CORN GRAIN YIELD AND PLANT CHARACTERISTICS IN TWO WATER ENVIRONMENTS

by

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Abstract

Corn (*Zea mays* L.) yields are often reduced by limited pumping capacity of irrigation wells drawing from the High Plains Aquifer. As a result of decreased well capacities in this region, many irrigation systems no longer have the ability to meet peak irrigation (water) needs during the growing season. The purpose of this study was to measure easily identifiable plant characteristics of corn hybrids and relate those characteristics with the ability to maintain yield under water-limited conditions. This study involved measuring several plant characteristics of 18 corn hybrids grown under irrigated and dryland conditions near Tribune, KS during the growing seasons of 2005, 2006, and 2007. During each year, hot and dry conditions occurred during silking which resulted in large differences, and many poor yields, in the dryland plots. The number of days and growing degree days (GDD) to initiation of silking were the variables most strongly correlated with grain yield in the dryland environment. The shorter the time it took to reach initiation of silking the greater the grain yield. The number of days, or the GDD, to initiation of silking in irrigated environments did not have a significant correlation with corn grain yield. Other characteristics including canopy temperature, PAR (photosynthetically active radiation), color, leaf angle, number of internodes, number of leaves, and leaf N had no significant correlation with corn grain yield for either dryland or irrigated environments in 2005 and 2006. In this study using hybrids with maturity ratings between 98 and 118 d, there were no significant differences in grain yield in the irrigated environment. In the dryland environment, the hybrids used (98 – 118 d) in this study resulted in a decrease in grain yield with an increase in maturity. By considering the maturity of a hybrid, a producer will potentially be able to better select a variety that will perform well in a growing season with potential or likely severe water cutbacks as a result of limited water supply or reduced well capacity.

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Introduction

Corn (*Zea mays* L.) is one of the most widely grown crops in the USA. It is grown under many conditions including in regions that typically don't receive enough precipitation to meet the evapotranspiration associated with the growth of corn. In these regions, corn production is often supplemented with irrigation. Irrigation water usually comes from rivers and streams or groundwater. With an increase in irrigation demand over time and increased demands on these water sources across the western USA to supply growing populations, water supply from surface sources may lack dependability and irrigation wells may see a reduction in water yield during the crop growing season. Depending on weather conditions of a growing season and irrigation dependability, a corn crop that was planted with expectations of enough irrigation water to supplement the crop can see an unexpected reduction in irrigation or precipitation causing the crop to suffer severe water stress. Reduction of, or insufficient, well capacity during the growing season is becoming more common on the High Plains where irrigation water is being supplied primarily from the Ogallala formation of the High Plains Aquifer. Significant water level declines in the Ogallala have reduced water yield capacity of wells and increased pumping costs.

Objective and Purpose

The objective of this study was to analyze the relationship between easily identifiable plant characteristics and the ability of corn hybrids to maintain grain yield in water-stressed environments. The purpose was to assess if easily identifiable plant characteristics can be identified with hybrids that are able to maintain yield in water-stressed conditions. If plant characteristics are identified, producers could use that knowledge in selecting hybrids that would perform well in growing seasons with potential or likely water cutbacks as a result of limited water supply or reduced well capacity.

The High Plains Aquifer

The High Plains Aquifer underlies 450,787 km^2 (McGrath and Dugan, 1993) of eight states including eastern Colorado, western Kansas, Nebraska, eastern New Mexico, western Oklahoma, southwestern South Dakota, the Texas panhandle, and southeastern Wyoming. Zwingle (1993) reported that >90% of water pumped from the High Plains aquifer is used for crop irrigation and accounts for ~30% of all groundwater used for irrigation in the USA. Irrigation water started to be pumped from the aquifer in the 1930's and 1940's (McGuire, 2006) with a substantial increase in groundwater pumping for irrigation after World War II (Moore and Rojstaczer, 2001). Since the predevelopment period before the 1950's, groundwater irrigation has played a major role in declines of water levels in the High Plains Aquifer (McGuire, 2004). The annual weighted average for water level in the High Plains Aquifer showed an increase of 0.17 m between 1993 and 1994 (Dugan and Sharpe, 1995). However, a decrease in water level is more common as seen in the annual weighted average for water level in the High Plains Aquifer between 2002 and 2003 (-0.37 m) and between 2004 and 2005 (-0.06 m) as was publicized by McGuire (2003) and McGuire (2006), respectively. The amount of change detected in water levels range from an increase of 26 m to a decrease of 84 m from the predevelopment period until 2005 (McGuire, 2006).

There were ~750,000 ha of irrigated land above the High Plains Aquifer in the 1940's (Moore and Rojstaczer, 2001), a maximum of 5.6 million ha in 1997, and a decrease to 5.1 million irrigated ha or 12% of the aquifer area in 2002 (McGuire, 2006). In 2000, ~2.6 million ha m of water were pumped for irrigation. By 2005, there had been a decrease of 31 million ha m of water since the predevelopment period, leaving ~360 million ha m of water in the aquifer (McGuire, 2006). Water loss from the aquifer can result from various influences both naturally and artificially, including evapotranspiration (ET) from soil and plants, seepage from the aquifer into springs and streams where the water table reaches the surface, human consumption, livestock watering, and irrigation of crops (McGrath and Dugan, 1993). The aquifer is recharged largely through precipitation percolating through soil with a smaller amount coming from seepage of streams and lakes mostly in the Platte River basin in Wyoming, Nebraska, and Colorado (McGrath and Dugan, 1993). There are many influences affecting the amount of water the aquifer is recharged with each year, including the amount and type of precipitation, soils, vegetation, land-uses, and underlying geology (McGrath and Dugan, 1993). Depending on amount and type of recharge and amount used for irrigation, the water level has shown an increase in parts of Nebraska to very large decreases in parts of the central and southern High Plains.

Western Kansas depends heavily on the High Plains Aquifer for irrigation and livestock watering. The aquifer underlies 78,995 km^2 of western Kansas or ~38% of the state. The water level in Kansas has declined an average of 5.9 m since predevelopment, with as much as 0.06 to 0.34 m decline from 2003 to 2005 (McGuire, 2006). The water level declines in Kansas range from ~7.6 to 30.5 m in northwestern Kansas and from ~7.6 to >45.7 m in southwestern Kansas from the predevelopment period to 2005 (McGuire, 2006).

Even with a large amount of water still available in the High Plains Aquifer, well yield and pumping costs limit the amount of water available for irrigation (McGrath and Dugan, 1993). A study by the High Plains Associates in 1982 indicated >400,000 ha of irrigated farmland will return to dryland production by 2020. These outcomes are starting to be seen as pumping costs increase and many wells are seeing reductions in the amount of water yielded.

Water Stress Characteristics of Corn

Water and heat stress can affect any crop anywhere in the world with little indication of when it is going to occur. Drought affects crop production almost as much as all other environmental factors (Boyer and Westgate, 2004). Both heat and water stress, whether occurring alone or in conjunction with each other, can affect many processes of plants from germination and growth through reproductive stages until the plant reaches physiological maturity. On the High Plains, water and heat stress is a common occurrence in dryland crop production because of warm summers, untimely rain events, or prolonged drought conditions. Irrigated production also can suffer from water-stressed conditions during periods of hot and dry weather in a field with a low water-yielding irrigation well that can't supply the amount of water needed to meet ET rates of the crop being produced. Limited water conditions affect many functions of a corn crop, especially when combined with heat.

Water potential is a direct measurement of the water status of a plant. Many plant responses to water-limited conditions can be attributed to water potential. Water potential has been shown to vary within a crop species throughout different geographical regions and growing conditions that require a degree of stress to cause a physiological response (O'Toole et al., 1984). However, low leaf water potential in corn can indicate the inhibition of photosynthesis, acceleration of leaf senescence, decrease of biomass, and reduction of the number and size of kernels (Westgate and Boyer, 1985).

Water potential changes throughout the day and at different rates depending on the amount of stress a crop is experiencing. In corn, leaf water potential will be at its maximum values around sunrise and its minimum values in early afternoon. The rate of change is also greater in plants in dry soil when compared with plants in wet soil (Turner, 1975). Plants in dry soil will show a decrease in leaf water potential during the day at twice the rate of plants in wet soil. The greater decrease in leaf water potential in the water-stressed plants shows that once the plants become stressed, the daily change in water potential is magnified causing the effects of stress to increase on the plant systems.

Many plant water stress measurements are compared with water potential because of its direct relationship to the status of water in the plant. They don't always show a linear relationship with water potential but can be used as a non-direct, nondestructive method when little plant material is available or when speed is needed for large populations (Turner, 1981).

Under water-stressed conditions stomatal closure is a well understood response. Stomatal closure occurs when water potential is reduced causing transpiration to decrease resulting in higher leaf temperatures. A high amount of stomatal conductance increases transpirational cooling when compared with plants with low stomatal conductance. Corn had the lowest stomatal conductance at midday when compared with sunflower (*Helianthus annus* L.) and sorghum (*Sorghum bicolor* L. Moench) near Manhattan, KS (Kirkham et al., 1984). This is partially the result of stomates closing at higher water potentials, even though a higher percentage of total leaf water is lost at high water potentials allowing for cooling of the leaves (Sullivan and Eastin, 1974). Sullivan and Eastin (1974) also mentioned that corn is more heat tolerant than sorghum, thus it can withstand the higher leaf temperatures caused by early stomatal closure. Turner (1975) demonstrated that stomata closed in corn when water potential reached a value of -1.5 MPa. This lower stomatal conductance and higher leaf temperature of corn resulted in less water lost from its leaves than sunflower (Kirkham et al., 1984). In order to conserve water, corn stomata are quicker to respond by closing at higher water potentials when compared with sorghum. However, corn lost more water than sorghum when stomates were open at higher water potentials (Sullivan and Eastin, 1974). Ackerson (1983) found that under water stress during reproductive stages, stomatal closure was complete when zero turgor was observed. Turner (1975) found that even with stomatal closure, further stress on a plant was not prevented but stomatal closure did reduce any further decrease in leaf water potential.

There are major direct effects on photosynthesis as a result of water stress. During normal corn growth, photosynthesis levels reach the highest rates during vegetative growth stages and decrease during tassel emergence and grain filling periods due to leaf age (Ackerson, 1983). Photosynthesis rates have been shown to be reduced by water stress (Dwyer et al., 1992; Westgate and Boyer, 1985). Sullivan and Eastin (1974) stated that a decrease in photosynthesis with an increase in water stress is a result of increased stomatal resistance. When photosynthesis is inhibited substantially by low water potential, dry matter accumulation vastly decreases (Boyer and Westgate, 2004).

The reduction of photosynthesis also causes a decline in sucrose and starch levels within corn (Ackerson, 1983). A decrease in chlorophyll content plays a part in the reduction of photosynthesis in water-stressed conditions. O'Neill et al. (2006) found that chlorophyll content was reduced by 5% and photosystem II was reduced by 30% when water-stressed corn was compared with non-stressed corn during the reproductive stage. They found that stomatal closure also negatively impacted photosynthesis. Photosynthesis was shown to be completely inhibited when water potential reached -1.6 MPa to -1.8 MPa in a study by Westgate and Boyer (1985). As photosynthesis decreases, the sucrose level also decreases (Ackerson, 1983) and more reserves are used to make up for photosynthetic losses. The mobilization of reserve photosynthates occurs at different rates at different stages of a corn plant. During pollination and shortly after, the mobilization of reserves is very low because of the rapid increase of stem and leaf dry weight before anthesis, depleting the reserves needed for reproduction (Westgate and Boyer, 1985). However, in later grain filling stages, Westgate and Boyer (1985) determined that there was a much higher mobilization of reserve photosynthates from the vegetative parts of the plant to the grain. Photosynthesis has an important role in the final yield of corn, so any kind of water stress that inhibits photosynthesis can ultimately decrease grain yield.

Water and heat stress of corn can occur at any growth stage with different responses occurring at reproductive stages compared with vegetative stages. Gardner et al. (1981a) observed that stress during vegetative stages had less effect on yield when compared with stress during pollination and grain filling stages. The reproductive stages of corn are often greatly affected by water stress resulting in lower yield (Sinclair et al., 1990). Salter and Goode (1967), in a review on maize from early 20th century studies, found that the largest response to irrigation is during early reproductive stages through early grain formation. Sani and Westgate (2000) stated that pollination, fertilization, and grain initiation are the most sensitive times for water stress. Boyer and Westgate (2004) confirmed that early in reproductive stages, kernel number is reduced because of water stress, whereas later in reproductive stages kernel size is reduced.

The reduction in kernel number as a result of water stress during early reproductive stages reduces final grain yield. During this time period, plants with low water potential (Ψ_w) are unable to translocate plant reserves (C and N) to the ear for reproduction, causing a reduction in kernel development (Schussler and Westgate, 1994). It is often thought that sterile pollen was the result of water stress, however, Schoper et al. (1987) found that pollen was more sensitive to heat stress usually associated with water stress rather than from water stress alone. Poor timing between pollination and silk emergence is one cause of poor kernel set. Herrero and Johnson (1981) found that mild to severe drought stress delayed silk emergence by 3 to 4 d. Rapid expansion of silks is required for successful pollination and seed set. Water stress has been shown to inhibit ear and silk growth more than tassel growth (Sani and Westgate, 2000). The small amount of reserves that are moved to the ear shoot during anthesis at low water potentials can reduce the ability of silk to gain enough turgor to emerge (Westgate and Boyer, 1985). In contrast, if silks emerge before pollination, they will loose receptivity to pollen as they age at quicker rates in water-stressed conditions (Boyer and Westgate, 2004).

With a reduction in kernel numbers due to poor synchronization of pollen and silking, female florets also cause kernel abortion in low moisture conditions. Kernel numbers were significantly decreased from a 6 d pollination gap (Cárcova and Otegui, 2001). Boyer and Westgate (2004) stated that pollen remained viable down to a water potential of -15 MPa but female florets became inhibited to kernel formation below -1.2 MPa. At low water potential before pollination, the kernel was aborted by the ovary even if high water potential became present later at pollination (Boyer and Westgate, 2004). Sani and Westgate (2000) stated that even with normal tassel emergence, silk emergence, and fertilization, a newly formed zygote rarely survived more than 2 to 3 d of water stress and the effects were irreversible.

During grain filling stages, yield can still be inhibited by the reduction of kernel size. This can be done by the limited rate and duration of reserve deposition caused by water stress and the heat usually associated with it (Sani and Westgate, 2000). Heat stress on the ear had different effects on kernel number depending where the stress was located. Cárcova and Otegui (2001) found that heating the tip of the ear did not affect kernel number but lateral heating did, while non-heated areas showed kernel formation. Heat stress will also increase the rate of kernel growth causing it to reach physiological maturity early which will reduce the amount of assimilate supply to the kernel because of leaf senescence (Sani and Westgate, 2000).

In studies by Westgate and Boyer (1985) and Sinclair et al. (1990), they found that drought stress causes early senescence and a reduction of biomass which is highly correlated to yield and resulted in a lower yield. Westgate and Boyer (1985) also noticed that the most viable leaves were lost and that water potentials remained constant due to the addition of small amounts of water until complete senescence. After the leaves senesced, the ear shoot and stem remained viable to transport reserves for grain fill, however fresh weight of aboveground biomass continued to decrease.

Physiological and Morphological Measurements

One of the most common ways to monitor water stress in corn is the use of physiological measurements. Canopy temperature, biomass, leaf color, and photosynthetically active radiation interception are some of the common physiological measurements studied. Water stress also has effects on morphological traits including leaf area index, leaf angle, length of internodes and number of internodes.

With the effects of water stress, there are a few characteristics that allow corn to avoid or tolerate stress. One of the main ways for a crop to avoid stress is through maturity length of the hybrid and ultimately its time to flowering. Sinclair and Muchow (2001) have looked at the effects of grain growth rate and duration. Long grain growth duration can cause a depletion of soil water leading to severe water stress. By increasing the grain growth rate and decreasing the duration, a plant might escape water deficits. However, their study also showed a decrease in yield because the plant could not accumulate enough mass. Bolaños et al. (1993) showed that a decrease in the anthesis-silking interval improved efficiency in selection of cultivars for yield. They also showed that a reduction in days to flower will help avoid water stress at critical reproductive stages. Differences in growing length can help a crop avoid stress, but if trying to avoid stress through shorter season corn, the overall yield can be affected by not accumulating enough biomass for a larger yield.

Canopy temperature has been a well-studied measurement of water stress in corn. Canopy temperature in corn, measured with infrared thermometers, is usually warmer on water-stressed plants when compared with non water-stressed plants (Gardner et al., 1981b). Canopy temperature increases as a result of stomatal conductance decreasing, resulting in a reduced amount of transpirational cooling (Kirkham et al., 1985) and lower leaf water potential (Sharratt et al., 1983). Temperature differences between water-stressed and non water-stressed plants do not usually appear until midday when transpiration is the highest (Gardner et al., 1981b).

With the use of infrared thermometers, canopy temperature shows the temperature over a large area, and can reduce the spatial, logistical, and temporal problems inherent with more direct measurements of leaf water potential and photosynthesis rates (O’Toole et al., 1984). Canopy temperature provides a quick non-destructive method for measuring water stress in corn.

Biomass accumulation is important for grain yield and can be attributed to canopy architecture. The interaction between leaf area and leaf angle contributes to how a plant intercepts light for photosynthesis. Light interception is important in mid and short season corn growing regions where leaf area index is less than required for maximum light interception (Stewart et al., 2003). Leaf area is an indicator of the amount of potential sun light intercepted and has been shown to have an influence on plant growth and grain yield (Sinclair, 1984; Dwyer and Stewart, 1986). Leaf angle determines the plants ability to intercept radiation from the sun and how much radiation will by pass the leaves and reach the soil surface. More upright leaf angles do not tend to close the canopy during the middle of the day when radiation is coming from directly overhead (Stewart et al., 2003). However, Tollenaar and Wu (1999) has shown that upright leaf angles allow more uniform distribution in solar radiation throughout the canopy (top to bottom) while Winter and Ohlrogge (1973) demonstrated that higher yields can be achieved with upright leaves at higher plant populations with a large leaf area index (LAI). Flatter, more horizontal leaves will tend to close the canopy sooner but can cause quicker senescence of lower leaves as solar radiation is limited in the lower canopy (Modarres et al., 1997; Maddonni et al., 2001). Through leaf orientation and size, a crop can achieve a higher rate of photosynthesis for grain filling and potentially store more photosynthates for water-stressed periods.

Canopy architecture and development has been monitored by determining how much photosynthetically active radiation (PAR) is intercepted by the canopy in the middle of the day. The concept uses an area meter that consists of PAR sensors imbedded in a meter-long probe to determine the percentage of light interception that is below the canopy when compared with the total amount of solar radiation (Westgate et al., 1997). Quicker canopy closure after emergence can increase the amount of photosynthates accumulated for grain yield when the hybrid is not prone to barrenness. Thus the plant can efficiently convert PAR into phytomass with hybrids adapted to the northern Corn Belt (Westgate et al., 1997).

Greater total leaf number often increases total leaf area which has an influence on grain yield by how much light interception is utilized. However, as a plant matures, total leaf number can be a cause of senescence in lower leaves by shading them after the canopy is closed (Modarres et al., 1997; Maddonni et al., 2001). A corn hybrid that reduces senescence and maintains green leaf area with “stay green” traits can accumulate more dry matter (Tollenaar and Wu, 1999), especially through water-stressed periods. Borrell et al. (2000) reported that sorghum hybrids that maintained green leaf area in water-stressed conditions resulted in a higher grain yield then hybrids with a high degree of senescence.

The amount of leaf N influences the amount of chlorophyll in leaves which influences leaf color. Water stress causes a decrease in N content, chlorophyll content, and in spectral reflectance as observed by Osborne et al. (2002). Dwyer et al. (1991a) found a strong relationship between chlorophyll readings with a SPAD 501 (Minolta Corp., Ramsey, NJ) meter and extractable chlorophyll in corn, which could be used to measure leaf color. The color of the leaf is directly related to chlorophyll concentration in the leaf, allowing a chlorophyll meter to be used for measuring the greenness of a leaf.

Materials and Methods

This field study was conducted on the Southwest Research Extension Center-Tribune Unit near Tribune, KS during the 2005, 2006, and 2007 cropping seasons. Plant characteristics of corn were measured in both irrigated and dryland fields. Research plots in the irrigated environments were on a Ulysses silt loam (fine-silty, mixed, superactive, mesic Aridic Haplustolls) soil following winter wheat in 2005 and following soybean in 2006 and 2007. The plot areas were conventionally tilled and irrigation was applied through a linear sprinkler system to meet evapotranspiration loss minus precipitation. The dryland environment was on a Richfield silt loam (fine, smectitic, mesic Aridic Argiustolls) soil in a no-till, wheat-corn-fallow cropping system. This environment was completely dependent on stored soil water and in-season precipitation.

Corn hybrids were selected for this study based on their being commercially-available and recommended for producer use in the region. Hybrids were not selected based on any plant growth or developmental characteristics. This study utilized a total of 19 corn hybrids from Pioneer Hi-Bred International, Inc. (Johnston, IA), Croplan Genetics (St. Paul, MN), and Triumph Seed Co., Inc. (Ralls, TX). The hybrids used from each company are listed in Table 1, along with treatment number used in this study for each hybrid as well as the advertised maturity range. The hybrids from Pioneer were 31N26, 33P66, 34A15, 35Y65, 37H24, 31G66, 33H25, 33B50, 34B97, 35P12, and 38H67. The Croplan Genetics hybrids were 496RR/BT, 579LL/HX, 610RR2, 691RR2, and TR1047RR2/BT. Croplan Genetics 496RR/BT was used for the 2005 and 2006 seasons and was replaced by 579LL/HX in the 2007 season because of a shortage of seed. The hybrids from Triumph were 1416, 5433, and 5461.

Research plots were set up in a randomized complete block design (Fig. 1 and Fig. 2) with four blocks. This resulted in 72 plots in the irrigated field and 72 plots in the dryland field for each growing season. Each plot was 3.05 m (four 0.76 m rows) wide and 15.24 m long in Dryland 2005 and 2006 and Irrigated 2005, and 12.19 m long in Dryland 2007 and Irrigated 2006 and 2007. Corn was planted on 5 May 2005, 10 May 2005, 9 May 2006, 2 May 2006, 14 May 2007, and 11 May 2007 for the Dryland 2005, Irrigated 2005, Dryland 2006, Irrigated 2006, Dryland 2007, and Irrigated 2007, respectively. The target planting population for the dryland site was 39,536 seeds ha^{-1} and for the irrigated site was 74,132 seeds ha^{-1}.

Plant characteristics were measured all three yr in both environments. The plant measurements taken in 2005 and 2006 consisted of plant emergence to silking interval, canopy temperature, percentage of canopy cover, leaf P, leaf N, leaf color, green leaf number, total leaf number, ear leaf angle, ear leaf area, number of internodes, length of internodes, plant height, plant population, tiller population, dryland biomass, and 100-kernel weight. For the 2007 growing season, only the plant emergence to silking interval, plant population, tiller population, ear population, dryland biomass, and 100-kernel weight were taken to confirm the results of these measurements from the previous two seasons.

Weather and Irrigation

Weather data were collected from a weather station located at the Southwest Research Extension Center in Tribune, KS near the dryland field site. Minimum air temperature, maximum air temperature, and precipitation data were gathered at the weather station. Precipitation data were also gathered at the irrigated site from April through October.

Soil water content was monitored throughout the growing season for each field study. Volumetric soil water content was taken at the beginning and the end of the growing season. For the 2005 and 2006 seasons, soil water content was also taken within a day of when canopy temperature was taken. For the 2007 season, soil water content was taken once a month. Aluminum access tubes were installed in treatments 1 and 11 representing the longest and shortest maturity hybrids studied, respectively. The eight plots the access tubes were installed in were 102, 104, 202, 210, 304, 317, 405, and 418 in both the irrigated and dryland environments for all three seasons. The measurements were taken with a neutron probe (CPN International, Inc., Concord, CA) through the aluminum access tubes at 0.30 m intervals from soil depths of 0.15 through 2.29 m. The counts data were placed in the following equations, with the probe calibrated for each environment:

Dryland

$$\text{Vol WC} = [[(\text{Tube reading}/\text{Std Count}) * 1.742109] + 0.4008]/12 \qquad \text{Eq [1]}$$

Irrigated

$$\text{Vol WC} = [[(\text{Tube reading}/\text{Std Count}) * 2.380347] - 0.071607]/12 \qquad \text{Eq [2]}$$

where Vol WC is the volumetric water content in m^3 of H_2O m^{-3} of soil. Std Count is the standard count taken to stabilize the probe's accuracy and the Tube reading is data from the neutron probe at each 0.30 m increment of soil depth.

Harvest and Grain Yield

For all three seasons, grain yield was taken by hand-harvesting ears from 6 m of each of the two center rows of each plot. Harvest was soon after all plots reached physiological maturity (black layer). Harvest dates were 24 Sept. 2005 for dryland, 1 and 2 Oct. 2005 for irrigated, 23 Sept. and 14 Oct. 2006 for dryland, 29 Sept. 2006 for irrigated, 22 Sept. 2007 for dryland, and 13 Oct. 2007 for irrigated. The 2006 dryland was harvested on two different dates because of large differences in dates of hybrids reaching black layer. Hybrids 5 and 11 were harvested at an earlier date because of reaching physiological maturity early and signs of lodging. The remaining hybrids were harvested at the later date because of high moisture content and not reaching physiological maturity by the first date.

A total of 12 m of rows was harvested with some of the outside rows in the dryland field being harvested if the stand was poor in the center rows. Ears were dried in a forced air oven at 60˚C for 1 wk. Ears were hand shelled and a small sample was dried at 60˚C to determine water content of the grain. Grain yield was then adjusted to 0.155 kg of water per kg of moist grain.

