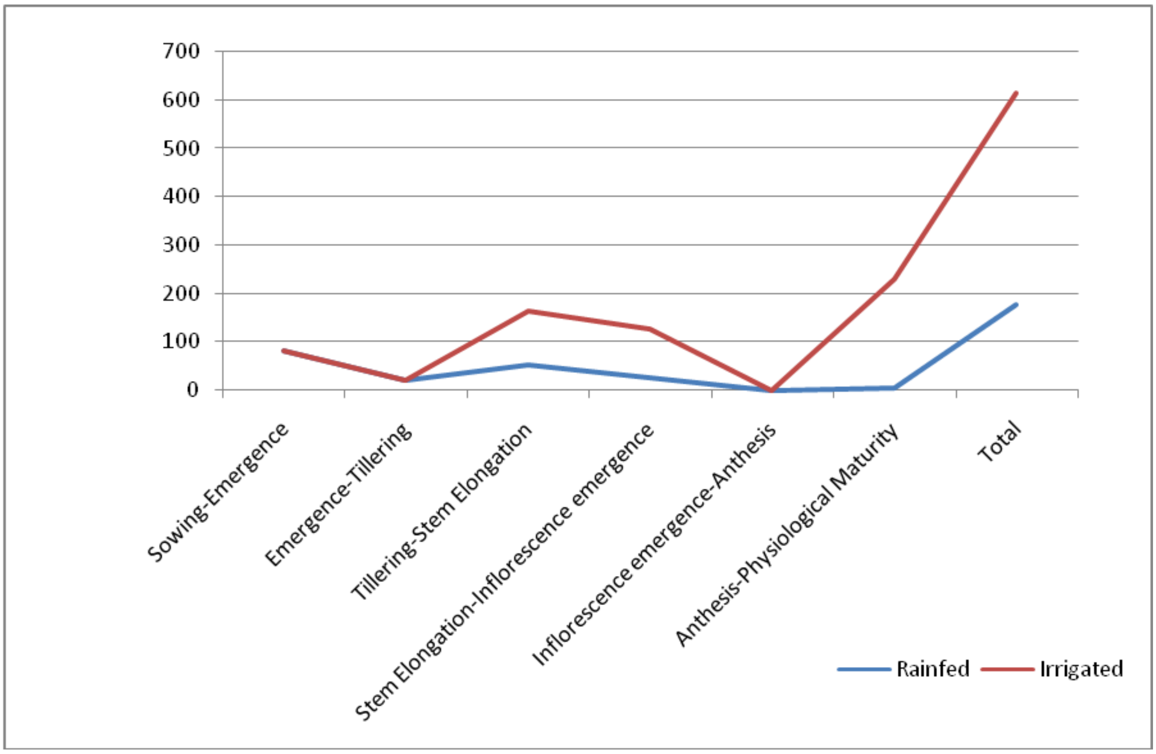
Amount of water that research area received as precipitation and irrigation in year 2003-2004 under NT regime is given in Figure 3.

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)



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.