Mass of 100 kernels was determined by hand counting 300 seeds and drying them at 60˚C for a minimum of 2 d. Dry mass was then divided by three to get the 100 kernel mass. The 100 kernel mass was then adjusted to 0.155 kg of water per kg of moist grain and reported. Biomass was taken on dryland plots just before harvest to collect production information in the dryland environment. Biomass samples were collected by randomly harvesting five complete plants from each plot. The biomass samples were then dried for 2 wk in a forced air oven at 60˚C and that dry mass was reported as the biomass yield in kg ha^{-1}. Ear populations were taken at harvest for all plots and reported as the number of ears per ha. Only ears with grain were counted in the ear population.

Silking

Dates of silking were taken all 3 yr. Number of days to initiation of silking and number of growing degree days (GDD) to initiation of silking were taken from the time of plant emergence to the date of silking initiation. Plant emergence dates were 11 May 2005 (dryland), 16 May 2005 (irrigated), 3 June 2006 (dryland), 8 May 2006 (irrigated), 20 May 2007 (dryland), and 17 May 2007 (irrigated). Plant emergence date for 2006 dryland was considerably later in the season because of extremely dry and hot conditions early in the season.

During the 2005 and 2006 growing seasons, the goal was to record the number of days from plant emergence to 50% silking. Because some hybrids never reached 50% silking in the dryland plots, the method was adjusted for the 2007 growing season. The first sign of silk emergence within plots (excluding plants near alleys) was recorded as the date of silking initiation for the 2007 growing season. For the 2005 and 2006 growing seasons, date of 50% silking was determined by taking a visual estimate of the percentage of silks emerged on each day as well as counting the number of silks visible on 10 plants at least once a week. Observations were made on plants in the two center rows in the middle of plots. Because some hybrids in the dryland environment of 2005 and 2006 did not reach 50% silking, silking data were examined to determine the initial silking date. The determination of silking initiation was made by looking at silking notes recorded for all four plots for a specific hybrid in each field. If only one plot was 50% silked on a day, initiation of silking was recorded for that day; if two plots were 50% silked on a day, 1 d was subtracted from that date for initiation of silking; and if three or four plots reached 50% silked on a day, 2 d were subtracted from the date for initiation of silking. During the 2007 growing season, the first sign of silk emergence was written down as the initiation of silking date for each plot. For each hybrid, the first plot that showed silk initiation, excluding plants by the alley, determined the date of initiation of silking.

The number of thermal units using the GDD 10 (Dwyer et al., 1991b; Gilmore and Rogers, 1958) method accumulated from emergence date until the initiation of silking date was determined for each hybrid. This method uses the following equation:

$$GDD = \sum[(T_{max} + T_{min})/2] - 10 \qquad \text{Eq [3]}$$

where T_{max} is maximum air temperature in °C, never exceeding 30°C, and T_{min} is minimum air temperature in °C, never less than 10°C. The base unit for GDD 10 is 10°C. This method has been widely used and had the least coefficient of variance when compared with other methods for calculating thermal units (Gilmore and Rogers, 1958). The number of cumulative GDD was calculated for each hybrid and then compared against yield for each treatment.

Canopy Temperature

Canopy temperature was taken three or four times throughout the 2005 and 2006 growing seasons. Only canopy temperature taken on 27 July 2005, 28 July 2005, and 20 July 2006 for Dryland 2005, Irrigated 2005, and Irrigated 2006, respectively, were used in the analysis with grain yield. A handheld infrared thermometer (Everest Interscience, Inc., Tucson, AZ) was used to measure temperature of sunlit leaves. Canopy temperature measurements were only taken within 2 h of solar noon on sunny days with no cloud cover. If cloud cover was observed, measurements were suspended until 15 min after a cloud passed to assure the canopy was transpiring at maximum rate. Measurements were taken at a 20° angle from horizontal, at a 20° angle to the row (Bolaños et al., 1993), from 1 m above the crop canopy surface (O'Toole et al., 1984). Canopy temperature was measured on the two center rows, one row at a time, getting the temperature from one row then turning to get the second row. This was done at both ends of a plot for a total of four measurements per plot. The field of view of the infrared thermometer is 4° and care was taken to view just the leaves, with no tassels or soil in the background. The infrared thermometer was calibrated with a calibration plate (Everest Interscience, Inc., Tucson, AZ) heated and cooled to get the range of temperatures that were observed in the field. The calibration was then used to correct the final data. Air temperature was taken with a shaded mercury thermometer above the canopy to get the actual temperature without the influence of solar radiation. Canopy temperature differential (Δ_T) was then calculated by subtracting ambient temperature from canopy temperature to be used in final analysis.

Vapor pressure deficit (VPD) was calculated in millibars in the same way as by Kirkham (2005) with the wet and dry bulb temperatures taken from a sling psychrometer (Kirkham et al., 1984) 1 m above the canopy (Idso et al., 1981; Idso and Reginato, 1982; O'Toole et al., 1984). The equation used is:

$$\mathrm{VPD} = (e^\circ - e) \qquad \text{Eq [4]}$$

where e° is saturated vapor pressure at the dry-bulb temperature (DB) which comes from information in the "Saturation Vapor Pressure Over Water" table in the Smithsonian Meteorological Tables (List, 1951) and where:

$$e = e^\circ_w - \gamma\,(\mathrm{DB} - \mathrm{WB}) \qquad \text{Eq [5]}$$

where e°_w is saturated vapor pressure at the wet-bulb temperature (WB) looked up on the "Saturation Vapor Pressure Over Water" table, and γ is the psychrometer constant equal to 0.66.

Wet and dry bulb temperatures were taken before and after canopy temperature was taken in each block.

Canopy Closure

Photosynthetically active radiation (PAR) was taken each week early in the 2005 and 2006 growing seasons to monitor the canopy closure that was necessary before canopy temperature was taken. PAR was taken with an AccuPAR LP-80 (Decagon Devices Inc., Pullman, WA) at a 45° angle (Wilhelm et al., 2000) between the two center corn rows. The PAR was only taken on non-cloudy days within 2 h of solar noon (Stewart et al., 2003) reducing the affect of the sun azimuth angle on the reading. However, Wilhelm et al. (2000), studying different leaf area index meters, found that the AccuPAR can accurately be used in a wide array of sky conditions. A standard radiation measurement was taken in an alley to provide a base to compare with in-plot measurements. Each plot was measured twice, once at each end of the plot between the two middle rows. The measurements were then averaged and monitored with the goal to get 80% of the incoming radiation absorbed, as was done by Bolaños et al. (1993) to reduce the chances of background being viewed when taking canopy temperature. Table 2 shows the percentage of canopy closure for 2005 and 2006 before canopy temperature was taken. The maximum canopy closure was determined from the final date PAR was taken each growing season. Dryland 2005 reached maximum PAR interception on 12 July 2005, Irrigated 2005 was on 13 July 2005, Dryland 2006 was on 27 July 2006, and Irrigated 2006 was on 13 July 2006. Not all treatments reached 80% interception in the dryland environment but came close and extra caution was taken measuring canopy temperature in those plots.

PAR interception was also used in a regression analysis with grain yield using measurements taken on 5 July 2005, 6 July 2005, 14 July 2006, and 27 June 2006 for Dryland 2005, Irrigated 2005, Dryland 2006, and Irrigated 2006, respectively. These dates were chosen to determine if the PAR interception differences seen between treatments (hybrids) early in the season had any relationship to final grain yield.

Leaf Color

A SPAD 502 meter (Minolta Corp., Ramsey, NJ) was used to determine chlorophyll differences in each of the hybrids during the 2005 and 2006 growing seasons. Measurements were taken on the leaf immediately below the ear leaf (Cerrato and Blackmer, 1991) halfway between the midrib and leaf margin and halfway between the stalk and leaf tip (Osborne et al., 2002). The chlorophyll contents in SPAD units were then interpreted as differences in color. The SPAD measurements were measured on six random plants per plot on sunny days with a high level of irradiance (Hoel and Solhaug, 1998). The measurements were taken after silking and before leaf senescence started to occur.

Leaf Angle

Leaf angle was measured on six random plants after plant growth slowed and after silking during the 2005 and 2006 growing seasons. Leaf angle was taken on the ear leaf and was measured using a protractor in a similar method to Maddonni et al. (2001) by taking the angle of the leaf in relation to the stalk.

Leaf Size

Leaf area measurements were taken on the ear leaf (Modarres et al., 1997) of six plants. Length was measured from the ligule to the tip (Modarres et al., 1997) while the width was measured at the widest spot on the leaf (Winter and Ohlrogge, 1973). Leaf area was determined by using the following formula from Maddonni et al. (2001):

Ear leaf area = length*width*0.75 Eq [6]

The measurements were taken after silking to ensure that the plants reached the maximum leaf size. Leaf area measurements were taken on 28 July 2005 for the 2005 dryland and irrigated environments and on 26 July 2006 for the 2006 irrigated environment. No ear leaf area measurements were taken on the 2006 dryland environment because of poor leaf conditions.

Number and Length of Internodes

Number and length of internodes was measured once maximum height was reached after the plants tasseled for the 2005 and 2006 growing seasons. This measurement was made on six random plants. For 2005, the total number of leaves was then used to determine the number of internodes, subtracting five leaves as those internodes are usually condensed (Ritchie et al., 1997) and minus the one leaf above the highest internode. The number of internodes was divided into the plant height to get the average length of the internodes. This method proved unreliable so the total plant height from the ground to the uppermost node was substituted for internode length for further analysis with grain yield. For more precise measurements in 2006, the distance from the first visible node to the highest visible node was measured and divided by the number of internodes counted in between.

Green Leaf Number and Total Leaf Number

Number of green leaves was measured throughout the growing season for all 3 yr and total leaf number was recorded after all of the leaves were fully expanded for the 2005 and 2006 growing seasons. Total leaf number was taken according to the growth stages of corn as defined by “How a Corn Plant Develops” (Ritchie et al., 1997). The number of green leaves takes into account any green leaf that has not senesced. A leaf was considered senesced when greater than 50% of the leaf had chlorosis (Dwyer and Stewart, 1986). Both measurements were done on six plants per plot. The average number of green leaves was determined by averaging every time green leaf number was taken throughout the growing season for each treatment. These data were used to compare against grain yield. One plot (treatment No. 1) in the 2006 dryland study did not have a total leaf number because it never tasseled and produced its maximum number of leaves. This plot was not used in the average of total leaf number for this treatment.

Leaf Nitrogen and Leaf Phosphorus

The leaf immediately below the ear leaf (Cerrato and Blackmer, 1991) was collected after silking and was tested for nitrogen (N) and phosphorus (P) content for the 2005 and 2006 irrigated plots and the 2005 dryland plots. Six whole leaves were clipped from each plot. The samples were dried at 60˚C for 1 wk and were then mechanically ground. The samples were analyzed by the Kansas State University Soil Testing Laboratory, Manhattan, KS. The samples were analyzed by digesting the plant material in sulfuric acid/hydrogen peroxide digest or a salicylic-sulfuric digest and analyzed concurrently using a Technicon AAII auto analyzer and a colormetric Industrial Method 334-74W/B using separate channels for N and P, respectively.

Plant Population

Plant population and the number of tillers were determined at the time of grain harvest for all three seasons. The number of plants and tillers within the 12 m of row harvested were counted and that number was calculated to result in the number of plants ha^{-1} and number of tillers ha^{-1}.

Soils

Characteristics for the soils within the study were determined by soil sampling in 0.30 m depth increments from the surface to the 2.44 m depth at six locations for each field site of all 3 yr (Fig. 1 and Fig. 2). Soil samples for the 2005 field sites were taken on 7 Nov. 2005, while the 2006 and 2007 field sites were sampled on 30 May 2007. Each 0.30 m soil sample was tested for bulk density, nutrient content, particle size distribution, and wilting point (-1.5 MPa) water content. The samples were taken with a hydraulic probe with a 6.60 cm diam. soil tube. The samples were then trimmed to yield 0.20 or 0.25 m undisturbed sections from each 0.30 m increment to determine bulk density (B_d). The soils were dried at 105°C for 48 h and weighed. Bulk density was determined by dividing the dry soil mass by the total volume of soil using the following equation:

$$B_d = M_d / V \qquad \text{Eq [7]}$$

where M_d is mass of the dry soil and V is total volume of the soil. Soil from within the 0.30 m increment that was not included in bulk density sample was then collected and analyzed for nutrients at the Kansas State University Soil Testing Lab. Samples from the top 0.30 m sample were analyzed for pH, Bray-1 P, Mehlich P, Olsen P, K, NH_4-N, NO_3-N, organic matter, and cation exchange capacity. The lower seven depths were analyzed for NH_4-N and NO_3-N.

Particle size analysis was determined for all soil depths and locations. Soil was ground using a mortar and pestle and passed through a 2 mm square sieve. Water content of the soil was determined to adjust sand, silt, and clay contents to the dry soil mass basis when reporting particle size analysis results. 50 g soil samples were mixed with 125 mL of Na hexametaphosphate dispersing solution and 125 mL of distilled water to soak overnight. The soil solution was then mechanically mixed for 5 min and transferred to a sedimentation cylinder filled to 1000 mL with distilled water. The sample settled for 8 h in a 22°C room, and a hydrometer was used to measure the clay content in suspension. The sample was washed through a No. 270 sieve (53 μm) to separate out the sand. The sand was dried in a 105°C oven for 48 h. Sample mass minus the mass of clay and sand was the calculated silt mass. Each soil sample was analyzed three times and the mean was calculated and reported.

Wilting point water content of each soil sample was determined using cellulose acetate membranes in a pressure plate system. Soil was added to the plates and 1.5 MPa (15 bar) of pressure was applied. The plates ran until no water ran out for a minimum of 12 h. The soil was weighed immediately out of the chamber and then dried at 105°C for 48 h and weighed again. The -1.5 MPa water content (WC) by mass was determined on a dry mass basis using the following equation:

$$WC = (M_W - M_D)/M_D \qquad \text{Eq [8]}$$

where M_W is wet mass of soil, and M_D is dry mass of soil. Each soil sample was analyzed three times and the mean was calculated and reported.

Fertilizer was applied as urea ammonium nitrate (UAN) before planting and a starter was dripped beside the row at planting for all locations. UAN was applied at 269, 135, and 269 kg N ha^{-1} on 17 Mar. 2005, 28 Feb. 2006, and 3 Apr. 2007, respectively, for the irrigated site. UAN was applied on 28 Mar. 2005, 14 Feb. 2006, and 2 May 2007 at 112 kg ha^{-1} on the dryland sites. A starter fertilizer applied at planting consisted of 5-17-0 at 75 L ha^{-1} for the 2005 and 2006 irrigated sites. A starter fertilizer of 10-34-0 was dripped beside the row at planting on the 2005 dryland (84 L ha^{-1}), 2006 dryland (75 L ha^{-1}), 2007 dryland (79 L ha^{-1}), and 2007 irrigated (69 L ha^{-1}).

Weeds were controlled as needed before and throughout the growing season. Herbicides used for the 2005 growing season were Harness Xtra, Balance Pro, Atrazine, Touchdown IQ, and AMS. Herbicides for the 2006 growing season were Lumax, Ultra Max II, and AMS. Herbicides Lumax, Ultra Max II, Atrazine 4L, and AMS were used for the 2007 growing season. Each year, herbicides were used at recommended rates to control the weeds present in the field.

Statistics

An ANOVA was ran using PROC GLM of SAS (SAS Inst., 2007) for each of the plant characteristics measured to determine if there were significant differences due to treatment in each year and environment. An LSD test was performed by PROC GLM to separate the treatment means statistically at the 0.05 significance level within each year and environment. PROC GLM failed to produce LSD tables when missing data points were present. The missing data points were caused by dry conditions in the dryland environment. In order to do the LSD test for treatments when data points were missing, PROC MIXED was used on these measurements and LSD results were obtained with the use of the PDMIX800 macro (Saxton, 1998) to create mean separations at the 0.05 significance level. Plant characteristic data were associated with grain yield in a regression analysis by using PROC GLM of SAS. Linear and quadratic models were used in analyzing the results. Yield was the dependent (y-axis) variable and each plant characteristic measured was the independent (x-axis) variable. Sample size, mean, standard deviation, max, min, standard error, and coefficient of variation for grain yield and soil measurements were determined using PROC MEANS.

Results

The amount of soil water throughout each season and environment as measured by the neutron probe is shown graphically in Fig. 3. We conducted two-treatment (varieties 1 and 11), four-block ANOVAs for each soil depth, water environment, and measurement date to determine if water content values for the two varieties were significantly different at the 0.05 probability level. In the dryland environment, there were 32, 24, and 40 ANOVA tests for years 2005, 2006, and 2007, respectively. Of these 96 ANOVAs, only seven interspersed comparisons showed a significant difference between the two varieties. Similarly, in the irrigated environment there were 32, 48, and 40 ANOVA tests for years 2005, 2006, and 2007, respectively. Of these 120 ANOVA tests, 14 interspersed comparisons showed a significant difference between treatments. Because the purpose of water content data was to show the relative water status of the three seasons and two water environments, and because of the few instances of a significant difference between treatments 1 and 11, soil water data for the two treatments (varieties) were combined and mean values across the two treatments are reported in Fig. 3. In the dryland environment, the amount of water in the root zone showed a decrease during the season as the plants used stored water, where the lower measurements stayed relatively constant each year. In the irrigated environment, the soil water content remained relatively steady during the season with the 2006 and 2007 seasons showing a greater decrease in water content at the medium depths when compared to the 2005 season. Soil neutron probe data are presented in Table 3, Table 4, Table 5, Table 6, Table 7, and Table 8 for Dryland 2005, Dryland 2006, Dryland 2007, Irrigated 2005, Irrigated 2006, and Irrigated 2007, respectively.

The soil characteristics for each of the three growing seasons describing the soil environment are presented in tables. Soil bulk density is presented in Table 9 and Table 10 for the dryland and irrigated field sites, respectively. Results for the top 0.30 m soil nutrient samples are presented in Table 11 for the dryland field and Table 12 for the irrigated field. Data for the NH_4-N and NO_3-N results from the 0.61 through the 2.44 m depth of the dryland and irrigated fields are presented in Table 13 and Table 14, respectively. Soil particle size analysis is presented in Table 15, Table 16, Table 17, Table 18, Table 19, and Table 20 for Dryland 2005, Dryland 2006, Dryland 2007, Irrigated 2005, Irrigated 2006, and Irrigated 2007, respectively. Data representing the wilting point water contents for the dryland and irrigated fields are in Table 21 and Table 22.

Weather for the 3 yr was warm and dry. Weather data are shown in Table 23 for air temperature and Table 24 for precipitation. Mean daily air temperature was above the 30-yr average for all months during the growing seasons except September 2006, April 2007, and June 2007. The above average air temperatures ranged from 0.05°C above average in August 2005 to 3.32°C above average in April 2006. The maximum air temperature for each year was 42.0°C, 42.0°C, and 39.8°C during July 2005, July 2006, and July and August 2007, respectively. Precipitation varied from 66.0 mm below the monthly average for the dryland field in July 2007 to 65.3 mm above the monthly average for the irrigated field in April 2007. Precipitation was above the 30-yr average for both 2005 irrigated and dryland field sites, and the 2007 irrigated field site during the growing season. However, precipitation was below average during the growing season for both irrigated and dryland field sites in 2006, and the dryland field site in 2007.

An ANOVA was used to determine if each of the individual plant characteristics was significantly different due to treatment (hybrid). The mean values of the plant characteristic for treatments (X variable) were used in a regression analysis against grain yield (Y variable) for each of the growing environments and years. The measurements were compared with a linear model:

$$Y = (\text{slope})X + (\text{y intercept}) \qquad \text{Eq [9]}$$

where Y is the dependent variable (grain yield) and X is the independent variable (GDD to initiation of silking, number of days to initiation of silking, Δ_T, percentage of canopy cover, leaf P, leaf N, leaf color, green leaf number, total leaf number, ear leaf angle, ear leaf area, number of internodes, length of internodes, plant height, plant population, tiller population, dryland biomass, and 100-kernel weight). Each of the plant characteristics measured was also evaluated in a quadratic regression model with grain yield where each plant characteristic (X and X^2 variables) were related to grain yield (Y variable). The quadratic term was not significant ($p > 0.05$) in any of the regression models related to corn yield except where just the quadratic term and model were significant in the Dryland 2005 ear population and just the quadratic term was significant in the Irrigated 2006 leaf angle. The Irrigated 2005 leaf color, Irrigated 2006 days to the initiation of silking, and Irrigated 2006 GDD to the initiation of silking showed a significant ($p < 0.05$) quadratic relationship with grain yield. However, because of the poor relationships and inconsistencies of significance each year with grain yield, none of the quadratic regression results are presented.

The ANOVA of grain yields as influenced by treatment (hybrids) and blocks showed significant differences in grain yield due to treatment for both fields all 3 yr (Table 25). In the dryland field study, grain yields ranged from a minimum of 25 kg ha^{-1} in 2007 to a maximum of 5774 kg ha^{-1} in 2005. The ANOVA for grain yield as influenced by treatment in dryland showed a statistical probability (P>F) of <0.0001, <0.0001, and 0.0273 for 2005, 2006, and 2007, respectively. The LSD showed fewer statistical differences in grain yield among treatments in the irrigated study, particularly in the Irrigated 2005 and 2006 studies, when compared with dryland studies. Irrigated grain yields ranged from a minimum of 9665 kg ha^{-1} in 2005 to a maximum of 16810 kg ha^{-1} in 2007. The ANOVA showed that all three irrigated years had a statistical probability (P>F) with treatment (hybrids) of <0.0001.

The only measured plant characteristic that when compared with grain yield in a linear regression analysis consistently showed a significant relationship for all three growing seasons was the maturity of the hybrid, measured as the time to initiation of silking. And this was found only for the dryland field studies. The data and linear models for the dryland and irrigated environments are given in Table 26 and Table 27, respectively. The tables show statistical differences among treatments in GDD or number of days to initiation of silking as represented by the LSD lettering within each of the growing environments.

For the dryland study, the number of days until initiation of silking as well as the number of GDD to initiation of silking showed a significant relationship to grain yield all 3 yr with a linear model ($p < 0.05$). The analysis showed that fewer number of days or GDD to initiation of silking was associated with greater grain yield, as indicated by the negative slope. The number of days to the initiation of silking in the dryland study had r^2 value of 0.488 ($p = 0.0013$), 0.315 ($p = 0.0154$), and 0.284 ($p = 0.0226$) for 2005, 2006, and 2007, respectively (Fig. 4). When dryland grain yield was tested against the number of GDD to the initiation of silking using a linear model, similar results were concluded with the r^2 for 2005 at 0.483 ($p = 0.0014$), for 2006 at 0.316 ($p = 0.0154$), and for 2007 at 0.285 ($p = 0.0226$). The models showed that less time to initiation of silking was related with significantly higher grain yield.

The irrigated study for all 3 yr showed no significant association between the number of days, or the number of GDD to initiation of silking, and grain yield with a linear equation (Fig. 5) or in 2005 and 2007, with a quadratic equation (data not shown). The linear equations had large probability values ($p > 0.05$) and low r^2 values, showing the maturity of the hybrids of this study had little association with grain yield in the irrigated environment.

Grain yield was significantly influenced by ear population in the dryland environment. From a linear regression analysis, ear population and grain yield had a significant and direct relationship in the dryland environment. A greater number of ears ha^{-1} resulted in higher grain yield. Ear population vs. grain yield from linear regression analysis is shown in Fig. 6, and resulted in an r^2 for 2005 of 0.931 ($p < 0.0001$), for 2006 of 0.917 ($p < 0.0001$), and for 2007 of 0.937 ($p < 0.0001$). The intercept for the 2006 equation was not significantly different from zero ($p < 0.05$). Along with the strong relationship between ear population and grain yield, ear population also showed a significant relationship with plant maturity. GDD to initiation of silking, and number of days to initiation of silking, were tested in linear regression analysis with ear population for the dryland studies, and the data are shown graphically in Fig. 7. Results from the linear regression analysis showed a significant linear relationship of GDD to initiation of silking and ear population with an r^2 of 0.449 ($p = 0.0023$), 0.303 ($p = 0.0179$), and 0.255 ($p = 0.0327$) for 2005, 2006, and 2007, respectively. Fewer GDD to initiation of silking were associated with greater ear population. Days to initiation of silking when related with ear population resulted in a significant relationship from linear regression. Results show an r^2 for 2005 of 0.454 ($p = 0.0022$), 2006 of 0.302 ($p = 0.0181$), and 2007 of 0.258 ($p = 0.0315$).

The different plant characteristics measured each year and in each environment showed statistically significant differences among treatments (hybrids). Dryland 2005 data (Table 28) showed statistical differences for all characteristics measured except CT (Δ_T), percentage of canopy cover, plant population, and biomass. The ANOVA revealed significant differences in all Dryland 2006 characteristics measured except canopy cover, green leaf number, and biomass (Table 29). In the Dryland 2007 environment (Table 30), all characteristics measured showed statistical differences except 100-kernel weight and biomass. Tables 28, 29, and 30 also show the means separation results from the LSD analysis. All measurements in the irrigated study showed significant differences by treatments (hybrids) from the ANOVA except for canopy temperature in 2005 and 2006 and tiller population in 2005, 2006, and 2007. Data are presented with LSD means separation results in Table 31 for Irrigated 2005, Table 32 for Irrigated 2006, and Table 33 for Irrigated 2007.

Results of CT (Δ_T), percentage of canopy cover, leaf P, leaf N, leaf color, green leaf number, total leaf number, ear leaf angle, ear leaf area, number of internodes, length of internodes, plant height, plant population, tiller population, dryland biomass, and 100-kernel weight associated with grain yield in linear regression analysis are summarized in Tables 34 and 35 for the dryland and irrigated studies, respectively. These tables also contain the results for GDD to initiation of silking, days to initiation of silking, and ear population results that were given earlier for all of the study environments. The rest of the plant characteristics measured in 2005 and 2006 in both the dryland and irrigated study showed no significant linear relationship with grain yield ($p < 0.05$) except the 2005 and 2006 dryland tiller population, the 2006 dryland ear leaf angle, the 2005 irrigated ear population, and the 2006 irrigated percentage of canopy cover.

Tiller population was associated with grain yield in the 2005 and 2006 dryland studies with an r^2 of 0.249 ($p = 0.0349$) and 0.280 ($p = 0.0240$), respectively. The 2006 dryland ear leaf angle with an r^2 of 0.225 ($p = 0.0469$) was significantly associated with grain yield. The ear population measured in the 2005 irrigated study was associated with grain yield with an r^2 of 0.234 ($p = 0.0418$). The 2006 irrigated percentage of canopy cover taken on 27 June 2006 was significantly associated with grain yield with an r^2 of 0.260 ($p = 0.0369$). These plant characteristics were associated with grain yield, however, a clear pattern was not present and the data were not consistent for the characteristics measured across years and environments.

Grain yield results from the two environments were used to create a ratio of irrigated yield divided by dryland yield to determine if there was any significant relationship between the plant characteristics and grain yield ratios. The grain yield ratio was compared with irrigated plant characteristics since measurements taken with no water stress might express true differences among hybrids. The number of GDD to initiation of silking was significantly related with grain yield ratio at the $p < 0.05$ level for two of the three seasons. Because the results were inconsistent over the three seasons and presented no clear pattern these data were not included. Regression results with the other plant characteristics associated with grain yield ratios showed no significant association and the regression results were not included in this thesis.

Discussion

Air temperature and precipitation are shown in Fig. 8 for each of the three growing seasons. Temperature and precipitation were taken at the weather station located at the dryland site from 1 May through 14 Oct. Air temperature for all 3 yr was above the 30-yr average for all but 3 mo. The precipitation for all 3 yr varied from well below average to above average. Dry conditions along with warm temperatures occurred during anthesis, causing extreme water stress in the dryland field studies all 3 yr. These conditions often caused poor silk emergence in the longer season corn hybrids, resulting in a reduction in grain yield in the dryland environment. Silking usually occurred in late July and early August where, for the three growing seasons studied, precipitation was well below the 30 yr average for July in all 3 yr and in August 2006. In August 2005 and 2007, precipitation was above the 30 yr average, but occurred late in the month after anthesis and too late to save grain yield potential.

Hybrid maturity, measured as the initiation of silking, was the only plant characteristic in the dryland environment significantly associated with grain yield under the water-stressed conditions of 2005, 2006, and 2007 and is illustrated in Fig. 4. Results showed that fewer days or fewer growing-degree units from plant emergence to initiation of silking were significantly associated with higher grain yield under the water-stressed dryland conditions. Shorter-season hybrids completed the reproductive growth stages, specifically silking, earlier in the season before the hot and dry conditions had as great a negative impact on these hybrids. Longer-season hybrids had very poor silk emergence or once the silks did emerge, pollen had already been shed leaving barren ears.

Herrero and Johnson (1981) showed that increased stress during anthesis causes a delay in silking until after pollen shed is initiated. They found that water stress during that period caused a larger negative effect on silks than on pollen shed. As ear leaf water potential decreases from water stress, it causes silk elongation to decrease in the morning and often cease before starting to elongate again in late afternoon or evening (Herrero and Johnson, 1981). Different hybrids respond differently to environmental conditions, for example, inhibiting growth during flowering (Borrás et al., 2007). Gardner et al. (1981a) found that water stress during the early vegetative stages caused less decrease in grain yield than water stress during the pollinating and grain filling stages.

The longer-season hybrids in the dryland environment expended the soil water available in producing vegetative growth, limiting the ability to silk and pollinate. The result was fewer ears and reduced grain yield when compared with the shorter-season hybrids. A study in the Sudan savannas by Kamara et al. (2009), found that shorter season hybrids (80 d) potentially grew quicker and flowered sooner before water stress had a negative impact on final grain yield when compared with longer season hybrids (120 d). A study by Sinclair et al. (1990) did show that drought stress will cause a decrease in biomass, which in turn will cause a decrease in grain yield. They also discovered that only severe stress will cause a reduction in harvest index (grain yield divided by biomass). Biomass samples taken before harvest in my study did not show any significant relationship with grain yield. Biomass was not significantly different due to treatment (hybrid) within any of the three dryland seasons, showing that final biomass yields of each hybrid studied were not affected differently in water-stressed conditions. Harvest index was not calculated in my study, but no reduction of biomass was associated with a lower grain yield.

The irrigated study had no visible water stress during the three growing seasons. The Irrigated 2005 plots were injured by hail on 19 Aug. 2005, after silking and anthesis. There was a high degree of visible leaf damage, but no estimation of leaf loss was made. Average grain yield was less for the Irrigated 2005 environment compared with the Irrigated 2006 and 2007 environments, possibly because of the hail damage. Average grain yield for all plots was 2908 kg ha^{-1} less in 2005 than the 2006 average grain yield and 2963 kg ha^{-1} less than the 2007 average grain yield. The ANOVA showed that irrigated grain yield in 2005 was significantly different due to treatment (hybrid) and the LSD showed some significant differences in grain yield among hybrids, but many of the hybrids were not significantly different (Table 25). The hail only seemed to affect the total potential yield of treatments (hybrid) in 2005 and not the differences or lack of differences between the treatments.

In the irrigated environment, there was no significant relationship between the number of days and the number of GDD from plant emergence to silking and grain yield (Fig. 5). The hybrids used ranged in maturity rankings from 98 to 118 d as advertised by the respective seed companies. Observed data showed a range of 58 to 71 d (612 to 804 GDD) from plant emergence to flowering in the irrigated environment. The shorter-season hybrids yielded relatively as well as the longer-season hybrids. This is in contrast to many studies where longer-season hybrids usually resulted in a higher grain yield (Capristo et al., 2007; Edwards et al., 2005; Dwyer et al., 1991b).

Capristo et al. (2007) studied corn hybrids ranging from 115 to 157 d from emergence to maturity grown in conditions without nutrient or water-stress in Argentina. They found that these hybrids ranged from 537 to 781 GDD from emergence to flowering and the shorter-season hybrids yielded less than the intermediate and longer-season hybrids. However, there was no increase in grain yields with longer-season hybrids over the intermediate hybrids. In a study by Edwards et al. (2005), found that short-season (73 d) and full-season (114 d) hybrids with observed thermal time from emergence to silking ranging from 457 to 703°C d had statistically similar yield potentials, but the short-season hybrids required over twice as many plants per hectare to reach the same yield as the full-season hybrid. Grain yield was highly correlated with number of GDD to 50% silking (556 to 720 GDD), with increasing GDD significantly related with increasing grain yield using hybrids ranging from <75 to 95 d in a study in eastern Canada by Dwyer et al. (1991b).

White and McRae (1989) conducted a study comparing grain yields of corn hybrids with differing maturities from 1981-1987 in the Maritimes of Canada and determined that earlier (<2300 corn heat units) hybrids were being developed that did not sacrifice yield potential. This genetic improvement in yield potential of shorter-season hybrids could be a factor in the minimal difference between yields in the irrigated environments of my study. The earlier maturing hybrids in the non water-stressed conditions were still able to produce as well as the longer maturity hybrids during these 3 yr of study in western Kansas. Also, in my study the maturity within the 18 hybrids ranged only from 98 to 118 d.

Data taken from Duiker et al. (2006) was used to look at the differences in maturity and grain yield of five hybrids. The study analyzed the effects of residue on hybrids and they found that tillage did not affect grain yield of hybrids (Duiker et al., 2006). The shortest maturity hybrid (103 d) yielded as well as the longest maturity hybrid (114 d) in 2003 and was just slightly less in 2002 and 2004. However, the second shortest maturity hybrid (108 d) yielded the lowest in 2003 and 2004 and was statistically similar to the longest maturity hybrid in 2002. Two 110 d maturity hybrids were split, with one yielding equal to the longest maturity in 2002 and 2003 and the other yielded statistically the lowest all 3 yr. The result of the data taken from Duiker et al. (2006) was that grain yield of hybrids was not related to maturity.

A study by O'Neill et al. (2004) looked at hybrids with differing maturities and the effect on grain yield caused by N and water stress. They found some hybrids more stress tolerant in water-limited conditions and yielded as well as the highest yielding hybrids in non-stressed conditions. A couple of the hybrids that maintained grain yield were shorter-maturity (106 d) hybrids that yielded as well as longer-maturity (118 d) hybrids in the non-stressed condition. They attributed the ability to maintain grain yield to a hybrid's ability to maintain kernel number with water or N deficient periods during flowering (O'Neill et al., 2004). Hybrids used in my study were not advertised as being more stress tolerant by the respective seed companies. However, some of the hybrids that maintained grain yield under water-stressed conditions of the dryland environment can be credited with the ability to set ears when under stress during silking, which resulted in higher kernel number. In the non-stressed environment, these hybrids produced yields comparable to the hybrids that did not produce well in the water-stressed environment.

Data from Wilhelm et al. (1991) in a study with two dryland environments in 1982 and 1983 (Lincoln, NE) and one irrigated environment in 1983 (Gothenburg, NE) were used to develop linear relationships between yield and the advertised maturities. The 1982 dryland environment had above average precipitation and slightly below normal temperature, where the 1983 dryland environment had above average precipitation early in the season but was below normal later in the season and above average temperatures. The irrigated environment precipitation was above average with normal temperatures. With advertised relative maturity of hybrids, there was a significant linear relationship with grain yield in the 1982 dryland environment. But, in the same analysis, the 1983 dryland environment or the irrigated environment the advertised relative maturity did not show a significant linear relationship with grain yield. The maturity of their hybrids ranged from 105 to 121 d and the yield within each of the environments had very little fluctuation between hybrids (Wilhelm et al., 1991).

Other studies that evaluated maturity vs. grain yield relationships showed that either longer-season hybrids yielded more, or that there was no difference in grain yield due to maturity. The studies where longer-season hybrids out yielded shorter-season hybrids usually consisted of hybrids with larger maturity differences between the short and long season hybrids than used in my study. The study by Capristo et al. (2007) had a difference of 244 GDD compared with the 160, 123, and 96 GDD for the irrigated 2005, 2006, and 2007 of my study, respectively. The study by Edwards et al. (2005) had a difference of 35 d from shortest to longest maturity hybrid, compared with the 20 d difference in my study. The studies where maturity had no influence on grain yield had a maturity difference between the short and long season hybrids more comparable with my study. The difference between shortest and longest maturity hybrids were 20, 11, 12, and 16 d for White and McRae (1989), Duiker et al. (2006), O'Neill et al. (2004), and Wilhelm et al. (1991), respectively.

One possible reason there was no significant relationship between maturity and grain yield in my irrigated environments is because there was not a large difference between the short season (98 d) hybrids and long season (118 d) hybrids. In 2005, hybrids ranged from 652 to 812 GDD from plant emergence to initiation of silking. The growing length for the 2006 season ranged from 671 to 794 GDD, and in the 2007 season ranged from 612 to 708 GDD, from plant emergence to silking. The differences each year in maturity are relatively small, possibly decreasing the likelihood of a potential yield difference among hybrids being related with maturity differences.

Plant characteristics measured in 2005 and 2006 in both environments had very poor relationships when compared with grain yield. The 2006 dryland study had poor emergence and a poor stand with varying plant sizes because of early-season water stress. Because of non-uniformity of the stand and poor condition of plants in the 2006 dryland environment, Δ_T, leaf N, leaf P, leaf color, and ear leaf area were not taken. Ford and Hicks (1992) found that later emerging plants were at a disadvantage because of the early emerging plants. They stated that the later maturing plants had smaller stems and were shorter, which was also visually observed in my study. The Ford and Hicks (1992) study found that final yield in the uneven stand was reduced, but not to less than if the stand was replanted late.

Internode length and number of internodes were measured at harvest in 2005 for both environments. Because of degradation of plants at harvest, number of internodes was determined by using the total leaf number and subtracting five to account for the compacted internodes that are at the base of the plant below ground level (Ritchie et al., 1997) and subtracting one for the leaf at the top of the plant above the uppermost internode. As a result of the poor condition of plants at this time, plant height was used instead of length of internodes for the 2005 measurements. For 2006, number of internodes and internode length were taken earlier in the season than in 2005 to get more precise measurements. The linear regression analysis relating number of internodes and internode length with grain yield were not significant in either environment or year. Plant height has been reported to show only a gradual reduction with increased water stress (Abrecht and Carberry, 1993). Decreased plant height was not observed in my study where plant height was measured in the dryland environment in 2005. However, plant height was overall shorter in the dryland environment when compared with the irrigated environment, agreeing with a decrease in height in water-stressed conditions.

Ear leaf area in the dryland environment of 2005 was not significantly associated with grain yield when evaluated by regression. There were significant differences in leaf area between treatments; however no pattern was seen in a relationship with yield. Visual observations showed that the hybrids that produced high grain yields in water-stressed conditions produced leaf area and reached silking early. The hybrids that tended to not produce a yield, produced similar amounts of leaf area and were still in vegetative stages when silking was occurring for the shorter-season hybrids. Hybrids that did not produce well used the water for producing leaf area, leaving extreme water-stressed conditions with highly withered leaves during the reproductive stages. It has been shown that large leaf area allows for greater transpiration from the plant, increasing water use. A model produced by Sinclair and Muchow (2001) tried to demonstrate that a decrease in leaf area in water-limited conditions can increase yield as the plant conserves water to avoid stress. Their results were not able to show an increase in grain yield with the smaller leaves. In the irrigated environments of my study, leaf area was significantly different among hybrids but did not show any significant relationship with grain yield. A study by Eik and Hanway (1966) compared the area of individual leaves at the middle and top of the plant and total leaf area, with yield. When studying total leaf area during silking, they found a poor association with grain yield when leaf area was large. They then studied if a portion of the leaves, either at the top or near the middle, were related with grain yield. Leaf area taken at the top or middle of the plant had no better association with final grain yields than total leaf area (Eik and Hanway, 1966).

Total leaf number has been studied in different water stress conditions, with the only observed difference being a delayed appearance of leaves in the drier conditions, rather than a difference in total leaf number (Abrecht and Carberry, 1993). My study showed no significant relationship of total leaf number with grain yield in either water-stressed or non-stressed conditions. Number of green leaves among hybrids in the dryland environment was significantly different. Abrecht and Carberry (1993) also showed that the delay in leaf appearance will also delay leaf senescence of the lower leaves. The delay of leaf appearance causing a delay in leaf senescence was not seen in my study. Hybrids that did not produce well in dry conditions had a large number of green leaves early in the season but, as the water-stressed conditions increased, the leaves senesced without losing chlorophyll or green color. Leaves that were dried out but still green were not considered part of the green leaf number. Plants looked in good condition but growth ceased when the leaves began to senesce. The average number of green leaves per plant had no significant relationship with grain yield in either environment.

Leaf angle of the ear leaf showed significant differences within treatments in the dryland environment and the irrigated environment, but were not significantly related with grain yield in 2005 or 2006. Some hybrids had more horizontal leaves compared to more vertical leaves, ranging from 25° to 15° from the stalk, respectively, (perfectly horizontal is 90° and perfectly vertical is 0°). A study by Pepper et al. (1977) found that hybrids with upright leaves and high LAI had yield advantages when compared with hybrids with horizontal leaves. Winter and Ohlrogge (1973) also found that more upright leaves with a high LAI have the potential to significantly increase yield. However at low LAI, Winter and Ohlrogge (1973) observed a decrease in yield with more upright leaves because of lower kernel weight resulting from reduced light interception and photosynthesis. From the results of these two studies (Pepper et al., 1977; Winter and Ohlrogge, 1973), in the dryland environment of my study, the more vertical leaves should have produced lower yields because of the lower plant populations and poorer stands leaving large spaces between individual plants. The more horizontal leaves would have been able to intercept more light in the large spaces. My 2006 dryland study showed a weak linear relationship with grain yield (Table 34), as the more horizontal leaves resulted in a higher grain yield, agreeing with the study by Winter and Ohlrogge (1973). My 2005 dryland environment ear leaf angle data showed no significant relationship with grain yield. Because of the inconsistency between years, it was concluded that other factors had a larger influence on grain yield than leaf angle. In the irrigated environment where LAI would be higher because of higher plant populations and moisture conditions, the vertical leaves should have played a larger role in final yield. However, because of the small variation in yield, leaf angle had no significant relationship with grain yield in the irrigated environments (Table 35).

Color of the leaf below the ear leaf is often attributed to the amount of N in the leaf. Green leaf color first develops in the leaf tips, and once the leaves are fully expanded, the leaf transmittance and reflectance values are similar from base to tip. The transmittance and reflectance values will begin to change when leaf senescence sets in with the tips losing color first (Earl and Tollenaar, 1997). During my study, leaf color was measured with a SPAD meter soon after silking and before the leaves began to senesce. Leaf color was taken in the dryland environment in 2005, but not in 2006. The 2006 growing season was not measured because of uneven stands creating large variations in plant age and silking date, and the extremely dry year causing early senescence. A study by Dwyer et al. (1991a) found that using a SPAD meter in low chlorophyll conditions showed a very poor relationship with actual chlorophyll concentrations. The spectral reflectance of leaves in drought conditions increases causing the SPAD meter to underestimate chlorophyll content (Schlemmer et al., 2005). Because of these factors, green leaf color taken with the SPAD meter would have been unreliable in the dryland environment of 2006. Measurements in the dryland environment of 2005 and the irrigated environments of 2005 and 2006 were taken on the same day and on the same leaves as those sampled for leaf N. Measurements were taken to see if any of the hybrids expressed an ability to maintain green leaves in water-stressed conditions, and if that might influence grain yield. The regression analysis showed that SPAD measurements related with grain yield were not significant in any of the study environments or years.

Leaf N samples were taken on the leaf immediately below the ear leaf in Dryland 2005, Irrigated 2005, and Irrigated 2006. Leaf N samples were not taken in 2006 dryland for the same reasons leaf color was not taken. In my study, none of the leaf N data collected by environment or year showed a significant relationship against grain yield. A different conclusion in a study by Cerrato and Blackmer (1991) showed that as leaf N concentrations increase, yield increased until it reached a plateau and no more yield increase was seen with an increase in N concentration. Schepers et al. (1992) also found that leaf N concentrations and SPAD meter readings associated with grain yield would plateau with high fertilizer rates.

It has been shown that different hybrids generally have similar trends in leaf N concentrations and SPAD meter readings except when N fertilizer rates are high, and then differences emerge (Schepers et al., 1992). With higher N rates, some hybrids maintained higher leaf N concentrations and were greener throughout the summer (Schepers et al., 1992). It has also been revealed by Subedi and Ma (2005) that SPAD readings at the 8 leaf stage (V8) and 4 wk after silking were the only times that the hybrids they were studying showed significant differences in N content. The poor relationship with yield in my study could be the result that N fertilizer was applied only to meet crop need, and SPAD and leaf N contents were taken shortly after silking resulting in no interaction between these measurements and grain yield.

Canopy temperature differential in my study had no significant relationship with grain yield in the dryland or irrigated environments. Measurements were taken in the 2005 dryland, 2005 irrigated, and 2006 irrigated seasons, with no measurements taken in the 2006 dryland study because of poor stands and plant conditions. Canopy temperature was measured in the middle of the day with high levels of radiation. Measurements were taken up to four times throughout each growing season in each environment. However, just one measurement with the best weather conditions from roughly the same growth stage was used from each of the three studies with canopy temperature data (Dryland 2005 and Irrigated 2005 and 2006). The other measurements were not used in the analysis because of high winds or intermittent cloud cover during the measurement period. A review by Gardner et al. (1992) showed that both wind and cloud cover, or periods of low solar radiation, will affect canopy temperature measurements. Wind causes a decrease in aerodynamic resistance and canopy temperature is unreliable at wind speed <2.5 m s^{-1} while wind speed >2.5 m s^{-1} should be of little concern (Gardner et al., 1992). Measurements in my study taken in the wind were highly variable due to gusts making it difficult to measure sunlit leaves at the target point. Wind speed was not measured to determine if measurements were affected by wind, but gusts caused the most variability in measurements. Cloud cover reduces solar radiation and once the clouds pass it takes time for the rate of transpiration to return to levels seen before the low radiation. Stone et al. (1975) found that canopy temperature is very responsive to variations in solar radiation and caution needs to be used when infrared thermometry is used at times with varying solar radiation. Gardner et al. (1992) found in a review that to get the most accurate measurements of canopy temperature, the measurements should not be taken when solar radiation is low or changing often because of cloud cover. For measurements in my study, a few were made when some clouds passed overhead causing a change in solar radiation. Measurements were suspended for at least 15 min after the clouds passed before they were started again. However, only measurements taken on days with high amounts of radiation were used in the regression with grain yield to avoid any influence caused by the passing clouds.

A study by Singh and Kanemasu (1983) found that millet yield in non-irrigated conditions was negatively and significantly correlated with canopy temperature, but in irrigated conditions it was not significantly correlated. This is similar to findings in the irrigated environment with corn in my study, however different than findings in the non-irrigated environment.

The use of canopy temperature to measure water stress has been studied quite extensively. It has been adapted to measure water stress through a crop water stress index (CWSI) that was developed by Jackson et al. (1981). The CWSI was not measured in my study because the objective was to use simple measurements to determine a hybrid's ability to maintain yield in water-stressed conditions, and the minimal differences in VPD at this site reduced the ability to create an accurate baseline for measurement. By measuring just canopy minus air temperature, the measurement is poor for measuring the amount of water stress until it is normalized with VPD as the CWSI does (O'Toole et al., 1984). Even though VPD was measured when canopy temperature was taken, canopy temperature was not normalized by VPD, possibly making it so water stress was not accurately measured in my study using canopy temperature, causing a poor relationship with grain yield.

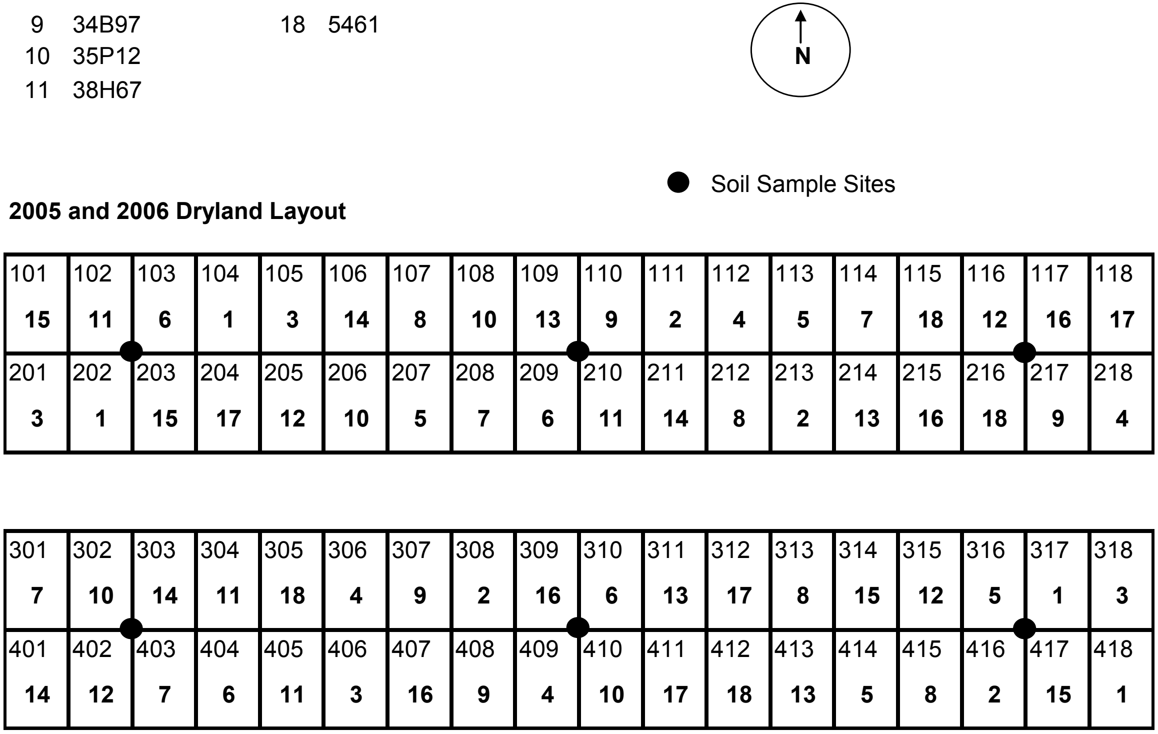
The only plant characteristics measured that had a significant relationship with grain yield in water-stressed conditions were ear population, number of GDD and number of days to initiation of silking. The shorter-season hybrids (98 d) in the dryland environment had a significantly higher grain yield each of the 3 yr. There was no significant relationship between hybrid maturity and grain yield in the irrigated environments, even though there were some significant differences in grain yield due to treatment. The other plant characteristics measured in either environment of 2005 and 2006 did not have a consistent and significant relationship with grain yield. The results showed that within the range of maturity (98 to 118 d) of the hybrids used in my study that in the irrigated environment the length of maturity had no influence in grain yield. In the dryland environment, the results showed a decrease in yield as the length of maturity increased from 98 to 118 d. In the event of a growing season with potential or likely irrigation cutbacks, from the results of my study, a hybrid with a shorter maturity length than would normally be planted could be selected and will yield well in the water-stressed conditions, but can potentially produce well if water supply is sufficient.

Figures

Figure 1. Map of Plots (Dryland 2005 and 2006)

The plot layout for dryland environments of 2005 and 2006. A list of hybrids used is included along with treatment number. For each of the plots, plot number is listed first and treatment number is listed below it. Each plot was 15.24 m long by 3.05 m wide (4 rows). The solid circles represent where soil samples were collected.