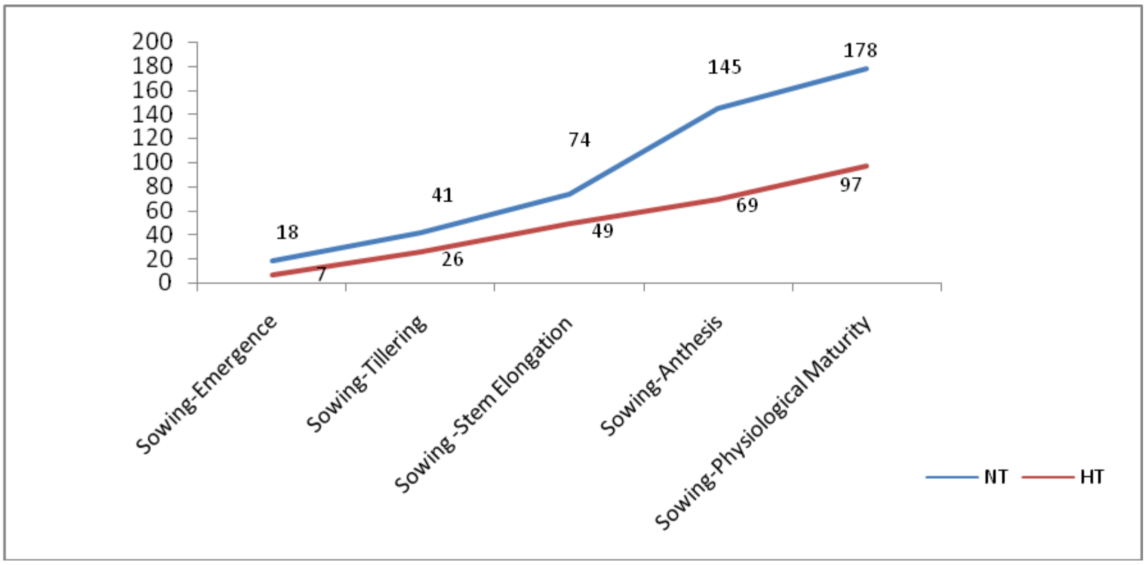
Investigations were conducted according to the method described mainly by Bell and Fischer (1994). Used Zadoks Growth Scale to follow plant phenological developments (Zadoks et al. 1974). To determine the amount of accumulated dry matter, certain lengths in the middle part of the plots were cut from the soil surface and divided into different plant sections. These procedures were 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 dry matter uptake rate was calculated by dividing the dry matter to relevant vegetation time (emergence-anthesis period or emergence-ripening period).

Heat regime was main and irrigation was sub-factor and established by the randomised block design for the variance analysis of datas. We used MSTAT-C program package for the statistical analysis. The resulting averages was analysed by LSD method.

3. Results and Discussion

HT, drastically reduced the duration of phenological periods. Phenological durations are given in Figure 5.

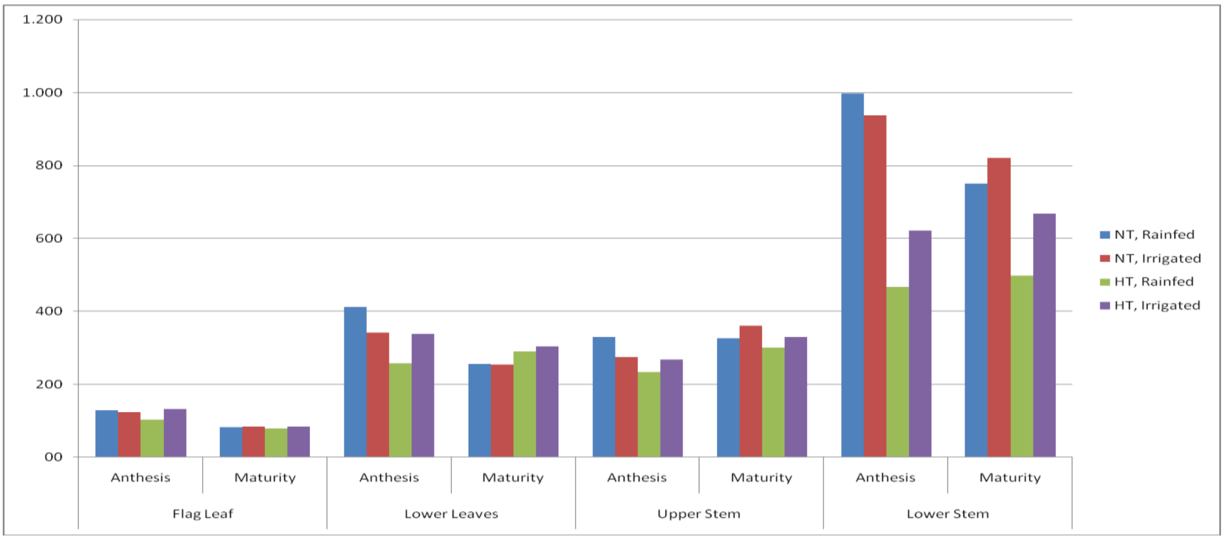
Figure 5. Phenological Durations Under Different Temperature Regimes (day)



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.