TRT		TRT	
	Pioneer		Croplan Genetics
1	31N26	12	496RR/BT 2005-2006
2	33P66	12	579LL/HX 2007
3	34A15	13	610RR2
4	35Y65	14	691RR2
5	37H24	15	TR1047RR2/BT
6	31G66		Triumph
7	33H25	16	1416
8	33B50	17	5433
9	34B97	18	5461
10	35P12		
11	38H67		



● Soil Sample Sites

2005 and 2006 Dryland Layout

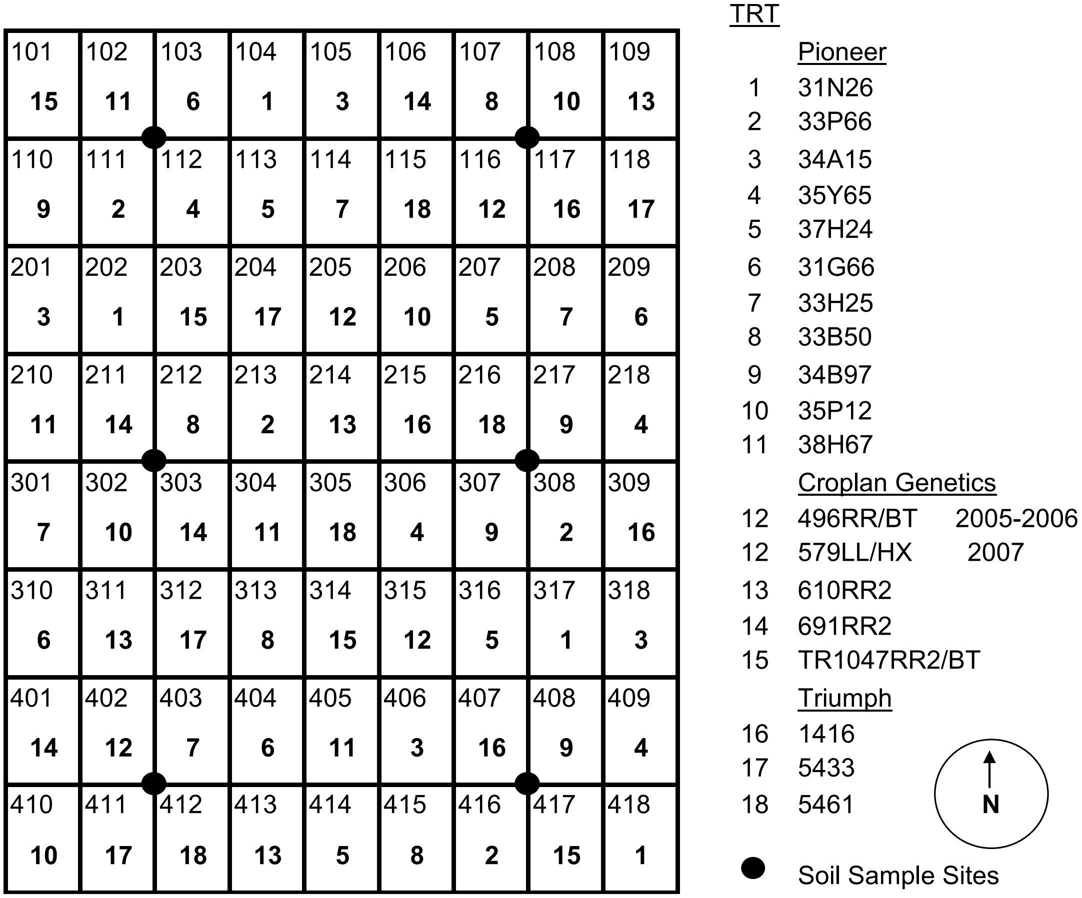
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
15	**11**	**6**	**1**	**3**	**14**	**8**	**10**	**13**	**9**	**2**	**4**	**5**	**7**	**18**	**12**	**16**	**17**
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218
3	**1**	**15**	**17**	**12**	**10**	**5**	**7**	**6**	**11**	**14**	**8**	**2**	**13**	**16**	**18**	**9**	**4**

301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318
7	**10**	**14**	**11**	**18**	**4**	**9**	**2**	**16**	**6**	**13**	**17**	**8**	**15**	**12**	**5**	**1**	**3**
401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418
14	**12**	**7**	**6**	**11**	**3**	**16**	**9**	**4**	**10**	**17**	**18**	**13**	**5**	**8**	**2**	**15**	**1**

Figure 2. Map of Plots

The plot layout for the dryland environment of 2007 and irrigated environments of 2005, 2006, and 2007. A list of hybrids used is included along with treatment number. For each of the plots, plot number is listed first and treatment number is listed below it. Each plot was 15.24 m long in 2005 and 12.19 m long in 2006 and 2007 by 3.05 m wide (4 rows). The solid circles represent where soil samples were collected.

2005, 2006, 2007 Irrigated Layout; 2007 Dryland Layout



101 **15**	102 **11**	103 **6**	104 **1**	105 **3**	106 **14**	107 **8**	108 **10**	109 **13**
110 **9**	111 **2**	112 **4**	113 **5**	114 **7**	115 **18**	116 **12**	117 **16**	118 **17**
201 **3**	202 **1**	203 **15**	204 **17**	205 **12**	206 **10**	207 **5**	208 **7**	209 **6**
210 **11**	211 **14**	212 **8**	213 **2**	214 **13**	215 **16**	216 **18**	217 **9**	218 **4**
301 **7**	302 **10**	303 **14**	304 **11**	305 **18**	306 **4**	307 **9**	308 **2**	309 **16**
310 **6**	311 **13**	312 **17**	313 **8**	314 **15**	315 **12**	316 **5**	317 **1**	318 **3**
401 **14**	402 **12**	403 **7**	404 **6**	405 **11**	406 **3**	407 **16**	408 **9**	409 **4**
410 **10**	411 **17**	412 **18**	413 **13**	414 **5**	415 **8**	416 **2**	417 **15**	418 **1**

TRT		
	Pioneer	
1	31N26	
2	33P66	
3	34A15	
4	35Y65	
5	37H24	
6	31G66	
7	33H25	
8	33B50	
9	34B97	
10	35P12	
11	38H67	
	Croplan Genetics	
12	496RR/BT	2005-2006
12	579LL/HX	2007
13	610RR2	
14	691RR2	
15	TR1047RR2/BT	
	Triumph	
16	1416	
17	5433	
18	5461	

● Soil Sample Sites

Figure 3. Soil Water Content

Soil water content is expressed as m^3 of H_2O m^{-3} of soil volume in the 2.44 m soil profile. Dates that soil water content was taken with a neutron probe is represented in the key for each environment.

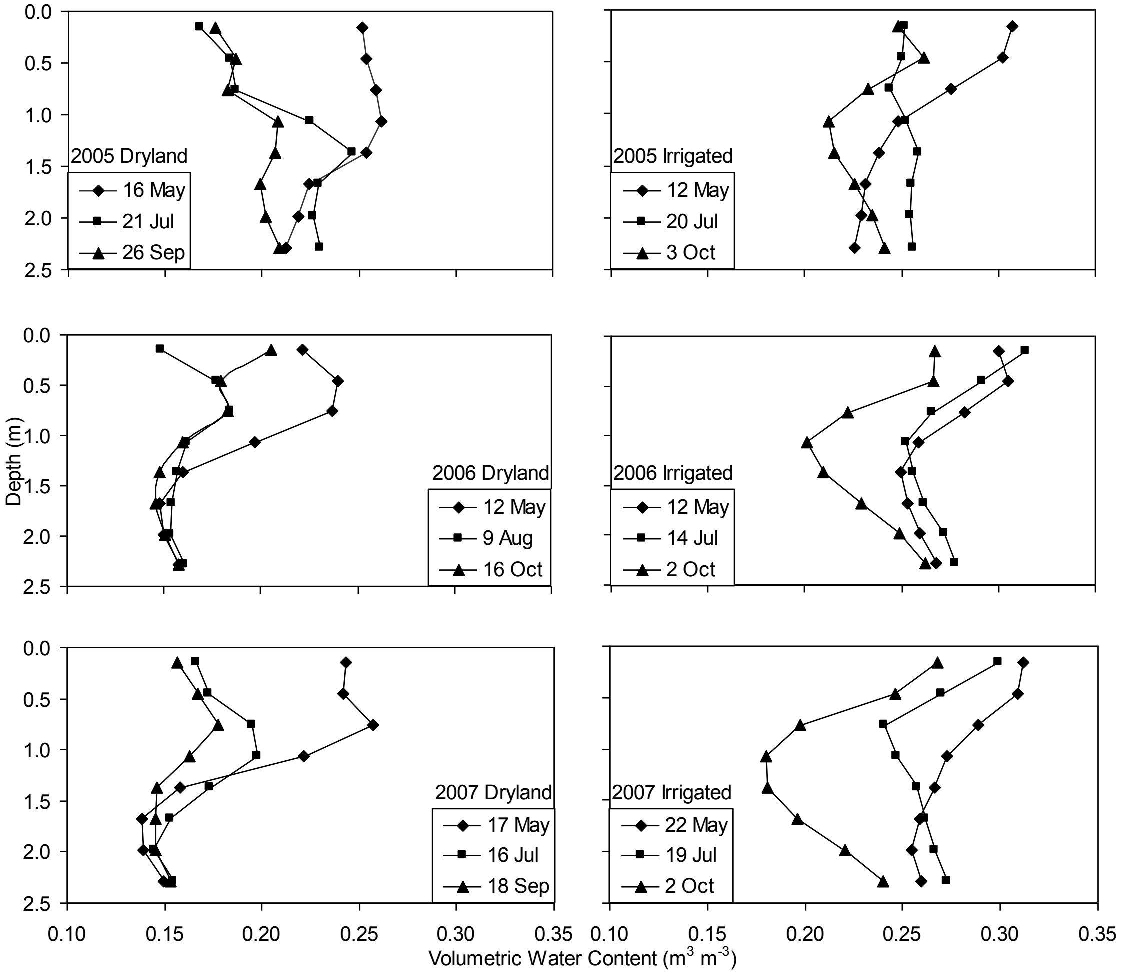


Figure 4. Dryland GDD and Days to Initiation of Silking

The summarization of linear regression between number of GDD to initiation of silking (X value) and grain yield (Y value), and number of days to initiation of silking (X value) and grain yield (Y value). For each equation on this figure, n = 18.

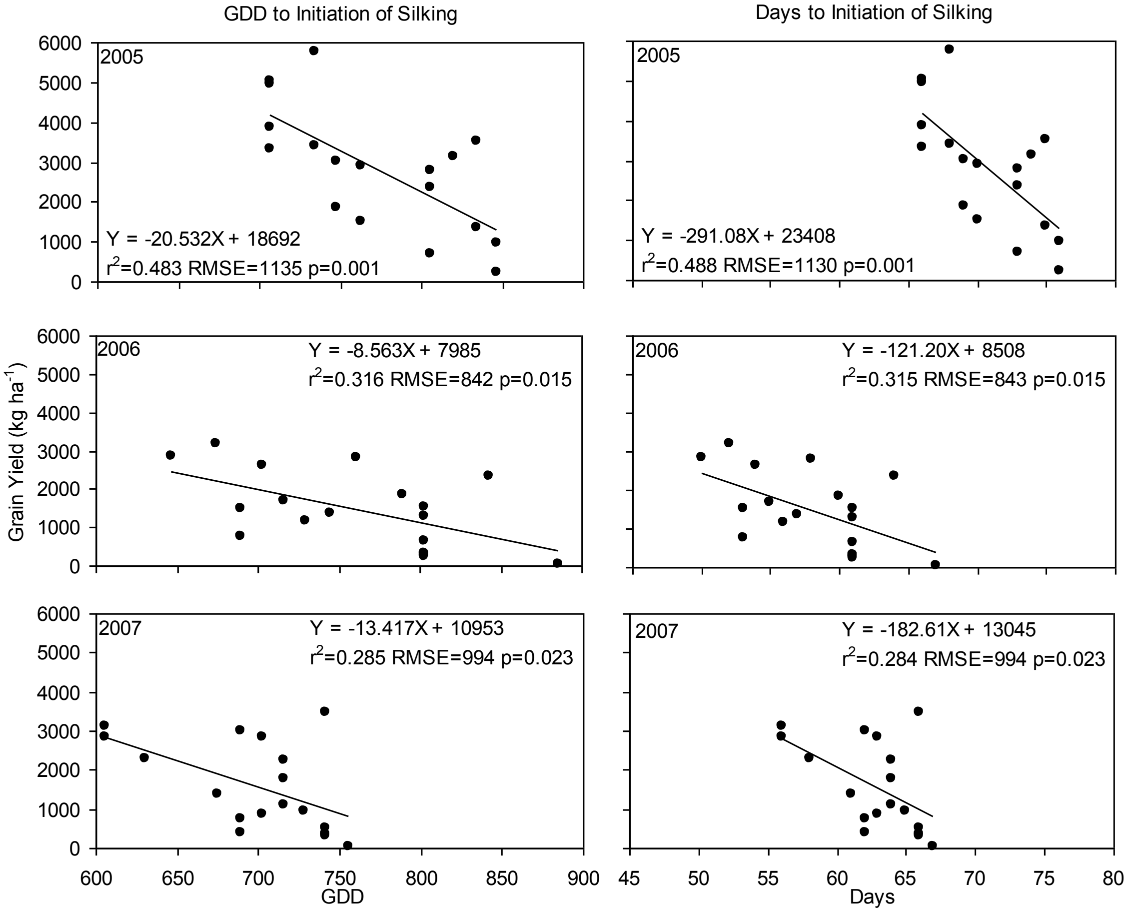


Figure 5. Irrigated GDD and Days to Initiation of Silking

The summarization of linear regression between number of GDD to initiation of silking (X value) and grain yield (Y value), and number of days to initiation of silking (X value) and grain yield (Y value). For each equation on this figure, n = 18.

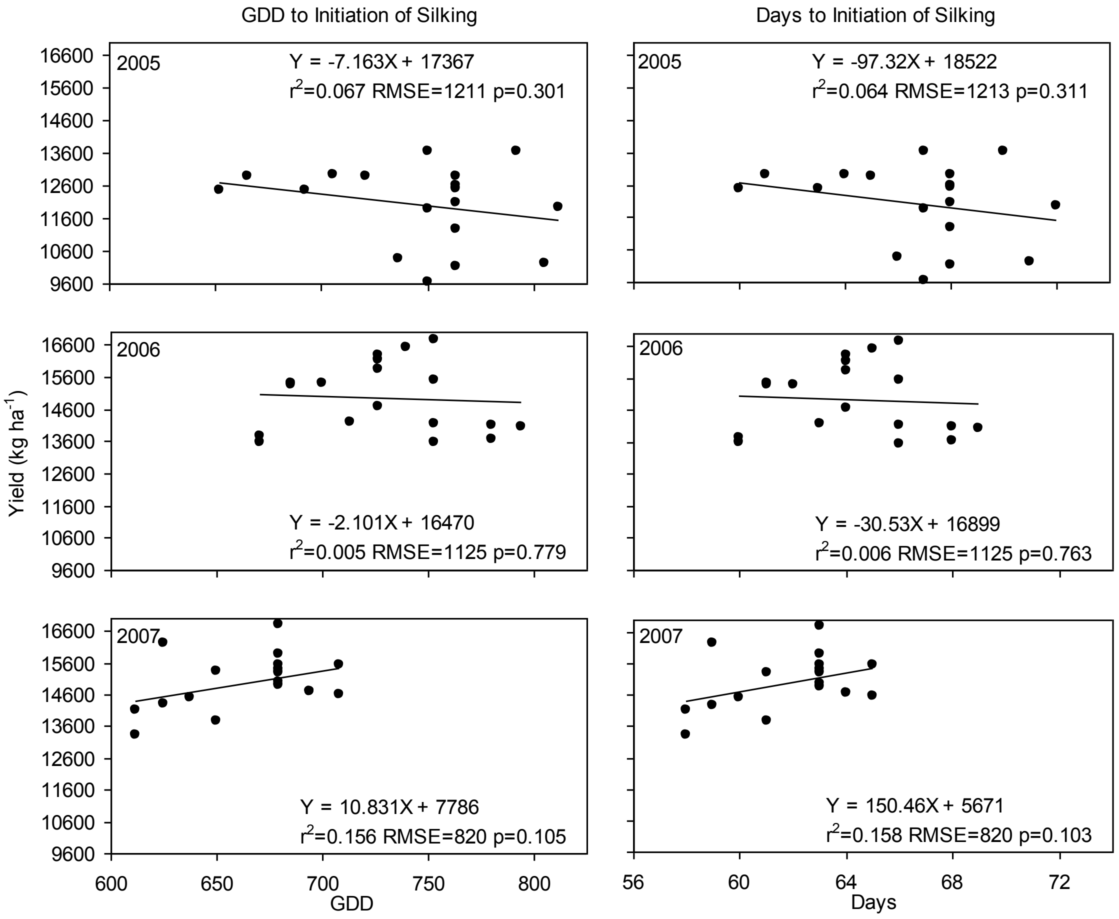


Figure 6. Dryland Ear population

The summarization of linear regression between ear population (X value) measured in the dryland environments and grain yield (Y value). For each equation on this figure, n = 18.

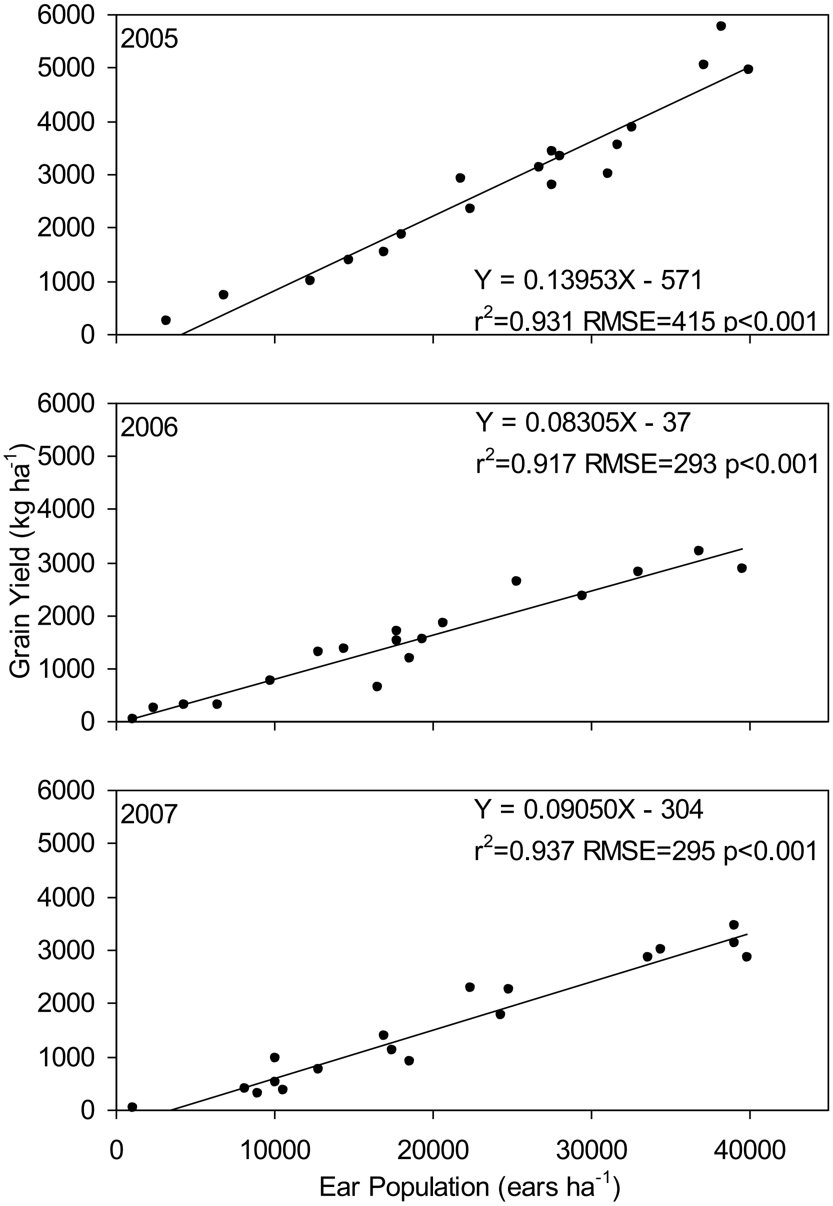


Figure 7. Dryland Ear Population and Maturity

The summarization of linear regression results where number of GDD to initiation of silking (X value) and number of days to initiation of silking (X value) were related with ear population (Y value) of the dryland environments. For each equation on this figure, n = 18.

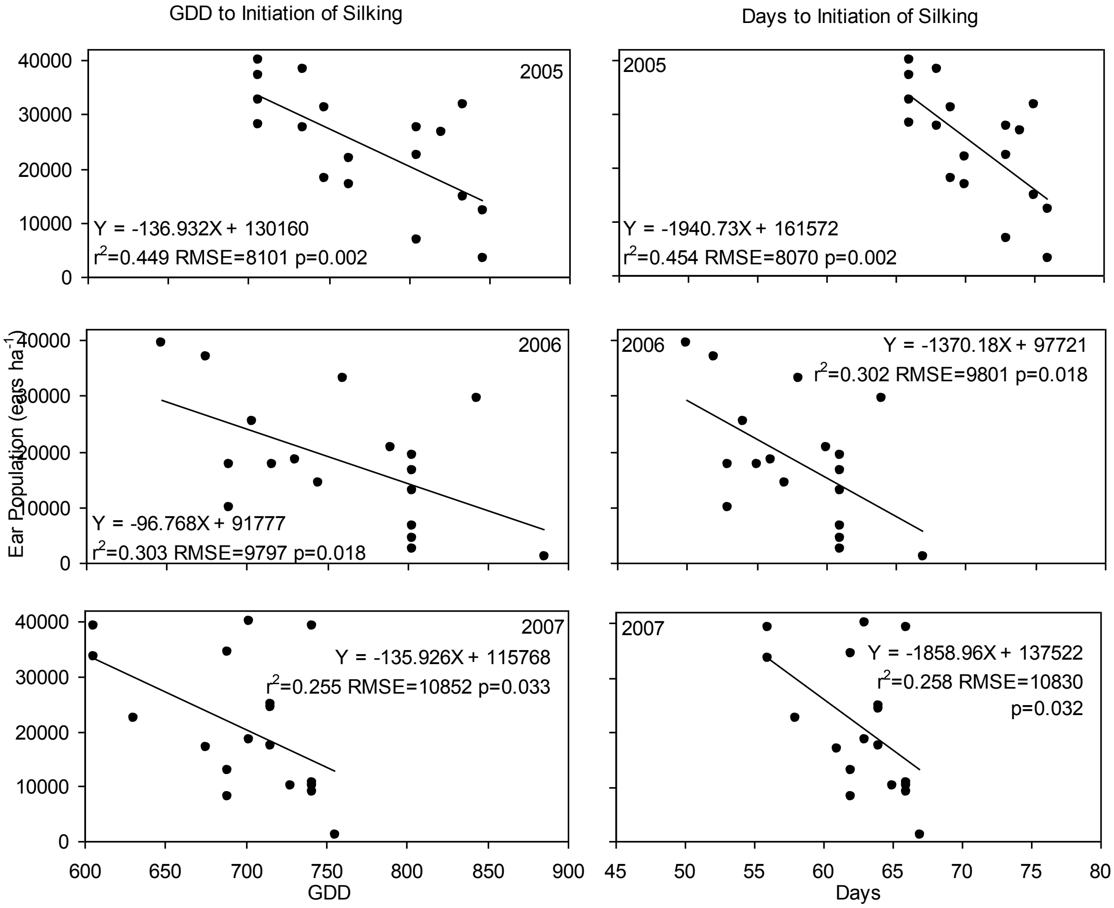
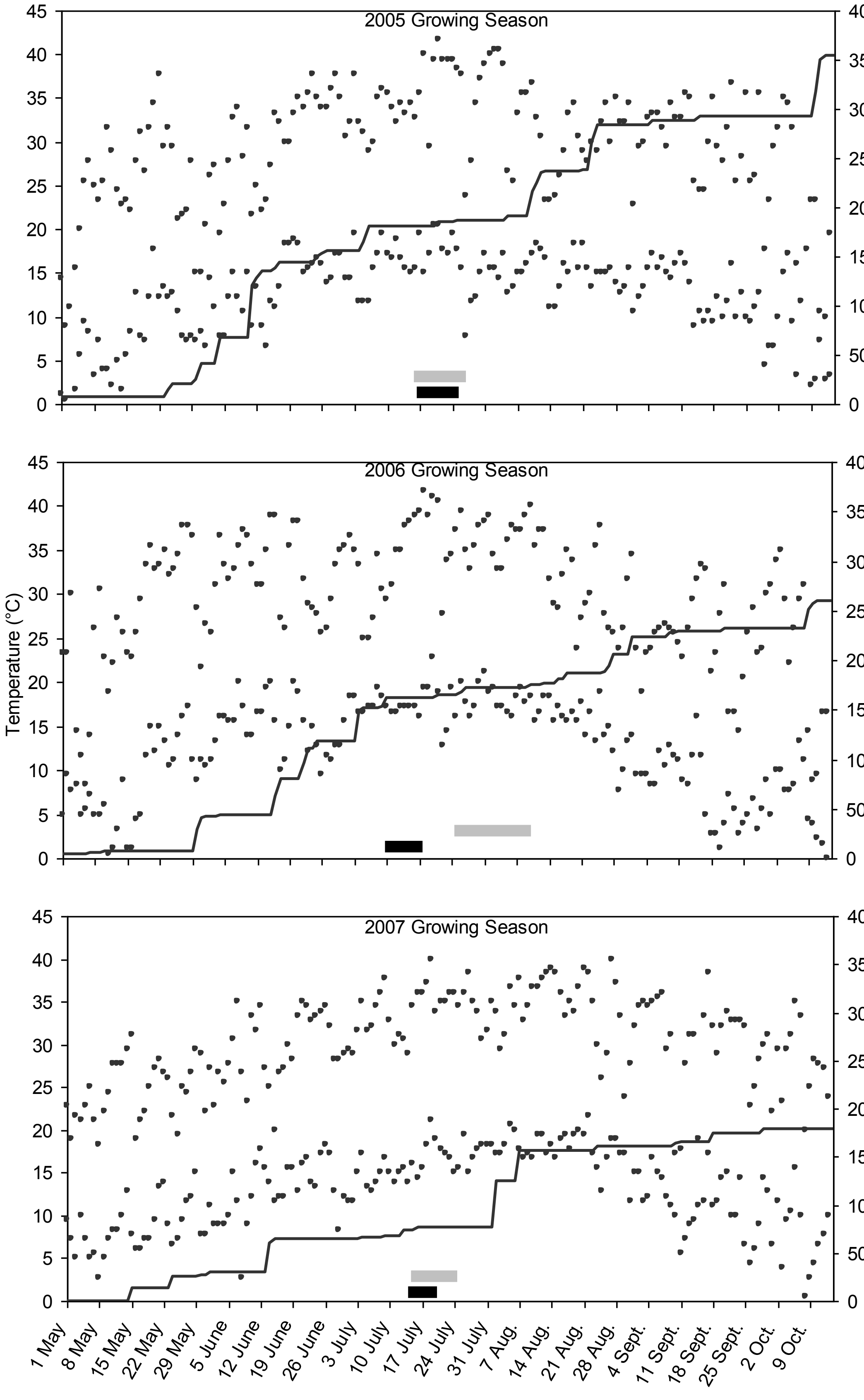


Figure 8. Temperature and Precipitation

A graphical representation of temperature and precipitation for the three growing seasons as taken at the dryland field weather station. Minimum temperature is represented by the lower points, maximum temperature is represented by upper points, and cumulative precipitation is represented by the horizontal line. Dryland silking dates are marked with grey horizontal bars and irrigated silking dates are marked with black horizontal bars.



Tables

Table 1. Hybrids

Hybrids used in this study were from three seed companies. The advertised days from planting to maturity and the growing seasons each hybrid was planted are listed. The treatment number is the number used in this study to link to the corresponding hybrid.

Trt	Hybrid	Advertised maturity	Seasons grown
No.	No.	d (planting to maturity)	
		Pioneer*	
1	31N26	118	05, 06, 07
2	33P66	114	05, 06, 07
3	34A15	108	05, 06, 07
4	35Y65	105	05, 06, 07
5	37H24	99	05, 06, 07
6	31G66	118	05, 06, 07
7	33H25	114	05, 06, 07
8	33B50	112	05, 06, 07
9	34B97	109	05, 06, 07
10	35P12	104	05, 06, 07
11	38H67	98	05, 06, 07
		Croplan Genetics*	
12	496 RR/BT	104	05, 06
12	579 LL/HX	108	07
13	610 RR2	108	05, 06, 07
14	691 RR2	112	05, 06, 07
15	TR1047 RR2/BT	106	05, 06, 07
		Triumph*	
16	1416	109-111	05, 06, 07
17	5433	105-107	05, 06, 07
18	5461	108	05, 06, 07

* Trade names used in this thesis are solely for the purpose of identifying differences between hybrids within the study. Mention of a trade name or proprietary product in no way specifies that one product is better or worse then any other listed and does not imply approval of the named product to the exclusion of other similar products.

Table 2. Canopy Closure

Canopy closure as the % of light intercepted in each treatment as measured by a PAR sensor above and below the canopy. These measurements were taken on 12 July 2005, 13 July 2005, 27 July 2006, and 13 July 2006 for Dryland 2005, Irrigated 2005, Dryland 2006, and Irrigated 2006, respectively. These dates show the amount of canopy coverage before canopy temperature was recorded.

	Dryl. 2005	Irrig. 2005	Dryl. 2006	Irrig. 2006
	% μmol $m^{-2}s^{-1}$			
1	75.9	96.6	69.3	97.9
2	82.3	96.8	77.1	97.4
3	75.5	94.4	72.8	97.0
4	78.0	94.1	65.9	97.4
5	76.5	96.0	79.4	97.3
6	78.8	92.2	79.4	95.8
7	78.1	94.4	83.8	97.1
8	81.0	92.9	84.4	97.9
9	76.6	94.8	74.4	95.5
10	85.6	97.3	80.9	97.9
11	78.5	94.1	71.7	98.5
12	84.5	96.7	81.8	98.2
13	86.7	95.5	79.0	96.7
14	78.6	95.0	83.0	98.2
15	86.9	95.1	86.9	97.6
16	85.0	96.1	86.2	97.2
17	78.5	94.2	80.4	97.7
18	86.6	97.4	85.5	98.5

Table 3. Dryland 2005 Soil Water Content

Mean soil water content of the 2005 dryland environment as taken by a neutron probe in 8 plots throughout the growing season and presented as m^3 of H_2O per m^3 of volume.

Date	Depth	N	Mean	Min	Max	SD	SE	COV
	m		--------------------m^3 m^{-3}--------------------					
16 May 05	0.15	8	0.252	0.232	0.271	0.014	0.005	5.72
16 May 05	0.46	8	0.254	0.242	0.264	0.007	0.003	2.88
16 May 05	0.76	8	0.259	0.249	0.266	0.006	0.002	2.35
16 May 05	1.07	8	0.261	0.242	0.276	0.012	0.004	4.64
16 May 05	1.37	8	0.253	0.237	0.272	0.014	0.005	5.42
16 May 05	1.68	8	0.224	0.206	0.264	0.020	0.007	9.08
16 May 05	1.98	8	0.218	0.201	0.239	0.013	0.005	5.87
16 May 05	2.29	8	0.212	0.197	0.230	0.012	0.004	5.48
21 Jul 05	0.15	8	0.168	0.152	0.208	0.019	0.007	11.07
21 Jul 05	0.46	8	0.183	0.176	0.193	0.006	0.002	3.21
21 Jul 05	0.76	8	0.186	0.164	0.203	0.012	0.004	6.62
21 Jul 05	1.07	8	0.225	0.188	0.252	0.023	0.008	10.09
21 Jul 05	1.37	8	0.247	0.230	0.264	0.013	0.005	5.35
21 Jul 05	1.68	8	0.230	0.205	0.265	0.021	0.007	9.10
21 Jul 05	1.98	8	0.226	0.205	0.249	0.015	0.005	6.51
21 Jul 05	2.29	8	0.230	0.207	0.249	0.015	0.005	6.69
27 Jul 05	0.15	8	0.155	0.141	0.181	0.014	0.005	8.89
27 Jul 05	0.46	8	0.177	0.166	0.186	0.005	0.002	3.09
27 Jul 05	0.76	8	0.177	0.160	0.188	0.009	0.003	4.82
27 Jul 05	1.07	8	0.207	0.171	0.246	0.024	0.008	11.38
27 Jul 05	1.37	8	0.238	0.213	0.261	0.019	0.007	8.11
27 Jul 05	1.68	8	0.226	0.203	0.268	0.024	0.008	10.43
27 Jul 05	1.98	8	0.224	0.201	0.251	0.017	0.006	7.52
27 Jul 05	2.29	8	0.227	0.205	0.248	0.014	0.005	6.19
26 Sep 05	0.15	8	0.176	0.153	0.214	0.023	0.008	13.12
26 Sep 05	0.46	8	0.186	0.169	0.200	0.010	0.004	5.42
26 Sep 05	0.76	8	0.182	0.171	0.192	0.008	0.003	4.15
26 Sep 05	1.07	8	0.197	0.175	0.222	0.017	0.006	8.52
26 Sep 05	1.37	8	0.207	0.171	0.255	0.032	0.011	15.71
26 Sep 05	1.68	8	0.199	0.168	0.261	0.036	0.013	18.07
26 Sep 05	1.98	8	0.202	0.178	0.234	0.020	0.007	9.85
26 Sep 05	2.29	8	0.209	0.187	0.232	0.015	0.005	7.10

Table 4. Dryland 2006 Soil Water Content

Mean soil water content of the 2006 dryland environment as taken by a neutron probe in 8 plots throughout the growing season and presented as m^3 of H_2O per m^3 of volume.

Date	Depth	N	Mean	Min	Max	SD	SE	COV
	m		------------------------------$m^3\ m^{-3}$	-----------------------------				
12 May 06	0.15	8	0.221	0.197	0.235	0.013	0.005	5.88
12 May 06	0.46	8	0.240	0.225	0.248	0.009	0.003	3.58
12 May 06	0.76	8	0.237	0.216	0.258	0.014	0.005	5.88
12 May 06	1.07	8	0.197	0.176	0.214	0.014	0.005	7.24
12 May 06	1.37	8	0.160	0.135	0.182	0.016	0.006	10.19
12 May 06	1.68	8	0.148	0.128	0.172	0.015	0.005	10.19
12 May 06	1.98	8	0.150	0.130	0.173	0.014	0.005	9.58
12 May 06	2.29	8	0.158	0.120	0.185	0.022	0.008	14.10
9 Aug 06	0.15	8	0.148	0.132	0.159	0.009	0.003	6.08
9 Aug 06	0.46	8	0.177	0.172	0.181	0.004	0.001	2.07
9 Aug 06	0.76	8	0.184	0.166	0.209	0.016	0.006	8.77
9 Aug 06	1.07	8	0.162	0.139	0.189	0.018	0.007	11.37
9 Aug 06	1.37	8	0.157	0.139	0.180	0.015	0.005	9.83
9 Aug 06	1.68	8	0.154	0.128	0.180	0.017	0.006	11.19
9 Aug 06	1.98	8	0.154	0.132	0.183	0.018	0.006	11.50
9 Aug 06	2.29	8	0.160	0.121	0.186	0.022	0.008	13.92
16 Oct 06	0.15	8	0.205	0.180	0.231	0.017	0.006	8.43
16 Oct 06	0.46	8	0.179	0.175	0.185	0.004	0.001	2.14
16 Oct 06	0.76	8	0.183	0.163	0.209	0.016	0.006	8.93
16 Oct 06	1.07	8	0.160	0.143	0.181	0.015	0.005	9.13
16 Oct 06	1.37	8	0.148	0.136	0.165	0.009	0.003	6.27
16 Oct 06	1.68	8	0.146	0.133	0.160	0.008	0.003	5.81
16 Oct 06	1.98	8	0.150	0.136	0.174	0.012	0.004	8.23
16 Oct 06	2.29	8	0.158	0.123	0.184	0.020	0.007	12.54

Table 5. Dryland 2007 Dryland Soil Water Content

Mean soil water content of the 2007 dryland environment as taken by a neutron probe in 8 plots throughout the growing season and presented as m^3 of H_2O per m^3 of volume.

Date	Depth	N	Mean	Min	Max	SD	SE	COV
	m		-----------------------------$m^3\ m^{-3}$	-----------------------------				
17 May 07	0.15	8	0.243	0.232	0.257	0.009	0.003	3.59
17 May 07	0.46	8	0.242	0.227	0.255	0.009	0.003	3.52
17 May 07	0.76	8	0.257	0.242	0.269	0.010	0.004	3.97
17 May 07	1.07	8	0.221	0.170	0.247	0.026	0.009	11.91
17 May 07	1.37	8	0.158	0.123	0.213	0.031	0.011	19.39
17 May 07	1.68	8	0.139	0.128	0.170	0.014	0.005	10.29
17 May 07	1.98	8	0.139	0.127	0.156	0.011	0.004	7.62
17 May 07	2.29	8	0.150	0.132	0.178	0.017	0.006	11.10
22 Jun 07	0.15	8	0.231	0.206	0.251	0.016	0.006	7.01
22 Jun 07	0.46	8	0.239	0.219	0.252	0.010	0.004	4.23
22 Jun 07	0.76	8	0.260	0.243	0.270	0.012	0.004	4.46
22 Jun 07	1.07	8	0.227	0.184	0.251	0.023	0.008	10.25
22 Jun 07	1.37	8	0.175	0.133	0.218	0.030	0.011	17.14
22 Jun 07	1.68	8	0.149	0.130	0.192	0.021	0.007	13.97
22 Jun 07	1.98	8	0.145	0.130	0.185	0.018	0.006	12.59
22 Jun 07	2.29	8	0.153	0.133	0.195	0.021	0.008	14.00
16 Jul 07	0.15	8	0.166	0.141	0.185	0.018	0.006	10.67
16 Jul 07	0.46	8	0.173	0.161	0.188	0.010	0.004	5.99
16 Jul 07	0.76	8	0.195	0.178	0.221	0.017	0.006	8.68
16 Jul 07	1.07	8	0.198	0.159	0.234	0.026	0.009	13.35
16 Jul 07	1.37	8	0.174	0.140	0.211	0.024	0.008	13.79
16 Jul 07	1.68	8	0.153	0.132	0.190	0.023	0.008	15.26
16 Jul 07	1.98	8	0.145	0.131	0.183	0.018	0.006	12.30
16 Jul 07	2.29	8	0.154	0.133	0.201	0.023	0.008	15.10
20 Aug 07	0.15	8	0.157	0.129	0.181	0.021	0.007	13.39
20 Aug 07	0.46	8	0.169	0.155	0.184	0.010	0.004	6.08
20 Aug 07	0.76	8	0.181	0.171	0.196	0.009	0.003	4.92
20 Aug 07	1.07	8	0.167	0.140	0.187	0.017	0.006	10.21
20 Aug 07	1.37	8	0.152	0.132	0.186	0.018	0.006	12.00
20 Aug 07	1.68	8	0.150	0.133	0.177	0.018	0.007	12.30
20 Aug 07	1.98	8	0.146	0.129	0.182	0.018	0.006	12.24
20 Aug 07	2.29	8	0.154	0.135	0.198	0.022	0.008	14.27
18 Sep 07	0.15	8	0.157	0.137	0.173	0.015	0.005	9.59
18 Sep 07	0.46	8	0.167	0.155	0.182	0.009	0.003	5.61
18 Sep 07	0.76	8	0.177	0.168	0.193	0.010	0.003	5.46
18 Sep 07	1.07	8	0.163	0.138	0.180	0.015	0.005	9.27
18 Sep 07	1.37	8	0.146	0.129	0.170	0.013	0.005	9.10
18 Sep 07	1.68	8	0.145	0.133	0.169	0.016	0.006	10.74
18 Sep 07	1.98	8	0.145	0.129	0.173	0.016	0.006	10.86
18 Sep 07	2.29	8	0.153	0.135	0.193	0.021	0.007	13.73

Table 6. Irrigated 2005 Soil Water Content

Mean soil water content of the 2005 irrigated environment as taken by a neutron probe in 8 plots throughout the growing season and presented as m^3 of H_2O per m^3 of volume.

Date	Depth	N	Mean	Min	Max	SD	SE	COV
	m		------------$m^3\ m^{-3}$------------					
12 May 05	0.15	8	0.307	0.290	0.323	0.012	0.004	3.91
12 May 05	0.46	8	0.303	0.290	0.333	0.013	0.005	4.39
12 May 05	0.76	8	0.275	0.259	0.289	0.012	0.004	4.33
12 May 05	1.07	8	0.248	0.212	0.263	0.016	0.006	6.33
12 May 05	1.37	8	0.238	0.205	0.260	0.019	0.007	7.84
12 May 05	1.68	8	0.231	0.195	0.254	0.020	0.007	8.63
12 May 05	1.98	8	0.229	0.183	0.248	0.021	0.008	9.34
12 May 05	2.29	8	0.226	0.182	0.252	0.021	0.007	9.24
20 Jul 05	0.15	8	0.252	0.230	0.264	0.012	0.004	4.74
20 Jul 05	0.46	8	0.250	0.226	0.293	0.029	0.010	11.41
20 Jul 05	0.76	8	0.244	0.215	0.284	0.026	0.009	10.49
20 Jul 05	1.07	8	0.252	0.226	0.278	0.018	0.006	7.03
20 Jul 05	1.37	8	0.259	0.238	0.275	0.013	0.005	5.09
20 Jul 05	1.68	8	0.256	0.226	0.282	0.018	0.006	7.06
20 Jul 05	1.98	8	0.254	0.212	0.280	0.021	0.007	8.26
20 Jul 05	2.29	8	0.256	0.213	0.272	0.020	0.007	7.84
28 Jul 05	0.15	8	0.266	0.231	0.288	0.019	0.007	7.07
28 Jul 05	0.46	8	0.232	0.199	0.276	0.026	0.009	11.22
28 Jul 05	0.76	8	0.210	0.187	0.251	0.025	0.009	11.98
28 Jul 05	1.07	8	0.229	0.199	0.265	0.024	0.008	10.42
28 Jul 05	1.37	8	0.248	0.227	0.264	0.016	0.006	6.45
28 Jul 05	1.68	8	0.250	0.215	0.283	0.022	0.008	8.70
28 Jul 05	1.98	8	0.253	0.212	0.280	0.021	0.007	8.18
28 Jul 05	2.29	8	0.252	0.211	0.273	0.020	0.007	8.08
3 Oct 05	0.15	8	0.248	0.204	0.279	0.027	0.009	10.77
3 Oct 05	0.46	8	0.262	0.218	0.290	0.024	0.008	9.08
3 Oct 05	0.76	8	0.232	0.190	0.268	0.031	0.011	13.16
3 Oct 05	1.07	8	0.213	0.161	0.247	0.030	0.010	7.97
3 Oct 05	1.37	8	0.215	0.157	0.245	0.030	0.010	13.74
3 Oct 05	1.68	8	0.225	0.164	0.258	0.031	0.011	13.72
3 Oct 05	1.98	8	0.235	0.181	0.259	0.024	0.009	10.26
3 Oct 05	2.29	8	0.241	0.197	0.257	0.019	0.007	7.97

Table 7. Irrigated 2006 Soil Water Content

Mean soil water content of the 2006 irrigated environment as taken by a neutron probe in 8 plots throughout the growing season and presented as m^3 of H_2O per m^3 of volume.

Date	Depth	N	Mean	Min	Max	SD	SE	COV
	m		----------------------------------		m^3 m^{-3}		---------------------------------	
12 May 06	0.15	8	0.300	0.285	0.327	0.015	0.005	5.16
12 May 06	0.46	8	0.305	0.268	0.352	0.031	0.011	10.29
12 May 06	0.76	8	0.283	0.253	0.331	0.030	0.011	10.52
12 May 06	1.07	8	0.259	0.233	0.296	0.024	0.009	9.42
12 May 06	1.37	8	0.250	0.235	0.283	0.019	0.007	7.45
12 May 06	1.68	8	0.253	0.233	0.281	0.018	0.006	7.14
12 May 06	1.98	8	0.259	0.233	0.288	0.023	0.008	8.82
12 May 06	2.29	8	0.268	0.236	0.305	0.028	0.010	10.45
14 Jul 06	0.15	8	0.314	0.304	0.329	0.008	0.003	2.61
14 Jul 06	0.46	8	0.292	0.237	0.343	0.037	0.013	12.62
14 Jul 06	0.76	8	0.265	0.219	0.341	0.049	0.017	18.35
14 Jul 06	1.07	8	0.252	0.226	0.304	0.034	0.012	13.41
14 Jul 06	1.37	8	0.256	0.227	0.305	0.032	0.011	12.33
14 Jul 06	1.68	8	0.261	0.232	0.301	0.026	0.009	10.10
14 Jul 06	1.98	8	0.272	0.238	0.311	0.028	0.010	10.23
14 Jul 06	2.29	8	0.278	0.241	0.325	0.033	0.011	11.71
20 Jul 06	0.15	8	0.276	0.249	0.301	0.015	0.005	5.41
20 Jul 06	0.46	8	0.269	0.234	0.321	0.036	0.013	13.41
20 Jul 06	0.76	8	0.249	0.200	0.326	0.050	0.018	19.90
20 Jul 06	1.07	8	0.240	0.204	0.296	0.035	0.012	14.70
20 Jul 06	1.37	8	0.250	0.225	0.297	0.030	0.011	12.04
20 Jul 06	1.68	8	0.259	0.234	0.296	0.025	0.009	9.83
20 Jul 06	1.98	8	0.268	0.237	0.313	0.029	0.010	10.84
20 Jul 06	2.29	8	0.276	0.243	0.323	0.031	0.011	11.14
3 Aug 06	0.15	8	0.262	0.236	0.292	0.016	0.006	6.22
3 Aug 06	0.46	8	0.252	0.216	0.311	0.037	0.013	14.86
3 Aug 06	0.76	8	0.224	0.186	0.307	0.050	0.018	22.37
3 Aug 06	1.07	8	0.217	0.178	0.283	0.041	0.015	19.11
3 Aug 06	1.37	8	0.233	0.196	0.283	0.034	0.012	14.48
3 Aug 06	1.68	8	0.251	0.215	0.295	0.029	0.010	11.71
3 Aug 06	1.98	8	0.263	0.232	0.304	0.029	0.010	10.99
3 Aug 06	2.29	8	0.272	0.234	0.319	0.033	0.012	12.06
9 Aug 06	0.15	8	0.259	0.233	0.296	0.018	0.006	7.07
9 Aug 06	0.46	8	0.243	0.206	0.299	0.037	0.013	15.41
9 Aug 06	0.76	8	0.215	0.177	0.296	0.046	0.016	21.54
9 Aug 06	1.07	8	0.206	0.165	0.277	0.041	0.014	19.89
9 Aug 06	1.37	8	0.220	0.182	0.273	0.035	0.013	16.08
9 Aug 06	1.68	8	0.241	0.198	0.286	0.029	0.010	12.19
9 Aug 06	1.98	8	0.258	0.223	0.297	0.029	0.010	11.22
9 Aug 06	2.29	8	0.271	0.231	0.321	0.035	0.012	12.99
2 Oct 06	0.15	8	0.267	0.246	0.308	0.022	0.008	8.09
2 Oct 06	0.46	8	0.267	0.225	0.336	0.040	0.014	14.98
2 Oct 06	0.76	8	0.222	0.177	0.304	0.048	0.017	21.45
2 Oct 06	1.07	8	0.201	0.160	0.271	0.041	0.014	20.29
2 Oct 06	1.37	8	0.210	0.164	0.273	0.041	0.014	19.47
2 Oct 06	1.68	8	0.229	0.183	0.277	0.032	0.011	14.08
2 Oct 06	1.98	8	0.249	0.211	0.298	0.032	0.011	12.88
2 Oct 06	2.29	8	0.262	0.219	0.317	0.037	0.013	13.97

Table 8. Irrigated 2007 Soil Water Content

Mean soil water content of the 2007 irrigated environment as taken by a neutron probe in 8 plots throughout the growing season and presented as m^3 of H_2O per m^3 of volume.

Date	Depth	N	Mean	Min	Max	SD	SE	COV
	m		m^3 m^{-3}					
22 May 07	0.15	8	0.311	0.294	0.330	0.011	0.004	3.41
22 May 07	0.46	8	0.309	0.297	0.328	0.009	0.003	2.97
22 May 07	0.76	8	0.289	0.270	0.307	0.011	0.004	3.98
22 May 07	1.07	8	0.273	0.265	0.282	0.006	0.002	2.14
22 May 07	1.37	8	0.266	0.246	0.281	0.012	0.004	4.35
22 May 07	1.68	8	0.259	0.233	0.270	0.012	0.004	4.54
22 May 07	1.98	8	0.255	0.232	0.278	0.013	0.005	5.03
22 May 07	2.29	8	0.259	0.242	0.276	0.012	0.004	4.81
21 Jun 07	0.15	8	0.300	0.284	0.312	0.010	0.003	3.24
21 Jun 07	0.46	8	0.318	0.310	0.338	0.009	0.003	2.91
21 Jun 07	0.76	8	0.299	0.275	0.308	0.011	0.004	3.60
21 Jun 07	1.07	8	0.284	0.275	0.300	0.009	0.003	3.28
21 Jun 07	1.37	8	0.278	0.265	0.287	0.007	0.003	2.56
21 Jun 07	1.68	8	0.270	0.253	0.280	0.009	0.003	3.43
21 Jun 07	1.98	8	0.269	0.255	0.293	0.014	0.005	5.20
21 Jun 07	2.29	8	0.272	0.248	0.288	0.013	0.004	4.65
19 Jul 07	0.15	8	0.299	0.280	0.312	0.013	0.005	4.46
19 Jul 07	0.46	8	0.270	0.255	0.289	0.011	0.004	4.25
19 Jul 07	0.76	8	0.241	0.204	0.265	0.020	0.007	8.18
19 Jul 07	1.07	8	0.247	0.234	0.260	0.012	0.004	4.69
19 Jul 07	1.37	8	0.258	0.249	0.264	0.005	0.002	1.91
19 Jul 07	1.68	8	0.262	0.245	0.276	0.010	0.004	3.84
19 Jul 07	1.98	8	0.266	0.248	0.286	0.014	0.005	5.08
19 Jul 07	2.29	8	0.273	0.246	0.291	0.014	0.005	5.16
16 Aug 07	0.15	8	0.329	0.303	0.349	0.018	0.006	5.32
16 Aug 07	0.46	8	0.283	0.259	0.321	0.024	0.009	8.57
16 Aug 07	0.76	8	0.230	0.207	0.267	0.021	0.007	9.09
16 Aug 07	1.07	8	0.214	0.177	0.236	0.017	0.006	8.04
16 Aug 07	1.37	8	0.217	0.178	0.235	0.018	0.006	8.40
16 Aug 07	1.68	8	0.232	0.191	0.256	0.021	0.007	8.92
16 Aug 07	1.98	8	0.246	0.229	0.260	0.012	0.004	4.91
16 Aug 07	2.29	8	0.260	0.236	0.273	0.013	0.005	4.99
2 Oct 07	0.15	8	0.267	0.241	0.307	0.024	0.009	9.15
2 Oct 07	0.46	8	0.246	0.206	0.283	0.026	0.009	10.70
2 Oct 07	0.76	8	0.198	0.167	0.251	0.030	0.010	14.98
2 Oct 07	1.07	8	0.180	0.146	0.221	0.027	0.010	15.25
2 Oct 07	1.37	8	0.181	0.151	0.216	0.026	0.009	14.58
2 Oct 07	1.68	8	0.196	0.160	0.237	0.025	0.009	12.51
2 Oct 07	1.98	8	0.221	0.191	0.251	0.020	0.007	9.14
2 Oct 07	2.29	8	0.240	0.226	0.257	0.013	0.005	5.37

Table 9. Dryland Soil Bulk Density

Bulk density taken from 6 locations within each of the dryland study areas to 2.44 m deep, with values presented as g of soil cm^{-3} of volume.