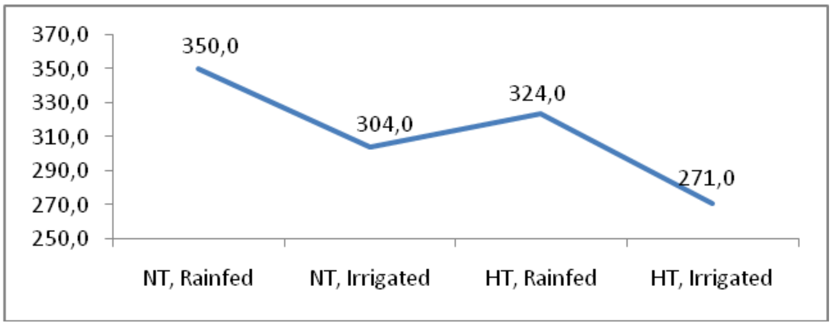
Dry matter (DM) contents (mg DM stem-1) of flag leaf, lower leaves, upper stem and lower stem at anthesis and maturity are given in Figure 6.

Figure 6. Dry Matter Accumulated (mg DM stem^{-1}) in the Flag Leaf, Lower Leaves, Upper Stem and Lower Stem at Anthesis and Maturity



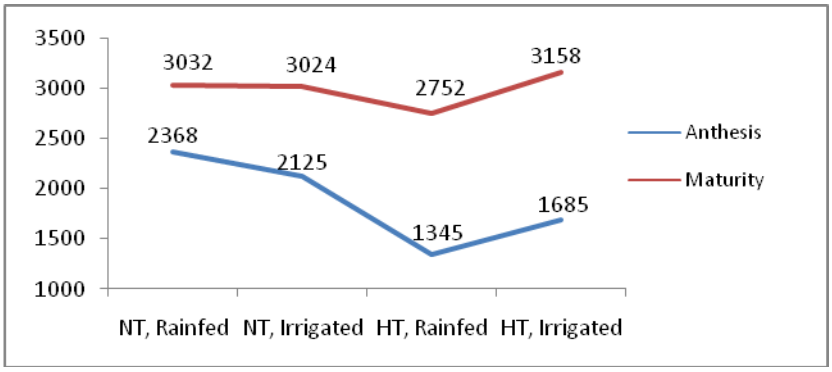
DM (dry matter) accumulation at flag leaf at anthesis was lowest under HT rainfed condition and highest at HT irrigated condition but there were no significant differences between applications at maturity. Dry matter accumulation at lower leaves at anthesis was lowest at HT rainfed condition but irrigation compensated a part of this reduction. At maturity, maximum dry matter was at HT irrigated condition. DM accumulation at upper stem at anthesis was lowest at HT rainfed condition but irrigation increased it at NT irrigated level. At harvest, maximum DM was at NT rainfed condition. DM content of lower stems was maximum at NT rainfed condition at anthesis but at maturity maximum value was at NT irrigated condition. DM accumulation at spikes at anthesis was minimum at HT irrigated condition and maximum at NT rainfed condition (Figure 7); both HT and irrigation reduced DM accumulated at spikes at anthesis.

Figure 7. DM Accumulation at Spikes at Anthesis (mg DM spike-1)



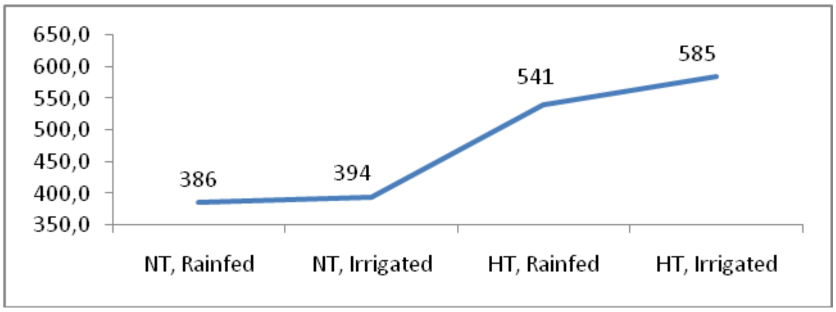
Maximum biomass production at maturity was under HT irrigated condition and minimum at HT rainfed condition (Figure 8).