Depth	N	Mean	Min	Max	SD	SE	COV
m		------------------------------g cm^{-3}------------------------------					
				2005 Dryland			
0.15	6	1.447	1.372	1.520	0.060	0.024	4.13
0.46	6	1.406	1.366	1.448	0.029	0.012	2.05
0.76	6	1.379	1.304	1.440	0.050	0.020	3.61
1.07	6	1.311	1.156	1.438	0.101	0.041	7.68
1.37	6	1.311	1.158	1.454	0.109	0.045	8.34
1.68	6	1.289	1.179	1.376	0.066	0.027	5.12
1.98	6	1.232	1.151	1.313	0.057	0.023	4.64
2.29	6	1.291	1.169	1.384	0.075	0.031	5.79
				2006 Dryland			
0.15	6	1.411	1.336	1.511	0.061	0.025	4.31
0.46	6	1.381	1.315	1.480	0.059	0.024	4.29
0.76	6	1.429	1.403	1.489	0.035	0.014	2.46
1.07	6	1.338	1.203	1.518	0.112	0.046	8.35
1.37	6	1.246	1.188	1.360	0.065	0.026	5.19
1.68	6	1.241	1.170	1.289	0.042	0.017	3.41
1.98	6	1.281	1.209	1.355	0.061	0.025	4.78
2.29	6	1.265	1.174	1.351	0.063	0.026	4.97
				2007 Dryland			
0.15	6	1.454	1.365	1.506	0.048	0.020	3.33
0.46	6	1.367	1.320	1.398	0.028	0.011	2.04
0.76	6	1.405	1.310	1.529	0.086	0.035	6.11
1.07	6	1.377	1.266	1.484	0.097	0.040	7.06
1.37	6	1.371	1.228	1.562	0.115	0.047	8.41
1.68	6	1.282	1.196	1.400	0.085	0.035	6.60
1.98	6	1.303	1.251	1.394	0.052	0.021	3.97
2.29	6	1.312	1.244	1.388	0.056	0.023	4.24

Table 10. Irrigated Soil Bulk Density

Bulk density taken from 6 locations within each of the irrigated study areas to 2.44 m deep with values presented as g of soil cm^{-3} of volume.

Depth	N	Mean	Min	Max	SD	SE	COV
m		-------------------------------g cm^{-3}-------------------------------					
				2005 Irrigated			
0.15	6	1.369	1.309	1.408	0.043	0.017	3.11
0.46	6	1.341	1.289	1.406	0.044	0.018	3.32
0.76	6	1.284	1.202	1.385	0.078	0.032	6.11
1.07	6	1.213	1.201	1.221	0.008	0.003	0.67
1.37	6	1.203	1.165	1.274	0.040	0.016	3.35
1.68	6	1.225	1.152	1.250	0.037	0.015	3.01
1.98	6	1.240	1.139	1.290	0.053	0.022	4.27
2.29	6	1.250	1.217	1.292	0.026	0.011	2.12
				2006 Irrigated			
0.15	6	1.401	1.281	1.453	0.063	0.026	4.53
0.46	6	1.344	1.264	1.493	0.084	0.034	6.23
0.76	6	1.318	1.212	1.494	0.100	0.041	7.58
1.07	6	1.243	1.193	1.342	0.054	0.022	4.33
1.37	6	1.227	1.167	1.387	0.083	0.034	6.74
1.68	6	1.202	1.139	1.347	0.082	0.034	6.83
1.98	6	1.286	1.182	1.363	0.068	0.028	5.29
2.29	6	1.270	1.217	1.353	0.054	0.022	4.23
				2007 Irrigated			
0.15	6	1.381	1.325	1.502	0.069	0.028	5.01
0.46	6	1.305	1.201	1.402	0.072	0.029	5.51
0.76	6	1.299	1.260	1.345	0.033	0.014	2.57
1.07	6	1.233	1.174	1.308	0.052	0.021	4.19
1.37	6	1.234	1.189	1.286	0.036	0.015	2.90
1.68	6	1.283	1.214	1.340	0.042	0.017	3.29
1.98	6	1.263	1.164	1.329	0.059	0.024	4.68
2.29	6	1.240	1.186	1.296	0.044	0.018	3.57

Table 11. Dryland 0.30 m Soil Nutrients

Soil nutrients taken from the top 0.30 m of soil in the dryland environments describing the nutrient contents of the soil.

Nutrient	Units	N	Mean	Min	Max	SD	SE	COV
				2005 Dryland				
pH		6	7.2	7.0	7.6	0.2	0.1	3.34
BrayP	ppm	6	45	37	60	8	3	17.57
Mehlich P	ppm	6	57	48	73	9	3	14.91
OlsenP	ppm	6	32	26	39	5	2	15.18
K	ppm	6	700	620	810	70	29	9.98
NH_4-N	ppm	6	4.10	3.43	5.81	0.92	0.38	22.43
NO_3-N	ppm	6	8.16	4.48	17.17	4.54	1.85	55.69
OM	%	6	1.5	1.5	1.6	0.0	0.0	2.69
CEC	meq 100 g^{-1}	6	19.4	16.2	26.0	3.5	1.4	18.06
				2006 Dryland				
pH		6	7.5	6.9	7.9	0.4	0.2	5.99
BrayP	ppm	6	23	12	35	9	3	36.87
Mehlich P	ppm	6	39	18	61	14	6	36.34
OlsenP	ppm	6	15	9	19	5	2	31.29
K	ppm	6	621	565	650	30	12	4.76
NH_4-N	ppm	6	3.17	2.20	3.70	0.65	0.27	20.53
NO_3-N	ppm	6	5.65	4.10	7.30	1.10	0.45	19.48
OM	%	6	1.5	1.2	2.0	0.3	0.1	18.86
CEC	meq 100 g^{-1}	6	18.7	14.6	21.6	2.4	1.0	13.00
				2007 Dryland				
pH		6	6.8	6.3	7.0	0.3	0.1	3.83
BrayP	ppm	6	34	30	38	3	1	8.92
Mehlich P	ppm	6	43	37	51	5	2	11.57
OlsenP	ppm	6	20	19	22	1	0	5.48
K	ppm	6	678	600	740	49	20	7.20
NH_4-N	ppm	6	3.43	2.40	5.20	1.01	0.41	29.34
NO_3-N	ppm	6	16.65	8.20	48.80	15.99	6.53	96.04
OM	%	6	1.4	1.2	1.7	0.2	0.1	14.03
CEC	meq 100 g^{-1}	6	18.5	15.7	19.6	1.5	0.6	8.04

Table 12. Irrigated 0.30 m Soil Nutrients

Soil nutrients taken from the top 0.30 m of soil in the irrigated environments describing the nutrient contents of the soil.

Nutrient	Units	N	Mean	Min	Max	SD	SE	COV
2005 Irrigated								
pH		6	8.2	7.9	8.5	0.2	0.1	2.82
BrayP	ppm	6	15	11	19	4	1	23.48
Mehlich P	ppm	6	23	15	33	7	3	31.51
OlsenP	ppm	6	7	4	11	3	1	36.14
K	ppm	6	715	660	790	46	19	6.42
NH_4-N	ppm	6	3.90	3.63	4.25	0.25	0.10	6.30
NO_3-N	ppm	6	6.41	3.53	11.52	2.84	1.16	44.25
OM	%	6	1.7	1.6	1.8	0.1	0.0	5.07
CEC	meq 100 g^{-1}	6	21.2	16.7	24.8	2.9	1.2	13.63
2006 Irrigated								
pH		6	8.0	7.9	8.1	0.1	0.0	1.26
BrayP	ppm	6	7	3	12	3	1	43.69
Mehlich P	ppm	6	19	10	37	10	4	52.22
OlsenP	ppm	6	6	3	8	2	1	30.90
K	ppm	6	539	461	580	43	18	8.06
NH_4-N	ppm	6	3.75	3.40	4.50	0.39	0.16	10.50
NO_3-N	ppm	6	9.47	4.80	26.80	8.54	3.49	90.24
OM	%	6	1.6	1.4	1.8	0.1	0.1	8.22
CEC	meq 100 g^{-1}	6	22.5	18.1	25.1	2.5	1.0	11.09
2007 Irrigated								
pH		6	7.9	7.4	8.2	0.3	0.1	3.42
BrayP	ppm	6	8	2	19	6	2	78.55
Mehlich P	ppm	6	15	8	27	7	3	46.38
OlsenP	ppm	6	7	5	13	3	1	43.61
K	ppm	6	525	485	610	45	18	8.61
NH_4-N	ppm	6	3.25	2.50	3.80	0.51	0.21	15.78
NO_3-N	ppm	6	31.92	8.60	68.60	25.08	10.24	78.59
OM	%	6	1.6	1.3	1.8	0.2	0.1	13.38
CEC	meq 100 g^{-1}	6	24.7	18.2	40.9	8.3	3.4	33.56

Table 13. Dryland 0.61 to 2.44 m Soil NH_4 and NO_3

The NH_4-N and NO_3-N concentrations for soil depths of 0.30 to 2.44 m in the dryland environment.

Zone	Variable	N	Mean	Min	Max	SD	SE	COV
m			--------------------------ppm-------------------------					
2005 Dryland								
0.30 - 0.61	NH_4	6	4.8	4.1	5.8	0.7	0.3	13.77
0.30 - 0.61	NO_3	6	6.1	3.0	9.8	2.5	1.0	40.45
0.61 - 0.91	NH_4	6	4.7	4.0	5.7	0.6	0.3	13.46
0.61 - 0.91	NO_3	6	3.8	2.6	5.5	1.0	0.4	27.00
0.91 - 1.22	NH_4	6	4.4	3.7	5.4	0.8	0.3	18.61
0.91 - 1.22	NO_3	6	7.1	3.1	13.1	3.5	1.4	49.11
1.22 - 1.52	NH_4	6	4.0	3.0	5.1	0.8	0.3	21.31
1.22 - 1.52	NO_3	6	8.7	3.1	16.1	4.8	2.0	54.97
1.52 - 1.83	NH_4	6	4.0	3.6	4.4	0.3	0.1	7.79
1.52 - 1.83	NO_3	6	11.5	3.8	25.4	8.6	3.5	74.58
1.83 - 2.13	NH_4	6	4.1	3.8	4.5	0.3	0.1	6.25
1.83 - 2.13	NO_3	6	10.1	3.2	26.0	8.4	3.4	82.70
2.13 - 2.44	NH_4	6	4.1	3.2	4.7	0.6	0.2	13.74
2.13 - 2.44	NO_3	6	8.9	2.7	23.3	7.8	3.2	88.37
2006 Dryland								
0.30 - 0.61	NH_4	6	2.9	2.0	3.7	0.7	0.3	24.53
0.30 - 0.61	NO_3	6	1.6	1.3	1.9	0.2	0.1	13.11
0.61 - 0.91	NH_4	6	3.0	2.1	4.6	1.0	0.4	32.59
0.61 - 0.91	NO_3	6	3.5	1.4	6.6	1.9	0.8	54.18
0.91 - 1.22	NH_4	6	2.8	1.6	3.9	0.8	0.3	30.08
0.91 - 1.22	NO_3	6	5.2	1.3	8.1	2.9	1.2	56.60
1.22 - 1.52	NH_4	6	2.9	2.3	3.4	0.5	0.2	16.76
1.22 - 1.52	NO_3	6	7.1	3.6	10.2	2.7	1.1	38.54
1.52 - 1.83	NH_4	6	2.8	2.2	3.6	0.6	0.2	20.67
1.52 - 1.83	NO_3	6	9.8	6.0	13.7	3.1	1.3	32.05
1.83 - 2.13	NH_4	6	2.6	1.3	3.7	1.0	0.4	40.81
1.83 - 2.13	NO_3	6	7.5	3.3	13.6	4.3	1.8	57.44
2.13 - 2.44	NH_4	6	2.3	1.7	2.7	0.4	0.2	16.81
2.13 - 2.44	NO_3	6	3.3	1.0	8.4	2.8	1.2	86.50
2007 Dryland								
0.30 - 0.61	NH_4	6	4.2	2.6	6.3	1.3	0.5	32.09
0.30 - 0.61	NO_3	6	8.6	1.6	21.4	7.1	2.9	83.27
0.61 - 0.91	NH_4	6	6.2	2.6	15.9	4.9	2.0	79.74
0.61 - 0.91	NO_3	6	18.3	1.6	45.7	15.7	6.4	85.76
0.91 - 1.22	NH_4	6	3.7	2.7	5.5	1.0	0.4	26.44
0.91 - 1.22	NO_3	6	10.8	0.7	22.5	9.4	3.8	87.06
1.22 - 1.52	NH_4	6	4.0	2.4	5.5	1.2	0.5	29.58
1.22 - 1.52	NO_3	6	11.7	2.8	33.3	11.7	4.8	100.01
1.52 - 1.83	NH_4	6	3.3	2.7	4.3	0.7	0.3	22.51
1.52 - 1.83	NO_3	6	8.5	3.8	13.9	4.3	1.8	50.30
1.83 - 2.13	NH_4	6	2.7	1.7	4.3	0.9	0.4	32.70
1.83 - 2.13	NO_3	6	5.4	1.0	11.0	3.6	1.5	66.81
2.13 - 2.44	NH_4	6	3.7	2.0	4.8	1.1	0.5	31.13
2.13 - 2.44	NO_3	6	4.4	0.9	8.7	2.7	1.1	62.70

Table 14. Irrigated 0.61 to 2.44 m Soil NH_4 and NO_3

The NH_4-N and NO_3-N concentrations for soil depths of 0.30 to 2.44 m in the irrigated environment.

Zone	Variable	N	Mean	Min	Max	SD	SE	COV
m			--------------------------ppm-------------------------					
				2005 Irrigated				
0.30 - 0.61	NH_4	6	3.7	3.2	3.9	0.3	0.1	7.45
0.30 - 0.61	NO_3	6	11.5	6.5	21.7	6.7	2.7	58.59
0.61 - 0.91	NH_4	6	3.8	2.9	5.3	0.8	0.3	22.13
0.61 - 0.91	NO_3	6	8.7	4.4	18.2	4.8	2.0	56.06
0.91 - 1.22	NH_4	6	3.6	3.4	4.0	0.2	0.1	6.20
0.91 - 1.22	NO_3	6	8.2	3.2	13.7	4.0	1.6	49.42
1.22 - 1.52	NH_4	6	3.3	2.6	3.5	0.3	0.1	10.06
1.22 - 1.52	NO_3	6	16.8	7.1	38.5	11.6	4.7	69.09
1.52 - 1.83	NH_4	6	3.3	3.0	3.6	0.3	0.1	7.80
1.52 - 1.83	NO_3	6	24.0	5.7	58.6	18.0	7.4	75.26
1.83 - 2.13	NH_4	6	3.3	2.7	4.0	0.5	0.2	15.66
1.83 - 2.13	NO_3	6	23.9	7.1	48.0	13.4	5.5	56.29
2.13 - 2.44	NH_4	6	2.8	2.2	3.1	0.3	0.1	11.29
2.13 - 2.44	NO_3	6	19.5	7.3	32.2	9.3	3.8	47.72
				2006 Irrigated				
0.30 - 0.61	NH_4	6	3.4	2.8	3.8	0.4	0.2	11.06
0.30 - 0.61	NO_3	6	2.1	1.3	3.7	0.9	0.4	43.35
0.61 - 0.91	NH_4	6	3.6	2.5	4.7	0.9	0.4	24.29
0.61 - 0.91	NO_3	6	2.9	1.0	5.4	1.5	0.6	50.71
0.91 - 1.22	NH_4	6	2.8	1.6	4.4	1.0	0.4	36.88
0.91 - 1.22	NO_3	6	3.3	0.7	5.7	1.7	0.7	52.33
1.22 - 1.52	NH_4	6	3.0	2.4	3.7	0.6	0.2	19.73
1.22 - 1.52	NO_3	6	3.0	0.6	4.6	1.5	0.6	48.87
1.52 - 1.83	NH_4	6	2.9	2.0	4.1	0.8	0.3	26.26
1.52 - 1.83	NO_3	6	1.7	0.9	3.4	0.9	0.4	54.20
1.83 - 2.13	NH_4	6	2.7	1.5	4.1	0.8	0.3	31.55
1.83 - 2.13	NO_3	6	1.5	0.5	2.6	0.8	0.3	55.34
2.13 - 2.44	NH_4	6	3.0	2.1	3.9	0.7	0.3	24.79
2.13 - 2.44	NO_3	6	1.7	0.6	4.6	1.5	0.6	85.73
				2007 Irrigated				
0.30 - 0.61	NH_4	6	3.4	2.6	4.0	0.5	0.2	16.21
0.30 - 0.61	NO_3	6	6.5	2.1	10.8	3.2	1.3	49.50
0.61 - 0.91	NH_4	6	3.1	2.3	4.2	0.8	0.3	27.33
0.61 - 0.91	NO_3	6	6.3	1.8	13.6	4.2	1.7	67.22
0.91 - 1.22	NH_4	6	2.8	2.2	3.5	0.5	0.2	18.22
0.91 - 1.22	NO_3	6	3.3	1.9	5.1	1.1	0.5	34.34
1.22 - 1.52	NH_4	6	2.6	1.4	3.2	0.6	0.3	24.22
1.22 - 1.52	NO_3	6	3.4	1.0	7.0	2.0	0.8	59.48
1.52 - 1.83	NH_4	6	3.0	2.1	3.6	0.6	0.2	19.60
1.52 - 1.83	NO_3	6	4.8	0.6	13.0	4.5	1.8	92.94
1.83 - 2.13	NH_4	6	3.0	2.5	4.0	0.6	0.2	20.05
1.83 - 2.13	NO_3	6	3.6	0.5	9.1	3.1	1.3	84.38
2.13 - 2.44	NH_4	6	2.5	1.6	2.9	0.5	0.2	18.39
2.13 - 2.44	NO_3	6	2.9	0.6	9.2	3.2	1.3	108.10

Table 15. Dryland 2005 Soil Particle Size Analysis

Particle size analysis for soil of the 2005 dryland environment. Data are presented as g of clay, sand, or silt kg^{-1} of soil for each 0.30 m zone from the surface to the depth of 2.44 m.

Zone	Size	N	Mean	Min	Max	SD	SE	COV
m			----------------------------	----------------g kg^{-1}	----------------------------			
0.00 - 0.30	Clay	6	264	243	291	17	7	6.33
0.00 - 0.30	Sand	6	250	208	291	36	15	14.35
0.00 - 0.30	Silt	6	486	456	523	30	12	6.10
0.30 - 0.61	Clay	6	314	303	327	10	4	3.14
0.30 - 0.61	Sand	6	224	208	240	13	5	5.62
0.30 - 0.61	Silt	6	462	443	483	17	7	3.61
0.61 - 0.91	Clay	6	315	286	365	27	11	8.47
0.61 - 0.91	Sand	6	157	133	170	16	7	10.40
0.61 - 0.91	Silt	6	528	495	581	29	12	5.56
0.91 - 1.22	Clay	6	316	268	355	30	12	9.39
0.91 - 1.22	Sand	6	129	105	166	23	9	17.46
0.91 - 1.22	Silt	6	555	519	587	23	9	4.08
1.22 - 1.52	Clay	6	258	201	311	36	15	13.82
1.22 - 1.52	Sand	6	148	116	203	31	13	21.12
1.22 - 1.52	Silt	6	594	573	609	12	5	1.98
1.52 - 1.83	Clay	6	205	187	224	13	5	6.33
1.52 - 1.83	Sand	6	178	153	240	33	13	18.33
1.52 - 1.83	Silt	6	618	573	633	23	9	3.67
1.83 - 2.13	Clay	6	197	184	219	13	5	6.57
1.83 - 2.13	Sand	6	186	157	272	43	18	23.29
1.83 - 2.13	Silt	6	617	539	646	40	16	6.44
2.13 - 2.44	Clay	6	184	169	199	10	4	5.48
2.13 - 2.44	Sand	6	197	167	283	43	18	21.98
2.13 - 2.44	Silt	6	619	549	642	35	14	5.61

Table 16. Dryland 2006 Soil Particle Size Analysis

Particle size analysis for soil of the 2006 dryland environment. Data are presented as g of clay, sand, or silt kg^{-1} of soil for each 0.30 m zone from the surface to the depth of 2.44 m.

Zone	Size	N	Mean	Min	Max	SD	SE	COV
m			-------------------------g kg^{-1}--------------------------					
0.00 - 0.30	Clay	6	288	266	316	18	7	6.31
0.00 - 0.30	Sand	6	200	190	207	7	3	3.26
0.00 - 0.30	Silt	6	513	488	528	15	6	2.92
0.30 - 0.61	Clay	6	326	299	355	21	9	6.53
0.30 - 0.61	Sand	6	171	156	180	9	4	5.28
0.30 - 0.61	Silt	6	503	467	526	21	8	4.13
0.61 - 0.91	Clay	6	355	325	407	35	14	9.77
0.61 - 0.91	Sand	6	133	100	156	19	8	14.01
0.61 - 0.91	Silt	6	513	476	548	25	10	4.95
0.91 - 1.22	Clay	6	281	260	329	26	11	9.29
0.91 - 1.22	Sand	6	147	103	183	29	12	19.51
0.91 - 1.22	Silt	6	572	556	587	14	6	2.41
1.22 - 1.52	Clay	6	232	221	250	11	4	4.56
1.22 - 1.52	Sand	6	168	137	197	23	9	13.71
1.22 - 1.52	Silt	6	600	581	627	16	7	2.67
1.52 - 1.83	Clay	6	217	210	226	7	3	3.03
1.52 - 1.83	Sand	6	168	133	203	30	12	18.12
1.52 - 1.83	Silt	6	616	574	650	29	12	4.78
1.83 - 2.13	Clay	6	202	186	220	13	5	6.43
1.83 - 2.13	Sand	6	193	140	316	65	27	34.00
1.83 - 2.13	Silt	6	527	219	657	173	70	32.77
2.13 - 2.44	Clay	6	206	189	231	14	6	6.85
2.13 - 2.44	Sand	6	267	135	549	165	67	61.78
2.13 - 2.44	Silt	6	605	498	657	60	24	9.86

Table 17. Dryland 2007 Soil Particle Size Analysis

Particle size analysis for soil of the 2007 dryland environment. Data are presented as g of clay, sand, or silt kg^{-1} of soil for each 0.30 m zone from the surface to the depth of 2.44 m.

Zone	Size	N	Mean	Min	Max	SD	SE	COV
m			---------------------------g kg^{-1}	----------------------------				
0.00 - 0.30	Clay	6	276	229	315	32	13	11.72
0.00 - 0.30	Sand	6	236	209	251	15	6	6.28
0.00 - 0.30	Silt	6	489	445	541	34	14	6.97
0.30 - 0.61	Clay	6	318	289	350	21	8	6.47
0.30 - 0.61	Sand	6	160	146	181	15	6	9.27
0.30 - 0.61	Silt	6	522	474	562	29	12	5.50
0.61 - 0.91	Clay	6	364	304	417	38	15	10.41
0.61 - 0.91	Sand	6	107	97	113	6	2	5.40
0.61 - 0.91	Silt	6	531	473	593	41	17	7.80
0.91 - 1.22	Clay	6	298	253	360	37	15	12.39
0.91 - 1.22	Sand	6	116	94	135	16	6	13.53
0.91 - 1.22	Silt	6	586	546	612	23	9	3.90
1.22 - 1.52	Clay	6	239	208	337	49	20	20.36
1.22 - 1.52	Sand	6	148	115	166	17	7	11.84
1.22 - 1.52	Silt	6	613	548	642	34	14	5.62
1.52 - 1.83	Clay	6	217	207	237	12	5	5.47
1.52 - 1.83	Sand	6	164	146	178	12	5	7.21
1.52 - 1.83	Silt	6	632	610	651	14	6	2.18
1.83 - 2.13	Clay	6	213	184	244	23	9	10.58
1.83 - 2.13	Sand	6	156	121	180	24	10	15.37
1.83 - 2.13	Silt	6	637	609	677	22	9	3.48
2.13 - 2.44	Clay	6	207	180	237	19	8	9.30
2.13 - 2.44	Sand	6	157	144	173	10	4	6.18
2.13 - 2.44	Silt	6	619	588	634	17	7	2.73

Table 18. Irrigated 2005 Soil Particle Size Analysis

Particle size analysis for soil of the 2005 irrigated environment. Data are presented as g of clay, sand, or silt kg^{-1} of soil for each 0.30 m zone from the surface to the depth of 2.44 m.

Zone	Size	N	Mean	Min	Max	SD	SE	COV
m			----------------------------g kg^{-1}----------------------------					
0.00 - 0.30	Clay	6	279	268	302	13	5	4.59
0.00 - 0.30	Sand	6	189	183	193	4	2	2.04
0.00 - 0.30	Silt	6	532	514	544	12	5	2.28
0.30 - 0.61	Clay	6	314	293	335	16	7	5.17
0.30 - 0.61	Sand	6	150	135	167	14	6	9.43
0.30 - 0.61	Silt	6	536	503	560	19	8	3.46
0.61 - 0.91	Clay	6	266	234	303	22	9	8.44
0.61 - 0.91	Sand	6	151	138	163	8	3	5.52
0.61 - 0.91	Silt	6	583	546	602	19	8	3.32
0.91 - 1.22	Clay	6	220	194	244	20	8	9.15
0.91 - 1.22	Sand	6	157	147	169	8	3	5.03
0.91 - 1.22	Silt	6	624	598	640	17	7	2.71
1.22 - 1.52	Clay	6	207	193	219	11	4	5.12
1.22 - 1.52	Sand	6	152	139	163	9	4	5.86
1.22 - 1.52	Silt	6	642	636	645	4	1	0.55
1.52 - 1.83	Clay	6	194	169	210	16	7	8.26
1.52 - 1.83	Sand	6	154	131	177	16	7	10.68
1.52 - 1.83	Silt	6	653	643	667	10	4	1.55
1.83 - 2.13	Clay	6	191	170	210	17	7	8.81
1.83 - 2.13	Sand	6	160	137	182	16	6	9.93
1.83 - 2.13	Silt	6	649	636	669	13	5	1.94
2.13 - 2.44	Clay	6	196	177	214	16	6	7.99
2.13 - 2.44	Sand	6	156	140	171	11	5	7.34
2.13 - 2.44	Silt	6	649	627	677	20	8	3.15

Table 19. Irrigated 2006 Soil Particle Size Analysis

Particle size analysis for soil of the 2006 irrigated environment. Data are presented as g of clay, sand, or silt kg^{-1} of soil for each 0.30 m zone from the surface to the depth of 2.44 m.

Zone	Size	N	Mean	Min	Max	SD	SE	COV
m			---------------------------g kg^{-1}	------------------------------				
0.00 - 0.30	Clay	6	327	303	371	23	10	7.16
0.00 - 0.30	Sand	6	150	140	159	8	3	5.38
0.00 - 0.30	Silt	6	523	489	538	18	7	3.41
0.30 - 0.61	Clay	6	346	309	435	45	18	13.09
0.30 - 0.61	Sand	6	113	96	129	11	5	9.89
0.30 - 0.61	Silt	6	542	469	584	40	16	7.42
0.61 - 0.91	Clay	6	287	269	318	18	7	6.15
0.61 - 0.91	Sand	6	124	109	137	10	4	8.38
0.61 - 0.91	Silt	6	590	570	606	15	6	2.49
0.91 - 1.22	Clay	6	255	240	265	10	4	4.00
0.91 - 1.22	Sand	6	127	110	136	9	4	7.04
0.91 - 1.22	Silt	6	618	603	629	9	4	1.53
1.22 - 1.52	Clay	6	236	229	248	7	3	3.00
1.22 - 1.52	Sand	6	122	114	133	7	3	5.92
1.22 - 1.52	Silt	6	643	627	652	9	4	1.42
1.52 - 1.83	Clay	6	227	215	238	9	4	4.02
1.52 - 1.83	Sand	6	122	107	133	10	4	7.98
1.52 - 1.83	Silt	6	652	637	670	14	6	2.09
1.83 - 2.13	Clay	6	228	201	258	20	8	8.71
1.83 - 2.13	Sand	6	122	94	140	16	6	13.00
1.83 - 2.13	Silt	6	647	623	669	18	7	2.77
2.13 - 2.44	Clay	6	230	211	246	15	6	6.33
2.13 - 2.44	Sand	6	123	116	140	9	4	7.62
2.13 - 2.44	Silt	6	651	612	680	25	10	3.90

Table 20. Irrigated 2007 Soil Particle Size Analysis

Particle size analysis for soil of the 2007 irrigated environment. Data are presented as g of clay, sand, or silt kg^{-1} of soil for each 0.30 m zone from the surface to the depth of 2.44 m.

Zone	Size	N	Mean	Min	Max	SD	SE	COV
m			------------------------------		g kg^{-1}	------------------------------		
0.00 - 0.30	Clay	6	331	307	373	24	10	7.38
0.00 - 0.30	Sand	6	146	115	168	21	8	14.04
0.00 - 0.30	Silt	6	523	504	541	13	5	2.52
0.30 - 0.61	Clay	6	335	304	374	24	10	7.19
0.30 - 0.61	Sand	6	121	94	148	18	8	15.19
0.30 - 0.61	Silt	6	544	530	562	14	6	2.60
0.61 - 0.91	Clay	6	276	255	301	16	7	5.94
0.61 - 0.91	Sand	6	128	116	136	7	3	5.66
0.61 - 0.91	Silt	6	596	572	621	20	8	3.31
0.91 - 1.22	Clay	6	251	236	268	12	5	4.82
0.91 - 1.22	Sand	6	138	127	152	9	4	6.39
0.91 - 1.22	Silt	6	612	597	633	15	6	2.47
1.22 - 1.52	Clay	6	233	221	246	10	4	4.41
1.22 - 1.52	Sand	6	132	122	149	9	4	6.82
1.22 - 1.52	Silt	6	635	605	652	18	7	2.81
1.52 - 1.83	Clay	6	224	213	239	10	4	4.37
1.52 - 1.83	Sand	6	134	114	154	13	5	9.99
1.52 - 1.83	Silt	6	642	625	660	14	6	2.22
1.83 - 2.13	Clay	6	226	206	239	14	6	6.04
1.83 - 2.13	Sand	6	139	114	160	15	6	11.11
1.83 - 2.13	Silt	6	641	630	661	10	4	1.63
2.13 - 2.44	Clay	6	226	217	238	8	3	3.57
2.13 - 2.44	Sand	6	134	122	143	9	4	6.75
2.13 - 2.44	Silt	6	635	602	666	23	9	3.63

Table 21. Dryland Wilting Point Water Content

Wilting point water content (-1.5 MPa matric potential) for each of the dryland soils used in the study for every 0.30 m zone from the surface to 2.44 m. Data are presented in g of H_2O g^{-1} of dry soil.

Zone	N	Mean	Min	Max	SD	SE	COV
m		--------------------------------g g^{-1}	--------------------------------				
			2005 Dryland				
0.00 – 0.30	6	0.127	0.110	0.139	0.011	0.004	8.32
0.30 – 0.61	6	0.139	0.133	0.147	0.006	0.002	4.13
0.61 – 0.91	6	0.140	0.131	0.161	0.011	0.004	7.85
0.91 – 1.22	6	0.152	0.134	0.165	0.011	0.005	7.41
1.22 – 1.52	6	0.139	0.114	0.155	0.015	0.006	10.58
1.52 – 1.83	6	0.121	0.105	0.127	0.008	0.003	6.64
1.83 – 2.13	6	0.114	0.101	0.119	0.007	0.003	5.79
2.13 – 2.44	6	0.109	0.095	0.116	0.008	0.003	6.94
			2006 Dryland				
0.00 – 0.30	6	0.126	0.122	0.133	0.004	0.002	3.26
0.30 – 0.61	6	0.141	0.134	0.150	0.007	0.003	5.05
0.61 – 0.91	6	0.155	0.134	0.180	0.018	0.007	11.79
0.91 – 1.22	6	0.130	0.114	0.161	0.018	0.007	13.68
1.22 – 1.52	6	0.116	0.111	0.127	0.007	0.003	5.92
1.52 – 1.83	6	0.111	0.106	0.120	0.005	0.002	4.75
1.83 – 2.13	6	0.107	0.091	0.118	0.009	0.004	8.36
2.13 – 2.44	6	0.099	0.077	0.113	0.015	0.006	15.11
			2007 Dryland				
0.00 – 0.30	6	0.118	0.102	0.133	0.013	0.005	10.91
0.30 – 0.61	6	0.139	0.127	0.150	0.008	0.003	5.61
0.61 – 0.91	6	0.168	0.156	0.178	0.008	0.003	4.87
0.91 – 1.22	6	0.150	0.134	0.176	0.015	0.006	9.97
1.22 – 1.52	6	0.127	0.116	0.161	0.017	0.007	13.47
1.52 – 1.83	6	0.115	0.109	0.121	0.005	0.002	4.34
1.83 – 2.13	6	0.115	0.105	0.128	0.008	0.003	7.38
2.13 – 2.44	6	0.113	0.108	0.124	0.006	0.002	5.26

Table 22. Irrigated Wilting Point Water Content

Wilting point water content (-1.5 MPa matric potential) for each of the irrigated soils used in the study for every 0.30 m zone from the surface to 2.44 m. Data are presented in g of H_2O g^{-1} of dry soil.

Zone	N	Mean	Min	Max	SD	SE	COV
m		--------------------------------g g^{-1}	--------------------------------				
				2005 Irrigated			
0.00 – 0.30	6	0.146	0.141	0.155	0.005	0.002	3.72
0.30 – 0.61	6	0.151	0.143	0.161	0.006	0.003	4.09
0.61 – 0.91	6	0.131	0.122	0.145	0.008	0.003	5.95
0.91 – 1.22	6	0.118	0.114	0.121	0.003	0.001	2.40
1.22 – 1.52	6	0.117	0.113	0.119	0.003	0.001	2.22
1.52 – 1.83	6	0.113	0.110	0.118	0.003	0.001	2.63
1.83 – 2.13	6	0.115	0.106	0.123	0.006	0.002	5.05
2.13 – 2.44	6	0.112	0.108	0.120	0.005	0.002	4.01
				2006 Irrigated			
0.00 – 0.30	6	0.151	0.138	0.179	0.015	0.006	9.82
0.30 – 0.61	6	0.159	0.143	0.195	0.019	0.008	11.74
0.61 – 0.91	6	0.133	0.128	0.145	0.006	0.003	4.77
0.91 – 1.22	6	0.121	0.112	0.131	0.007	0.003	5.58
1.22 – 1.52	6	0.120	0.115	0.129	0.005	0.002	4.06
1.52 – 1.83	6	0.118	0.113	0.131	0.007	0.003	5.84
1.83 – 2.13	6	0.119	0.108	0.144	0.013	0.005	11.12
2.13 – 2.44	6	0.119	0.110	0.139	0.011	0.004	9.00
				2007 Irrigated			
0.00 – 0.30	6	0.157	0.143	0.191	0.018	0.007	11.25
0.30 – 0.61	6	0.154	0.138	0.171	0.013	0.005	8.26
0.61 – 0.91	6	0.130	0.124	0.141	0.006	0.003	4.82
0.91 – 1.22	6	0.121	0.112	0.126	0.005	0.002	4.12
1.22 – 1.52	6	0.116	0.112	0.118	0.003	0.001	2.18
1.52 – 1.83	6	0.115	0.107	0.119	0.004	0.002	3.75
1.83 – 2.13	6	0.115	0.110	0.120	0.003	0.001	3.00
2.13 – 2.44	6	0.114	0.110	0.119	0.003	0.001	2.68

Table 23. Air Temperature

Max air temperature, min air temperature, mean air temperature, and departure from the 30 yr avg for each month during the growing season for all 3 yr. Air temperature data were taken from the weather station at the dryland field.

	April		May		June		July		August		September		October	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
	---°C---													
	2005													
Average	18.4	1.4	24.1	7.0	29.9	13.2	34.4	15.8	31.6	14.9	29.7	12.1	21.7	4.0
Extreme	28.7	-6.3	37.6	-1.3	37.6	6.5	42.0	7.6	40.4	10.9	36.5	4.3	34.8	-5.7
Mean	9.9		15.6		21.6		25.1		23.3		20.9		12.8	
Departure	0.4		0.6		0.3		0.9		0.0		2.7		1.6	
	2006													
Average	22.9	2.7	26.6	8.1	32.1	14.5	34.7	17.5	32.4	15.9	25.1	7.8	19.9	2.8
Extreme	33.7	-6.9	37.6	0.4	38.7	9.3	42.0	12.6	39.8	7.6	34.3	0.9	34.8	-6.9
Mean	12.8		17.4		23.3		26.1		24.1		16.4		11.3	
Departure	3.3		2.4		2.0		1.9		0.9		-1.8		0.1	
	2007													
Average	15.3	0.7	24.2	8.3	29.3	12.7	33.7	15.7	34.2	17.7	30.3	11.3	23.1	4.2
Extreme	29.3	-7.4	30.9	2.6	34.8	2.6	39.8	11.5	39.8	11.5	38.1	4.3	34.8	-3.0
Mean	8.0		16.2		21.0		24.7		26.0		20.8		13.6	
Departure	-1.5		1.2		-0.3		0.4		2.7		2.5		2.4	
30 Yr Avg	9.5		15.0		21.3		24.3		23.3		18.3		11.3	

Table 24. Precipitation

Recorded precipitation in mm for each month and the departure from the 30 yr avg. of the three growing seasons, taken at both the dryland and irrigated fields. The amount of irrigation that was added was included for the irrigated field.

	Monthly Precipitation						6 mo Total	Annual Total**
	Apr.	May	Jun.	Jul.	Aug.	Sept.	Apr. - Sept.	Jan.-Dec.
	mm							
				2005 Dryland				
Actual	46.5	41.7	113.8	30.7	97.8	8.6	339.1	482.3
Departure	13.7	-28.4	47.2	-48.0	44.7	-24.6	4.6	39.4
				2006 Dryland				
Actual	4.6	40.6	77.5	53.6	39.6	25.4	241.3	483.1
Departure	-28.2	-29.5	10.9	-25.1	-13.5	-7.9	-93.2	40.1
				2007 Dryland				
Actual	84.3	27.7	36.3	12.7	84.1	18.5	263.7	368.8
Departure	51.6	-42.4	-30.2	-66.0	31.0	-14.7	-70.9	-74.2
30 Yr Avg	32.8	70.1	66.5	78.7	53.1	33.3	334.5	443.0
				2005 Irrigated				
Actual	79.0	54.1	120.7	19.3	116.1	39.4	428.5	428.5
Departure	47.8	-17.5	64.5	-54.6	63.2	6.6	110.0	110.0
Irrigation		44.5	37.8	185.9	132.3		400.6	
				2006 Irrigated				
Actual	4.3	40.4	61.0	42.2	9.9	30.0	187.7	187.7
Departure	-26.9	-31.2	4.8	-31.8	-42.9	-2.8	-130.8	-130.8
Irrigation	73.9*	58.7	119.4	170.2	160.8		582.9	
				2007 Irrigated				
Actual	96.5	29.2	74.2	52.3	67.8	8.1	328.2	328.2
Departure	65.3	-42.4	18.0	-21.6	15.0	-24.6	9.7	9.7
Irrigation			24.1	160.5	148.6		333.2	
30 Yr Avg	31.2	71.6	56.1	73.9	52.8	32.8	318.5	318.5

*Irrigation April 2006 is preplant irrigation.

**Yearly total for irrigated field is only recorded for 6 mo.

Table 25. Grain Yield

Mean grain yield for treatments in all environments along with the statistical significance level (P>F) from ANOVA. Grain yields for treatments are not statistically different when represented by the same LSD letter.

Trt	2005 Dryl.	2006 Dryl.	2007 Dryl.	2005 Irrig.	2006 Irrig.	2007 Irrig.
	kg ha^{-1}					
1	245i	41i	496de	10207e	13645e	15547bcd
2	715hi	250hi	373de	13638a	14076e	14680defg
3	3412bcd	1368defgh	382de	12875abc	15407bc	16237ab
4	3867bcd	1507cdefg	2293abcd	12938ab	15378bcd	14292fgh
5	4941abc	2851ab	3131ab	12473abc	13749e	13341h
6	3531bcd	2345abcd	3463a	11939bcd	14039e	14575defg
7	1817defghi	303fghi	1763abcde	13643a	16501ab	15887abc
8	3014def	1695bcde	1116bcde	12903abc	16119ab	15536bcd
9	2346defgh	1849bcde	2262abcde	12603abc	13562e	14981cdef
10	5044ab	2627abc	760cde	12486abc	15425bc	14510efg
11	3341bcde	3189a	2843abc	12900abc	13584e	14104fgh
12	1525efghi	640efghi	2839abc	9665e	15832abc	14882def
13	2782defg	752efghi	1375abcde	11871bcd	14658cde	15325bcde
14	2914def	1287defgh	955bcde	12074abc	15525abc	14675defg
15	3123cdef	288ghi	886bcde	10123e	14147e	15402bcde
16	1372fghi	1523cdef	298de	12529abc	16736a	16810a
17	5774a	2805ab	2906abc	10373de	14178de	13763gh
18	979ghi	1178defgh	25e	11275cde	16296ab	15297bcde
Mean Grain Yield	2822	1472	1565	12029	14936	14991
P>F	<0.0001	<0.0001	0.0273	<0.0001	<0.0001	<0.0001

Table 26. Dryland GDD and Days to the Initiation of Silking

GDD to initiation of silking and number of days to initiation of silking in the dryland environment for the three growing seasons. Treatment means are not statistically different when LSD lettering is the same within an individual season and measurement. Regression models relating crop maturity to grain yield are included at the bottom with GDD to initiation of silking or number of days to initiation of silking as the independent (X) variable and grain yield as the dependent (Y) variable.

Trt	2005 Dryl.	2006 Dryl.	2007 Dryl.	2005 Dryl.	2006 Dryl.	2007 Dryl.
	--------GDD to Initiation of Silking----------			----------Days to Initiation of Silking-----------		
1	848ab	907a	752cd	76ab	68ab	67cd
2	830bcd	879a	822a	75bcd	67a	72a
3	734gh	752defg	716cdef	68gh	57efg	64cdef
4	697hi	724fg	663fg	65h	56fg	60fg
5	697i	656h	615g	65h	51h	57g
6	829bcd	879a	745cde	75bcd	67a	66cd
7	795def	801cde	726cde	72def	61de	65cde
8	762fg	760def	726cde	70fg	58ef	65cde
9	788ef	786de	736cde	72ef	60ef	66cde
10	724hi	742efg	712def	67gh	57efg	64def
11	708hi	692gh	615g	66h	53gh	57g
12	763fg	864abc	713def	70fg	65abcd	64def
13	814bcde	738defg	760cd	74bcde	56efg	67cd
14	838bc	804abcde	745cd	76bc	61bcde	66cd
15	806cde	803cd	713def	73cde	61de	64def
16	882a	874ab	766bc	79a	66abc	68bc
17	731ghi	745defg	692ef	68gh	57efg	62ef
18	851ab	805bcde	814ab	76ab	61cde	71ab
P>F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Model	Y=-20.532X+18691	Y=-8.563X+7985	Y=-13.417X+10953	Y=-291.08X+23408	Y=-121.20X+8508	Y=-182.61X+13045
r^2	0.483	0.316	0.285	0.488	0.315	0.284
RMSE	1135	842	994	1130	843	994
P	0.0014	0.0153	0.0226	0.0013	0.0154	0.0226

Table 27. Irrigated GDD and Days to the Initiation of Silking

GDD to initiation of silking and number of days to initiation of silking in the irrigated environment of three growing seasons. Treatment means are not statistically different when LSD lettering is the same within an individual season and measurement. Regression models relating crop maturity to grain yield are included at the bottom with GDD to initiation of silking or number of days to initiation of silking as the independent (X) variable and grain yield as the dependent (Y) variable.

Trt	2005 Irrig.	2006 Irrig.	2007 Irrig.	2005 Irrig.	2006 Irrig.	2007 Irrig.
	---------GDD to Initiation of Silking----------			------------Days to Initiation of Silking-----------		
1	804a	787ab	715ab	71a	69ab	66a
2	785abc	784ab	698bcd	70abcd	68ab	64bc
3	750cd	689f	641ef	67def	61f	60ef
4	735de	696f	634f	66ef	62f	60f
5	649f	709ef	612g	60g	63ef	58g
6	801a	794a	718a	71ab	69a	66a
7	757bcd	743cd	690cd	68cde	65cd	64bc
8	760bcd	727de	691cd	68cde	64de	64bc
9	750cd	767bc	694cd	67def	67bc	64bc
10	711e	689f	641ef	64f	61f	60ef
11	649f	689f	612g	60g	61f	58g
12	760bcd	703ef	687d	68cde	62ef	64c
13	767abcd	700f	654e	68bcde	62f	61de
14	792ab	764bc	705abc	70abc	67bc	65ab
15	754bcd	763bc	691cd	67cde	67bc	64bc
16	771abcd	767bc	683d	69abcde	67bc	63c
17	750cd	706ef	658e	67def	63ef	62d
18	760bcd	693f	690cd	68cde	62f	64bc
P>F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Model	Y=-7.163X+17367	Y=-2.101X+16470	Y=10.831X+7786	Y=-97.32X+18522	Y=-30.53X+16899	Y=150.46X+5671
r^2	0.067	0.005	0.156	0.064	0.006	0.158
RMSE	1211	1125	820	1213	1125	820
P	0.3009	0.7788	0.1045	0.3114	0.7631	0.1026

Table 28. Dryland 2005 Measurement ANOVA

Treatment means and ANOVA results summary for all characteristics taken in the Dryland 2005 environment. LSD letters are included for all characteristics that were significantly different at the $p < 0.05$ level. Data are not statistically different when represented by the same letter. The following abbreviations are used, CT is Δ_T, CC is percentage of canopy cover, LP is leaf P, LN is leaf N, LC is leaf color, GLN is green leaf number, TLN is total leaf number, ELAN is ear leaf angle, ELAR is ear leaf area, NI is number of internodes, PH is plant height, PP is plant population, TP is tiller population, EP is ear population, KW is 100 kernel weight adjusted to 0.155 kg of water kg^{-1} of moist grain, and BIO is dry biomass.

Trt	CT	CC	LP	LN	LC	GLN	TLN	ELAN
	°C	% $\mu mol\ m^{-2}s^{-1}$	% P	% N	SPAD Units	leaves plt^{-1}	leaves plt^{-1}	degrees
1	0.7	60.8	0.228de	1.68ef	46.0bcdefg	7.61fg	21.32a	15.3fg
2	0.7	69.8	0.228de	1.67ef	45.3bcdefg	9.99cde	20.09cde	15.1g
3	0.2	65.5	0.233bcde	1.78def	45.1bcdefg	10.24bcd	19.84cdef	16.4efg
4	0.8	65.9	0.265ab	1.90bcde	48.1abcde	10.11bcde	19.81cdef	19.0bcdef
5	1.2	70.0	0.208e	1.77def	46.6bcdef	8.57def	19.67ef	25.1a
6	0.2	58.0	0.233bcde	1.85cde	42.1g	11.96ab	22.53	11.5h
7	0.7	70.8	0.260abc	1.93bcd	43.3efg	10.86abc	19.79def	16.5efg
8	0.5	69.3	0.273a	2.05abc	44.4cdefg	9.95cde	18.83g	19.6bcde
9	0.5	61.5	0.263ab	2.05abc	49.2ab	10.91abc	19.75ef	18.1cdefg
10	0.8	68.5	0.253abcd	2.16a	51.7a	11.10abc	19.67ef	22.3ab
11	1.1	68.0	0.170f	1.77def	45.0bcdefg	8.35ef	18.92g	24.8a
12	0.9	73.8	0.173f	1.62f	45.3bcdefg	6.21g	20.29c	20.8bc
13	1.1	68.3	0.218e	1.75def	43.0fg	11.03abc	19.62f	15.1g
14	0.4	66.0	0.278a	2.12ab	46.9bcdef	12.54a	20.83b	17.3defg
15	0.5	65.8	0.250abcd	2.06abc	49.2ab	10.83abc	20.25cd	22.3ab
16	0.8	68.8	0.230cde	2.02abc	48.5abc	11.31abc	20.13cde	18.8cde
17	0.6	64.5	0.250abcd	1.75def	43.8defg	9.89cde	19.62f	16.8efg
18	0.7	76.5	0.250abcd	2.03abc	47.9abcd	11.02abc	20.92ab	20.6bcd
P>F	0.0696	0.2634	<0.0001	<0.0001	0.0044	<0.0001	<0.0001	<0.0001

Trt	ELAR	NI	PH	PP	TP	EP	KW	BIO
	cm^2	No. plt^{-1}	cm	plts ha^{-1}	tillers ha^{-1}	ears ha^{-1}	g	kg ha^{-1}
1	607.2bc	15.50	147j	39917	50853cde	3281h	22.0j	10697
2	613.0bc	14.09bcd	151ij	40737	62609ab	6835gh	29.9defg	11563
3	583.3cde	13.84bcde	170ab	42104	36636fg	27614bcd	31.4cde	13619
4	611.9bc	13.81bcde	166abc	41622	23202h	32658abc	31.7cde	13795
5	523.5gi	13.67de	163cde	43169	40061fg	40018a	31.5cde	12665
6	721.3	16.54	177	41831	15584h	31715abc	27.3fghi	11594
7	632.5ab	13.79cde	159efg	40910	45658def	18117defg	25.8hij	12776
8	649.2a	12.83f	157fgh	42378	33629g	31168abc	31.2de	10611
9	552.6efg	13.75de	156fghi	40190	45385def	22419cdef	30.5def	11900
10	572.0def	13.67de	165bcd	42104	19958h	37183ab	36.1ab	12346
11	492.7i	12.92f	153hi	39917	59055bc	28161abcd	29.5efg	11170
12	540.9fg	14.29b	154ghi	41657	37332fg	16951defg	30.0defg	10120
13	556.8efg	13.62e	155fghi	42378	71085a	27614bcd	25.3ij	11918
14	638.4ab	14.83a	172a	41557	41831efg	21872cdef	37.1a	12508
15	548.2fg	14.25bc	167abc	40464	53040bcd	26794bcde	34.8abc	13001
16	629.0ab	14.13bcd	160def	40190	45658def	14764efgh	33.2bcd	11761
17	593.1cd	13.62e	156fghi	40190	42924efg	38276ab	29.0efgh	12779
18	564.4def	14.92a	167abc	41284	69991a	12303fgh	26.8ghi	11621
P>F	<0.0001	<0.0001	<0.0001	0.2429	<0.0001	<0.0001	<0.0001	0.0601

Table 29. Dryland 2006 Measurement ANOVA

Treatment means and ANOVA results summary for all characteristics taken in the Dryland 2006 environment. LSD letters are included for all characteristics that were significantly different at the $p < 0.05$ level. Data are not statistically different when represented by the same letter. The following abbreviations are used, CC is percentage of canopy cover, GLN is green leaf number, TLN is total leaf number, ELAN is ear leaf angle, NI is number of internodes, LI is length of internodes, PP is plant population, TP is tiller population, EP is ear population, KW is 100 kernel weight adjusted to 0.155 kg of water kg^{-1} of moist grain, and BIO is dry biomass.