Figure 8. Total Biomass Production (mg DM stem^{-1})



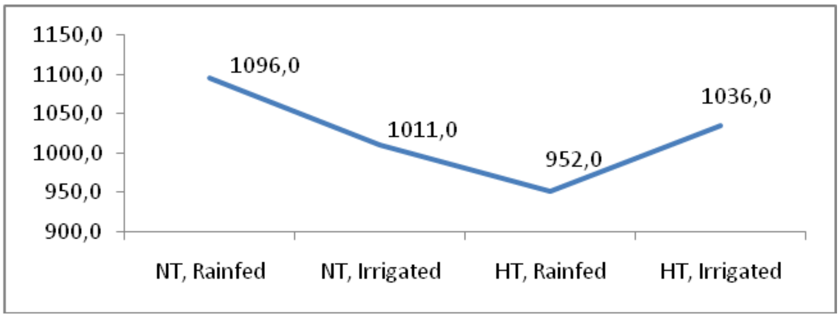
Irrigation promoted biomass production under HT both at pre-anthesis and post-anthesis stages. DM accumulation at husks-awn-axis at maturity has increased with HT and irrigation (Figure 9).

Figure 9. Dry Matter Accumulation at Husks-Awn-Axis at Maturity (mg DM spike^{-1})



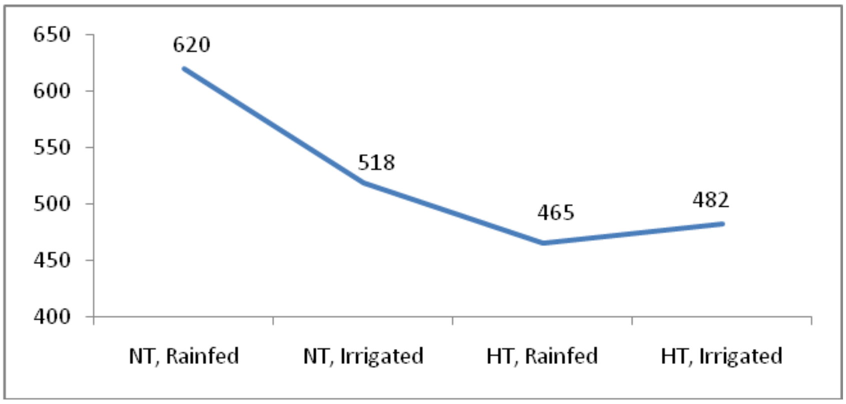
DM accumulation of grains was highest at NT rainfed and minimum at HT rainfed condition (Figure 10).

Figure 10. DM Accumulation of Grains at Harvest (mg DM spike^{-1})



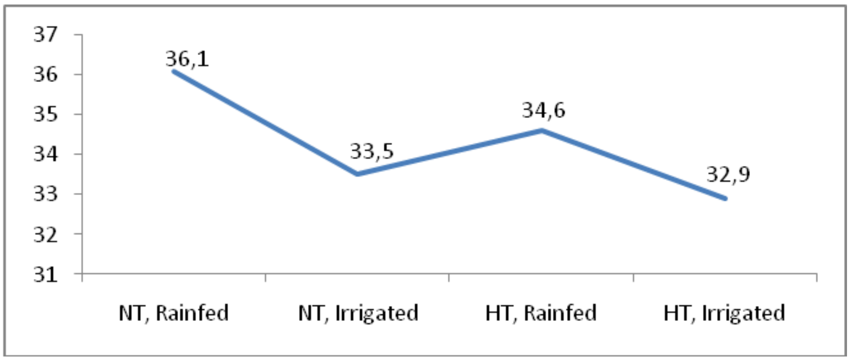
Grain yield was maximum at NT rainfed condition (6.20 t/ha) and minimum at HT rainfed condition (4.65 t/ha) (Figure 11).

Figure 11. Grain Yield (mg DM m-^{2})



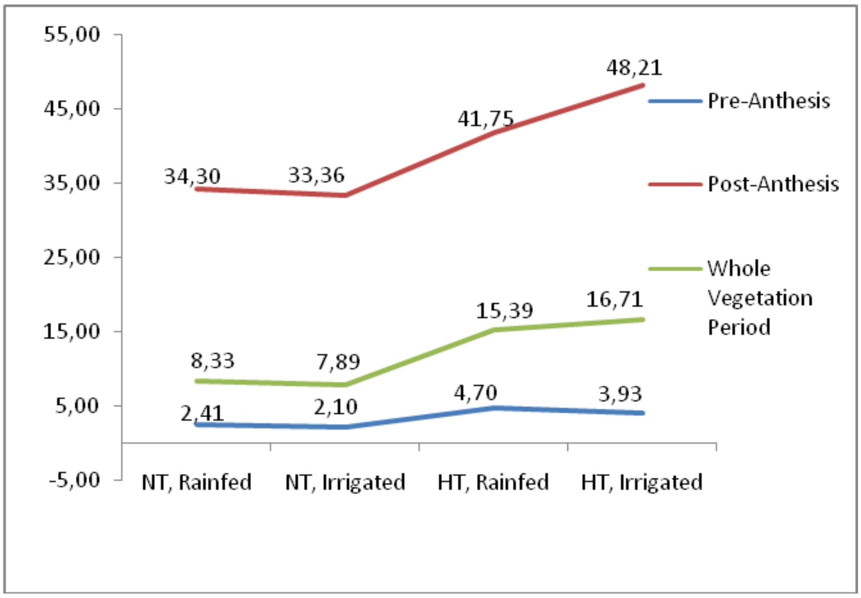
Harvest index was reduced both by HT and irrigation and was minimum at HT irrigated condition (Figure 12).

Figure 12. Harvest Index (%)



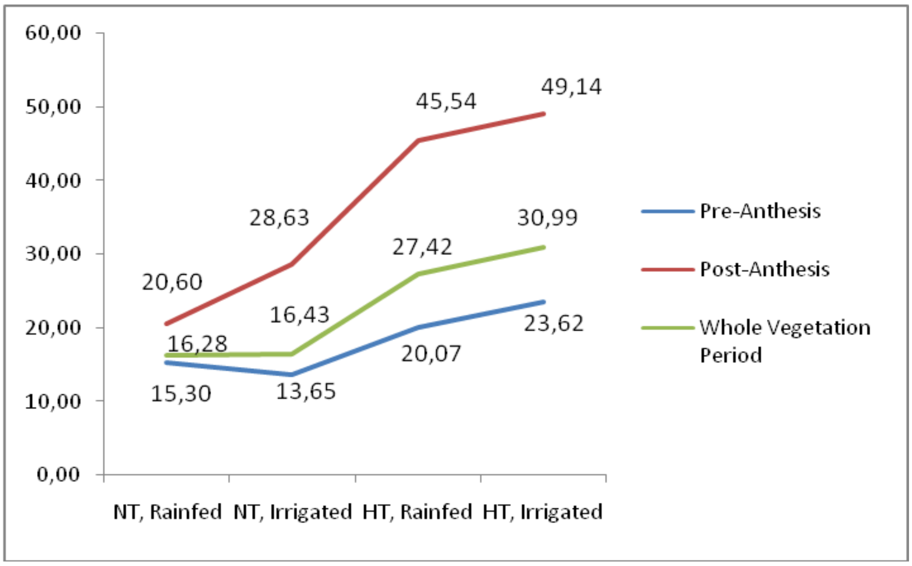
DM production rate of spikes at pre-anthesis, post anthesis and whole vegetation period was higher at HT (Figure 13).

Figure 13. DM Accumulation Rate of Spike (mg day^{-1})



DM production rate of spikes was higher at post-anthesis compared to pre-anthesis. HT increased DM production rate of whole plant; maximum was at HT irrigated conditions (Figure 14).

Figure 14. DM Accumulation Rate of Plant (mg day^{-1})



DM production rate was higher at post-anthesis compared to pre-anthesis

4. Conclusions

Maximum dry matter content was at lower stem and minimum at flag leaf both at anthesis and maturity. When we compared different growth conditions, lowest dry matter content of plant parts was at high temperature rainfed conditions except lower leaves at maturity. And irrigation increased dry matter content at all plant parts under high temperature regime. Total biomass production (at maturity), dry matter accumulation rate of spikes (pre-anthesis, post-anthesis and whole vegetation period) and dry matter accumulation rate of plant was highest under high temperature irrigated condition. But instead of exsistance of enough source for producing high grain yield, harvest index was minimum under high temperature irrigated condition and as a result grain yield was low under this condition (4.65 t/ha). Grain yield was maximum at normal temperature rainfed condition (6.20 t/ha). This indiates an exsistance of a problem other than dry matter production under high temperature condition.

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