Trt	CC	GLN	TLN	ELAN	NI
	% µmol m^{-2}s^{-1}	leaves plt^{-1}	leaves plt^{-1}	degrees	No. plt^{-1}
1	67.3	7.23	20.64ab	17.0g	13.08bcd
2	68.5	7.79	19.63c	15.8g	12.38ef
3	67.5	8.04	19.91c	18.0efg	13.09bcd
4	68.5	7.98	19.54c	21.8cd	12.21fg
5	62.0	6.61	19.46c	24.7ab	12.88bcde
6	66.5	7.61	22.08	15.8g	14.79
7	66.8	8.40	19.54c	20.9cd	12.46def
8	73.0	7.79	18.71d	20.7cd	11.63g
9	58.8	6.19	19.52c	17.2g	12.96bcde
10	74.5	10.19	19.83c	20.2def	12.75bcdef
11	58.8	6.71	18.84d	26.4a	11.58g
12	71.0	8.13	21.04a	22.1bcd	13.38b
13	76.5	7.44	19.87c	18.0efg	12.92bcde
14	65.0	8.56	20.89ab	17.6fg	14.08a
15	66.5	8.73	20.84ab	18.0efg	14.09a
16	60.5	8.04	20.54b	22.2bcd	13.25bc
17	67.8	8.42	19.67c	20.5cde	12.67cdef
18	71.5	7.56	20.92ab	22.9bc	12.63cdef
P>F	0.1378	0.8954	<0.0001	<0.0001	<0.0001

Trt	LI	PP	TP	EP	KW	BIO
	cm	plts ha^{-1}	tillers ha^{-1}	ears ha^{-1}	g	kg
1	8.74	48939abc	38003abcd	1094j	23.65fghi	12000
2	10.38def	42924d	47846a	2461ij	30.67bcde	9190
3	11.03bcde	47846bc	17498fg	14490efgh	28.66defg	10674
4	11.58abc	45385cd	3828h	17771def	29.14bcdef	11253
5	11.02bcde	49486abc	13123gh	39643a	24.60hi	10662
6	10.04ef	46342bcd	18318fg	29528abc	29.90bcde	10386
7	10.69cdef	47572bc	31715bcde	4374hij	26.99efghi	11057
8	12.12a	46205bcd	17771fg	17771def	26.76efghi	10753
9	10.55cdef	45658bcd	31715bcde	20779cde	28.72cdefg	9733
10	11.26abcd	47572bc	16131fgh	25427bcd	32.37abc	10914
11	11.42abcd	48939abc	42104abc	36909a	27.01efghi	11421
12	10.92cdef	47572bc	34996bcd	16603defg	27.91defgh	9735
13	10.67cdef	52493a	32262bcde	9843fghij	25.37ghi	12980
14	9.97ef	45658bcd	31168cde	12850efghi	34.76a	12626
15	9.87f	46132bcd	43975ab	6509ghij	32.56ab	9537
16	10.64cdef	47572bc	21599efg	19412cdef	31.49abcd	10818
17	10.97bcde	45658bcd	15311fgh	33082ab	23.45i	9756
18	12.01ab	50033ab	27340def	18591def	27.89defgh	11489
P>F	<0.0001	0.0474	<0.0001	<0.0001	<0.0001	0.1189

Table 30. Dryland 2007 Measurement ANOVA

Treatment means and ANOVA results summary for all characteristics taken in the Dryland 2007 environment. LSD letters are included for all characteristics that were significantly different at the $p < 0.05$ level. Data are not statistically different when represented by the same letter. The following abbreviations are used, PP is plant population, TP is tiller population, EP is ear population, KW is 100 kernel weight adjusted to 0.155 kg of water kg^{-1} of moist grain, and BIO is dry biomass.

Trt	PP	TP	EP	KW	BIO
	plts ha^{-1}	tillers ha^{-1}	ears ha^{-1}	g	kg ha^{-1}
1	51400ab	46205a	10116cd	29.44	8759
2	49486bcdef	36909a	10663cd	20.06	7617
3	49759bcdef	0h	8202cd	22.83	8179
4	47846cdef	0h	22419abc	25.80	10977
5	51400ab	5195efgh	39097a	24.35	9069
6	47025def	1094gh	39097a	26.19	12266
7	50306bcd	10389defg	24333abc	26.30	9649
8	50853abc	1914fgh	17498bcd	21.54	9662
9	50033bcde	19138bcd	24880abc	29.52	9317
10	50033bcde	4648fgh	12850cd	24.25	8082
11	47025def	25153b	33629ab	24.31	8317
12	50033bcde	547h	39917a	23.45	11939
13	53860a	24059bc	16951bcd	24.74	9006
14	46479f	2734fgh	10116cd	28.48	8908
15	46752ef	11483def	18591bcd	26.35	9538
16	50306bcd	2734fgh	9022cd	28.76	8170
17	48119bcdef	547h	34449ab	19.88	9127
18	50580abc	14490cde	1094d	29.46	8206
P>*F*	0.0046	<0.0001	0.0004	0.1002	0.1827

Table 31. Irrigated 2005 Measurement ANOVA

Treatment means and ANOVA results summary for all characteristics taken in the Irrigated 2005 environment. LSD letters are included for all characteristics that were significantly different at the $p < 0.05$ level. Data are not statistically different when represented by the same letter. The following abbreviations are used, CT is Δ_T, CC is percentage of canopy cover, LP is leaf P, LN is leaf N, LC is leaf color, GLN is green leaf number, TLN is total leaf number, ELAN is ear leaf angle, ELAR is ear leaf area, NI is number of internodes, PH is plant height, PP is plant population, TP is tiller population, EP is ear population, and KW is 100 kernel weight adjusted to 0.155 kg of water kg^{-1} of moist grain.

Trt	CT	CC	LP	LN	LC	GLN	TLN	ELAN
	°C	% µmol m^{-2}s^{-1}	% P	% N	SPAD Units	leaves plt^{-1}	leaves plt^{-1}	degrees
1	-3.2	84.8cde	0.185cdef	1.87cde	48.3f	14.43ab	21.56ab	18.8gh
2	-2.8	81.0cdefg	0.198abcde	2.04abcd	52.2de	13.85bcd	20.61c	18.8gh
3	-2.6	83.3cdefg	0.170ef	1.82de	52.7cde	12.98ef	19.29hi	17.3h
4	-2.4	82.8cdefg	0.213abc	2.03bcd	52.6cde	12.86ef	19.63efgh	22.4def
5	-2.8	93.5a	0.185cdef	1.95bcde	54.2bcd	12.84ef	19.67efgh	28.9a
6	-2.5	72.0h	0.193bcdef	2.08abcd	49.9ef	15.25	22.00a	16.4h
7	-2.5	87.0abcd	0.215ab	2.14abc	52.0def	14.06abc	19.75efg	23.5cde
8	-2.8	78.3efgh	0.225a	2.34a	55.6abcd	13.25de	19.00ij	23.0def
9	-2.7	80.3defg	0.213abc	2.20ab	56.1abc	13.25de	19.54fgh	21.8ef
10	-2.9	87.5abc	0.210abcd	2.21ab	57.1ab	12.94ef	19.54fgh	25.8bc
11	-2.6	85.0bcde	0.208abcd	2.14abc	54.7abcd	12.08gh	18.71j	26.8ab
12	-2.7	84.3cdef	0.165f	1.71e	49.1ef	11.75h	19.92def	24.0cde
13	-2.6	77.3fgh	0.200abcd	2.18ab	53.7bcd	13.88bc	19.75efg	20.8fg
14	-2.6	76.5gh	0.213abc	2.18ab	55.1abcd	14.54a	20.54c	23.8cde
15	-2.8	82.8cdefg	0.215ab	2.18ab	53.9bcd	13.71cd	20.05de	25.9bc
16	-2.8	83.8cdef	0.183def	2.20ab	56.6ab	13.90bc	20.25cd	24.6bcd
17	-2.7	88.0abc	0.208abcd	1.95bcde	49.8ef	12.58fg	19.46ghi	20.7fg
18	-2.7	92.0ab	0.213abc	2.23ab	58.1a	13.67cd	21.08b	22.1ef
P>F	0.5032	<0.0001	0.0038	0.0074	<0.0001	<0.0001	<0.0001	<0.0001

Trt	ELAR	NI	PH	PP	TP	EP	KW
	cm^{2}	No. plt^{-1}	cm	plts ha^{-1}	tillers ha^{-1}	ears ha^{-1}	g
1	709.6bcde	15.57a	220abcde	80107bcdef	547	71085efg	36.86a
2	742.6ab	14.61b	228a	84755ab	0	83115ab	34.26c
3	626.1hi	13.29gh	211defg	82841abcde	0	81748abcd	33.96cd
4	702.1cde	13.63defg	212cdef	76280efgh	0	73545defg	33.29cde
5	605.9i	13.67defg	200ghi	78740bcdefg	273	80107abcd	33.99cd
6	768.7a	16.00a	230a	76553efgh	0	75733bcdef	31.94efg
7	731.3bc	13.75def	216bcde	84208abc	0	82294abc	33.34cde
8	718.1bcd	13.00hi	196i	77647cdefgh	0	76006bcdef	30.48fg
9	690.5def	13.54efg	209efgh	74639fgh	0	70811efg	33.25cde
10	659.2fgh	13.54efg	212cdef	83388abcd	0	83115ab	34.75bc
11	600.7i	12.71i	201fghi	77100defgh	273	78193bcde	30.70fg
12	655.2fgh	13.92cde	197hi	81474bcde	0	74639cdefg	30.32g
13	655.0fgh	13.75def	216bcde	88856a	0	88036a	26.95
14	719.6bcd	14.54b	224abc	71905h	0	69444fg	36.11ab
15	674.7efg	14.05cd	216bcde	73272gh	0	66984g	33.08cde
16	709.8bcde	14.25bc	222abcd	79014bcdefg	0	75733bcdef	32.26def
17	677.3efg	13.46fg	201fghi	77100defgh	0	76006bcdef	23.8
18	652.2gh	15.08	226ab	78740bcdefg	273	76553bcdef	33.05cde
P>F	<0.0001	<0.0001	<0.0001	0.0003	0.6376	0.0003	<0.0001

Table 32. Irrigated 2006 Measurement ANOVA

Treatment means and ANOVA results summary for all characteristics taken in the Irrigated 2006 environment. LSD letters are included for all characteristics that were significantly different at the $p < 0.05$ level. Data are not statistically different when represented by the same letter. The following abbreviations are used, CT is Δ_T, CC is percentage of canopy cover, LP is leaf P, LN is leaf N, LC is leaf color, GLN is green leaf number, TLN is total leaf number, ELAN is ear leaf angle, ELAR is ear leaf area, NI is number of internodes, LI is length of internodes, PP is plant population, TP is tiller population, EP is ear population, and KW is 100 kernel weight adjusted to 0.155 kg of water kg^{-1} of moist grain.

Trt	CT	CC	LP	LN	LC	GLN	TLN	ELAN
	°C	% µmol $m^{-2}s^{-1}$	% P	% N	SPAD Units	leaves plt^{-1}	leaves plt^{-1}	degrees
1	-3.4	83.3cde	0.185de	1.77f	51.3gh	11.57defg	20.50a	20.0kl
2	-3.1	79.5e	0.203bcde	2.19abcde	53.2efg	11.79cdef	20.00bc	25.8def
3	-3.4	87.3abcd	0.203bcde	2.25abcd	55.5cde	11.24efg	19.46efg	18.8l
4	-3.7	81.3de	0.203bcde	1.93ef	52.7fg	11.09gh	19.71cdef	23.8fghi
5	-3.4	87.0abcd	0.265a	2.36ab	55.0cdef	10.55h	19.79cde	32.0a
6	-3.4	81.3de	0.205bcd	2.20abcde	52.9efg	13.85	22.08	20.6jkl
7	-3.8	85.3bcde	0.220bcd	2.29abc	53.7defg	12.24bc	19.50efg	23.1ghi
8	-3.1	85.0bcde	0.228bc	2.31abc	56.9abc	11.27efg	18.92hi	27.2cd
9	-3.7	82.3cde	0.215bcd	2.34ab	57.5abc	12.47ab	19.96bcd	21.5ijk
10	-3.0	88.3abc	0.235ab	2.34ab	57.6abc	11.14fgh	19.33fgh	30.2ab
11	-3.3	85bcde	0.235ab	2.41a	56.6bc	9.88i	18.67i	31.0a
12	-3.3	92.8a	0.235ab	2.34ab	59.4a	11.85bcde	20.58a	26.5cde
13	-3.1	87.8abcd	0.193cde	2.23abcd	53.3defg	11.74cdefg	19.21gh	25.2defg
14	-2.9	79.8e	0.203bcde	2.03cdef	55.8cd	12.99a	20.58a	25.0defgh
15	-3.0	85.0bcde	0.220bcd	2.09bcde	53.8defg	11.54defg	20.38ab	28.4bc
16	-3.5	91.0ab	0.168e	1.98def	56.9abc	11.94bcd	20.46a	24.9defgh
17	-3.0	83.3cde	0.203bcde	1.98def	49.8h	10.50hi	19.54defg	22.8hij
18	-3.5	91.3ab	0.203bcde	2.27abcd	59.1ab	11.59cdefg	20.58a	24.7efgh
P>F	0.1790	0.0036	0.0008	0.0014	<0.0001	<0.0001	<0.0001	<0.0001

Trt	ELAR	NI	LI	PP	TP	EP	KW
	cm^2	No. plt^{-1}	cm	plts ha^{-1}	tillers ha^{-1}	ears ha^{-1}	g
1	697.1cde	12.88efg	16.49def	88036cdef	273	83388cdef	35.86abc
2	712.7abc	12.67fgh	17.22abc	91043abcd	0	79014fg	32.20d
3	679.4defg	12.59gh	16.99abcd	91317abcd	273	88309abc	31.42d
4	702.5bcd	12.42h	16.73bcd	83935fgh	0	81474defg	32.39d
5	604.5h	12.63fgh	14.66	89403bcde	0	89129abc	35.83abc
6	803.0	14.38	16.80bcd	82294gh	0	69171h	34.43c
7	733.2a	12.79fg	16.88abcd	88036cdef	0	85575bcde	35.55abc
8	709.0abcd	12.00i	17.24ab	86942defg	0	85302bcdef	31.19d
9	728.1ab	12.87efg	17.43a	85575efg	0	66710h	35.45abc
10	690.3cdef	12.54gh	16.12efg	91864abc	273	91317ab	37.32a
11	602.8h	11.83i	15.75g	86942defg	273	85849bcde	31.89d
12	617.9h	13.21cde	16.81bcd	89403bcde	0	87216abcd	36.40abc
13	623.5h	12.96def	16.63cde	94598a	820	89950ab	30.99de
14	728.0ab	13.79a	16.82bcd	79560h	273	75733g	37.13ab
15	657.0g	13.58ab	17.02abcd	83388fgh	273	79560efg	37.08ab
16	665.7fg	13.42bc	16.84abcd	93504ab	273	92410a	32.08d
17	670.1efg	12.58gh	15.98fg	89129bcde	0	89129abc	29.12e
18	609.7h	13.25bcd	16.87abcd	89676bcde	0	88309abc	35.23bc
P>F	<0.0001	<0.0001	<0.0001	<0.0001	0.7498	<0.0001	<0.0001

Table 33. Irrigated 2007 Measurement ANOVA

Treatment means and ANOVA results summary for all characteristics taken in the Irrigated 2007 environment. LSD letters are included for all characteristics that were significantly different at the $p < 0.05$ level. Data are not statistically different when represented by the same letter. The following abbreviations are used, PP is plant population, TP is tiller population, EP is ear population, and KW is 100 kernel weight adjusted to 0.155 kg of water kg^{-1} of moist grain.

Trt	PP	TP	EP	KW
	plts ha^{-1}	tillers ha^{-1}	ears ha^{-1}	g
1	80107ab	0	77920ab	38.70abcd
2	76280bcde	273	72452cd	34.93efg
3	79560abc	0	78740ab	36.84bcde
4	71632ghi	273	71085cde	34.55efg
5	75186defg	0	75186bc	38.86abc
6	71905ghi	0	67804ef	38.72abcd
7	77373abcd	0	74913bc	36.93bcde
8	76280bcde	0	75186bc	33.47g
9	72178fghi	273	69991def	36.50cdef
10	80654a	273	79560a	39.54ab
11	78193abcd	0	77920ab	34.50efg
12	72725efghi	273	72452cd	33.01gh
13	80107ab	0	79560a	33.82fg
14	70811hi	273	66710f	38.42abcd
15	70265i	547	68077ef	40.98a
16	80107ab	0	79560a	34.17efg
17	76006cdef	0	74639bc	30.19h
18	74639defgh	273	73545cd	35.90defg
P>F	<0.0001	0.6855	<0.0001	<0.0001

Table 34. Dryland Regression Analysis of Grain Yield

Linear regression equations for all dryland characteristics measured (X variable) in 2005, 2006, and 2007 and the associated grain yields (Y variable). Results show the RMSE, model significance level, and r^2 for each characteristic. The linear regression equation was considered significant only if $p < 0.05$. All equations were calculated with $n = 18$. The following abbreviations are used, GDD is number of GDD from plant emergence to silking initiation, Days is number of days from plant emergence to silking initiation, EP is ear population, CT is Δ_T, CC is percentage of canopy cover, LP is leaf P, LN is leaf N, LC is leaf color, GLN is green leaf number, TLN is total leaf number, ELAN is ear leaf angle, ELAR is ear leaf area, NI is number of internodes, PH is plant height, LI is average length of internodes, PP is plant population, TP is tiller population, KW is 100 kernel weight at 0.155 kg water kg^{-1} of moist grain, and BIO is dry biomass.

Measurement	Units	Linear Equation	r²	RMSE	*P>F*
		Dryland 2005			
GDD	GDD	Y = -20.532X + 18692	0.483	1135	0.001*
Days	d	Y = -291.08X + 23408	0.488	1130	0.001*
EP	ears ha^{-1}	Y = 0.13953X – 571	0.931	415	0.001*
CT	°C	Y = 50.2X + 2788	0.001	1579	0.970
CC	% µmol m^{-2}s^{-1}	Y = -8097.00X + 8274	0.047	1535	0.349
LP	% P	Y = 5538X + 1511	0.012	1569	0.661
LN	% N	Y = 1415.00X + 154	0.025	1559	0.532
LC	SPAD Units	Y = 33.87X + 1257	0.003	1516	0.823
GLN	leaves plt^{-1}	Y = 155.1X + 1249	0.025	1559	0.528
TLN	leaves plt^{-1}	Y = -553.43X + 13949	0.099	1499	0.204
ELAN	degrees	Y = 141.65X + 199	0.107	1492	0.185
ELAR	cm^{2}	Y = -3.261X + 4749	0.013	1568	0.650
NI	No. plt^{-1}	Y = -568.8X + 10851	0.108	1491	0.182
PH	cm	Y = 70.546X – 8525	0.140	1466	0.129
PP	plts ha^{-1}	Y = 0.65787X – 24279	0.177	1433	0.082
TP	tillers ha^{-1}	Y = -0.04883X + 4975	0.249	1368	0.035*
KW	g	Y = 163.45X – 2115	0.177	1432	0.082
BIO	kg ha^{-1}	Y = 0.66071X – 5004	0.170	1437	0.087
		Dryland 2006			
GDD	GDD	Y = -8.563X + 7985	0.316	842	0.015*
Days	d	Y = -121.20X + 8508	0.315	843	0.015*
EP	ears ha^{-1}	Y = 0.08305X – 37	0.917	293	0.001*
CC	% µmol m^{-2}s^{-1}	Y = -6255.45X + 5690	0.097	965	0.201
GLN	leaves plt^{-1}	Y = -16.2X + 1327	0.000	1017	0.883
TLN	leaves plt^{-1}	Y = -325.67X + 8011	0.080	976	0.254
ELAN	degrees	Y = 154.52X – 1617	0.225	896	0.047*
NI	No. plt^{-1}	Y = -220.2X + 4320	0.031	1001	0.472
LI	cm	Y = 550.4X – 4455	0.205	907	0.059
PP	plts ha^{-1}	Y = 0.02192X + 434	0.002	1016	0.850
TP	tillers ha^{-1}	Y = -0.04316X + 2634	0.280	864	0.024*
KW	g	Y = -50.33X + 2908	0.025	1005	0.530
BIO	kg ha^{-1}	Y = -0.04928X + 2006	0.000	1016	0.838
		Dryland 2007			
GDD	GDD	Y = -13.417X + 10953	0.285	994	0.023*
Days	d	Y = -182.61X + 13045	0.284	994	0.023*
EP	ears ha^{-1}	Y = 0.09050X – 304	0.937	295	0.001*

* calculated $p < 0.05$ therefore significant at $p = 0.05$

Table 35. Irrigated Regression Analysis of Grain Yield

Linear regression equations for all irrigated characteristics measured (X variable) in 2005 and 2006 and the associated grain yields (Y variable). Results show the RMSE, model significance level, and r^2 for each characteristic. The linear regression equation was considered significant only if $p < 0.05$. All equations were calculated with $n = 18$. The following abbreviations are used, GDD is number of GDD from plant emergence to silking initiation, Days is number of days from plant emergence to silking initiation, CT is Δ_T, CC is percentage of canopy cover, LP is leaf P, LN is leaf N, LC is leaf color, GLN is green leaf number, TLN is total leaf number, ELAN is ear leaf angle, ELAR is ear leaf area, NI is number of internodes, PH is plant height, LI is length of internodes, PP is plant population, TP is tiller population, EP is ear population, and KW is 100 kernel weight at 0.155 kg water kg^{-1} of moist grain.

Measurement	Units	Linear Equation	r^2	RMSE	*P>F*
		Irrigated 2005			
GDD	GDD	$Y = -7.163X + 17367$	0.067	1211	0.301
Days	d	$Y = -97.32X + 18522$	0.064	1213	0.311
CT	°C	$Y = 2140.6X + 17806$	0.108	1180	0.171
CC	% $\mu mol\ m^{-2}s^{-1}$	$Y = -2734.39X + 14307$	0.014	1244	0.635
LP	% P	$Y = 17698X + 8469$	0.070	1209	0.290
LN	% N	$Y = 2945.3X + 5907$	0.158	1150	0.103
LC	SPAD Units	$Y = 174.22X + 2720$	0.167	1144	0.093
GLN	leaves plt^{-1}	$Y = 134.2X + 10253$	0.010	1247	0.705
TLN	leaves plt^{-1}	$Y = -448.27X + 21003$	0.102	1188	0.199
ELAN	degrees	$Y = 6.52X + 11882$	0.000	1253	0.944
ELAR	cm^2	$Y = 3.779X + 9447$	0.021	1240	0.567
NI	No. plt^{-1}	$Y = -448.3X + 18313$	0.102	1188	0.199
PH	cm	$Y = 11.237X + 9633$	0.010	1247	0.694
PP	plts ha^{-1}	$Y = 0.06124X + 7175$	0.048	1223	0.382
TP	tillers ha^{-1}	$Y = -2.008X + 12181$	0.067	1210	0.299
EP	ears ha^{-1}	$Y = 0.10733X + 3781$	0.234	1097	0.042*
KW	g	$Y = 96.49X + 8907$	0.061	1214	0.322
		Irrigated 2006			
GDD	GDD	$Y = -2.101X + 16470$	0.005	1125	0.779
Days	d	$Y = -30.53X + 16899$	0.006	1125	0.763
CT	°C	$Y = -656.0X + 12761$	0.027	1113	0.519
CC	% $\mu mol\ m^{-2}s^{-1}$	$Y = 13861.67X + 3123$	0.260	973	0.037*
LP	% P	$Y = -10287X + 17114$	0.043	1103	0.410
LN	% N	$Y = 177.8X + 14549$	0.001	1127	0.909
LC	SPAD Units	$Y = 187.33X + 4620$	0.200	1009	0.063
GLN	leaves plt^{-1}	$Y = 187.0X + 12763$	0.025	1114	0.534
TLN	leaves plt^{-1}	$Y = -40.05X + 15736$	0.001	1127	0.909
ELAN	degrees	$Y = -15.41X + 15323$	0.003	1126	0.836
ELAR	cm^2	$Y = -0.154X + 15041$	0.000	1128	0.976
NI	No. plt^{-1}	$Y = 124.1X + 13334$	0.004	1125	0.781
LI	cm	$Y = 573.9X + 5394$	0.118	1059	0.164
PP	plts ha^{-1}	$Y = 0.05786X + 9843$	0.044	1103	0.404
TP	tillers ha^{-1}	$Y = -0.323X + 14985$	0.004	1125	0.803
EP	ears ha^{-1}	$Y = 0.06523X + 9473$	0.189	1015	0.071
KW	g	$Y = 5.15X + 14761$	0.000	1128	0.962
		Irrigated 2007			
GDD	GDD	$Y = 10.831X + 7786$	0.156	820	0.105
Days	d	$Y = 150.46X + 5671$	0.158	820	0.103

* calculated $p < 0.05$ therefore significant at $p = 0.05$

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